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#### Otimização Económica de Parques Eólicos em Função do Custo da Energia Produzida

Economic Optimization of Wind Farms in Function of the Cost of Energy Produced

Universidade de Aveiro Departamento de Economia, Gestão e Engenharia 2013 Industrial

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# Economic Optimization of Wind Farms in Function of the Cost of Energy Produced

Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Economia, realizada sob a orientação científica do Professor Doutor António Jorge Fernandes, Professor Auxiliar do Departamento de Economia, Gestão e Engenharia Industrial da Universidade de Aveiro e Professor Doutor Joaquim José Borges Gouveia, Professor Catedrático do Departamento de Economia, Gestão e Engenharia Industrial Industrial da Universidade de Aveiro.

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CIÊNCIA E TECNOLOGIA SECRETARIA DE ESTADO I dedicate this thesis to my wife, Francidalva, my sons, Heron and Darah, my lovely relatives, Antonio and Ebenezer.

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**palavras-chave** Otimização económica, parques eólicos, custo de energia produzida, energia renovável, fator de competitividade.

#### resumo

Esta tese apresenta um estudo sobre otimização económica de parques eólicos, com o objetivo de obter um algoritmo para otimização económica de parques eólicos através do custo da energia produzida. No estudo utilizou-se uma abordagem multidisciplinar.

Inicialmente, apresentam-se as principais tecnologias e diferentes arquiteturas utilizadas nos parques eólicos. Bem como esquemas de funcionamento e gestão dos parques. São identificadas variáveis necessárias e apresenta-se um modelo dimensionamento para cálculo dos custos da energia produzida, tendo-se dado ênfase às instalações *onshore* e ligados a rede elétrica de distribuição.

É feita uma análise rigorosa das características das topologias dos aerogeradores disponíveis no mercado, e simula-se o funcionamento de um parque eólico para testar a validade dos modelos desenvolvidos. Também é implementado um algoritmo para a obtenção de uma resposta otimizada para o ciclo de vida económico do parque eólico em estudo.

A abordagem proposta envolve algoritmos para otimização do custo de produção com multiplas funções objetivas com base na descrição matemática da produção de eletricidade. Foram desenvolvidos modelos de otimização linear, que estabelece a ligação entre o custo económico e a produção de eletricidade, tendo em conta ainda as emissões de CO<sub>2</sub> em instrumentos de política energética para energia eólica.

São propostas expressões para o cálculo do custo de energia com variáveis não convencionais, nomeadamente, para a produção variável do parque eólico, fator de funcionamento e coeficiente de eficiência geral do sistema. Para as duas últimas, também é analisado o impacto da distribuição do vento predominante no sistema de conversão de energia eólica. Verifica-se que os resultados obtidos pelos algoritmos propostos são similares às obtidas por demais métodos numéricos já publicados na comunidade científica, e que o algoritmo de otimização económica sofre influência significativa dos valores obtidos dos coeficientes em questão.

Finalmente, é demonstrado que o algoritmo proposto  $(LCOE_{wso})$  é útil para o dimensionamento e cálculo dos custos de capital e O&M dos parques eólicos com informação incompleta ou em fase de projeto. Nesse sentido, o contributo desta tese vem ser desenvolver uma ferramenta de apoio à tomada de decisão de um gestor, investidor ou ainda agente público em fomentar a implantação de um parque eólico.

keywords Economic optimization, wind farms, cost of energy produced, renewable energy, competitiviness factor. abstract This thesis presents a study on economic optimization of wind farms, with the goal of obtaining an economic optimization model for wind farms through the cost of energy produced. The study used a multidisciplinary approach. Initially, the main technologies and different architectures used in wind farms. As well as the operating schemes and management of wind farms. Variables needed are identified and presented a sizing model for calculation of the cost of energy produced; we had focused on onshore installations and distribution power on-grid applications. It is made a rigorous analysis of the characteristics of real and topology of aerogenerators simulating the operation of a wind farm to test the validity of models developed. Is also implemented an algorithm for obtaining an optimal response for economic life-cycle of the wind farm in the study. The proposed approach involves algorithms for production cost optimization with multiple objective functions based on the mathematical description of the electricity production. Models have been a developed optimization linear model, which establishes the link between the production cost and  $CO_2$ emissions in energy policy instruments for wind power. Expressions are proposed for calculation of the cost of energy with nonconventional, such as, for the variable production of the wind farm, capacity factor, and overall system efficiency coefficient. For the latter two, is also shown the impact of the distribution of predominant wind in wind energy conversion system. It is noticed the results achieved by the proposals are similar to those obtained by other numerical calculation already published in scientific community, and the algorithm for economic optimization significantly is influenced the values obtained for the coefficients in question. Finally, it is shown the proposed algorithm  $(LCOE_{wso})$  is useful for dimensioning and calculation of the wind farms cost of capital and O&M, within incomplete information or in the planning phase. Accordingly, the contribution of this thesis should be a tool of support for manager/investor or a public agent in supporting the implementation of a wind farms.

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### LIST OF ACRONYMS

Notation	Description
AAE	Asociación Empresarial Eólica
AG	Asynchronous Generator
APERC	Asia Pacific Energy Research Centre
AWEA	American Wind Energy Association
BWEA	British Wind Energy Association
BNDES	The Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social)
BOP	Balance Of the Plant
CanWEA	Canadian Wind Energy Association
CAPM	Capital Asset Pricing Model
CEC	Clean Energy Council
CERs	Certified Emission Reductions
CoPS	Complex Product System
CSCF	Constant Speed Constant Frequency
DCF	Discounted Cash Flows
DD	Direct-Drive
DDSG	Direct-Drive Synchronous Generator
DFIG	Doubly-Fed Induction Generator
DG	Distributed Generation
DGGE	Directorate General for Geology and Energy (Direcção Geral de Geologia e Energia)
DSO	Distribution System Operator
DTI	Department of Trade and Industry
ECOA	Economic Optimization Algorithm
EDP	Energias de Portugal (Energies of Portugal)
EEA	European Environment Agency
EER	Emerging Energy Research
EIA	Energy Information Administration
EMP <sub>yr</sub>	Expected market price
ENOA	Engineering Optimization Algorithm
EPC	Engineering Procurement Construction
ERSE	The Energy Services Regulatory Authority (Entidade Reguladora dos Serviços Energéticos)

ES	Evolutionary Strategies
EU	European Union
EWEA	European Wind Energy Association
FDE	Frequency Domain Experiments
FESG	Field-Excited Synchronous Generators
FinDE	Finite Difference Estimation
GA	Genetic Algorithms
GBSM	Gradient Based Search Methods
GST	General System Theory
GWEC	Global Wind Energy Council
HAWT	Horizontal Axis Wind Turbines
HM	Heuristic Methods
HVAC-HVDC	High Voltage Alternative And Direct Current
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IG	Induction Generators
IMF	International Monetary Fund
IP	Index of Performance
IPPs	Independent Power Producers
IS	Importance Sampling
ITC	Investment Tax Credit
LIDAR	Light Detection And Ranging
LR	Likelihood Ratio Estimators
LWST	Low Speed Wind Turbine Program
MACRS	Modified Accelerated Cost Recovery System
NASA	National Aeronautics and Space Administration
MC	Multiple Comparison
MPPT	Maximum Power Point Tracking Technique
NEA	Nuclear Energy Agency
NO <sub>x</sub>	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
NS	Net Savings
NWCC	National Wind Coordinating Collaborative
NWF	Nearshore Wind Farm
NZWEA	New Zealand Wind Energy Association
O&M	Operations and Maintenance
OECD	Organization for Economic Cooperation and Development
OEMs	Original Equipment Manufacturers

OFWF	Offshore Wind Farm
OOR	Overall Rate-of-Return
OWF	Onshore Wind Farm
OWFLO	Offshore Wind Farm Layout Optimization
PA	Perturbation Analysis
PC	Performance Criteria
PCC	Point of Common Connection
PI	Performance Index
PMSG	Permanent Magnet Synchronous Generators
PPA	Power Purchase Agreement
R&D	Research and Development
RD&D	Research, Development and Demonstration
RE	Renewable Energy
REN	National Electric Grid (Rede Eléctrica Nacional)
REPs	Renewable Energy Projects
RES	Renewable Energy System
RETs	Renewable Energy Technologies
RSM	Response Surface Methodology
RH <sub>n</sub>	Research Hypothese " <i>n</i> "
RS	Ranking and Selection
SA	Simulated Annealing
SCADA	Supervisory Control And Data Acquisition
SCIG	Squirrel-Cage Induction Generator
SIR	Savings-to-Investment Ratio
SM	Statistical Methods
SO	Stochastic Optimization
$SO_2$	Sulfur dioxide
SS	Simplex Search
TPWind	The European Technology Platform for Wind Energy
TS	Tabu Search
TSO	Transmission System Operator
UKERC	United Kingdom Energy Research Centre
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
US DOE	United States Department of Energy
VAWT	Vertical Axis Wind Turbines
VSCF	Variable Speed Constant Frequency
VSVF	Variable Speed Variable Frequency

WCD	World Commission on Dams
WECS	Wind Energy Conversion System
WECs	Wind Energy Converters
WEO	World Energy Outlook
WPU	Wind Power Unit
WT	Wind Turbine
WWEA	World Wind Energy Association

## LIST OF SYMBOLS

Symbol	Description	Unit
α	Inverse of URCF	[—]
ρ	Air density $(1.255 \text{ kg/m}^3)$	$[kg/m^3]$
β	Equivalent to UCRF	[-]
ς ς	Unit cost per $WF_{cap}$ for $CP_{CM}$ calculation	[\$/MW <sub>e</sub> ]
к	Percentage of capital costs for contingencies	[%]
ε	Final value paid by government	[\$/kW <sub>e</sub> h]
<i>E</i> <sub>c</sub>	Government credit given for each MWh <sub>e</sub> of $LCER_{CO_2}$	[\$/MW <sub>e</sub> h]
$\varepsilon_0$	Initial value paid by government	[\$/kW <sub>e</sub> h]
V	Gradient function	[-]
$\overline{\sigma}$	Percentage of $LCCCM_{WF}$ for $O\&M_{fixed_{out}}$ cost calculation	[%]
$\Psi_{total}$	Final value of subsidies for <i>REI<sub>CM</sub></i> calculation	[\$/kW <sub>e</sub> ]
$\psi_0$	Initial value of subsidies for <i>REI<sub>CM</sub></i> calculation	[\$/kW <sub>e</sub> ]
$\xi_n$	Percentage for each energy policy instrument for REPIM	[%]
Y	Coefficient of skewness	[—]
$V_w$	Wind speed	[m/s]
$\eta_{e}$	Electrical transmission efficiency	[-]
$\eta_{\scriptscriptstyle m}$	Mechanical transmission efficiency	[-]
$\eta_{\scriptscriptstyle wecs}$	Wind power plant efficiency	[-]
$\eta_{{\scriptscriptstyle wecs_{(ref)}}}$	Wind power plant efficiency reference	[-]
η	System electro-mechanic efficiency	[-]
$a_i$	Equality constraint functions	[-]
A	Swept turbine area	[m <sup>2</sup> ]
AAR	Average Annual Revenue	[\$M]
$AAR_{yr_n}$	Average Annual Revenue in year " <i>n</i> "	[M\$/yr]
$A_{WT}$	Area per wind turbine for S&RV calculation	[m <sup>2</sup> /wt]
AEP <sub>avail</sub>	Annual Energy Production Available	[kW <sub>e</sub> h]
AEP <sub>gross</sub>	Annual Energy Gross Production	[kWh]
AEP <sub>net</sub>	Annual Energy Net Production	[kWh]
AEP <sub>rated</sub>	Annual Energy Rated Production	[kWh]

$AEP_s$	Cumulated Annual Energy Production	[kWh]
AFF	Annual Failure Frequency	[—]
Amort	Amortization	[\$M]
$AR_{CM}$	Annual Replacement Cost Model	[\$/kW]
b	Learning parameter	[—]
BCR	Benefit-to-Cost Ratio	[-]
$b_k$	Inequality constraint functions	[—]
<b>B</b> ld <sub>area</sub>	Building area for <i>SI</i> <sub>CM</sub> calculation	[m <sup>2</sup> ]
$Bld_{cost}$	Building cost for SI <sub>CM</sub> calculation	[\$/m <sup>2</sup> ]
BOP	Balance Of Plant	[\$M]
с	Current costs for TI calculation	[\$/kW]
С	Constant in <i>Eqn 5.11</i> , <i>5.12</i> and <i>5.13</i>	[—]
$c_0$	Initial costs for TI calculation	[\$/kW]
CAB <sub>cost</sub>	Cables costs including skilled labor	[\$/m]
$C_F$	Capacity factor	[%]
$CF_{wf}$	Wind farm capacity factor	[%]
$C_i$	Cash inflows	[\$M]
$C_{Mhr_{RM_{WT}}}$	Cost of man-hour for $RM_{WT}$	[\$/m-h]
$C_{Mhr}$	Cost of man-hour	[\$/m-h]
$C_o$	Cash outflows	[\$M]
$C_{O\&M}$	Cost of Operations and Maintenance	[\$M]
$Co_0$	Initial Investment	[\$M]
COE	Cost Of Energy	[\$/kWh]
COP	Coefficient Of Performance	[-]
$Co_t$	Cash outflows in period t	[\$M]
$C_{Mhr_{RM_{CT}}}$	Cost of man-hour for $RM_{CT}$	[\$/m-h]
$C_{Mhr_{S\&RV}}$	Cost of man-hour for S&RV	[\$/m-h]
$C_{md_{RM_{WT}}}$	Cost per day for $RM_{WT}$	[\$/day]
$C_{md_{S\&RV}}$	Cost per day for S&RV	[\$/day]
$D_{m_{RMWT}}$	Time of utilization for machines/equipment for $RM_{WT}$	[day]
$D_{m_{S\&RV}}$	Time of utilization for machines/equipment for S&RV	[day]
Depr <sub>WT<sub>inst</sub></sub>	Depreciation of wind turbines with towers	[\$/kW]
$Depr_{Y_{RC}}$	Depreciation in the year of major review	[\$/kW]
$C_{kW}$	Cost of kW installed for $CM_{WT}$ calculation	[\$/kW]
$C_{md}$	Cost per day for DCM <sub>WF</sub> calculation	[\$/day]
$CM_{WT}$	Cost of wind turbine for manufacturer	[\$/kW]
$C_P$	Coefficient of dynamics performance	[%]
$C_{PBetz}$	Betz Limit's coefficient of performance ( $C_{PBetz}=16/27$ )	[%]

$CP_{CM}$	Collecting Point Cost Model	[\$/kW]
CRF	Capital Recovery Factor	[—]
$C_{steel}$	Cost of steel	[\$/kg]
D	Rotor diameter	[m]
$DCM_{WF}$	Wind Farm Decommissioning Cost Model	[\$/kW]
$D_m$	Time of utilization for machines/equipment	[day]
DPB	Discounted Payback	[years]
DT	Development	[\$/kW]
$D_v$	Disinvestment value	[\$M]
$E_A$	Annual energy of the array	[kWh]
$E_{avail}$	Available electrical energy	[kW <sub>e</sub> h]
$EF_c$	Electrical facilities for wind farm substation	[\$/kW]
$EF_{el}$	Electricity Emission Factors	[tCO <sub>2</sub> /MW <sub>e</sub> h]
EG	Engineering	[\$/kW]
EOAP	Economic Optimization Algorithm Proposed	[—]
$E_{pi}$	Energy policy instruments	[—]
$E_{theo}(park)$	Theoretical electrical energy	[kW <sub>e</sub> h]
$E_T$	Annual energy of one isolated turbine	[kWh]
FCR	Fixed Charge Rate	[—]
$F_t$	Fuel expenditures in the year <i>t</i>	[\$M]
F <sub>CM</sub>	Financing Cost Model	[\$/kW]
$FLH_{wf}$	Full load hours of production for a wind farm	[h]
FS	Feasibility Studies	[\$/kW]
$GHG_{EM_{ff}}_{co_2}$	GreenHouse Gas Emission of CO <sub>2</sub> from fossil fuel	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$GHG_{EM_{wecs} co_2}$	GreenHouse Gas Emission of CO <sub>2</sub> from WECS	[tCO <sub>2</sub> /MW <sub>e</sub> h]
g	Annuity	[]
$G_{bd}$	Hours for grid breakdown	[h]
$G_{main}$	Hours for grid maintenance	[h]
GW	Gigawatt	[—]
GWh	Gigawatt-hour	[—]
$H_{prod}$	Hours of production	[h]
$H_h$	Hub height	[m]
i	Discount rate	[%/yr]
<i>if</i> <sub>r</sub>	Inflation rate	[%/yr]
IPT	Industrialized Product Taxes	[%]
IRR	Internal Rate of Return	[%]
$I_t$	Investment expenditures in the year t	[\$M]
$K_0$	Present value	[\$M]

$k_{col}$	Coefficient for number of wind turbines in a column	[-]
KE	Kinetic energy	[J]
kg	Kilogram	[-]
kPa	Kilopascal	[-]
k <sub>row</sub>	Coefficient for number of wind turbines in a row	[-]
$K_t$	Payment value	[\$M]
kV	Kilovolt	[-]
kW	Kilowatt	[-]
kWe	Kilowatt electric	[-]
kWh	Kilowatt hour	[-]
$LCER_{CO_2}$	Life-Cycle Emission Reduction of CO <sub>2</sub>	[tCO <sub>2</sub> /MW <sub>e</sub> h]
LCCCM <sub>WF</sub>	Wind Farm Life-Cycle Capital Cost Model	[\$/kW]
LCOE	Levelized Cost Of Energy	[\$/kWh]
$LCPM_{WF}$	Wind Farm Life-Cycle Production Model	[kWh/yr]
$L_{w_{a_v}}$	Average losses of WECS	[-]
$LCOE_{wso}$	Levelized Cost Of Energy proposed by WSO	[\$/kWh]
LEPC	Levelized Electricity Production Cost	[\$/kWh]
LF	Layout Factor	[kW <sub>e</sub> h]
$L_g$	Local grid length	[m]
LLC	Land Lease Cost	[\$/kWh]
LRC	Levelized Replacement Cost	[\$/kW]
LRCM	Levelized Replacement Cost Model	[\$/kW]
$L_t$	Transmission line length	[m]
$L_{wt}$	Wind turbines layout	[-]
LWTG <sub>CM</sub>	Local Wind Turbines Grid Cost Model	[\$/m/kW]
$L_{x_{row}}$	Area with length (for row)	[m <sup>2</sup> ]
$L_{x_{col}}$	Area with length (for column)	[m <sup>2</sup> ]
т	Mass	[kg]
$M_t$	Operations and maintenance expenditures in the year $t$	[\$M]
$M_{hr_{\scriptscriptstyle RM_{\scriptscriptstyle WT}}}$	Man-hour for $RM_{WT}$	[m-h]
$M_{hr_{RMCT}}$	Man-hour for $RM_{CT}$	[m-h]
$M_{hr_{S\&RV}}$	Man-hour for S&RV	[m-h]
$MC_A$	Market Cost Adjustment	[\$/kW]
$M_{hr}$	Man-hour	[m-h]
MLC	Maintenance Labor Cost	[\$/m-h]
MR	Machine Rating	[kW]
MW	Megawatt	[-]
MW <sub>e</sub>	Megawatt electric	[-]

MWh	Megawatt hour	[-]
N <sub>row</sub>	Number of wind turbines rows in the wind farm	[-]
$N_{col}$	Number of wind turbines columns in the wind farm	[-]
$n_{\varepsilon}$	Time of policy energy instrument for $\varepsilon$ calculation	[yr]
NB	Net Benefits	[\$M]
n <sub>fin</sub>	Duration of pre-operational phase	[yr]
$n_{\Psi}$	Time of policy energy instrument for $\psi$ calculation	[yr]
Ν	Lifetime of wind farm/Number of periods	[yr]
<i>n<sub>mlh</sub></i>	Number of maintenance labor hours	[h]
<i>n</i> <sub>tlh</sub>	Number of technical labor hours	[h]
$N_m$	Number of machines/equipment	[-]
$N_{m_{RN_{WT}}}$	Number of machines/equipment for $RN_{WT}$	[-]
$N_{m_{S\&RV}}$	Number of machines/equipment for S&RV	[-]
NPC	Net Present Cost	[\$M]
NPV	Net Present Value	[\$M]
N <sub>rs</sub>	Rotor speed	[rpm]
$n_t$	Number of towers	[-]
$n_w$	Period of warranty for O&M costs	[yr]
$N_{WT}$	Number of turbines in the wind farm	[-]
$O\&M_{ccm}$	Costs covered by manufacturer	[%]
$O\&M_{fixed}$	Fixed costs of operations and maintenance	[\$/kWh]
$O\&M_{manag}$	Operations and Maintenance management of wind farm	[-]
O&M <sub>variable<sub>CM</sub></sub>	Variable costs of operations and maintenance	[\$/kWh]
O&M <sub>WFCM</sub>	Wind Farm O&M Cost Model	[\$/kWh]
Р	Air pressure	[Pa or N/m <sup>2</sup> ]
P&D <sub>LM factor</sub>	P&D Losses Model factor	[-]
$P_{w_{a_v}}$	Average power production by WECS	[kWh]
$P_{w_{avail}}$	Electrical power output available	$[W_e]$
$P_{w_{(e)}}$	Electrical power output	$[W_e/m^2]$
$P_A$	Available power density	$[W/m^2]$
$P_D$	Power delivered	[kWh]
$PO_{CM}$	Pre-operational Cost Model	[\$/kWh]
PPAR	Power Purchase Agreement	[\$/kWh]
PR	Progress Ratio	[-]
PTC	Production Tax Credit	[\$/kWh]
$PV_{ci}$	Present value of cash inflows	[\$M]
$PV_{co}$	Present value of cash outflows	[\$M]
$PV_{sAEP}$	Present value of cumulated annual energy production	[kWh]
$P_w$	Wind turbine power	[W/m <sup>2</sup> ]
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$P_{w_{out}}$	Power extracted by rotor	[W/m <sup>2</sup> ]
R	Specific gas constant for air (287 J/kg K)	[J/kg K]
r	Discount rate	[%/yr]
RC	Repair Costs	[\$/kWh]
$RCM_{WF}$	Wind Farm Removal Cost Model	[\$/kW]
$R_{CT}$	Removal of concrete	[\$/kW]
$RC_{WT}$	Percentage cost for the wind turbine component	[%]
$RC_T$	Percentage cost for the wind tower component	[%]
$r_D$	Debt cost before tax	[\$M]
r <sub>debt</sub>	Debt interest rate	[%/yr]
$r_E$	Equity cost	[\$M]
REI <sub>CM</sub>	Renewable Energy Investment Credit Mode	[\$/kW <sub>e</sub> ]
REP <sub>CM</sub>	Renewable Energy Production Credit Mode	[\$/kW <sub>e</sub> h]
REPIM	Renewable Energy Public Incentive Mode	[\$/proj]
$RM_{WT}$	Removal of wind turbines	[\$/kW]
RR	Required Revenues	[\$M]
<b>R</b> <sub>taxes</sub>	Revenue taxes	[%]
$RVM_{WF}$	Wind Farm Residual Value Model	[\$/kW]
<i>r<sub>WACC</sub></i>	Tax of Weighted Average Cost of Capital	[%/yr]
S&RV	Seeding and re-vegetation	[\$/kW]
$SB_c$	Substation cost of transmitting	[\$/kWh]
$SC_{O\&M}$	Scheduled maintenance	[\$/kWh]
$SD_x$	Separation distances between wind turbines	[m]
$SD_{x_{row}}$	Separation distances between wind turbines (for row)	[m]
$SD_{xcol}$	Separation distances between wind turbines (for column)	[m]
SI <sub>CM</sub>	Supporting Infra-structure Cost Model	[\$/m <sup>2</sup> /kW]
SPB	Simple Payback	[\$M]
Т	Air temperature in Kelvin (°C +273)	[K]
T <sub>mass</sub>	Mass of each tower	[kg]
$t_x$	Taxes for WACC	[%]
ť	Linear approximation for SPB	[yr]
t	Number of periods for Eqn 5.14	[-]
TAC	Total Annualized Cost	[\$M]
T&D losses	Transmission and Distribution losses	[%]
$T_{CM}$	Towers Cost Model	[\$/kW]
TI	Technology improvements	[\$/kW]
TLC	Technical Labor Cost	[\$/m-h]

$TL_c$	Transmission line cost	[\$/m]
TLCC	Total Life-Cycle Cost	[\$M]
$TL_r$	Transmission line thermal rating	[1/kW]
$TO_{CM}$	Technological Obsolescence Cost Model	[\$/kW]
$TS_{CM}$	Transmission System Cost Model	[\$/kW <sub>e</sub> ]
TSR	Tip Speed Ratio	[-]
$TS_{VM}$	Tower Scrap Value Model	[\$/kW]
TWh	Terawatt hour	[-]
UCRF	Uniform Capital Recovery Factor	[-]
UPAC	Unitary Present Average Cost	[\$/kW]
USC <sub>O&amp;M</sub>	Unscheduled maintenance	[\$/kWh]
V	Current cumulative volume for TI calculation	[kW]
$V_0$	Initial cumulative volume for TI calculation	[kW]
W	Watt	[-]
WACC	Weighted Average Cost of Capital	[%/yr]
WACC <sub>proj</sub>	Weighted Average Cost of Capital for the project	[%]
$W_{F_{CM}}$	Percentage of $WACC_{proj}$ for $F_{CM}$ cost calculation	[%]
$W_D$	Capital Structure	[%]
$WF_{PE}$	Wind Farm Production Efficiency	[%]
$WF_{CM}$	Wind Farm Capacity Model	[kWe/yr]
$WT_{main}$	Hours for wind turbine maintenance	[h]
$WT_{bd}$	Hours for wind turbine breakdown	[h]
$WF_{cap}$	Wind farm electric installed capacity	[kW]
WT <sub>inst</sub>	Wind turbines installations	[\$/kW]
WT <sub>weight</sub>	Weight of a wind turbine	[kg]
$WT_{CM}$	Wind Turbines Cost Model	[\$/kW]
$WT_{rated}$	Wind Turbine rated capacity	[kW]
WTS <sub>VM</sub>	Wind Turbine Scrap Value Model	[\$/kW]
x	Set of all the independent variables	[-]
$Y_{RC}$	Year of the replacement or overhaul	[-]

## **CHAPTER 1**

# **INTRODUCTION**

- 1.1 Presentation
- 1.2 Interest and scope of the thesis
- 1.3 Thesis outline
- 1.4 List of publications
  - 1.4.1 Papers in scientific journals
  - 1.4.2 Oral communications in scientific meetings and conferences
- 1.5 References

This chapter starts by describing the context of the Ph.D. research work. The interest and scope of this thesis is briefly explained. The main objective of this research is also presented. The scientific publications and communications resulted from this research is listed. In the end is added a short description of the chapters with the respective references.

## **1.1 PRESENTATION**

Interest in the use of renewable energy sources has grown dramatically during the last decade, largely as a reaction to concerns about the environment impact of the use of fossil and nuclear fuel. However, the subject of renewable energy is of far wider interest than to environmental issues alone. The use of fossil and nuclear fuels is so central to industrialized societies that any examination of the difficulties they cause or their potential solutions raises a wide range of issues: of technology and design, politics, social structure, economics, planning and even history. This is an area in which there are many views, of varying degrees of insight and expertise, but little certainly.

One of the most exciting aspects of the study of renewable energy is that it is inherently positive. It is an area which offers the possibility of solutions to some of society's most difficult problem. Again, this appears most clearly when a broad approach is taken. Thus the study of renewable energy involves much more than the technical possibilities of replacement of fossil and nuclear fuels. Some of the major scientific areas of interest are:

- i. *Environmental science* the comparative impact of fossil, nuclear and renewable energy sources on the atmosphere, waterways, and the plant and animal life on the earth. This includes considerations of the greenhouse gases effect, acid rain and pollution of the seas. Related issues include the dynamics of climate ant its relationship to the biosphere.
- ii. *Earth sciences* the origins of and physical principles underlying the various forms of renewable energy.
- iii. *Technology* the design and implementation of renewable energy based technologies, and their integration with existing technologies and distribution systems. Related issues include the technical possibilities for improving the efficiency of present energy use, in buildings, machinery, appliances, power plants, etc.
- iv. *Social sciences* the technological/economical/social/philosophical issue of large-scale systems versus small-scale local systems. The difference between the relatively concentrated reserves of fossil fuels in some countries and the wider distribution of renewable energy resources has major political implications and may influence patterns of industrialization and economic development. Changing fuels prices have a dramatic effect upon the world's economies.
- v. *Planning* the sitting of power stations, transmission lines, wind farms, tidal barrages, biomass plantations or hydroelectric plant, which has a major planning impact, with legal and social implications. Transport planning, too, is intimately related to the mix of fuels and other energy sources available.
- vi. Architecture, building and design the design of buildings and neighborhoods for energy efficiency and to incorporate integrated energy supply systems which mix renewable and others sources.

As can be noticed, for studying renewable energy sources and technologies it is necessary a multidisciplinary understanding, so the way these projects can be measure or optimized take us to a body of knowledge for a complete and more comprehensive analysis of a power station planning and management, case of wind farms, at a microeconomics view.

To optimize a wind farm, each aspect and typical assumption must be challenged and carefully evaluated. The challenge in the evaluation has been determining the life-cycle economic implications of aspects such as lost availability, losses at full load, and no-load losses so they can be included in the design process. Three economic factors condense the complexities of the wind farm business model into a form that can be conveniently used in simple spreadsheet calculations to optimize techno-economic power plant for maximized profitability (Maddaloni, 2005). These factors can be determined from the unique economic characteristics of a specific project, including wind regime, cost of money, tax treatment, and expected project return on investment.

Wind energy investment decisions are driven by economics, not necessity. The wind farm must have the lowest possible total life-cycle cost for the project to maximize its economic potential. A specific design choice may have a complex effect on the project financial performance, affecting capital costs, taxes, insurance, energy revenue, maintenance costs, and government subsidies. A method is required to simplify the calculations so that alternate design proposals may be compared and an optimal solution chosen based on the specific economic and engineering factors of the particular wind farm project.

An optimal solution is a result of an optimization process. Optimization is an important tool in decision science and in the analysis of physical systems. To use it, we must first identify some *objective*, a quantitative measure of the performance of the system under study. This objective could be profit, time, potential energy, or any quantity or combination of quantities that can be represented by a single number. The objective depends on certain characteristics of the system, called *variables* or *unknowns*. Our goal is to find values of the variables that optimize the objective. Often the variables are restricted, or *constrained*, in some way (Nocedal & Wright, 1999).

The process of identifying objective, variables, and constraints for a given problem is known as *modeling*. Construction of an appropriate model is the first step — sometimes the most important step — in the optimization process. If the model is too simplistic, it will not give useful insights into the practical problem, but if it is too complex, it may become too difficult to solve. Once the model has been formulated, an optimization algorithm can be used to find its solution. Usually, the algorithm and model are complicated enough that a computer is needed to implement this process. There is no universal optimization algorithm. Rather, there are numerous algorithms, each of which is made to a particular type of optimization problem. It is often the user's responsibility to choose an algorithm which would be more appropriate for their specific application.

This research aims to develop an algorithm for *Economic Optimization of Wind Farms in Function of the Cost of Energy Produced*. The cost of energy produced that has to be minimized by changing the design variables and others parameter influence cost of energy such as wind speed, wind farm layout, wind production losses, O&M cost parameters and control parameters. The optimization must maximize the profit obtained during the useful lifetime of the wind farm studied.

## **1.2 INTEREST AND SCOPE OF THE RESEARCH**

There is not a single price and cost of energy for wind farms. Both depend on the location, size and number of turbines, in addition to being influenced by political incentives or subsidies granted by governments. The initial investment costs — cost of equipment, feasibility study, installation, and O&M are essential to determine the final cost of the technology. In general, the main variables that make up the production cost of wind energy are the investment costs of fuel and operations and maintenance (Morthorst & Chandler, 2004; Wizelius, 2007).

In the case of wind power there is no dependence of the cost of fuel, but the investment cost is still higher than that of conventional sources. However, the costs of wind farms are decreasing, indicating that this trend is likely to continue due to several factors such as the development of larger turbines and more efficient, technological advancement, reduction in the cost of O&M, among others. An extremely important factor that contributes to raise the cost of wind power is its capacity factor, generally around 30% to a maximum of 40%, while conventional plants varies between 40% and 80%. The cost of electricity production by wind in Europe declined in the last 15 years approximately 80%. At the same time, the installed capacity has increased exponentially in scale, from less than 100 MW to 34,400 MW in 2004. During the past ten years the price of wind turbines decreased by 5% each year, while at the same time revenue increased by 30% (Zervos & Kjaer, 2008).

Despite the reduction on the costs in recent years, some problems still there are hindering investments in wind energy projects. When connecting a wind farm to the electricity grid transmission, it is needed to check the power factor, voltage and final production of harmonics caused by the turbines, and investment costs are still higher than the conventional power plants of oil and natural gas. Moreover, the presence of wind turbines may threaten birds and cause visual and noise impact (Gipe, 1995; Heier, 1998).

With regard to wind energy production, economic optimization and evaluation of projects in renewable energy, it is also needed on other factors, such as potential exposure from this source in the energy world, especially in regions where wind speeds are expressive. As the output power is extremely sensitive to wind speed, variability significantly impacts on financial investments and O&M costs. Given to this, it is highlighted the importance of developing evaluation methodologies for economic and financial evaluation and management for energy projects considering the uncertainties associated with this type of technology (EWEA, 2009).

Both onshore and offshore wind energy minimizing the cost per kWh produced it is necessary because when it is going to be sold to the grid, the high and variable cost of wind energy represents a real risk to the investor or wind farm promoter. So when a wind farm is evaluated by deterministic indicator such as NPV, IRR, SPB, DPB and others economic and financial indicator usually applied for it, but such evaluation reflects a set of parameters adjusted and assumptions considered in order to show the results for a unchangeable market situation. In Economics Sciences it's called "coeteris paribus".

On the other hand, the wind energy system and *green* energy markets have some inherent features that should be taken into consideration. As renewable energies have been receiving supports by

government's incentives such as production tax credits (PTCs), modified accelerated cost recovery system (MACRS) and others finance supports which become wind energy technology competitive comparing to conventional ones and other renewable energies technologies. However, given the fast growth of wind power during the last decade and the expectations for the future, wind power penetration levels may increase to levels where engineering and economic optimization for this kind of system starts to be more and more necessary. Note that in this thesis, the *optimization model* is defined as a suggested methodology able to evaluate a wind farm in both economical and engineering aspects.

According to Benatiallah, Kadia, and Dakyob (2010) the main objectives of the optimization design are power reliability and cost. Minimizing the total cost, we can achieve an inexpensive and clean electric power system. In addition, the proposed method can adjust the variation in the data of load, location. Various modeling techniques are developed by researchers to model components of Wind system. Performance of individual component is either modeled by deterministic or probabilistic approaches. The economic study should be made while attempting to optimize the size of integrated power production systems favoring an affordable unit price of power produced. The economic analysis of the wind system has been made and the cost aspects have also been taken into account for optimization of the size of the systems. The total cost of system takes into account the initial capital investment, the present value of operation and maintenance cost, the inverter replacement cost and the wind system replacement cost.

The key objectives of the researches have been to find the lowest cost and highest reliability design of a wind farm. Developing methodologies with approaches for structural and economic optimization of onshore and offshore wind farms are still a challenge due to its multivariable nature and its nonlinear behavior. The importance of using new optimization techniques for short-term energy planning is due to the existence of multiple uncertainties (Fleten, Maribu, & Wangensteen, 2007).

For Baños et al. (2011) the investment decision on production capacity of a wind farm is difficult when wind studies or data are neither available nor sufficient to provide adequate information for developing a wind power project. Some researchers have analyzed in detail how to determine the probable wind power availability at a given site according to historical wind speed data, and its capacity to meet a target demand. At the start of this research project, the primary concern was about the correlation between wind speed and cost of energy produced at a specific site, but after an extensive literature review it became clearly that an economic evaluation by classical economic engineering approach considering deterministic methodologies such as Discounted Cash Flow (DCF) analysis would not be sufficient. It is a multivariable problem and engineering aspects must be taken into consideration. The central research question of this thesis is:

What is the minimum difference between maximum power production and minimal total costs based on LCOE/NREL methodology proposed for a wind farm? If any, which possible strategies could be followed?

## **1.3 THESIS OUTLINE**

The Ph.D. thesis is composed of three parts. The first one, which includes five chapters has been shown the interest and scope of the thesis, research objective and approach; the relationship among energy, economy and society; global status of wind energy; wind energy conversion system with the theoretical foundation of the research work, providing a framework on wind energy, economic measurements for wind energy and physics relations. The second part of this thesis, which includes two chapters, the methodological aspects with its details, mathematical model developed and numerical simulations and validation of theoretical framework developed for optimization process. The last part, third one, of this thesis, which also includes two chapters, has been shown the results and discussions with conclusions and impactions for theoretical contributions and managerial implications, limitations and suggestions for future research.

Chapter 2 has presented an historical overview of the humanity in the energy resources context. This chapter has been addressed the evolution and revolution of changing human societies in the History in order to establish a framework for men's relation within himself and the environment. It was explored the development of societies and energy resources; the influence from energy resources in the structure of societies; energy and environmental impacts of some renewable energy resources and some impacts of electricity production activities (hydroelectric, biomass and wind).

Chapter 3 has presented an overview of the global status of wind energy market. This chapter addresses wind energy situation worldwide in order to establish a context for understanding the contemporary wind energy industry. It explores the global character of wind energy sector, describing its R&D trends, technological evolution and diffusion process, investment focus, wind energy policy, global market share and the global drivers for the expansion of this renewable technology, both in terms of demand and supply, giving a special focus on the onshore wind energy projects.

Chapter 4 has reviewed the relevant literature concerning the wind energy conversion system (WECS), aiming to introduce the history and its evolution. It examines the wind energy converters types, physics basics, describes how energy is extracted from the wind, explain about power coefficients and its limitations on wind power systems. It also demonstrates the design of converters, which factors determine the conversion process and what problems must be considered. In addition, it presents specificities of the wind farms designs (layouts), with a special focus on onshore wind energy conversion system.

Chapter 5 has reviewed the relevant literature concerning the economic measures and optimization models applied for renewable power systems, aiming to introduce and confront the different techniques of economic evaluation, in a microeconomic view. It is also reviewed optimization models applied to wind energy projects in different application: design of wind farm layout for maximum wind energy capture, electrical system design, O&M cost reduction, maximize the NPV, etc. This chapter also examines the importance and limitations of the different approaches and methods studied. It also demonstrates how to process an economic evaluation of power projects, what steps should be taken, which variables determine a significant impact on results and what problems or limitation to face. In addition, it presents specificities of wind energy projects, with a special focus on the onshore wind energy projects.

Chapter 6 has discussed the way in which the research process was carried out. It introduces the rationale of the study and the research framework, providing the main objectives and research questions, and describing the theoretical framework, including the hypotheses. The research design, focusing on the relation of variables and research boundary, mathematical model structuring and numerical simulation and validation process, is also presented. After discussing and justifying the methodological choices for the research, the Chapter 7 describes in details the numerical simulation and validation model proposed for economic evaluation of wind farms and Chapter 8 has presented the results and discussion of the model proposed too.

Chapter 7 has shown the simulations of a hypothetical wind farm. It starts by presenting the full description of mathematical model developed and power system features, both economic and technical issues.

Chapter 8 has demonstrated and interpreted the results of the simulations carried out in Chapter 7. It starts with the analysis of the behavior of the wind farm performance, relationships among variables studied.

Finally, in the last chapter, the main findings and the overall conclusions of the thesis are discussed. It also provides a review of the theoretical and managerial implications of the study, and finishes with a discussion about its limitations and suggestions for future research.



Figure 1.1 Ph.D. thesis` structure overview. Source: Own elaboration

## **1.4 LIST OF PUBLICATIONS**

The major results obtained during this work were submitted to the scientific international community through the following papers.

#### 1.4.1 PAPERS IN SCIENTIFIC JOURNALS

- 1. Oliveira, W.S. and Fernandes, A.J. (2012). "A Review of Wind Energy Conversion System", Engineering Journal (EJ), Vol ? (?) "Accepted in Reviewing"
- 2. Oliveira, W.S. and Fernandes, A.J. (2012). "*Economic feasibility analysis of a wind farm in Caldas da Rainha, Portugal*", International Journal of Energy and Environment (IJEE), Vol 3 (3), 333-346.
- 3. Oliveira, W.S. and Fernandes, A.J. (2012). "*Global Wind Energy Market, Industry and Economic Impacts*", Energy and Environment Research (EER), Vol 2 (1), 79-97. doi: 10.5539/eer.v2n1p79
- 4. Oliveira, W.S. and Fernandes, A.J. (2012). "Cost analysis of the material composition of the wind turbine blades for Wobben Windpower/ENERCON GmbH model E-82", Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Renewable Energy (JRSE), Vol 3, No. 1 January Edition.
- 5. Oliveira, W.S. and Fernandes, A.J. (2012). "Optimization model for economic evaluation of wind farms how to optimize a wind energy project economically and technically", International Journal of Energy Economics and Policy (IJEEP), Vol 2 (1), 10-20.
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- 9. Oliveira, W.S. and Fernandes, A.J. (2011). "*Economic feasibility applied to wind energy projects*", International Journal of Emerging Sciences (IJES), Vol 1 (4), 659-681.
- 10. Oliveira, W.S. and Fernandes, A.J. (2011). "*Economic evaluation applied to wind energy projects*", Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Renewable Energy (JRSE), Vol 2, No. 9 September Edition.

11. Oliveira, W.S., Fernandes, A.J. and Gouveia, J.B. (2011). "Economic metrics for wind energy projects", International Journal of Energy and Environment (IJEE), Vol 3 (6), 1013-1038.

#### 1.4.2 Oral communications in scientific meetings and conferences

- Oliveira, W.S. and Oliveira, F.V. (2012). "Energy citizenship: educational and behavioral aspects in energy consumption". Proceedings of the 3rd International Conference on Financial Education, Aveiro, Portugal, 3rd to 4th July (Available on http://pmate4.ua.pt/conferencias/edufin2012)
- Oliveira, W.S., Fernandes, A.J. & Pereira, E.T. (2010). "Emissions of Greenhouse Gases: Case of Aveiro". Proceedings of the Earth Summit: global heating, society and biodiversity/International Forum of Environment, Vol 1: 37-47, ISBN: 978-85-7745-532-4, Olinda, Brazil, 26 to 29 May.
- Oliveira, W.S., Fernandes, A.J. & Pereira, E.T. (2009). "Analysis of Alternative Scenarios of GHG Emissions to Av. Dr. Lourenço Peixinho in Aveiro – Portugal". Proceedings of the 5<sup>th</sup> Conference of Engineering "Engineering 2009 - Innovation and Development", Covilhã, Portugal, 25<sup>th</sup> to 27<sup>th</sup> November.
- Oliveira, W.S., Fernandes, A.J. & Gouveia, J.B. (2009). "Methodological review of unit cost calculation by life-cycle cost and RETScreen® for wind energy". Proceedings of the 1° Congresso Lusófono sobre Ambiente e Energia/3ª Jornadas de Energia de Cascais, Estoril, Portugal, 20<sup>th</sup> to 22<sup>th</sup> September.
- 5. Oliveira, W.S., Fernandes, A.J. & Pereira, E.T. (2009). "Trends of Electricity Price at Global Wind Industry to 2050". Proceedings of the 1<sup>st</sup> Cape Verde Congress of Regional Development, the 15<sup>th</sup> Congress of the Portuguese Association for Regional Development and the 3<sup>rd</sup> Congress of Nature Management and Conservation, Cape Verde, 6<sup>th</sup> to 11<sup>th</sup> July.

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"Be fruitful and multiply and fill the earth and subdue it and have dominion over the fish of the sea and over the birds of the heavens and over every living thing that moves on the Earth."

Genesis 1:28

## **CHAPTER 2**

## **RENEWABLE ENERGY, ENVIRONMENT, ECONOMY AND SOCIETY**

- 2.1 Introduction
- 2.2 Development of societies and energy
- 2.3 The energy and structure of societies
- 2.4 Energy and environmental impacts
  - 2.4.1 Energy and environment
    - 2.4.2 Impacts of electricity production activity
      - 2.4.2.1 Some impacts of hydroelectric
      - 2.4.2.2 Some impacts of biomass
      - 2.4.2.3 Some impacts of wind power
- 2.5 Summary and conclusions
- 2.6 References

This chapter has presented the relationship among energy, economy and society. It discusses about the development of societies and energy; energy and structure of societies. It is discussed the environmental impacts from energy production and utilization, contribution to greenhouse gases and other pollutants emissions. Summary and conclusions are presented at the end, with the respective references.

## 2.1 INTRODUCTION

Over the centuries, mankind has used energy from many sources to meet their food needs, housing, transportation, health and improve their living conditions. The two main sources of energy, the sun and nuclear fission, and their relative abundances, influenced and still do in the current human activities. As alternating forms of social grouping of men, so too would be changing the use of energy resources. The primitive savages who hunted and collectively, their food in nature depended primarily on their own energy. Today in much of the world population is able to resort to fossil fuels, but also in developing countries makes the use of animal power, human strength and wood fuel (Cook, 1976). Whatever type of energy used, the man always had to expend energy to meet their survival needs. Vast supplies of fossil energy allowed countering the increase in population. Birth rates remain high while the reserves of energy, especially fossil fuels are declining ... That's how we look to the future, when the world population to be served has nearly doubled compared to the present day. We are concerned to know what strategies can be applied to meet a demand for energy increased so tremendously.

Before we can draw up plans to introduce greater efficiency and renewable energies in the current energy matrix, it becomes necessary to gather much information about the costs of energy used in different processing systems for the production and distribution of goods essential for survival of mankind. Such costs must be brought into confrontation with the energy supplies that would be available. Accordingly, this chapter is to explore the interdependencies between energy, economy and their impacts on society. It is my hope that such analysis as a basis for understanding the context and that in fact the economic process in any society defines the profile of energy production and consumption, as well as its impact on society as a whole. For Akella, Saini, and Sharma (2009) renewable energy technologies can have dramatically reduced as well as widely dispersed environmental impacts, rather than larger, more centralized impacts that in some cases are serious contributors to ambient air pollution, acid rain, and global climate change. Keeping in mind, the social, economic and environmental effects of renewable energy system could also mean a way to start changing the modern humankind energy behavior.

This chapter has characterized the environmental impacts from the use of energy sources derived from fossil and renewable resources. Man evolution is closely linked to energy, since the beginning of time man has to know it and seeking it ever more on the environment. He began to enjoy and benefit from its potential fossil and renewable resources. The use of more efficient technologies, along with the application of sustainable energy policies has contributed to a general reduction in the intensity of  $CO_2$  emissions by energy production and consumption. It begins with a contextualization of the development of societies and energy (section 2.2), and briefly presents the energy resources the influence on structuring of societies (section 2.3). Section 2.4 has discussed about energy resources and environmental impacts in demand and supply side, the relation of energy and environment (section 2.4.1) in the point of view of consumption and emissions of  $CO_2$ . The impacts of electricity production was also discussed in section 2.4.2.2) and wind power (section 2.4.2.3). Finally, section 2.5 presents the summary and conclusions of the whole chapter. Section 2.6 presents the references used.

## **2.2 DEVELOPMENT OF SOCIETIES AND ENERGY**

Societies throughout history of mankind in order to ensure their basic survival needs - food and health, housing and safety - always found itself closely linked to energy supply, so the energy in all its forms is part of their own nature of man. Along this route, man has used energy from many sources. Starting with your own energy and sunlight (solar energy), then passed to the wood fuel, animal traction, force of water and wind. Later it was developed into power of machines powered by wood, coal, oil and nuclear energy. The man power used to modify or manipulate the land, water, plants and animals in order to provide himself food, clothing and shelter materials. Discover, control and use power forward took the man's primitive life to a stable civilized. Man is the only animal capable of thinking creatively and using science and technology, getting benefits from energy and other environmental resources.

Energy is also used to control disease organisms; to obtain and purify and store water, to produce antibiotics and other chemical drugs, and to implement various public health measures. Although public health is an aspect of security, is both to stability are also associated with the protection of men among themselves, a group of people against the actions of other rival groups. Social harmony depends not only on the rules set by governments but also the efficiency of police and military forces used to enforce the law. Both governments and police forces and military spend enormous amounts of energy. In so-called *"civilized societies"* of developed nations in the world today, the amount of energy used by the government and police and military forces is significantly higher than that used to grow food for the population governed (Cottrell, 1955).

The availability of surplus energy enables the man creates more complex structures that the first hunter-gatherers. The present state of utilization of energy resources represents a dramatic change in relation to that one of a recent past in the search for adequate food was the main concern of the man and ran their activities. According to White (1943) the evolution of man can be broken down into three main stages: (1) population "wild" in the hunter-gatherers who lived from natural feeding, (2) population "barbaric", primitive agricultural and pastoral societies and (3) "civilization", the development of machines and intensive use of fossil energy to produce food and other useful items. These steps are all related to changes in supplies of energy used by man. White [3] considered that "this would have stayed indefinitely at the level of savagery if I had not learned the amount of power under his control". This includes the total amount of energy controlled by man and the surplus energy that he has higher than necessary to meet the essential needs of food, clothing, shelter and health.

Energy use has accommodated the modern society in such way that societies with little access to energy resources present consequently lower evolutions than for other societies that have increased access to energy. Countries located in continents like Africa, have very low rates of energy consumption, but the poverty rate is high due to lack of technology supported by strong energy sources. With the lack of energy the Government weakens and impoverishes society. Given the continued dependence of man on energy, and knowing perfectly fits an overall historical society constantly seek new outlets for production, without which you cannot get a strong, competitive economy (Willrich, 1978). It may be noted that currently, at what humankind has done and continues to do in pursuit of energy kind. We highlight here the oil, which continues to keep wars. Countries seek power over that coveted energy potential, which is able to influence society in such way that moves a country and makes the mankind drives through essential principles for harmony between peoples. It is also evident that so-called developed countries are those with greater energy consumption, this because they need energy to keep all their energy potential and technology, it can be noted by observing that countries like the United States and much of Europe where energy consumption is very high, thus causing pollution indexes thunderous. However, we can highlight concerns about the relentless pursuit of energy, a quest that will surely come to an end.

The government assumes leading role in the development of each society, and must provide access for the whole society to energy resources, acting as a valve which regulates how much and how to use energy resources, which cannot be neglected, governments can fulfill its role of accessibility to all energy forms becomes a major factor for the evolution of a society, but that does not fulfill that role will eventually contain the development of its population in addition to harming the environment (Hinrichs & Kleinbach, 2004). Energy is essential for the development of any society. Given the constantly evolving experience that is in modern society and knowing that it is highly linked with this indestructible goods called *energy*, should be imposed on society information about the rational use and respect the environment, from which it is extracted, so that we do not achieve results in the formation of a harmful at all, thus implying the reverse evolution (Hammond, 1972).

Modern economies have been depending on incessant and increasing amount of fossil fuels and electricity, but the relationship between economic growth and energy resources use has been both dynamic and complex: It changes with developmental stages, and although it displays some predictable regularity, a closer analysis reveals many specificities that drive any normative conclusions about desirable rates of energy supply and consumption. High-energy civilization is now really and factual global — but millions of people still has no access to electricity and its benefits remain far away. Although the huge international differences in the use of commercial energy have narrowed considerably since the 1960s, an order-of-magnitude difference in *per capita* consumption of fuels still separates most poor from rich nations, and the gap in the use of electricity remains even wider. There are also large disparities among different socio-economic groups within both high and low-income nations (Smil, 2000).

## **2.3** The energy and structure of societies

The hunting-gathering societies were small, rarely more than 500 individuals and were simple. As the demand for food and shelter was time consuming and a lot of energy, almost there were no other individual and collective activities. However, with the development of agriculture, became available larger amounts of food, fiber and energy surplus. Concurrently, there are, in human societies, the greater interdependence among people and more incentives to increase productivity (Bews, 1973; Lee. R.B. & DeVORE. I., 1976; Service, 1962). This factor was also important the fact that, as they increase their output of food, also increased the stability of food supplies. Companies once forced to be nomads to monitor their food supply has improved with regard to safety and permanence. Even in primitive agricultural societies, food production was still the principal activity of man and as a consequence, their social interaction remained relatively narrow. The introduction of animal draft power in crop production released greater amounts of time and energy of man. This surplus of energy and more time allowed the man to participate in several new activities, which led to making more complex social systems.

The water wheel and windmill added new forms of energy to those who initially has used the man in their production processes, particularly in the food production system. Now, instead of using draft animals whose feed and care require energy, man resorted to force of the water and wind. With this change, the man was to have more power at less cost (calculated in terms of human energy expenditure) than in the past. Thus, the amount of surplus energy available to the society was largely increased. The transportation of goods and similar things were done by the direct utilization of human force, as has been shown in Figure 2.1.



Figure 2.1 Transport of solid stone monument in 660 bC. Source: Loftness (1984)

The invention of the steam engine was a highly significant milestone in energy use, as marking the beginning of the use of fossil fuels as primary energy source. This machine, and later those who used coal and liquid fuels, has given the man an immense power to control their environment and change the whole economic structure, political and social society, while there is greater stability and expertise of work.

The society's structure of the first hunter-gatherers was minimal. At most, a boss or a group of elderly people ran the camping or village. Most of these leaders were forced to hunt and collect together with other members, because they were scarce surplus food and other vital resources to allow it work at all times a chief or a village council. The agricultural development has altered this pattern of work monotypic. The primitive family farm could reap 30 to 10 kg of grain per kg sown. Part of this surplus food/energy was returned to the community and ensured the maintenance of non-farmers, such as chiefs or village councils, doctors, priests and even warriors. The nonfarmers in those primitive societies assumed the government and ensured the stability and security to the farmer population, so that could increase the surplus of food production/energy (Cottrell, 1955; Fakhry, 1969). Under favorable conditions in agriculture and improving agricultural technology began to obtain considerable energy surplus and as a result, there have been major population groups or even cities. With the population concentration in larger cities, appeared the specialization of tasks. Specialists such as masons, carpenters, blacksmiths, merchants, traders and sailors, proved more efficient than the non-experts. Goods and services provided by artisanstechnologists have determined an improved quality of life, a higher standard of living and, for most societies, an increased stability.

Egypt, during the reign of the Pharaohs, is a striking example of a primitive society that has environmental resources in favor of establishing a stable agriculture, which created an efficient agricultural technology. The Nile brought water to the cultivated land and valuable nutrients, which replaced those crops of cereals and other products taken from the soil. Thanks to its periodic flooding, the Nile deposited nutrient-rich sludge to arable land, which thus remained productive. He was also a source of water for irrigation trustworthy. Furthermore, and with equal importance, had to consider the hot climate of Egypt is highly conducive to agricultural production. This productive agricultural system sustains 95% of Egypt's population directly involved in agriculture, and provided enough surplus food/energy to keep 5% of population that does not worked in agriculture. To sustain the small ruling class, a relatively small quantity of food energy was enough. The naturally isolated location of Egypt ensured protection against intrusions without requiring large expenditures to sustain a military class. Consequently, the 5% of the population engaged in agriculture were not used by the Pharaohs as slave labor to build pyramids and storing these goods and materials for a life that, according to the Egyptians believed would follow the life on Earth (Cottrell, 1955).

Throughout this period, the Egyptian population has remained relatively constant because of demand made by the heads. Once the men were in excess sufficiently capable to work were used to build the pyramids. These men were forced to perform many hours of hard work and were literally *"used until death"* during a period of a few years of slave labor. When they died, were replaced by new elements selected from among the redundant workers. All this was done without

compromising the fundamental agricultural system that required the efforts of almost all the Egyptian people. During the age of the Pharaohs, which occupied the years from 2780 to 1625 b.C., Egypt had a population of about 3 million, far less than the 38 million nowadays. An excess energy of 5% in about 3 million people is not much. In *per capita* basis of 100-150 kcal<sup>1</sup> per day, equivalent to 10-15 kg of wheat per person per year. In relation to 3 million, the total reaches 30-40 x 106 kg of wheat per year surplus (Cottrell, 1955; Fakhry, 1969).

The construction of the pyramid of Cheops over 20 years has used an amount of energy that equaled the surplus energy produced during the life of about 3 million Egyptians∴During the construction period, the labor force was applied to some 100,000 slaves per year. Assigning each slave 300 to 400 kg of food per year, the total cost would have been 30-45 x 106 kg, or the whole of the surplus food/energy from agriculture in Egypt. In later periods of Egyptian history, similar levels were used to maintain large military forces that won some of the neighboring countries of Egypt. These military operations have provided some additional land and food and often conquered peoples were brought to Egypt as slaves. However, long distances in desert regions that the Egyptian troops were forced to travel and limited supply of these military operations. It was necessary to spend large amounts of energy only to protect the roads and transport military supplies.

On other occasions, when the population increased greatly in relation to land resources and agriculture, there is no longer in Egypt surplus agricultural resources. Under these conditions on overcrowding and failure instead of surpluses, the Egyptian society was only able to sustain itself. Sometimes, under these pressure conditions, there were civil wars and social problems. Such conditions often led to declines in effective population size, since those societies were not productive either unstable in agriculture and in other essential activities.

Thus, the primitive history of Egypt is an excellent example of the role that energy, measured in surplus food/energy, played in the structure and activities of a primitive society. Although the structures of the societies of today are much more complex, the energy continues to be an important factor in the development of mankind. Humanity will have to adapt and find new energy potential, as it did throughout its history. New energies come exhaustible or not, clean or not, but they will be distributed equally? It does not help the vast energy production if the same will not be distributed and enjoyed by all people equally.

<sup>&</sup>lt;sup>1</sup> Historically, the definition of a calorie was a quantity of heat required to increase by 1 degree Celsius temperature of 1 gram of water. With the development of measurement technique, it was found that the specific heat was not constant with temperature. So we tried to standardize it to a narrow range and calorie was then redefined as the heat exchanged when the mass of one gram of water from 14.5°C to 15.5°C. A kcal is the amount of energy required to increase up by 1 degree Celsius temperature of 1 kilogram (kg) (equivalent to 1 litter) of water. Thermodynamics: An Engineering Approach, 5th edition by Yunus A. Çengel and Michael A. Boles.

### 2.4 ENERGY AND ENVIRONMENTAL IMPACTS

The production and use of energy have environmental and social consequences locally, regionally and globally. These impacts are spread over the lifetime of a system of energy based on fossil resources and can manifest itself in a shorter time scale, medium or long term. Proper assessment of these impacts and their inclusion in decision-making process on energy is a key to ensuring a sustainable energy sector (UNDP, 2000). Local impacts, although affecting a small group of people can be extremely important, especially if involving occupational diseases and accidents affecting workers or members of the public. Local impacts are also more relevant to renewable technologies. For example, concern over the development of wind farms typically refers to visual intrusion on landscape and noise emissions (European Commission., 1995).

However, large thermal power plants or renewable energy or fossil fuels also can have adverse effects on local resources related to excessive consumption of water, soil and groundwater pollution, or deforestation. The sustainable energy strategies of the plan of the *United Nations Development Program* (UNDP) presented some examples of regional impacts related to energy production, such as acid deposition, habitat destruction, large-scale displacement of people due to construction and operation of projects large hydroelectric or radiation due to accidents at nuclear power plants (UNDP, 2000). Globally, the link between energy and the effects of global warming around the world is documented.∴Other relevant global impacts include loss of biodiversity and land degradation.

European Commission. (1998) states that impacts should be evaluated over their lifetimes. Although EC presents uncertainties for the long term impacts such as global warming or high level radioactive waste disposal. Likewise, Weisser (2007) recalls that in economies where the carbon has a fixed price or emissions of greenhouse gases (GHGs), embarrassed, do not respond adequately to GHG emissions in the life cycle in the production of electricity, can be advantage for transnational technologies, which makes the accounting for significant emissions within the lifecycle of a project outside the boundaries of laws and policies to mitigate greenhouse gases.

This section examines the impacts of different electricity production technologies based on literature review. Section 2.4.1 focuses on the close relationship between energy and environment, detailing trends in  $CO2^2$  emissions from the consumption of primary energy and electricity production activities, outlined in the Kyoto Protocol and European Union regulatory in promoting environmental performance in the energy sector. The impacts of the activity of electricity production are described in section 2.4.2 for both fossil fuels and the main renewable energy technologies. This section discusses in detail the environmental and social impacts of hydroelectric, biomass and wind energy technologies, discusses the effects of integration on the electrical system and discusses the social acceptance of these technologies.

 $<sup>^2</sup>$  There are six greenhouse gases recognized under the Kyoto Protocol. The analysis focuses principally on CO<sub>2</sub>. This is the most important anthropogenic greenhouse gas accounting for 82% of total emissions greenhouse gas emissions in EU-27 and 79% of emissions of greenhouse gases in Portugal in 2005.

#### 2.4.1 Energy and environment

Energy production and consumption is strongly associated with the environmental pressure on the planet. For example, emissions of  $SO_2$  (sulfur dioxide), greenhouse gases and other  $CO_2$  and  $NO_x$  (nitrogen oxides) for a certain period, depends on the amount of electricity produced and the technological mix of plants operating in each electrical system for some period. The actions of each of the fossil fuels, nuclear and renewable operate with the efficiency of each production center represent the key mechanisms available to assess the environmental performance of the electricity system of a country.

According to the report of the EEA (2007) for the EU-15<sup>3</sup>, the main factors responsible for reduction of  $CO_2$  emissions from the system for producing electricity and heat are the improvement in efficiency, fuel substitution derived from coal to gas and to a lesser extent, increasing the share of renewable energies. Portugal is a particular case in which  $CO_2$  emissions are heavily dependent on rainfall conditions. The emission level shows significant variations in relation to fluctuations accentuated hydropower production, which is heavily dependent on annual rainfall. However, the close relationship between energy consumption and  $CO_2$  emissions from the energy sector is evident.

Figure 2.2 has shown the close relationship between energy consumption and  $CO_2$  emissions worldwide. World consumption of primary energy is increasing and between 1990 and 2004 grew 29%.  $CO_2$  emissions showed a similar trend in 2004 also has increased about 27% compared to 1990. The small difference between the rates of increase allows a small reduction in  $CO_2$  emissions per unit of energy consumed.



**Figure 2.2** Trends in global consumption of energy and electricity,  $CO_2$  emissions and  $CO_2$  emissions intensity of energy consumption. Source: EIA (2007)

<sup>&</sup>lt;sup>3</sup> Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Spain, Portugal, Sweden and United Kingdom.

At EU-15 there is a general trend of increasing consumption of energy, as shown in Figure 2.3. However, the use of more efficient technologies and renewable energy, along with some structural changes that occur in members of the EU and the introduction of specific policies and measures, contribute to a less significant increase in  $CO_2$  emissions. As a result, between 1990 and 2005,  $CO_2$  emissions per unit of energy consumption dropped by 12%.



**Figure 2.3** Trends in the EU-15 and electric energy consumption,  $CO_2$  emissions and intensity of  $CO_2$  emissions from energy consumption. Source: EEA (2007); EIA (2007)

Demand for electricity is growing fast and, to some extent, offset the increase in consumption of the environmental benefits achieved through technological advances and fuel switching. A similar effect occurs in the transport sector. Transport emissions in the EU-15 increased significantly during the same period as a result of a continued increase in demand for road transport. This has offset much of the decline in other sectors (EEA, 2006). In general, the CO<sub>2</sub> emissions associated with energy consumption and real electricity showed a downward trend between 1990 and 2005, indicating movement toward the mix of less carbon intensive fuels in Europe.

Energy production and consumption are the major emission sources of GHGs in the EU. Figure 2.4 has shown that in 2005 the CO<sub>2</sub> emissions produced by industry in Portugal and the EU- $27^4$ . About 90% of total CO<sub>2</sub> emissions in Portugal are related to energy, which means they are a result of the activities of energy consumption. This figure rises to 94% in EU-27. Particularly relevant is the

<sup>&</sup>lt;sup>4</sup> Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

role of the sector of electricity and heat. About a third of  $CO_2$  emissions deriving from fossil fuels to generate electricity, with each core are able to send millions of tons of  $CO_2$  annually.

Limit the concentration of  $CO_2$  in the atmosphere requires a reduction in  $CO_2$  emissions across the economy. The electricity production sector has some special characteristics that makes it an important target for reducing  $CO_2$ , as have pointed out by Johnson and Keith (2004) in relation to emission sources distributed in the sector of transportation, electricity production plants can achieve reductions depth with minimal impact on energy infrastructure, property and centralized management of the power industry regulation and facilitates the producers have gained considerable experience in recent years with increasingly tight controls on conventional pollutants, and it is unlikely that producers of electricity movement for the least-regulated as could happen for the industry.



**Figure 2.4** Percentage of  $CO_2$  emissions of air pollutants by activity in 2005, EU-27 and Portugal. Source: EEA (2007); EIA (2007)

In Portugal, in 2005,  $\text{CO}^2$  emissions from the operation of a coal were about 844g/kWh (EDP, 2006). Whereas from the operation of central CCGT<sup>5</sup> this value was about 375g/kWh (Turbogas, 2006). The results of Hondo (2005) have indicated that, even nuclear power plants emit approximately 24g CO<sub>2</sub>/kWh during its life cycle, particularly uranium enrichment. The wind power plants are responsible for 29g CO<sub>2</sub>/kWh mainly released during the construction and

<sup>&</sup>lt;sup>5</sup> Combined Cycle Gas Turbine. A production plant uses a combined cycle gas turbines and associated steam in a single center, both producing electricity from the burning of same fuel. The heat in the exhaust gases of gas turbines is recovered to generate steam necessary to drive the steam turbine. Thermodynamics: An Engineering Approach, 5th edition by Yunus A. Cengel and Michael A. Boles.

installation. Renewable energies have generally low  $CO_2$  emissions and are heavily favored by environmental regulations for the energy sector.

An important factor in future development of energy sector and the definition of current and future energy policy is the Kyoto Protocol. Under the Kyoto Protocol, the EU pledged to reduce emissions of greenhouse gases to 8% during the first commitment period, from 2008 to 2012. This objective is shared between the Member States under a legally binding burden-sharing, which sets emission targets for each individual Member State. In particular, Portugal could increase the average emissions of 27% of 1990 emissions level. Growth reduction in electricity consumption will be crucial in the environmental point of view, especially in relation to consumption of electricity produced by fossil fuels.

The renewable energies sources do not generate  $CO_2$  (or very little), do not throw radioactive waste, and generally have significantly lower levels of other pollutants. Improving the environmental performance of fossil fuel plants is also essential and can be reached with the increasing use of abatement technologies effectively and improve efficiency. The need to reduce the pressures imposed on the environment through the use of energy worldwide and in the continuing effort to promote and utilize renewable energies sources and supplemented by changes in consumer of energy behavior.

## 2.4.2 IMPACTS OF ELECTRICITY PRODUCTION ACTIVITY

There is growing recognition of the importance of social and environmental impacts of the production of electricity. As described in the previous section, the energy production process involves, in which the shares of producers of electricity cannot be adequately reflected in market prices of product. EIA (1995) has classified the externalities attributable to electricity production in four categories: air pollutants, greenhouse gases, quantity and water quality and land use values.

Clarifying the full costs of energy production for regulators and policy makers is particularly critical because of the non-price differentiation between suppliers of electricity produced from different sources with emissions of pollutants potentially very different. The basic purpose of social accounting is to make explicit the full magnitude of the direct costs and environmental costs of electricity derived and supported by society in order to influence decision makers in making investment decisions in the energy sector to improve the welfare social (Venema & Barg, 2003).

Develop defensible estimates of externalities are a complex and costly exercise (Rowe, Lang, & Chestnut, 1996). Externality values for the production of electricity have been developed in the U.S. and Europe. Freeman III (1996) and the EIA (1995) have presented some key studies on estimates of external environmental costs that result from adding the ability of a system for producing electricity.

The European Commission, together with the Department of Energy launched a joint research project to assess the environmental externalities of energy use in 1991. During the project, an accounting framework for the operational assessment of external costs of energy technologies,

called *ExternE* (Externalities of Energy) was developed. The U.S. suspended its participation in the project at the end of the first phase. The methodology and results are widely accepted and have been used to support other studies and projects, some relating to different sectors or regions as APERC (2005), Venema and Barg (2003), NEA (2003), HEATCO (2006) among many others<sup>6</sup>.

Technologies models		Air pollution impacts (PM <sub>10</sub> ) and other impacts	Greenhouse gas impacts
✡	Biomass technologies	High	Low
✡	Existing coal technologies (no gas cleaning)	High	High
✡	Natural gas technologies	Low	High
✡	New coal technologies	Low	High
✡	Nuclear	Low	Low
✡	Wind	Low	Low

Table 2.1 Overall results of the ExternE

Source: adapted from European Commission. (2003)

In general, as shown in Table 2.1, wind power technologies are environmentally friendly with respect to emissions of pollutants, including emissions of greenhouse gases. However, the results also indicate some variation of external costs attributed to wind due to noise impacts or other utility, mainly depending on local conditions of each park studied. Nuclear technologies have low emission levels and generate low external costs, even considering the low probability of accidents with high consequences. As for biomass, due to the large number of technologies, changes in external costs are high, although in general they generate greenhouse gas emissions very low in their life cycle. The gas technologies are clean with respect to conventional pollutant (not including greenhouse gases), but depending on the efficiency of the technology can impact on climate change due to  $CO_2$  emissions. Coal technologies generate high emissions of  $CO_2$ , even for new, more efficient technologies. Old coal plants are highly polluting units for each type of pollutant considered (European Commission., 2003).

For fossil fuels, global climate change is very fundamental question that dominates the current energy policy. For nuclear fuel, potentially large consequences of an accident, and long-term impacts of radioactive waste are the key to the major decision. The expansion of renewable energy technologies has resulted in a growing opposition in certain portions of affected local population on account of the impacts of increasing usefulness. Potential impacts on the local ecosystem by, for example, hydro, offshore wind farms or biomass plantations in particular have raised objections from interest groups that traditionally consider green renewable energy technologies as a viable alternative instead of nuclear energy (Krewitt, 2002). The calculations of Mirasgedis, Diakoulaki, Papagiannakis, and Zervos (2000) have indicated that mortality associated with the effects of air

<sup>&</sup>lt;sup>6</sup> A list of related projects can be found in ExternE at <u>http://www.externe.info/</u>.

pollution and the effects of global warming are the major components of externalities attributed to conventional power plants.

For biomass power plants, the external costs associated with global warming are considered void and the impacts of high priority are close to those identified for the plants to conventional oil. As for wind farms and hydroelectric plants, the main external cost refers to the noise and accidents. Although renewable energy sources are generally associated with lower external impacts on the power plants that use fossil fuels, particularly coal, are not entirely free of impact. In fact, significant negative impacts were studied for the most common renewable energy technologies used. The potential of renewable energy sources is enormous as they can in principle meet many times the world's energy demand. Renewable energy sources such as small hydropower, wind, solar, biomass, and geothermal can provide sustainable energy services, based on the use of routinely available, indigenous resources (Akella et al., 2009).

#### 2.4.2.1 Some impacts of hydroelectric

As for the hydroelectric sector, a large number of benefits or positive impacts can be described in Almeida, Moura, Marques, and de Almeida (2005), U.S. Department of Energy<sup>7</sup> and World Bank<sup>8</sup>:

- ★ Energy impacts associated with: the economic value of electricity and energy supply, economic benefits of potential reserves, drive dynamic response of these technologies and emissions avoided. Furthermore, it is a source of domestic energy and renewable. REN (2006) notes that high levels of availability and production flexibility are two major advantages of hydropower.
- ✤ Impacts of water resources, associated with the contribution to irrigation, water supply and minimum in stream flows during the dry season.
- Socio-economic development impacts associated with the creation of new activities or sports-related tourism, producing new jobs and diversifying the economy. Agricultural activities can also benefit from flood control and water availability. Most hydropower installations are required to provide public access to the reservoir to allow him opportunities to exploit.

However, some important disadvantages or negative impacts are also reported in the literature as Almeida et al. (2005), U.S. Department of Energy, World Bank, International Rivers Network<sup>9</sup>):

Environmental impacts associated with loss of habitat and biodiversity, loss of fish stock, landscape changes or obstruction of movement of migratory fish. Dams also change the pattern of river flow, reducing its overall volume and seasonal variations. All parts of the ecology of a river may be affected by changes in their flow.

<sup>&</sup>lt;sup>7</sup> For more details, check on <u>http://www1.eere.energy.gov/windandhydro/hydro\_ad.html</u>.

<sup>&</sup>lt;sup>8</sup> For more details, check on <u>http://www.worldbank.org/html/fpd/em/hydro/ihd.stm</u>.

<sup>&</sup>lt;sup>9</sup> For more details, check on <u>http://www.irn.org/index.php?id=basics/impacts.html</u>.

- ✤ Energy impacts. The capacity of electricity production is heavily dependent on rainfall conditions.
- Socioeconomic impacts. New hydro can compete with other land uses that may be more valued than electricity production. Local people could lose their homes and lands. Local cultures and historic sites can be invaded.
- ✤ Loss of local convenience. Noise and vibration due to construction activities can disturb the local wildlife and human populations nearby.

A detailed description of the impacts of hydropower can be found at the World Bank, along with a description of possible mitigation measures.

The WCD (2001) supports the idea that the dams have been promoted as an important means for meeting water and energy needs and long term strategic investment with the ability to deliver multiple benefits. Regional development, job creation and promotion of an industry base with export potential are often cited as benefits. However, these benefits must be weighed against the environmental and social impacts of large dams. The huge investment required to build large dams, and its enormous impact social, environmental and economic projects makes them highly controversial.

## 2.4.2.2 Some impacts of biomass

Bioenergy is a heterogeneous aggregation of different feed materials, conversion technologies and use of energy resources thin. In the European context, the biomass is taken to include agricultural and industrial waste as a potential source of fuel for heating and electricity (McKay, 2006). The main positive and negative impacts of biomass technologies in the literature are listed below:

- Environmental impacts. As with other forms of combustion, burning wood emits air pollutants. The amount and type of pollutants depend on both the specific combustion process involved and the extent of controlled burning. Compared with fossil fuel combustion plants fed with forest residues emit similar levels of nitrogen oxides, but significantly less sulfur dioxide (Miranda & Hale, 2001).
- Energy impacts. Among renewable energy sources, biomass is one of the few resources whose availability is not dependent on weather conditions, seasonal and diurnal and can be stored for use on demand (Thornley, 2006). This represents an important advantage, allowing the production of electricity more predictable. Moreover, a source of domestic energy, contributing to the diversification of the fuel mix and supply security.
- Socioeconomic impacts. The bioenergy projects involving energy crops could have significant contribution to rural incomes, or increased employment. Energy crops can lead to changes in patterns of agricultural work and make positive contributions to diversify the rural economy (Thornley, 2006). Results of surveys on local public opinion of a biomass

gasifier proposed in the UK indicate that the potential impact on employment was further confirmed the benefit (Upham & Shackley, 2007).

Emissions from transport and infrastructure requirements and associated the new capacity of biomass can result in adverse reaction from segments of the local community (Thornley, 2006). Upreti (2004) has given some examples to show that the major obstacle to the promotion of biomass energy is the opposition of local people. In general, biomass technologies have fewer environmental impacts compared to conventional sources. Moreover, important benefits for rural populations and contribute to the security of electricity supply. However, there are significant local impacts that may raise questions and generate opposition to the development of biomass power stations. The effects of pollutant emissions are a major concern with the loss of quality of life caused by increased traffic and the installation of the plant.

#### 2.4.2.3 Some impacts of wind energy

Studies have been published concerning the impact of wind energy development on the environment, economic development, on the functioning and security of the electricity system as well as the final cost of delivered energy. Manwell, McGowan, and Rogers (2002) have noted that the development of wind energy has positive and negative impacts. On the positive side, the authors point out that wind energy is generally considered environmentally friendly compared to conventional power plants for electricity on a large scale. However, the more wind turbines are installed; the importance of their negative impacts becomes more noticeable. The problems most often cited for the wind farms are the sound and visual impacts of wind turbines on the landscape of public opinion. Other concerns cited include the impact on birds and wildlife and issues regarding the integration of wind energy into electricity grids linked to perceived insecurity, high cost and low efficiency. Other effects are less frequently reported electromagnetic interference and land use (Devine-Wright, 2005; Wolsink, 2007).

☆ Avian interactions with wind turbines:

The development of wind farms can adversely affect the birds due to collision and electrocution of birds foraging habits change, reducing the available habitat and change in breeding and nesting. Positive aspects of this technology can also arise, such as protection areas, land supply, hunting and protection of nesting birds or indiscriminate hunting (Manwell et al., 2002). There is no consensus among experts about the importance of the impacts of wind farms on birds. According to Travassos et al. (2005) and Fielding, Whitfield, and McLeod (2006) have indicated that studies in this field are far from homogeneous. The results depend on issues such as the location of wind farms; the type of birds analyzed, or weather conditions. The ExternE report on wind energy (European Commission., 1995) assigns a medium priority for this impact and concludes that the existence of European studies and experience provide no evidence of significant impact for collisions of birds in the turbines. In contrast, Drewitt and Langston. (2006) have concluded that although many of the studies are either inconclusive or indicate that the effects are not significant for a particular kind of place and season, this should not be used as justification

for failure or bad rating future developments. According to these authors, there are relatively few studies that indicate significant impact that the improper location of wind farms can adversely affect wild bird populations.

☆ Visual impact of wind turbines:

Wind power installations have been heavily criticized for being a new element and they are sometimes located in highly visible locations in order to exploit the wind conditions (Kaldellis, Kavadias K., & Paliatsos A., 2003). The impacts of landscape are sometimes aggravated by the fact that sites with good wind resources are precisely the areas that are exposed upland valued for their scenic qualities, so they are environmentally sensitive (Moran & Sherrington, 2007).

Authors such as Bishop and Miller (2007), Manwell et al. (2002) and Kaldellis et al. (2003) have agreed that a major public concern and an important factor in determining public opposition to wind farms is the visual impact. The ExternE project considers the visual intrusion of turbines and related equipment, such as an impact that high on wind energy projects (European Commission., 1995). Regarding the visual impact of wind turbines are not well established and evaluation of the landscape is quite subjective (Manwell et al., 2002). Bergmann, Hanley, and Wright (2006) have studied on attitudes of people in relation to renewable energy indicates that the aesthetic pleasure of proposed wind energy is a controversial issue. Some people feel that wind farms are enjoyable to watch and represent renewable energy, while others consider them intrusive and a visual damage to the landscape.

Wolsink (2007) has examined some works on public attitudes in favor of wind power, concluding that the visual impact of wind on the landscape is by far the dominant factor to explain why some oppose the use of wind power, while other support. Devine-Wright (2005) presents the view that despite the predominant emphasis of the literature on the visual impacts of turbines, there is little evidence that wind turbines are universally perceived as ugly. The view on the visual impact of wind on the landscape varies between different countries and so the emphasis on aesthetics of a wind farm varies from country to country. Moreover, studies in the UK reveal that the preservation of valued landscape motivates most of the opposition (see, e.g. TNS (2003) and Warren, Lumsden, O'Dowd, and Birnie (2005)).

☆ Noise from wind turbines:

Noise levels can be measured, but the public's perception of the noise impact of wind turbines is very subjective. The ExternE project gives high priority to the impact and supports the idea that, while technical adjustments can be expected to reduce the problem, public awareness of the effects of noise of the wind turbine can still be significant (European Commission., 1995). Wind farms can be built without significant injury to the convenience, since the turbines are placed at a sufficient distance from homes. Appropriate planning requirements are essential to minimize this impact, but as Manwell et al. (2002) have noted, because of the wide variation in individual tolerance to noise, there is no completely satisfactory way to predict the adverse reactions.

Both mechanical and aerodynamic noise produced by wind turbines decrease with improved technology (Manwell et al., 2002; Moran & Sherrington, 2007). According to Kaldellis et al. (2003) due to the current output at low speed. However, studies such as Van den Berg G. (2004) have shown that there is not an insignificant issue. This author studied the noise of a wind farm in Germany, where residents of more than 500 meters from the park reacted strongly to the noise, as residents up to 1900 meters distance expressed annoyance. The main conclusions were that the actual noise levels were considerably higher than expected, and that wind turbines can produce sound with an impulsive character, further increasing the discomfort.

The economic, social and environmental perspectives are all included in the key elements of a sustainable energy system: sufficient growth of energy supplies to face human needs, energy efficiency and conservation measures, addressing public health and safety issues and protection of the biosphere. Thus, the sustainable development and sustainable energy planning are based on the same three dimensions, we mean, *economic, environmental* and *social* (Jefferson, 2006).

Energy resources have driven humanity life and history is still fundamental for continued human development and evolution. Throughout the course of history, with the evolution of civilizations, the human demand for energy has continuously risen up. The global demand for energy is rapidly increasing with human population growth, urbanization and modernization into societies. The growth in global energy demand is projected to rise exponentially over the next years. The world heavily relies on fossil fuels resources to meet its energy needs — fossil fuels such as oil, gas and coal are providing almost 80% of the global energy demands. On the other hand presently renewable energy and nuclear power are, respectively, only contributing 13.5% and 6.5% of the total energy needs (Asif & Muneer, 2007). The enormous amount of energy resources being consumed across the globe is having adverse implications and complications on the ecosystem of the planet.

## 2.5 SUMMARY AND CONCLUSIONS

Humankind evolution is closely linked to energy, since the beginning of time man has to know it and seeking it ever more on the environment. He began to enjoy and benefit from their potential. Thus obtained, greater adaptation to the environment that was often hostile and consequently sparsely inhabited. Respecting the means and knowledge of each period of evolution, man became sovereign in the environment, acquired with so much more responsibility, while that on the environment imposed serious changes to meet its development. As it evolved, the company acquired powers stemming from the nature and gradually increased his power over her, needing to preserve the environment in order to continue its development in a healthy way.

The primitive man first discovered, the potential energy contained in his body, received power to feed itself and the rest was consumed in the transportation and protecting other animals. Primitive man learned to use the energy contained in your body and thus dominate other species and survive in poorly relevant to the human race. Started to use the energy contained in the animals that could tame and over time learned to use this trick to get around, from horses and wagons to trains and aircraft. Moreover, he discovered the fire and according to Loftness (1984) the first discovery of man using fire as energy for cooking was their food and keep warm. With the discovery of fire and of course, the mastery over it began to prepare their best food, and not rely solely on the sun for lighting. Still used the fire to defend themselves against other animals or dangerous places that used to live. Thus, there is clearly a capability that the man had since primary season to adapt to the environment in which they live. According to the conditions that were exposed, he learned to manage them so that you could take greater advantage to them and to the society. From the moment we learned to take advantage of the benefits the fire, such as energy, brought to him, the man managed to improve their living conditions, therefore, enabled him to enjoy greater comfort in their day-to-day living day best in their community.

Over time, different energy sources were being explored allowing the evolution of man and society, with this development and from the moment the man was able to provide energy in a comprehensive manner the entire society. Currently available are several potential energy and have as main sources of energy, petroleum, coal, essential for society to evolve until the present time, however, there is great concern about the indiscriminate use, since attitudes yesterday are already reflected in many of the conditions in which we find ourselves. Energy production and use have unquestionable environmental impacts, contributing significantly to greenhouse gases and other pollutants. The use of more efficient technologies, together with the implementation of sustainable energy policies has contributed to an overall reduction in the intensity of  $CO_2$  emissions from energy consumption, particularly evident in Europe. However, the overall increase in energy consumption often outweighs the environmental benefits achieved as described for the particular case of Portugal. The need for renewable energy called for the implementation of environmental legislation, where the environmental performance of electricity production is a priority line of action. Important steps include ratification of the Kyoto Protocol<sup>10</sup> and a large set of European

<sup>&</sup>lt;sup>10</sup> The *Kyoto Protocol* is an international agreement linked to the *United Nations Framework Convention on Climate Change*. The major feature of the *Kyoto Protocol* is that it sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions .These amount to an average of five per cent against 1990 levels over the five-year period 2008-2012 (Greiner & Michaelowa, 2003).

directives: the promotion of electricity produced from renewable sources, creating the Emissions Trading Scheme and limiting emissions from large combustion plants.

Renewable energies have generally lower emissions than conventional power stations, making them strongly favored by the environmental regulations for the energy sector. However, renewable energy technologies are not free of negative impacts, although the public attitude in relation to renewable energy is generally positive, local people may react negatively to specific projects. In the particular case of wind energy impacts on the ecosystem, noise pollution (noise) and negative impacts on the landscape have been reported. By using variable production technologies such as wind power to generate electricity differs from electricity production by conventional power plants. Fluctuations in wind energy production occur in random pattern and must be compensated by the scalable production capacity compared to conventional production system (Rosen, Tietze-Stockinger, & Rentz, 2007). Because of this, wind power does not work as simple fuel savings because it cannot be controlled easily and accurately predicted (Olsina, Roscher, Larisson, & Garcés, 2007).

To properly assess the potential effects of wind on the system cost of electricity compared to other existing production systems should take into account the fuel savings and emissions avoided. Both the amount of  $CO_2$  reduction and additional costs attributed to the system depends on the characteristics of the electricity system under analysis. As the report stresses the EWEA (2005) the size and flexibility inherent in the power system are crucial aspects that determine the system's ability to accommodate large amounts of wind. Obviously, there are various environmental, social and economic benefits of emission reductions. However, calculating these benefits requires totally different modeling framework that have been considered beyond the scope of econometric and engineering approaches used for this kind of analysis.

Holttinen and Hirvonen (2005) have concluded that wind energy contributes to the reduction of end use of fossil fuel emissions, but in high levels of penetration, an ideal system may require changes in the mix of conventional capacity. Also Rosen et al. (2007) have noted that a growing range of fluctuations is a challenging phenomenon and the resulting effects cannot be ignored, nor the operation of the power system, or in long term planning for the expansion of wind energy. Variations of wind power will affect the scheduling of conventional power plants to an extent that depends on forecasting, as well as the flexibility of conventional energy producers in the geographic area of the system under consideration (EWEA, 2005). Although the possible impacts of wind energy also have significant variability (Dragoon & Milligan, 2003). So EWEA (2005) has pointed out that both supply and demand of electricity are variable and the variability of wind power can be provided in large measure. Regarding possible negative impacts associated with the irritation of noise intrusion and disturbance of the landscape ecosystem, its magnitude is specific to the local aspect. The installation of wind turbines is a critical issue in determining the level of impact (European Commission., 1995; Manwell et al., 2002).

In general, renewable energy technologies, named the wind power can provide an important contribution to reducing fossil fuel consumption and meet international environmental commitments. However, interconnection capacity, the combination of the existing capacity of production and characteristics of the wind power system to have a significant effect on how the variable production is assimilated by the system and on the extent of their contribution to meet the needs of modern society. The extent of this contribution deserves to be evaluated in economic terms via methods of economic and financial evaluation for these projects and their costs in order to ensure proper integration of wind power to meet current and future energy needs.

As has stated Khatib (2011) in a world in which the majority of us take the absolute availability of electricity and commercial fuels for granted, there are still 1.4 billion people that lack access to electricity. Also 2.7 billion people today still rely on biomass, and likely to increase to 2.8 billion in 2030 according to WEO 2010. This energy poverty is one of the big tragedies of our universe. Till today more than 40% of the world's population relies on non-commercial fuels in the form of biomass, waste, trees, dung, etc. to provide them with the necessary energy for cooking and heating.

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Ecclesiastes 1:6

## CHAPTER 3

# **GLOBAL STATUS OF WIND ENERGY**

- 3.1 Introduction
- 3.2 Organizational model in wind energy industry
  - 3.2.1 The diffusion model of wind power
  - 3.2.2 Trends in R&D for wind energy
  - 3.2.3 Structures and technologies to support innovation in wind power
  - 3.2.4 Analytical framework for wind power business
- 3.3 Wind resources worldwide
- 3.4 World wind energy market outlook
  - 3.4.1 Global wind energy market
  - 3.4.2 Wind energy converters manufacturers
  - 3.4.3 Economic impacts from wind energy industry
- 3.5 Summary and conclusions
- 3.6 References

This chapter presents the current situation of global wind energy industry. It is discussed about organizational model in wind energy industry within its diffusion process, R&D trends, innovation support schemes and the analytical framework for wind power business. World wind resources available and global wind energy market outlook are also presented. Summary and conclusions are presented at the end, with the respective references.

## 3.1 INTRODUCTION

Humanity is facing several critical global challenges at the beginning of the 21st century. One of which includes the quest for alternative energy resources that mitigate the dependence on fossil fuels. Whereas fossil fuels are available *in situ* at all times, the utilization of renewal energies has to cope with large temporal fluctuations ranging from seconds to seasons. The passing shadow of a cloud over solar panels causes the fastest variability of power output followed by the gustiness of the wind, the rise and fall of the tides and the seasonal and annual variations of the availability of biological resources for energy production. Thus, the kinds of questions being asked of the research community have changed over the last decades, reflecting the increasing awareness of the finite nature and the instability of fossil fuel supply.

Capturing wind energy has been widely employed for centuries — i.e. the traditional windmills of the Netherlands being a significant landscape element for centuries. To date, the emerging market for wind power energy is experiencing remarkable global growth rates which affect not only the problem of how to technically link these into existing power systems, but also effect deeply rural landscapes and local livelihoods. In many instances, initial positive local acceptance altered to the contrary, leading to sometimes strong opposition against the installment of wind turbines and wind farms in rural landscapes. Hence, solving this problem requires additional input of economists and social-political scientists. The emerging interdisciplinary research increased the understanding and helped to develop adequate solutions to many of the problems revolving around wind power energy. However, the disciplinary integration and interdisciplinary understanding must be much further advanced.

This chapter is a compilation of the different aspects of wind energy power systems. It combines several scientific disciplines to cover the multi-dimensional aspects of this yet young emerging research field. It brings together findings from natural and social science and especially from the extensive field of numerical modeling. Harvesting wind power requires the erection of towers with rotating wings in the landscape or at sea. Such artificial buildings with moving parts modify drastically the natural views of the panorama. This raises the question of what are the initial necessary societal preconditions and attitudes to erect a wind turbine.

This chapter examines the topic of global status of wind energy in order to establish a context for understanding the contemporary wind energy industry. It begins with a contextualization of the organizational model in wind energy industry currently (section 3.2), and briefly presents the diffusion model of wind power evolution (section 3.2.1), trends in R&D for wind energy (section 3.2.2), structures and technologies to support innovation in wind power (section 3.2.3) and analytical framework for wind power business (section 3.2.4). Section 3.3 relates wind resources worldwide with the global wind distribution, while the following section presents mains concerns and how wind resources worldwide are spreaded globally. Section 3.4 is related to world wind energy market outlook, especially emphasis on global wind energy market (3.4.1), wind energy converters manufacturers (3.4.2) and economic impacts from wind energy industry (3.4.3) which devotes special attention to the job creation by wind energy industry. Finally, section 3.5 presents the summary and conclusions of the whole chapter. Section 3.6 presents the references used.

## 3.2 ORGANIZATIONAL MODEL IN WIND ENERGY INDUSTRY

## 3.2.1 The diffusion model of wind power

Wind power systems are type of CoPS (Complex Product System) which are high-cost, engineering-intensive systems and never mass products for the final consumers. They are designed and produced on a project basis as one-offs for professional business. Unlike the final consumer, intermediate customers are intimately involved in the innovation process throughout the life cycle of the project. Technological accumulation is produced by the design, building and operation of the complex product system. The incremental improvement of technological improvement in complex product systems comes along as technological trajectory and they diffuse throughout the actor of best practice methods in design, manufacturing and construction (Davies & Hobday, 2005; Hobday, 1998). Wind power system also has multiple aspects such as technological system (Hughes, 1983), which receives the influence of non-physical artifact such as institution. To evaluate the effect of technology and policy in the diffusion process and recognize the mechanism which promotes this process is also our concern. In this paper, we propose a dynamic diffusion model in which supply and demand of innovations make progress by coexisting with existing energy system (e.g. fossil power station, nuclear power station). It is supposed more rational that wind power is carried out in complementing the existing energy system rather than supplying electric energy independently.



**Figure 3.1** Diffusion model for wind power production system. Source: Inoue and Miyazaki (2008)

This diffusion model of wind power is shown in Figure 3.1. To promote the diffusion of wind power, economic factor is essentially important. For example, investment costs should be collected by electricity obtained by wind power. In order to collect investment cost, equipment has to be enlarged and we should pursue raising economies of scale. While the demand level about quality and safety is high in the market for using electricity obtained from wind power, the value is relatively low. Although its electricity is now approaching to produce profits, there are several

problems in economic efficiency under the present circumstances. At first, the battle against global warming initiates the supply target of innovation (wind power), which could coexist with other existing energy system and help to reduce global warming. Government, industry and academic organizations are involved and the acts which could solve the above-mentioned problems are taken into consideration institutionally since it would not be a problem attributed only to industry.

The emphasis of technological development is put on safety, improvement in performance and reduction of manufacturing cost so as to penetrate this technology in the market by industry-government-academia collaboration. Industry raises the knowledge in connection with manufacturers to get over the critical point lying ahead. Then learning effect reduces the installation costs of wind power systems. In parallel, government could support the installation of wind power systems to get over the critical point so that the wind power systems have the competitive edge by which running cost can compete with other existing energy system on the basis of net present value. Even if a wind power systemic measures that avoid some critical points are taken into consideration in this institution, from the stand point of a battle against global warming or energy security (Mowery & Rosenberg, 1979, 1998).

Often, collaborative R&D needs public support. The EU through the *Sixth and Seventh Framework Programmes* for research and development introduced the concept of technology platforms. These provide an opportunity for collaboration between a wide range of stakeholders, including industry, academia, politicians, the public, etc. In the present technology platforms in the renewable energy sector exist for solar photovoltaic, wind power, solar water heating and biofuels (IEA, 2010).

Rogers (1982) analyzed the diffusion problem most vigorously from a sociological standpoint and he showed the model of the innovation-decision process as a process through which an individual passes and the diffusion curve with labeling for the five adopter categories. Rogers explained the relation between the influence of communicating information and adoption decision in the earlier phase as well as the characteristics of adopters and the relative time progress of diffusion in the latter phase. However, Rogers' model is taking into consideration only for the diffusion process of the demand side. In the case of the standard concept which is unified in producing diffusion of innovations, Rosseger (1996) mentioned that standard versions of a new technology do emerge, 'bugs' are worked out by early adopters, market results are reported, and thus the quality of information which is available to later adopters improves. However this assumption is not demonstrated with the on-going phenomenon of supply and demand side (Ortt & van der Duin, 2008).

Institutions are broadly defined by economists and innovation theorists as social, political, and economic organizations that determine the working environment for systems to develop within. Institutional economists emphasize the role that institutions play on the outcomes of economic operations more than their neoclassical-school counterparts. How important an industry's working environment is when examining technology development and cycles. For instance, the direction of domestic technology innovation can be influenced by knowledge spillovers due to international trade, the flexibility and ease of information flow from the university system, and the structure and patent making ability of the legal system. These institutional dynamics can vary widely across

countries, both within and across different development levels. As such, global rates of technology development do not always imply similar rates of technology diffusion in particular domestic markets (Kobos, Erickson, & Drennen, 2006).

The types of institutions influencing innovation, and ultimately technology diffusion, have been categorized as horizontal, nonmarket, and vertical. Horizontal institutions include those in which large technical interdependencies exist between products or organizations. Positive feedbacks can emerge between horizontal institutions as, for instance, RD&D in one industry can lead to innovation or increased market potential in the other. In renewable energy technology, horizontal manufacturing structures may be necessary to successfully penetrate the market. For example, energy efficient home construction would benefit from well-designed solar thermal water heating systems. Nonmarket institutions are designed for goals not explicitly focused on short-run profits. These include professional societies, governmental agencies, and university-level research centers. These institutions often provide the necessary basic research and generic market promotion for incubating new technologies. They are often designed as subsidies to industry development and their effectiveness is often dependent on political goals and agendas when *'society has found it necessary to supplement the usual market mechanism by additional institutions''* (Mohan Reddy, Aram, & Lynn, 1991).

Government and other organizing entities can often work to administer a coordination system. Figure 3.2 illustrates a conceptual framework for learning between individuals (e.g. workers and groups of workers) and the organization as a whole. The solid arrows represent flows of knowledge spillovers; the dashed arrows represent knowledge feedbacks. These feedbacks reinforce the role of knowledge stock solidarity (standardization) and quality control. For example, a knowledge spillover or *feed forward* from the organizational level to the individual level can include implicit on-the-job training. While a feedback from this knowledge transfer (production) would include suggestions and discussions, these individuals have with the management directing the organizational training programs and work environments.



Figure 3.2 A dynamic process of organizational learning. Source: Kobos et al. (2006)

Today, wind power is often subsidized, but it is approaching a cost level that makes it economically attractive compared to established energy production methods, assuming good wind conditions. As the experience curve of electricity produced by wind turbines is not entirely flat — a proposed ratio of 0.91 according to Neij (1997).

Cost reduction effects are specified as a three-parameter functional form, which by design permits the determination of optimized levels of R&D support for a given technology (Miketa & Schrattenholzer, 2004). The experience curves and bottom-up evaluations of wind turbines indicate that further cost reductions will be possible in the future. (However, these cost reductions cannot be seen in the price development path of wind turbines at present). In general, the results show incremental cost reductions for both on-shore and off-shore wind turbines, and the reduction in the cost of wind-produced electricity will be greater than the reduction in the cost of wind turbines. Bottom-up evaluations support an incremental development path of wind turbines —which may be reflected in an extrapolation of the experience curve — i.e. using a learning rate of approximately 10% for both on-shore and offshore wind turbines. To illustrate the greater cost reduction identified for producing electricity (including efficiency improvements and reduction of operating and maintenance costs), a higher learning rate should be used, e.g. a learning rate of 15% for wind turbines and wind turbines placed in less windy areas and a learning rate of 20% for off-shore wind turbines and wind turbines placed in windier areas (Neij, 1997).

A restriction on further cost reductions in wind produced electricity will arise due to the limitation of favorable sites, as many of the best sites for wind turbines have already have been used. However, this will be a greater problem in countries that have already invested in large numbers of wind turbines. Due to the consensus on incremental improvement of wind power, a sensitivity range of 72% of the learning rate is suggested (Neij, 2008). Wind energy has grown a lot over the last years and this spectacular growth has attracted a broad range of players from across the industry value chain — from local, site-focused engineering enterprises to global, vertically-integrated utilities (see Figure 3.3).



Figure 3.3 Wind energy industry value chain. Source: EER (2007)

Since Europe's surge in 2005 to an annual market of over 6.5 GW of new capacity, the industry's value chain has become increasingly competitive as a multitude of enterprises seek the most profitable balance between vertical integration and specialization (EWEA, 2009). More and more utilities take position on the wind energy value chain to comply with national renewable targets, and/or to take the initiative of seeking international expansion with this newer production technology. Large-scale utilities have thus started to build sizeable project pipelines with long-term investment plans what lead to an overall scaling up of the sector. To maximize profitability, utilities have steadily migrated from risk-averse turnkey project acquisition, to greater vertical

integration with in-house teams for development and operations and maintenance (O&M). Strategies devised by these players for meeting their objectives have largely depended on their experience in the sector as well as on their desire to expand geographically. At the same time a market remains for independent players able to contribute development skills, capital and asset management experience.

As a result, Europe's wind energy value chain is currently shifting as asset ownership is redistributed, growth is sought in maturing markets and players seek to maximize scale on an increasingly pan-European stage. Utilities build up GW-size portfolios, through their own strategy initiatives or government prompting. IPPs seek to compete for asset ownership in booming Western European markets. In general, development activity continues to shift towards new regions in the east. The proliferation of players looking to develop, own or operate wind farms has pushed competition to a new level, underlining the key elements of local market knowledge, technical expertise and financial capacity as crucial to positioning on the value chain. Before utilities began adopting wind energy, vertically-integrated independent power producers (IPPs) started aggressively exploiting wind turbine technology to improve their positioning. There are two main types of IPP in Europe (EWEA, 2009):

- integrated IPPs, which have capabilities across the project development value chain and exploit these for maximum control and returns on their project portfolio,
- wind project buyers, which tend not to play a direct role in the development of wind plants in their portfolio as these enterprises are often financial investors, rather than energy players.

The number of these players that are active has continuously increased as utilities have sought acquisitions among this field of asset and pipeline holding competitors, though those that are already a significant size may be positioned for long-term growth. In terms of development, integrated IPPs are continuing to expand internationally, through green field project development and acquisitions, in order to compete with utilities. Players with strong holds in Spain, France or Germany consistently look for growth in Eastern Europe, while some are also taking the plunge offshore. More risk-averse IPPs are seeing the number of quality projects available for acquisition in mature markets continues to dwindle.

As wind power owners, IPPs are facing harder competition from utilities as several project portfolios have been acquired in markets such as Spain, Germany, France and the UK. IPPs generally have higher capital costs than utilities and those that can create assets organically through development on their own are generally better positioned to enlarge their portfolio. As asset managers on the value chain, integrated wind IPPs and project purchases are distinctly different, with integrated players increasingly focusing on O&M to maximize asset values. The boom in MW additions in the last years means many turbines are coming out of their warranty periods, requiring IPPs to make key strategic decisions on how to manage their installations.



Figure 3.4 Europe wind value chain positioning. Source: adapted from EER (2007)

In the USA, utilities have been, from the beginning on, the main players in the wind energy market. The value chain of a component producer like the China Wind Energy Inc. looks as the following in Figure 3.5.



Figure 3.5 Value chain – production of wind components. Source: EER (2007)

A less well understood feature of innovation processes is the intermediate stage between demonstration and diffusion that can be considered a market formation or '*early*' deployment stage (often referred to as niche markets) (Anadon & Holdren, 2009). Governments can play a crucial role creating initial markets; in doing this, governments can encourage reductions in costs, improvements in quality and functionality, and overall a better definition of the product for the customer (Gallagher, Anadon, Kempener, & Wilson, 2011).

The innovation literature highlights other important findings. Innovation is a product of complex systems, in which feedbacks from the different stages of the innovation chain and the ability to learn from market experience are crucial. Also, major innovations involve co-evolution of technologies and institutions that support them. There may be several reasons for this low inherent innovation-intensity. Processing large amounts of energy may inherently involve big capital investment and long timescales, which naturally increases risk and deters private finance; each stage in the innovation chain can take a decade, and diffusion is equally slow (Grubb, 2004).

## 3.2.2 TRENDS IN R&D FOR WIND ENERGY

The beginning of the process is the Research and Development (R&D), followed by demonstration and pilot production. This leads to early market introduction and finally, market diffusion. While different RETs are at different phases of market development, the research in diffusion analysis in renewable energy sector points towards the following approaches (Rao & Kishore, 2010). Empirical analysis of the historical development, current status, and future expectations for wind energy electrical power production (i.e. onshore power production) can be summarized as a 3-stage empirical industry life cycle illustrated in Figure 3.6, featuring three generic Stages of Exploration (or Development), Acceleration (or Dominant Design), and Maturation.



**Figure 3.6** Wind energy technological innovation – projected 210 years industrial technology life cycle. Source: Dismukes, Miller, and Bers (2009)

The change in policy to support private research — as opposed to collaborative research in the public domain — is likely to increase the influence of market forces on the choice of the project — and therefore the choice of technology. While this may be beneficial in terms of short-term deployment of new renewable technologies (RETs) alone, this may mean less opportunity that might exist to regulate the support given to specific technologies ...If the trend appears in the field of renewable energy, it is likely that brings a short-term perspective, possibly reducing the support for RD&D in technologies that are considered to have a great potential long-term, but are still relatively distant from the market, compared with more mature alternative (IEA, 2008).

The European Technology Platform for Wind Energy (TPWind) identified as thematic areas for R&D in wind energy for the next 30 years, the following aspects (IEA, 2010; TPWind, 2010b) as shown in Table 3.1.

Thematic areas	Focus
Wind conditions	Develop more efficient methods for determining wind resources and identifying regions rich in poorly-exploited wind resources, in order to enable increased and more cost-effective wind farm assets. <i>Key areas in</i> <i>this thematic may include: advanced sitting and wind characterization</i> <i>models. Wind resource mapping, advanced wind power forecasting</i> <i>techniques. Advanced measurements techniques including remote sensing.</i>
Wind power systems	Aspects of wind turbine technology, both offshore and onshore, which have the potential to increase the competitiveness of wind energy, and to minimize the lifetime cost of electricity produced by wind power systems. <i>Key areas in this thematic may include: Materials, Drive-trains, Blades, O&amp;M and Wind turbine design and efficiency increase.</i>
Wind energy integration	Large-scale integration of wind power (300 GW), by enabling high penetration levels (>20%) with low integration costs, while maintaining system reliability (security of electricity supply). <i>Key areas in this thematic may include: Grid codes/communication standards, Grid structure and planning, Grid operation and energy management (prediction tools, probabilistic capacity planning, and storage facilities), Energy market integration (converting stochastic wind energy production into energy market products, providing additional grid services to TSO's and DSO's).</i>
Offshore deployment and operations	Environmental impact, social acceptance, spatial planning and the economic impact of R&D and innovation for offshore wind energy. <i>Key areas in this thematic may include: safety and access to offshore turbines, new and improved concepts for offshore wind turbines, design and fabrication of offshore substructures, new concepts for assembly installation and hookup of large scale developments, offshore cables and connectors, operations and maintenance, spatial planning and decommissioning.</i>

 Table 3.1 Thematic areas with R&D focus for wind energy by TPWind

Source: Strategic Research Agenda/TPWind (2010b)

It is noteworthy that efforts RD&D already have excellent results, such as core R&D engineering at the University of Risoe, Denmark, successfully completed the first practical tests of a new wind turbine — the gigantic fan responsible for energy production wind — that can anticipate and react to changes in the wind by optimizing the production of electricity. The results show that this system can predict the wind direction, wind intensity and even turbulence. With this, it is estimated that a future production of wind turbines may increase energy production and at the same, reduce extreme loads that impact on their lifetime.

The system added to the wind turbine is a kind of laser anemometer, which scientists call "LIDAR of wind". LIDAR (Light Detection And Ranging) is a kind of "radar light", which uses a laser beam to detect the spatial distribution of temperature and humidity in the atmosphere. It likes a radar sends radio waves and measure their reflections, a LIDAR sends light waves. The "eco" in this case, this wave is the reflection of light by different layers of the atmosphere. The incorporation of LIDAR means that wind turbines are now able to "see" the wind through the detection of variations in air mass. In predicting the wind to reach the next moment, the turbine can optimize their position and adjust the pitch of its blades for wind to be used more efficiently and last longer than the turbine. The engineers say the laser technology increases energy production by up to 5%, mainly because it allows the use of longer blades. For a wind turbine with capacity of 4 MW, this represents a financial gain of \$ 200,000 per year (DTU, 2010). LIDAR system can be used to enhance the durability of the blades by allowing them better cope with the irregularities in the wind. In a second step, it becomes possible to manufacture blades longer. This will increase the production of energy and make wind electricity competitive. The wind turbine industry is booming, it is expected to grow tremendously in coming years, thanks to the global focus on renewable energy and in response to climate changes (IEA, 2010).

Finally, it is necessary that all countries have access to technologies that enable them to build the most efficient new power plants and industrial facilities and install energy efficient equipment. Much of the development of this technology is currently being undertaken within the OECD countries, but most of its deployment will need to be elsewhere (Clark, 1985). As example of a network which can help in technology development deployment is the IEA Implementing Agreements (in which both member and non-member countries work and co-operate), which provide a framework for joint research projects, discussion of specific technology issues and information exchange.<sup>11</sup>

According to Wagner and Epe (2009) to promote wind energy, the research needs need to be identified and the research work carried out. Initially, there are such environmental and social challenges as integration into the landscape, noise impact, bird flight paths, life cycle analysis and sustainability. And of course, wind turbine and component design have to be improved continually, i.e. basic research in aerodynamics, structural dynamics, dynamic forces, new materials, feasibility studies into new systems, generators using permanent magnets, gear boxes, etc. For planning and building wind turbines and wind farms, commonly accepted certification procedures must be formulated and standardized.

Governments, industry, research institutions and the wider energy sector will need to work together to achieve this goal. Best technology and policy practice must be identified and exchanged with emerging economy partners, to enable the most cost-effective and beneficial development. The technology road map for some of the most important technologies (wind energy) developed by the IEA (2009). At the industry level, two methods to track the diffusion of wind turbine technology provide some insight. If technological change is occurring in wind turbines, we would expect that the cost of electricity from these turbines is decreasing, since cost is the performance characteristic about which users care most. Additional insight is gained from further exploring the trend of

<sup>&</sup>lt;sup>11</sup> IEA (2007), Energy Technologies at the Cutting Edge.

decreasing cost of electricity. The three primary means of reducing the cost of electricity from wind turbines are (1) reducing the capital cost of the turbine, (2) reducing operations and maintenance (O&M) costs, and (3) producing more electricity without an offsetting increase in either capital or O&M costs (Loiter & Norberg-Bohm, 1999).

## 3.2.3 Structures and technologies to support innovation in wind power

As currently understood, then, technological innovation is characterized by multiple dynamic feedbacks between different stages of the process; as Fri (2003) states, *"the process of innovation is typically incremental, cumulative, and assimilative."* It is nonetheless often useful for analytical and prescriptive purposes to treat the stages separately, and we frequently do so in this article. The stages of energy technology innovation to be considered comprise fundamental research, applied research, development, demonstration, pre-commercial and niche deployment, and widespread deployment (often also called diffusion). Technology transfer between countries is often envisioned as a part of diffusion, but it can also occur at earlier stages (Gallagher, Holdren, & Sagar, 2006).

The wind energy market surpasses its own record every year. The market growth rates are in the same range of technologies such as high technology (internet, phone and so on). Europe leads the world in terms of facilities and production, with most of the ten largest manufacturers of being European. A popular misconception is to consider wind power as a mature technology, where R&D efforts are not necessarily needed. As a result, there is a risk of progressive loss of European leadership, as demonstrated by recent developments in wind energy sector: (i) High demand has increased the time of delivery of wind turbines and the prices of raw materials like steel and copper have increased in recent years, which means that the cost of wind turbines has increased and (ii) Although most manufacturers of wind turbines is still Europeans, two Chinese companies (Goldwind, Sinovel) and an Indian company (Suzlon) entered the market (IEA, 2010).

The private sector in funding research is significant, but exact figures are hard to find. Many companies can invest in the region of 3-5% of revenues in research. In some cases, the RD&D intensity is even greater. In Europe, after the start of the *Technology Platforms* for individuals and groups of technologies, the private sector is being encouraged to interact with the public sector, especially in long-term research; the intention is that private companies can share the investment with the public sector. The TPWind is the indispensable forum for the crystallization of political and technological research and development paths for the wind energy sector, as well as a new opportunity for informal collaboration between the Member States, including the least developed in terms of wind energy. The aim is to identify areas of TPWind greater innovation, research new and existing development tasks. These, then, to be prioritized based on urgency of the technology sector; the main objective being global (social, environmental and technological) is cost savings∴This will help achieve the objectives of the EU in terms of renewable energy production. The platform is to develop coherent recommendations, detailing specific tasks, approaches, participants and the necessary infrastructure within the private investment in R&D as well as Member State and EU programs, such as FP7. TPWind will also assess the overall funding available for this work, from public and private sources (TPWind, 2010a).

Wind power is the technology leader in renewable energy. Having regard to the right support could provide up to 28% of EU electricity by 2030. However, this target will be achieved if the sector and policy makers continue to think in the short term. Long-term, strategic technology and policy research are fundamental: TPWind facilitates the development of effective and complementary national and EU policy to build markets, and a collaborative strategy for the development of technology. Your ultimate goal is to reduce costs to parity with cheaper technologies for alternative production of electricity (TPWind, 2010a).

TPWind is composed of stakeholders from industry, government, civil society, R&D institutions, financial organizations and most of the energy sector in the Member State and EU. It is unique: the only body with sufficient representation or "critical mass" of knowledge wind and specific experience to be able to fully understand and map the paths and realistic priorities for policy and technology R&D, taking into account the wide range of needs the sector. In parallel, the European target of 20 percent of energy production from renewable sources poses new challenges. In its recently published *Strategic Research Agenda*, the European platform for wind energy, TPWind proposed an ambitious vision for Europe and viable. In this view, 300 GW of wind power capacity would be delivered in 2030, representing up to 28 percent of EU electricity consumption. To implement this vision, an average of 10 to 15 GW of additional capacity will be manufactured, delivered and deployed in Europe each year. This is equivalent to more than 20 turbines of 3 MW to be installed on each day (GWEC, 2010; TPWind, 2010a). Moreover, the vision TPWind includes a sub-goal of wind power represents about 10 percent of EU electricity consumption by 2030. They propose an intermediate step of the execution of 40 GW by 2020, compared to 1 GW today. In this sense, R&D is needed on two fronts:

- 1. An efficient implementation of TPWind vision for wind energy, supporting the implementation of european goals and,
- 2. Ensuring European leadership in the long term through technological leadership.

According to Xu, He, and Zhao (2010) recently, along with the establishment of market economy system and wind power market, the wind power industry has achieved "*market-oriented operation, industrial management*" and now it has stepped into a fast development stage.

The high degree of complexity for wind energy industry with respect to each of the four generic radical innovation challenges and resultant *hurdles*<sup>12</sup> has exerted a significant influence on life cycle development time. From a science and technology standpoint, the multidisciplinary knowledge needed for successful wind energy electrical systems spanned a number of fields that only came into being progressively during the entire 20th Century. These include: fundamental aerodynamics of converting wind power to electrical power, power electronics, electrical control systems, development and manufacture of large, cost effective composite wind turbine designs, computing, communication and information technology, and reliable and cost effective linking to

<sup>&</sup>lt;sup>12</sup> According to Dismukes et al. (2009) "hurdles "can be understood as Scientific and Technological Challenges, Business and Organizational Challenges, Market and Societal Challenges, and Cluster and Network Challenges. The authors developed a new ARI model for providing a holistic approach to understanding the dynamics of the industrial technology life cycle for a wide variety of radical innovations as well as wind electrical power. For more information read Dismukes, J. P., Miller, L. K., & Bers, J. A. (2009). The industrial life cycle of wind energy electrical power production: ARI methodology modeling of life cycle dynamics. *Technological Forecasting and Social Change*, 76(1), 178-191. doi: 10.1016/j.techfore.2008.08.011

the electric utility grid.



**Figure 3.7** Stages of the technological process in the wind energy industry. Source: Adapted from IEA (2010)/R&D Trends Worldwide

According to Figure 3.1 and Figure 3.2 energy policy can influence the development of technology and capturing market (marketing), through the interaction of three main types of policies that target families or subsets of these technologies in progressive stages of technological maturity:

- Policy Research, Development and Demonstration (RD&D);
- Policy deployment market (also called policy of support or promotion), and
- General Policies of the energy market.

As featured in Figure 3.8 the structure of TPWind, where the issues raised by themes, are concentrated in areas where improved technology leads to significant cost reductions.



Figure 3.8 TPWind organizational structure. Source: TPWind (2010a)

Through a strategic research agenda, TPWind encourages Member States, EU institutions and the wind industry to intensify research efforts in accordance with market needs, in view of medium and long term. TPWind encourage research results in the long term, taking into account that new prototypes for wind energy are being developed.

For Kaldellis and Zafirakis (2011) what is important to consider is that for the aforementioned goals to be realized, R&D targets set must be put forward by the wind energy industry, with the main directions and actions to be taken including the following:

- New wind turbines need to reduce their overall costs
  - Large scale turbines of 10-20 MW going offshore (R&D programs for prototypes already initiated)
  - Improved design and reliability of components (Testing facilities to assess efficiency and reliability of wind turbines)

- Development of innovative logistics (Cross industrial programs)
- Deeper waters and larger turbines for offshore
  - Development and industrialization of support structures for sea installations, both fixed and floating (Structure concepts to be developed and tested at different depths and under different conditions)
- Achieve grid integration for even greater wind energy penetration
  - Introduction of large-scale energy storage systems and high voltage<sup>13</sup> alternative and direct current (HVAC-HVDC) interconnections (Offshore farms connected with more than one grid, long distance HVDC, R&D of energy storage systems)
- Resource assessment and spatial planning
  - More sophisticated assessment of wind resources (High quality measurements and databases for wind data as well as short-term wind speed forecasting with the use of neural networks)
  - Spatial planning through social and environmental considerations (Development of planning tools and methodologies)

It is necessary to clarify the energy sector, in others words, wind energy industry is a technology cluster. Another aspect of importance is the concept of technology clusters. This is based on the fact that a technology does not develop alone but is related to and depends on other technologies as well as infrastructures, institutions, networks of actors, etc. Multiple interrelated diffusion processes contribute to the evolution. Adoption and diffusion of technology occurs as a collective evolutionary process. The complex interactions where technologies mutually reinforce and cross-enhance each other drive to the conformation of technological clusters, that is, families of technologies evolving and diffusing together, and the constitution of associated networks of economic and social actors. The members of a cluster are related by multiple links that contribute to magnify their economic, social and environmental impacts. These multiple relations contribute to make progress in one of them relevant, directly or indirectly, to other members of the cluster, as it helps to reinforce their own position in the marketplace (Barreto & Kemp, 2008).

#### 3.2.4 ANALYTICAL FRAMEWORK FOR WIND POWER BUSINESS

In a business that aims to create value, the diffusion of a technology may be the key to its success. To that end, one should increase the availability through technological innovation, to ensure use by many people and create economic value for the business owners, who are the principal actors.

<sup>&</sup>lt;sup>13</sup> The power supply system is divided into: a) low voltage (LV) system (nominal voltage up to 1kV); b) medium voltage (MV) system (nominal voltage above 1kV up to 35kV) and c) high voltage (HV) system (nominal voltage above 35kV). For more details, please see at (European Commission, 2001)

Actor	во	во	ЕРС	Manufac.	EPC	во	Elec.Comp.
Process	Investigation Discussion Environmental Assessment	Project finance Investment	Grand design Selection of WT,Electric Procurement	Wind turbine Electric Equip.	Scheduling Transportation Installation Testing	E.Generation Feed in Maintenance	E.Purchace Transportation Distribution
Typical Period	1-2 Y	4	0.5Y	0.5Y	0.5-1Y	Over 17Y	
Phase	Develop.	Finance	Design	Manufact.	Const.	0 & M	Power Dist.
	EPC Engineering Procurement Construction O & M: Operation & Maintenance		S service	<b>BO Business</b>	owner		

#### CHAPTER 3 GLOBAL STATUS OF WIND ENERGY

Figure 3.9 Structure of wind power business process. Source: Inoue and Miyazaki (2008)

As shown in Figure 3.9 the initial verification of the business process of wind power production might be worthwhile. The business process of wind power production can be broken down into the development phase, involving 1) wind survey and an environmental evaluation at the point of wind power production, 2) financing phase in which construction funds are raised, 3) system design and procurement phase in which wind turbines and system interface for electrical facilities are designed and constructors are selected, 4) equipment manufacturing phase in which wind turbines and system interface for electrical facilities are built, 5) testing phase in which transportation, installation and testing are carried out, 6) operation and maintenance phase and power distribution phase.

No problem can be envisaged because the business process of wind power is designed to allow economic value to be obtained by the competitive strategies of the electric companies, wind power proprietors, EPC (Engineering Procurement Construction) builders, and equipment manufacturers, all of whom participate. This business process seems free of any potential obstacle to the successful acquisition of economic value for four reasons. Firstly, the power company would gain from the margin between the prices paid by the power company to purchase power from the wind power producer and the power charges paid by consumers. Secondly, the wind power owner would benefit from saving on its costs of power production with wind turbines located under good wind conditions. Thirdly, the EPC builder would benefit from savings made by man-hours, derived from a reduced procurement cost and efficient construction scheduling. Fourthly, the equipment manufacturer would benefit from saving costs from the experience effect.

For Lund (2007, 2009) the commercialization process of new technologies can analytically be explained through so-called learning curves that effectively integrate policies and associated learning investments into a unit cost curve that decrease with cumulative volume. At the breakeven point, the new energy technology becomes cost-effective over the traditional energy. The policy measures supporting commercialization can be split into two main categories namely *technology push* such as R&D that improve the innovations and *market pull* measures such as market deployment support that increase demand for the new technology. These main categories are further elaborated in Figure 3.10 into more specific measures. A market breakthrough often requires optimal mastering of the whole process and a right balance of different measures over time. In addition to the traditional energy policy measures, more renewable energy

technology/product specific support may be very important to enhance industry growth. An important market pull policy measure in several countries is induced demand, such as feed-in-tariffs, green certificates, investment grants, RES quotas, etc. (Arentsen et al., 2007).



Figure 3.10 Commercialization process of new energy technologies. Source: Lund (2009, p. 54)

Hence, in order to interact, enterprises and other actors need to identify themselves as part of a system, see the common problems and opportunities they face and the value of collective action for framework of wind power business work as a perfect chain. In essence, therefore, network formation reflects the consciousness and practical realization of parts of the collective dimension of the innovation and diffusion process for wind energy business. Without such a consciousness, user–supplier relationships will be arms-length, university–industry relationships may not develop and political networks will not be formed (Bergek, Jacobsson, & Sandén, 2008).

## 3.3 WIND RESOURCES WORLDWIDE

The development of wind energy in many regions of the world faces the lack of reliable and detailed wind resource data in that site. Availability of these data is necessary for public authorities and other economic agents involved to identify wind power production potential and to promote rightly actions on that information. To overcome this difficulty, the National Renewable Energy Laboratory (NREL) and other organizations have, since the last five years developed new methods and approaches to more accurately assess the wind resource and produce detailed high-resolution (l-km) wind maps for essentially anywhere in the globe∴The NREL methodology for creating large-area wind resource maps is force-task for unifying global terrain and climatic data sets, Geographical Information Systems (GIS) technology, and analytical and computational techniques (Elliott, 2002). The modeling and wind resource predictions that do not need to rely on countrysupplied data were permitted by the global data sets and analytical tools at NREL. In many regions of the globe, reliable surface wind data are sparse and often not available for areas of interest for producing electricity by wind technology. However, the use of weather balloon and satellitederived wind data with computer mapping system enables NREL to create wind resource maps with reliable information even if high-quality surface wind data are not available yet. Wherever available, reliable surface wind data are useful in providing field truth verification of the model predictions.

When we analyze different technologies of power production including fossil fuel or renewable energies the main concern the fuel consumed or avoided. What is the best technology of power production (of electricity or heating)? Are the power plants in the right places? How much is it available for electricity demand? What is the production cost for each kWh of electricity produced? What emissions does it have for each kWh of electricity produced? How much residue does it leave? For wind power technology, the wind resource is "*free of fuel*" and "*free of charge*" and these questions are as relevant as they are for any other source. As wind is "*free*" and "*green*" so the concern about fuel makes no sense∴Questions about wind resources, however, are very important and essential for wind technology development. When we talk on a global scale, it is not difficult to find many studies about the enormity of the wind resource, and how it could be theoretically used for facing the global electricity demand in several times over. For example the collaboration by researchers at Harvard University in the United States and VTT in Finland that concluded that "*a network of land-based*, 2.5 MW turbines, restricted to non-forested, ice-free and nonurban areas, operating at as little as 20% of their rated capacity could supply more than 40 times current worldwide consumption of electricity" (Lu, McElroy, & Kiviluoma, 2008).

A comprehensive study by researchers from Stanford University's Global Climate and Energy Project focuses its conclusions on five years of data from the US National Climatic Data Center. Using an extensive set of surface and balloon measurements, they concluded that 13% of the sites tested had a good wind resource (Class<sup>14</sup> 3) at 80 meters off the ground, and using one in five of these sites for power production would allow wind energy to meet the world's electricity demand

<sup>&</sup>lt;sup>14</sup> Wind classes determine which turbine is suitable for the normal wind conditions of a particular site. They are mainly defined by the average annual wind speed (measured at the turbine's hub height), the speed of extreme gusts that could occur over 50 years, and how much turbulence there is at the wind site. The three wind classes for wind turbines are defined by an *International Electrotechnical Commission* standard (IEC), and correspond to high, medium and low wind. For more information, please see <u>http://www.iec.ch/</u>.

(considering the data of year 2000) seven times over (Archer & Jacobson, 2005). In the same objective, an earlier study in 2003 by the German Advisory Council on Global Change calculated that the global technical potential for electricity production from both onshore and offshore wind technologies was 270,000 TWh per year. Considering 10% to 15% of this was executable in a sustainable manner, the resulting 39,000 TWh would meet more than double the current global electricity demand. A literature search shows up numerous similar studies with broadly similar conclusions (GACGC, 2004). According to Rosa (2009, p. 5) "30% of the 173,000 TW of solar radiation incident on Earth is reflected back into space as the planetary albedo<sup>15</sup>. Of the 121,000TW that reach the surface, 3% (3600TW) are converted into wind energy, and 35% of this is dissipated in the lower 1km of the atmosphere. This corresponds to 1200TW. Since humanity at present uses only some 15TW, it would appear that wind energy alone would be ample to satisfy all of our energy needs".

The studies have different results, because it depends on its assumptions used. For estimation of wind power potential is necessary to make assumptions about the size, capacity factor and rated power of the turbines used, which varies from study to study. We must highlight the higher the wind turbine is working, the better the wind resource is. Further, higher wind turbines or wind farms are less to be affected by turbulence caused by natural topography, surface roughness or other effects of *orography*<sup>16</sup>. Even more, the technology evolution can not only increase the capacity factor of wind turbines, but also the range of wind speeds in which they can work, thus broadening the range of sites at which they can be installed.

Another variable concerns assumptions about the land areas on which wind turbines can be deployed. While most studies will focus on conservation areas, forests and urban sites, some types of agricultural land such are easily compatible with wind farms installations without constraining the overall wind potential of a region ... In the case of offshore wind resources the methodologies for evaluation of its availability also differ in terms of assumptions used. An assumption needs to made concerning the areas in which wind farms can be built, both for technical reasons (maximum technical/economical distance to shore, water depth etc.), as well as taking into account environmental and regulatory limitations (nature reserve areas, shipping lanes, minimum distance to shore, etc.). Some new configurations that deploy turbines on floating structures and are thus suitable for use in deep water are at a preliminary stage of test deployment (Bilgili, Yasar, & Simsek, 2011). These could dramatically increase the technically usable fraction of the offshore wind potential. Evidence from a large number of studies into the world's wind resources suggests that there is no shortage of suitable sites for wind power development. However, it is worth noting that the rate of deployment of wind power in each county has largely been dependent on political will rather than resource criteria. Germany has a lower wind potential than many other European countries, yet its favorable political climate has led to fast and large-scale deployment of wind power. On the other hand, there are several parts of the globe with a good wind resource – places such as Argentina, Russia and South Africa – where development of wind power has barely started (GWEC, 2011a).

<sup>&</sup>lt;sup>15</sup> The amount of energy reflected by a surface is called *albedo*. Albedo is measured on a scale from zero to one (or sometimes as a percent). For more explanation, please see Goode et al. (2001). <sup>16</sup> It is the study of the formation and relief of mountains and can more broadly include hills, and any part of a region's elevated terrain.

<sup>&</sup>lt;sup>16</sup> It is the study of the formation and relief of mountains and can more broadly include hills, and any part of a region's elevated terrain. For more information, please see Petersen, Mortensen, Landberg, Højstrup, and Frank (1998).

#### CHAPTER 3 GLOBAL STATUS OF WIND ENERGY

The wind resources are spread globally, as we know the wind is fundamentally a form of solar energy. Wind is the result of simple air motion. It is caused by the unequal heating of the earth surface by the sun heat. Since the earth surface is made of different kinds of continents and oceans, it absorbs the sun heat at different rates, and the different temperature could cause the different pressure. The heat is distributed to the poles by ocean currents and atmospheric circulation (Maddaloni, 2005). As we can see in Figure 3.11, world wind map at 80m high, into a wind speed scale from 3-9 m/s, there are some regions on the globe (RETScreen® International Clean Energy Decision Support Centre, 2009). When it is necessary take into account the wind resources as an initial input or datum for wind farms economic evaluation, researchers as Marafia and Ashour (2003), Archer and Jacobson (2005), Arslan (2010), Ahmed (2011), Oliveira (2010), Gökçek and Genç (2009) show that a wind speed range starting from 3m/s as a minimum wind speed for wind power project gives economic returns to the investor. Wind energy projects are generally as more as financially viable in "windy" sites. This is due to the fact that the theoretical power output in the current wind technology is equal to the cube of the wind speed. However, the power production profile of a wind turbine is typically more proportional to the square of the average wind speed (Manwell, McGowan, & Rogers, 2002).



**Figure 3.11** World wind map at 80m. Source: 3TIER, Inc/REmapping the World Initiative/ RETScreen® International Clean Energy Decision Support Centre (2009)

North America and Antarctica are the best locations for electricity production by wind energy technology. But they are also very favorable to electricity production by wind energy technology in the northern Europe, especially along the North Sea, the southern tip of South America (*Tierra del* 

*Fuego or Fireland*) and Tasmania, in Oceania. According to Herbert, Iniyan, Sreevalsan, and Rajapandian (2007) the theoretical potential of wind energy onshore is very large —  $20,000 \times 10^9$  to  $50,000 \times 10^9$  kWh per year in comparison with the current total annual global electricity consumption of approximately  $15,000 \times 10^9$  kWh, in 2005. Archer and Jacobson (2005) concludes that:

- 1. About 13% of all stations worldwide belong to class 3 or greater (i.e., annual mean wind speed  $\geq 6.9$  m/s at 80m) and they are indicated for electricity production by wind energy technology. In addition, wind power potential in these areas studied was underestimated in comparison to other studies.
- The wind speed average calculated at 80m was 4.59 m/s (class 1) when including all stations; if only stations in class 3 or higher are considered, the average was 8.44 m/s (class 5). For comparison, the wind speed average observed at 10m from all stations was 3.31 m/s (class1) and from class ≥ 3 stations was 6.53 m/s (class 6).
- 3. The greatest numbers of stations in class ≥ 3 are in Europe and North America, whereas the greatest percentages are Oceania and Antarctica, 21% and 60%, respectively. Northern Europe along the North Sea, the southern tip of the South American Continent, the island of Tasmania in Australia, the Great Lakes region, the northeastern and western coasts of Canada and the United State have a strong wind power potential.
- 4. The wind speed was global-averaged at 80m was higher during the day (4.96 m/s) than night (4.85 m/s). The average nocturnal wind speed at above ~120 m was higher than the diurnal average.

The European Wind Energy Association (EWEA) and Greenpeace with their action for evaluation of global wind resources called *"Wind Force 12"* has concluded that the world's electricity production by wind energy technology considering only 10% of the Earth's land area would be available for development, which figures the double of projected world electricity demand in 2020. Addition, a larger share of the land area could be used for electricity production by wind energy technology in sparsely populated and wind-rich regions in the globe as e.g. the Great Plains of North America, northwest China, eastern Siberia, and the Patagonian region of Argentina (Brown, 2003).

For a successful application of wind turbines is necessary the study of geographical distribution of wind resources, speeds profiles, topography and local wind flow and measurement of the wind speed are very essential in a complete and robust wind resource evaluation. The main and most direct mechanism by which global climate change could impact directly in the wind energy industry is by changing the geographic distribution due to its inter-and intra-annual variability of the wind resource available. For Pryor and Barthelmie (2010) the global climate change may change the geographic distribution of wind resources in order to the variability of wind resource in a inter or intra yearly basis and it could change as result other the conditions for wind developments. As in a traditional industry sitting, the production and distribution of its process depending on the place where the vital resources can be found, in the case of the wind energy industry, the wind resources.

## 3.4 WORLD WIND ENERGY MARKET OUTLOOK

## 3.4.1 GLOBAL WIND ENERGY MARKET

For Wiser and Hand (2010) the global wind power capacity is growing fast in the last ten year, as a result, wind power has quickly become part of the mainstream in the global electricity industry. In 2007, roughly 20 GW of new wind capacity was increased globally, yielding a cumulative total of 94 GW (see Figure 3.12). Since 2000, cumulative wind capacity has grown at an average annual rhythm of 27%. The vast majority of this capacity has been located on land; offshore wind capacity surpassed 1 GW at the end of 2007, with accelerated growth expected in the future, especially in Europe. The expectations for wind power market growth in 2011 were mixed, as the low level of orders seen during the financial crisis worked their way through the system. The results of this were felt much more strongly in 2010 than in the previous year, and the overall annual market shrunk by 7% to 35.8 GW, down from 38.6 GW in 2009. The new capacity added in 2011 is equivalent in direct investments worth EUR 47.3 billion (USD 65 billion) (GWEC, 2011b, 2012).



Figure 3.12 Global annual installed wind capacity 1996-2011. Source: GWEC (2012)

As shown in Figure 6.1 the global cumulative installed wind capacity in 1996-2011, in the year 2011, the wind capacity reached worldwide 237,669 MW, after 197,637 MW in 2010, 158,738 MW in 2009, 120,291 MW in 2008, and 93,820 MW in 2007. New wind turbines investment has declined in many parts of the globe. For the first time in more than twenty years, the market for new wind turbines was smaller in comparison with the last year and totalized an overall size of 40,564 MW in 2011, 38,828 MW in 2010 and after 38,610 MW in 2009. The recovering of the wind industry worldwide totalized 40 billion (55 billion US\$) in 2010, after 50 billion (70 billion US\$) in the year 2009. The decrease is impact of lower prices for wind turbines and a shift towards China. The US market installed almost 50% less than in 2009. In the European market, new installed capacity in 2010 was 7.5% down on 2009, despite a 50% growth of the offshore market in countries like the UK, Denmark and Belgium, otherwise Romania, Bulgaria and Poland had a fast growth (WWEA, 2011). In December 2011, the ten biggest countries in cumulative capacity installed of wind power were distributed as shown in Figure 3.13.



Figure 3.13 Top 10 cumulative capacity Dec 2011. Source: GWEC (2012)

(\*\*) Provisional figure

The main markets driving growth are Europe and Asia, which installed 96.6 GW and 82 GW respectively in the end of 2011. However, emerging markets in Latin America are beginning more competitive, led by Argentina and Brazil. In cumulative terms, the Latin America and Caribbean market grew by more than 58% in 2011. China, USA, Germany and Spain lead the global wind market with a share of 67.2% which has a great impact in the global energy matrix and in their domestic economies. We could see that 50% of all new wind power was increased outside of the traditional markets of Europe and North America in 2011(GWEC, 2012). In the case of Asia, what pushes this continent forward is the continuing boom in China, with 17.6 GW of new installations in 2011. China had at the end of 2010 42.3 GW of wind power, which represents an increase of 39% in relation to the end of the year 2010 and has surpassed the USA in wind power capacity (see Table 3.2).



Figure 3.14 Top 10 new installed capacity Jan-Dec 2011. Source: GWEC (2012)

The growing Chinese wind power market has pushed forward domestic production of wind turbines and components, because of this the Chinese manufacturing industry has been increasingly mature and this fact reflects over the whole supply chain. China has become the world's largest producer of wind energy equipment and components made inside the country (see Figures 3.16 and 3.17). China started to not only satisfy domestic demand, but also meet international market. Sinovel and Goldwind have given a step ahead for entering into international markets, which is justified the world's top five wind turbine manufacturers in 2009 (GWEC, 2011c).

		End 2010	New 2011	End 2011	
Africa &	Cabo Verde	2	23	24	
Middle East	Morocco	286	5	291	
	Iran	90	3	91	
	Egypt	550	-	550	
	Other <sup>1</sup>	137	-	137	
	Total	1,065	31	1,093	
Asia	PR China	44,733	17,631	62,364	
	India	13,065	3,019	16,084	
	Japan	2,334	168	2,501	
	Taiwan	519	45	564	
	South Korea	379	28	407	
	Vietnam	8	29	30	
	Other <sup>2</sup>	69	9	79	
	Total	61,106	20,929	82,029	
Europe	Germany	27,191	2,089	29,060	1) South Africa, Israel, Lebanon,
-	Spain	20,623	1,050	21,674	Nigeria, Jordan, Kenya and Libya
	France**	5,970	830	6,800	
	Italv	5,797	950	6.737	2) Bangladesh, Indonesia,
	UK	5.248	1.293	6.540	Philippines,Sri Lanka, Thailand
	Portugal	3 706	377	4 083	
	Denmark	3 749	178	3 871	3) Romania, Norway, Bulgaria,
	Sweden	2 163	763	2 070	Hungary, Czech Republic, Finland,
	Notherlands	2,105	703 69	2,970	Ukraine, Cyprus, Luxembourg,
	Trata	2,209	00	2,520	Switzerland, Latvia, Russia, Faroe
	Turkey	1,329	470	1,799	FYROM, Iceland, Liechtenstein,
	Ireland	1,392	239	1,631	Malta
	Greece	1,323	311	1,629	
	Poland	1,180	436	1,010	1) Austria Belgium Bulgaria
	Austria	1,014	/3	1,084	Cyprus, Czech Republic,
	Deigiuiii Dest of Europe	2 807	192	1,078	Denmark, Estonia, Finland, France, Germany, Greece
	Rest of Europe <sup>3</sup>	2,807	900	3,708	Hungary, Ireland, Italy, Latvia,
	1 otal	86,647	10,281	96,606	Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal,
Latin Amarica	Drogil	64,030	9,010	95,947	- Romania, Slovakia, Slovenia,
& Caribbean	DI azli	927	285	1,509	Spain, Sweden, UK
& Carlobcan		172	33 70	205	5) Carribean: Jamaica, Cuba
	Argentina Casta Disa	50	19	130	Dominica, Guadalupe, Curacao,
	Uosta Kica	119	102	152	Aruba, Martinica, Bonaire
	Honduras	-	102	102	6) Colombia, Ecuador, Nicaragua,
	Dominician Republic	-	33	33	Peru, Uruguay
	Carribean <sup>3</sup>	9I 119	-	91 129	** Provisional Figure
	Other Total	118	10	128	
North America		1,478	6 810	2,330	Please note:
Norui America	USA Canada	40,298	0,810	40,919	Project decommissioning of
	Callaua	4,008	1,207	5,205	approximately 528 MW and rounding affect the final sums
	Total	519 11 825	30 8 127	50 752	rounding arrest the final sums
Pacific Region	Australia	1 000	0,127	2,735	
i actite Region	New Zealand	1,990 51/	100	2,224 673	
	Pacific Islands	12	109	12	
	Total	2 516	343	2 850	
	World total	197.637	40.564	237.669	

 Table 3.2
 Global installed wind power capacity (MW) – Regional Distribution

Source: GWEC (2012)

## Africa & Middle East

Wind energy could help African continent to face the lack of electricity. About a quarter of the world's population has no access to electricity, and the problem is especially acute in peri-urban and rural areas in Sub-Saharan Africa. Although Africa and Middle East has shown a great development of wind power technology, especially in wind power capacity in MW. We highlight Cabo Verde and Morocco. When it is considered the end of 2010 and the end of 2011, these countries has an increase in wind power capacity of 1,100%, 2% respectively. At the end of 2011 Cabo Verde had installed 24 MW and Morocco 291 MW (GWEC, 2012). Africa and Middle East have increased 3%, in the same period and had as wind power capacity installed about 1 GW.

## Asia

Asia in terms of wind energy has been surprising globally. According to the Global Wind Energy Council (GWEC) (GWEC, 2012). Asia at the end of 2011 had installed almost 82 GW (82,029 MW). China was the world's largest market in 2011 with 17.6 GW of new capacity installed and goes ahead of the USA and India and became the global leading wind power country (see Figure 3.14). However, there are indications that only about half of the turbines in China are really in operation. Many of the wind farms are not connected to the grid because of quality problems or grid weakness, and appear to have been constructed to allow large utility companies to gain incentives in order to expand their coal-fired operations. The whole market is still heavily dominated by onshore projects. Of the total cumulative capacity only 2.1 GW is offshore of which about 689 MW was installed last year. Of special significance are the 209 MW wind farm project Horns Rev II and Germany's first offshore wind farm Alpha Ventus, with a capacity of 60 MW (Markard & Petersen, 2009). The Chinese market had increased its capacity from 44.7 GW in 2010 to 62.3 GW at the end of 2011; it is an increase of 39% in the same period. In the case of India, the Indian wind power market awaked and increased its capacity from 13 GW in 2010 to 16.0 GW at the end of 2011; it is an increase of 23% in the same period. In terms of new installed capacity during 2011 and comes in third position behind China and the USA (see Figure 2.14). Wind power accounts for 70% of this renewable installed capacity. In 2010 the official wind power potential estimates for India were revised upwards from 45 GW to 49.1 GW by the Centre for Wind Energy Technology (C-WET). Other Asian countries with new capacity additions in 2011 include Japan (2,3 GW, for a total of 2.5 GW), Taiwan (519 MW for a total of 564 MW) and South Korea (379 MW for a total of 407 MW). The Chinese market, in particular, now has three manufacturers among the top 10 global players and has shown potential for more new businesses. The acceptance of new wind turbines on the market depends on their suitability for international trade and the successful operation of their first projects. Most of the new players still have to prove this, particularly regarding the quality and long-term stability of turbine operations. In mid-2009, the South Korean firm Daewoo Shipbuilding & Marine Engineering (DSME), the world's second largest shipbuilder, announced its entry into the wind energy market by acquiring DeWind for around US\$50 million. DeWind is a medium-sized wind turbine manufacturer that has installed around 570 wind turbines in the 500 kW to 2 MW range (Wiese, Kleineidam, Schallenberg, Ulrich, & Kaltschmitt, 2010). Asia has increased 34, in the same period and had as wind power capacity installed about 82 GW.

## Europe

The Europe continent has been facing serious economics and financial problems in its EU Members States. The EU Member States have tried to reduce unemployment situation, low productivity, in other words, come back to growth road and stop economic recession. Related to wind power, reflected investment in RE technologies since decades ago, the wind power installed across Europe in the end of 2011 reached 96.6 GW. This represents an increase only of 11% compared to 2010. According to EWEA (2012) the annual onshore market increased by over 13% compared to 2009, while the annual offshore market grew by 51%, and accounted for 9.5% of all capacity additions. In terms of total capacity installed, we must highlight Germany and Spain, at the end of 2011, with 29 GW and 21.6 GW, respectively. In terms of new installations German was the largest market in 2011, installing 2 GW followed by UK with 1.2 GW and Spain. For Spain 2010 was a good year for wind power, and the country's wind farms produced 42.7 TWh of electricity, which figures 16.6% of total Spanish power consumption. Five out of Spain's 17 regions now host 1 GW or more of wind power (AEE, 2006, 2011).

France, Italy and Portugal had a total wind power capacity installed by the end of 2011 with 6.8 GW, 6.7 GW and 4 GW, respectively. This same European country has increased their wind power capacity in 20%, 24% and 23% compared with the end of 2010. The French government set a target to achieve 25 GW of installed wind energy capacity by 2020, including 6 GW of offshore wind. The Italian wind power sector now employs more than 28,000 people, of which some 10,000 directly. For Portugal the total wind power capacity installed by the end of 2011 was 4 GW∴An interesting situation happened — Portugal went ahead of Denmark with wind power capacity installed, 4,083 MW and Denmark with 3,871 MW at the end of 2011. According to GWEC (2011b, p. 11) Turkey, Belgium, Poland and Sweden had presented in 2010 the biggest rates of growth in wind power capacity installed, with 66%, 62%, 53% and 39%, respectively. In the United Kingdom, around 40 new wind farms were opened in 2010, totaling 962 MW of additional capacity and taking the country's total installed wind power capacity to 5.2 GW. With 1.3 GW of installed capacity, the UK continues to be the world's leading offshore wind market. The majority of wind farms in the UK are located in Scotland (2.3 GW), in the North West (1 GW) and in Wales (0.5 GW). Only Scotland installed a third of all new wind power capacity in 2010 (0.4 GW) (GWEC, 2011c). Europe has increased 11%, in the same period and had as wind power capacity installed more than 96.6 GW.

## Latin America & Caribbean

Latin America and Caribbean is a region of the globe with best wind resources (see Figure 3.11). The rest of the world has putted the eyes in Latin America because it is considered prime territory for the deployment of wind power. In the beginning the development of RE technologies have been modest, but nowadays there are no doubts that the region is an opportunity for an exponential developing of wind power industry to complement its rich hydro and biomass (and potential solar) resources, most notably in Brazil and Mexico. Brazil is the country where wind power is making the most progress; it is also the largest economy of the region. This country has many areas with tremendous potential for wind energy technology, combined with a growing electricity demand and solid industrial and grid infrastructure (GWEC, 2011c). We must highlight Argentina and Brazil. These main latin countries have increased the wind power capacity installed by 160% and 60%

respectively. Brazil had 1.5 GW and Argentina had 0.13 GW at the end of 2011. Brazil and Argentina are in top positions in terms of wind power capacity installed at Latin America. Chile, Costa Rica and Caribbean these countries almost reach 0.4 GW of wind power capacity installed. An interesting country is Chile, which had nearly 0.2 GW (205 MW) of wind power in operation at the end of 2011. The total wind power capacity installed in the Latin America and Caribbean grew by 58% during 2011, and more than 2 GW of wind power capacity were installed.

## North America

The USA wind energy market installed 6.8 GW in 2011, only about half of the 2010 market. The country now has 46.9 GW of wind power capacity (up from 40.2 GW at the end of 2011), thereby conceding its global leadership to China. By 76% of the American states now have utility-scale wind installations and 28% of those had more than 1 GW installed. The leading state was Texas with more than 10 GW of total installed capacity and wind power now generates 7.8% of the state's electricity demands. Iowa is in second place with 3.6 GW, and now receives close to 20% of its electricity from wind power, followed by California, Minnesota and Washington State (AWEA, 2011). The American manufacturing sector, meanwhile, appears to view 2010's slowdown as short-term. New component suppliers continued to enter the wind energy industry last year, and over 400 US manufacturing plants now serve the industry. Around half of the wind production equipment deployed in the USA is now manufactured domestically. In addition, the construction pipeline for wind power is healthy, with 5.6 GW currently under construction. Given such indicators, the industry finished 2011 well ahead of 2010 numbers (GWEC, 2011c). Canada's wind energy industry took a step ahead in 2011 with the addition of 1,267 MW of installed wind energy capacity, ranking Canada in 9<sup>th</sup> position globally in terms of new installed capacity and 6<sup>th</sup> for overall cumulative installed capacity (see Figure 3.13 and 3.14). Canadian wind energy industry had done a record year in 2011 with approximately 1.2 GW of new wind energy capacity; reflect of an investment of \$3.1 billion and creating 13,000 person-years of employment in the Canadian wind energy industry. Canada has increased the wind power capacity installed by 11% and 5.2 GW of wind energy installed capacity. For the end of 2011, Canada had shown a total of wind energy installed capacity around 5.2 GW. In 2011, new wind energy projects were built and commissioned in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia (CanWEA, 2012; GWEC, 2011b). The total wind power capacity installed in the North America grew by 18% during 2011, and more than 52.7 GW of wind power capacity were installed.

## **Pacific Region**

Australia wind power market at the end of 2011 had installed 2.2 GW, an increase of 12% in relation to the end of 2010. There were 52 operating wind farms in the country, mostly located in South Australia (907 MW) and Victoria (428 MW). Australia's expanded Renewable Energy Target (RET) Scheme, which entered into force in January 2010, mandates that 45 TWh or 20% of Australia's electricity supply will be sourced from renewable energy in 2020 (CEC, 2012; GWEC, 2011c). The initial goal was 12.5 TWh, and this could be gradually increased until 2020. After a good year in 2009, the rate of development in New Zealand dropped with just 8.8 MW of new wind capacity added, taking the total up to close to 506 MW, representing an increase by 2% at the end of 2010. Wind energy currently supplies just over 3% of New Zealand's annual electricity demand.

The world energy scenario has changed and it is important to highlight some its aspects. First of all, wind energy technology is more nature than ten years ago due to heavily R&D investments and renewable energies penetration has increased (NZWEA, 2012). For the Pacific Islands had only 12 MW as total wind power capacity installed at the end of 2011, and no increase was register in the period. The total wind power capacity installed in the Pacific Region grew by 14% during 2011, and more than 2.8 GW of wind power capacity were installed.

The total wind power capacity installed worldwide grew by 20% during 2011, and more than 237 GW of wind power capacity were installed. In global terms, we can say that wind market is continuing to attract new players and a significant number of new companies in Europe and Asia are developing new wind turbines to enter the market in the coming years. It is necessary to give emphasis the increasing trend of professionalism in the market. One example of this is continuous flow production; it is the need of increase output and quality and to reduce costs. Many manufacturers, including GE, REpower, Vestas and Enercon, began this process between 2003 and 2006 but had little success due to the many different wind turbine types needed to satisfy customer demands∴Currently the products of the wind energy industry are more standardized; this kind of production is becoming more effective; examples of successful factories include Siemens and GE. Apart from Europe, the USA and Asia, other markets for wind energy they are still with a small market share. We must highlight, there are notable wind farm projects being planned and starting-up in the developing world. In South America, the growing markets are specially concentrated in Brazil, Chile and Argentina, while the African market is still dominated by Egypt and Morocco.



Figure 3.15 Annual installed capacity by region 2003-2011. Source: GWEC (2012)

According to GWEC (2012) the six regions worldwide has shown as annual installed capacity an interesting behavior (see Figure 3.15). In Latin America & Caribbean, Asia and North America had demonstrated highest growth with, 58% of increase and 2.3 GW (2011), 34% of increase and 82

GW (2011) and 18% of increase and 52.7 GW (2011), respectively. Also in Figure 3.15 we could conclude that the lowest growth was represented by Pacific Region, Latin America & Caribbean and Africa & Middle East with 2.8 GW (2011), 2.3 GW (2011) and 1 GW (2011), respectively. For Saidur, Islam, Rahim, and Solangi (2010) there have been a remarkable increase in any type of energy demand due to the economic and technological developments worldwide. The global economy has grown 3.3% per year over the last 30 years and in the same period energy demand has increased 3.6%. It is noticed that energy policy could help increasing wind energy industry. Oliveira and Fernandes (2011) conclude that human evolution is closely linked to energy, since the beginning of time man has to know it and seeking it ever more on the environment.

#### 3.4.2 WIND ENERGY CONVERTERS MANUFACTURERS

In the wind energy industry, there is intense competition between the wind energy converters (WECs). Vestas and GE Energy have the largest market shares but no company controls more than 20% of the market (see Figure 3.16). However, there are distinct regional differences. Enercon, for example, dominates the German market with a share of 60%, but at the same time the company might have difficulties maintaining its global market share if the German market slows down. The situation for GE Energy in the US and Gamesa in Spain is similar. At any rate, since there is a trend towards ever-larger models that is accompanied by increasing capital requirements, larger companies will benefit on long-term (Green Rhino Energy, 2009).



Figure 3.16 Wind turbine manufacturers' share. Source: Green Rhino Energy (2009)

When we take a look at turbine manufacturing features, Vestas one more time got the largest share (19.0%) of the global wind market, with approximately 37 GW (see Table 3.3). However, the enterprise has lost market share since 2008 and is near followed by GE Wind, whose market share

was almost 18.0% in 2010. Amazingly for the first time there are also two Chinese enterprises in the top five suppliers list: Sinovel ranks sixth with 5.0% and Goldwind is seventh with 4.0% (see Figure 3.16). Although the wind power industry saw manufacturing volumes remain constant at their 2009 levels, manufacturing capacity increased substantially during 2010<sup>17</sup>. Project developers were challenged by competition with natural gas prices at three-year lows (leading to reduced sales), the continued challenge of obtaining project finance, and access to transmission. Industry leaders Vestas, Gamesa, Hansen Transmissions, and GE Wind all lowered sales forecasts during 2010...Growth opportunities were focused mainly on China and other emerging markets as GE Wind supplied turbines to Brazil; Gamesa planned to triple investments in China by 2012; and Repower and Suzlon signed contracts in Turkey and Bulgaria<sup>18</sup>. Among the top 10 global manufacturing enterprises, Vestas of Denmark easily retained its number-one ranking, but Sinovel of China edged ahead of GE Wind in 2010 to take second place<sup>19</sup> (see Figure 3.17).



Figure 3.17 Market shares of top 10 wind turbine manufacturers in 2010. Source: REN21 (2011)

In China, enterprises Sinovel, Goldwind, Dongfang, and United Power saw strong growth driven by continued political and regulatory support and lower labor and manufacturing costs. Continued technology development at these enterprises also meant a smaller and closing gap in technological

<sup>&</sup>lt;sup>17</sup> For more details, please see Steve Sawyer, Global Wind Energy Council (GWEC), personal communication with REN21, 19 April 2011.

<sup>&</sup>lt;sup>18</sup> According to Rikki Stancich, "2010 in Review: Peaks and Troughs for the International Wind Energy Sector," WindEnergyUpdate.com, 6 December 2010.

<sup>&</sup>lt;sup>19</sup> Note that Suzlon Energy (IND) and Repower (GE) are listed as a Suzlon Group for the first time in BTM Consult's *World Market Update*. Rankings and data in Figure 13 from BTM Consult – A Part of Navigant Consulting, *World Market Update 2010* (Ringkøbing, Denmark: 2011), provided by Birger Madsen, BTM Consult, personal communication with REN21, March and June 2011. Note that the total quantity of capacity supplied exceeds 100% of the global market because some capacity was in transit or under construction and not yet commissioned at year-end. Data were adjusted for Figure 3.17 such that the sum of shares supplied totals 100%.

parity with overseas enterprises. Sinovel, for example, launched a 5 MW turbine model in 2010<sup>20</sup>. It appeared that industry consolidation might be on the horizon in China as a draft government policy called for narrowing the industry to far fewer than the existing 100-plus enterprises. The major developers of wind projects in China remained predominately state-owned enterprises: Longyuan, Datang, Huaneng, Huadian, CPI, and Guohua<sup>21</sup>. In Europe, industry activity focused increasingly on offshore technologies and on project development in Eastern Europe. The largest turbine to be financed so far, RePower's 6 MW model, was deployed in C-Power's 300 MW Thornton Bank project in Belgium, one of nine offshore wind farms developed in 2010.<sup>22</sup> And Transpower's high-voltage cable transmission infrastructure is being installed in the North Sea, laying the base for German offshore connectivity by 2013. Project developers became more aggressive in Eastern Europe, for example in Ukraine, where at least 10 project developers were active in 2010 due to a new feed-in tariff.<sup>23</sup>

In the United States, 14 new turbine manufacturing plants were established in 2010.<sup>24</sup> The U.S. industry was hampered, however, by late extension by the U.S. Congress of the Investment Tax Credit (ITC), low natural gas and electricity prices, and transmission access issues; so that project developers managed only half the number of projects they did in 2009. Leading owners of wind power projects in the United States include NextEra, Iberdrola Renewables, Horizon-EDPR, MidAmerican/PacifiCorp, and E.ON Climate & Renewables.<sup>25</sup>

According to Markard and Petersen (2009) it is possible to differentiate the value chain of wind energy industry into five distinct parts. The first one is the *turbine manufacturing* which might include the development and production of wind turbines and auxiliary equipment. The second one is the *project development* with its sub-tasks such as planning, licensing, leasing of the land (onshore) and wind farm construction. The third is the *investment operation* that is about the provision of funds for a wind farm and forth is *operation* that concerns about managing the business including metering and billing of electricity production and maintenance of the technical components. And finally the fifth is *load management and power distribution* that is always combined tasks related to balance the intermittent power supply of wind farms and distributing and selling the electricity to end consumers. It is easy to notice when the sectorial value chain is simplified as there are further tasks (e.g. environmental impact evaluation, wind farm insurance or provision of meteorological services) that also need to be taken care of.

Direct-drive turbine designs captured 18% of the global market, led by Enercon (Germany), Goldwind (China), and Hara XEMC (China). Preferred turbine sizes were 2.5 MW in the U.K., 1.4 MW in China, and 1.2 MW in India. Globally, the average turbine size increased to 1.6 MW, up from 1.4 MW in 2007. Vestas launched the largest commercial turbine thus far, the dedicated

<sup>&</sup>lt;sup>20</sup> Sinovel, "SL5000," <u>www.sinovel.com/en/procducts.aspx?ID=148</u>, viewed 19 April 2011.

<sup>&</sup>lt;sup>21</sup> Shi Pengfei, Chinese Wind Energy Association and GWEC, personal communication with REN21, April 2011.

<sup>&</sup>lt;sup>22</sup> Repower Corporation, "*REpower: 295 MW Contract Signed for Thornton Bank Offshore Wind Farm*," press release (Hamburg/Antwerp: 25 November 2010).

<sup>&</sup>lt;sup>23</sup> Vanya Drogomanovich, "*Can Wind Turn Ukraine's Orange Revolution Green*?" Bloomberg New Energy Finance Monthly Briefing, October 2010, p.12.

<sup>&</sup>lt;sup>24</sup> American Wind Energy Association (AWEA), Wind Energy Weekly, 8 April 2011.

<sup>&</sup>lt;sup>25</sup> Emerging Energy Research, North America Wind Plant Ownership Rankings 2010: Trends and Review (Cambridge, MA: 31 March 2011).

offshore V164 7 MW turbine, targeting North Sea opportunities.<sup>26</sup> Li and Chen (2008) made a comparison with geared-drive wind generator systems and concluded that most important advantages of direct-drive wind generator systems were the higher overall efficiency, reliability and availability due to no gearbox is necessary. The direct-drive generators usually have larger size, but it could not be disadvantage for the offshore wind energy applications.

	Installed in 2010		Accumulated installed		
	Number	MW	Number	MW	
V52-850 kW	340	289	3,764	3,199	
V60-850 kW	15	13	15	13	
V80-1.8 MW	0	0	1,016	1,829	
V80-2.0 MW	267	534	2,981	5,962	
V82-1.5 MW	0	0	213	320	
V82-1.65 MW	273	450	2,883	4,757	
V90-1.8 MW	269	484	572	1,029	
V90-2.0 MW	763	1,527	3,286	6,544	
V90-3.0 MW	834	2,502	2,170	6,510	
V100-1.8 MW	20	36	20	36	
V112-3.0 MW	2	6	2	6	
Other	1	1	26,511	6,729	
Total	2,784	5,842	43,433	36,934	

 Table 3.3
 Track record by turbine type

Source: Vestas (2011)

The search for more productivity in the power output what forward trends for larger wind turbines, about 82% of all wind turbines installed in 2009 falling into the range of 1.5 MW to 2.5 MW, but the growth is still slow. Wind turbines in onshore wind farms generally have a range between 2 MW to 3 MW in countries with a good infrastructure. Although, larger wind farms with smaller turbines (up to 1.5 MW) are under development or have been installed in areas with poorer infrastructure. The REpower 6M and the Enercon E-126 are particularly well-known. The 6M has a rated capacity of 6.15 MW while the Enercon E-126 is available with 6 MW of rated capacity (Wiese et al., 2010).

The power output of a wind turbine is roughly proportional to the rotor area, so fewer larger rotors at higher towers use the wind resources more efficiently than more numerous, smaller wind turbines. The biggest commercial wind turbines today are 5–6 MW units with a rotor diameter of up to 126 m. Every five years wind turbines have doubled in size approximately, but this rate seems to be slow for onshore turbines, due to operational and installation constraints. The expected lifetime of a commercial wind turbine currently is 20–25 years. Lifetime spans may stretch as the technology continues to mature. However, due to the youth of the industry, as we know today, and the re-powering of wind farms with the updated turbine technology, few turbines have been around long enough to test this consideration. Due to extensive testing and certification, the reliability of

<sup>&</sup>lt;sup>26</sup> See Chris Red, "Wind Turbine Blades: Getting Bigger and Bigger", CompositesWorld.com, viewed 20 June 2011.

wind turbines — the proportion of the time they are technically available for operation — is approximately 99% (Furkan, 2011). During the last ten years power electronics have represented a key factor in the evolution of wind turbines towards more efficient wind energy capture, better quality of voltage output, better grid integration, etc. Efficiency is an important issue for wind turbines when comparing different systems because losses reduce the average power produced by the wind energy converter and, so on, they reduce incomes (Amirat & Benbouzid, 2007, p. 28). The Table 3.4, it is shown a list of top 10 globally wind turbine manufacturers in 2009 with its currently used generator concepts and power ranges.

Manufacturer	Concept	Rotor diameter	Power range
Vestas (Denmark)	DFIG	52 – 90 m	850 kW – 3 MW
	GFC PM	112m	3 MW
General Electric (US)	DFIG	70.5 – 82.5 m	1.5 MW
	GFC PM	100 m	2.5 MW
	DD PM	110 m	4.0 MW
Sinovel (China)	DFIG	60 – 113 m	1.5 – 3 MW
Enercon (Germany)	DD EE	33 – 126 m	300 kW – 7.5 MW
Goldwind (China)	DD PM	70 – 100 m	1.5 MW – 2.5 MW
Gamesa (Spain)	DFIG	52 – 97 m	850 kW – 2 MW
	GFC PM	128 m	4.5 MW
Dongfang (China)	DFIG	-	1 – 2.5 MW
Suzlon (India)	CS	52 – 88 m	600 kW – 2.1 MW
Siemens (Germany)	GFC IG	82 – 107 m	2.3 – 3.6 MW
	DD	101 m	3 MW
Repower (Germany)	DFIG	82 – 126 m	2 – 6 MW

**Table 3.4** Top 10 globally wind turbine manufacturers of 2009, currently used generator concepts and power ranges

Source: Polinder (2011). CS: constant speed with gearbox and induction generator, possibly with extended slip or two speeds; DFIG: variable speed with gearbox, doubly-fed induction generator and partly rated converter; DD EE: variable speed direct-drive synchronous generator with electrical excitation and full converter; DD PM: variable speed direct-drive permanent-magnet generator and full converter; GFC PM: variable speed with gearbox, permanent-magnet generator and full converter.

Table 3.4 starts with describing the most commonly used generator systems in wind turbines manufacturers' leader worldwide. Each manufacturer is market-oriented and size and concept differ during the period of time. The most important trend in the marketplace is the progressive increase in the size of commercial wind turbines as a result of a bigger power output search. The average wind turbine size has thus increased by about 12% per year over the last decade (Hansen & Hansen, 2007). In chapter 4, it is discussed technical aspects of each concept and other important issues about wind energy conversion systems. Subsequently, some of the most important developments in wind turbine generator systems are discussed. Finally, some conclusions are drawn.
#### 3.4.3 ECONOMIC IMPACTS FROM WIND ENERGY INDUSTRY

Wind power plants installations can create jobs in a country where local economies are often dependent on local business activities. Local jobs refer to construction-related activities; operation and maintenance of the facility after it is constructed, and jobs induced by the money addition in the local economy by the temporary workers. Lantz and Tegen (2008) made some studies about the variables affecting in an economic development process by wind energy activities. Lantz and Tegen (2008) state that "creating policies to ensure maintenance materials are supplied by in-state business and that the local labor force is trained to perform wind turbine maintenance is also likely to have a large impact for wind power plants operating for 20 or more years". The maximization of economic benefits by wind energy development is linked to the improvement of related in-state businesses and trained labor force.

Greater energy independence, improved environmental benefits from reduced greenhouse gas emissions and positive economic impacts have been appointed as the main three main reasons for investing on wind energy industry. When we have to face our climate responsibilities and the opportunity to build a low-carbon economic base, job creation is an especially question to discuss about. The development of indigenous sources of renewable energy technology, as wind power, will forward the creation of more jobs locally than *'business as usual'* fossil-fuel economies of the last century (Engel & Kammen, 2009). The focus on finding solutions for mitigating global warming has resulted in renewable energy technologies gaining importance. Improvements accomplished in technology resulted in a fast growth in wind power worldwide  $\therefore$  Among the renewable energy technologies, wind power is one of the fastest growing technologies globally at an average annual growth rate of more than 26% since 1990 (Resch et al., 2008).

According to WWEA (2011) by the end of the year 2010, about 670,000 people were employed worldwide directly and indirectly in the many areas in the wind industry. During the last five years, the number of jobs almost tripled, from 235,000 in 2005. There is an increasing demand for a very broad range of jobs, from engineers, skilled workers to managers, financial, environmental and legal experts. One of the positive aspects of the wind energy industry is the impact on employs, but few studies have systematically dealt with this matter (Blanco & Rodrigues, 2009). The development of renewable energy industry has become a way to accomplish environmental objectives and a long way of increasing energy self-sufficiency and employment in general (Connor, 2003: Dincer, 2000: Hillebrand, Buttermann, Behringer, & Bleuel, 2006: Laitner, Bernow, & DeCicco, 1998; Moreno & López, 2008; Thothathri, 1999). The adoption of renewable energies technologies represent an opportunity to reduce energy dependence, reduce the emission of  $CO_2$  and create new employs and revenues. The engagement of local economic agents is extreme necessary for the future development of RE technologies, especially in regions whose industrial activity mix was based on traditional energy sources. Wind energy industry in Europe is a predominantly male business with 78% employment, where men represent the majority of the labor force in fields of construction, production and engineering (Moreno & López, 2008).

The development of wind power can create new opportunities for more domestic jobs per currency invested and/or per kilowatt-hour produced than fossil fuel power production. *Manufacturing of wind power utilities and equipment, constructing and installing* the wind projects, and *operating* 

*and maintaining* the projects over their lifetime usually create direct jobs (Lewis & Wiser, 2007). The wind energy industry has become a major job generator globally: within only three years, the wind industry worldwide almost doubled the number of jobs from 235,000 in 2005 to 440,000 in the year 2008 (see Figure 3.18). These 440,000 employees in the wind energy industry worldwide, most of them highly skilled jobs, have been contributing to the production of 260 TWh of electricity (WWEA, 2011).



Figure 3.18 Green jobs on wind energy sector worldwide. Source: WWEA (2011)

Wind energy industry represents an attractive source of employment worldwide. Activities as construction, O&M, legal and environmental studies are best driven at local level; we can notice a positive correlation between the location of the wind farm and the number of jobs it creates. The location of a wind farm determine where can be located large manufacturing centers, however, microeconomic factors such as, skilled labor force, easy access roads, grids infrastructure and regional and municipal authorities have a role to play. Another relevant issue is that wind energy employment is following the opposite trend to the general energy industry, particularly coal extraction and electricity production, and measures that encourage the transfer of workers from general energy industry to wind energy activities could be highly beneficial from both social and economic aspects (Blanco & Rodrigues, 2009; Thothathri, 1999).

According Hamilton and Liming (2010) the process of getting energy from the wind into the home is so complex, in business terms, that is why it involves many players simultaneously. A modern and commercial wind turbine consists of an estimated 8,000 parts. Turbines must be designed,

built, transported, and erected before they can start producing energy. As we have said the chain of wind industry can be classified into three major phases: *manufacturing*, *project development*, and *operation and maintenance*. A wind energy successful project, each of these phases overlap and there is substantial communication among players in all these three phases. The manufacturing sector hosts most of the jobs, followed by construction, and operation and maintenance. However, in the case of new wind farms forward the repower process, for manufacturers can take advantage of returns to scale. Figure 3.19 shows the distribution of jobs in American wind power industry in 2010.



Figure 3.19 Jobs in wind power, 2009. Source: Hamilton and Liming (2010)

<sup>(1)</sup> "*Other jobs*" includes the following: some manufacturing, parts-related services, financial and consultant services, developers and development services, contracting and engineering services, and transportation and logistics.

Large wind turbines are made of complex pieces of machinery designed and built by companies known as Original Equipment Manufacturers (OEMs). Most of OEMs are large transnational corporations for which wind turbine manufacturing phase is only a small piece of their global business. Wind farm development is a challenging process that usually takes several years from conception to construction. The beginning of this process is the selection of an appropriate site. This step involves a great number of factors, such as wind speed and frequency, availability of area, ground constitution for supporting the weight — often more than 1,000 t — of turbine structures, environmental concerns — such as local avian populations and the feasibility of transporting large turbine components to the site chosen. In the phase of *project development* also has many legal and financial issues such as contract development and financing. All of this work representing the pre-operational phase of the wind energy project. The self-running of wind energy projects is a way it works by itself with little need for human supervision (remote controlling). Energy companies employ monitors, either locally or remotely, to observe energy flows and report technicians of any problems. All wind farms employ local workers, but remote monitoring of wind turbines can allow for a cost-effective way to ensure that the wind turbine (wind farm) is working most efficiently as possible and that local technicians are alerted to any potential problems advised (Ayee, Lowe, & Gereffi, 2009).

The initial spending on the *construction* and *operation* phases of the wind farm has a second and economic effect, usually referred as *"indirect impacts"*. Indirect impacts during the construction phase representing the changes on relations inter-industry from the direct final demand changes

which includes construction spending on materials, wind farm equipment; other purchases of related-goods and offsite services. And increase in some final product represent an also increase in its components to produce it as well as an increase in the economic activity at local site (Goldberg, Sinclair, & Milligan, 2005). Indirect impacts reflect on all supply chain component impacts/manufacturing-related activities; therefore, the final phase of turbine assembly process, which includes gearbox assembly, blade production, and steel rolling are all included under the construction period indirect impacts category. Also the manufacturers of turbine parts such as bearing producers, steel producers, and gear producers are also in this same category. Indirect impacts during operating years refer to the changes in inter-industry purchases resulting from the direct final demand changes (Lantz & Tegen, 2008).

Landowners who lease their land to wind developers benefit from having a stable source of revenues. This option is usually greater than that from ranching or farming if we compare on a per acre basis, the revenue receive from leasing their land by wind developers. Landowners can be compensated in a variety of ways: option payments, construction disturbance or installation payments, land leases, and/or royalties. While royalty is a percentage of gross revenues received by the wind farm owner from the sale of power (Pedden, 2006).

According to Goldberg et al. (2005) it is possible to classify the total effect of developing a wind power plant into three types of impacts. They can be defined as *direct effect*, *indirect effect*, and *induced effect*:

- 1. *Direct effect:* they are general on-site or immediate effects created by expenditures. In constructing a wind power plant, it refers to the on-site jobs of the contractors and crews hired to construct the plant. It also includes the jobs at the turbine manufacturing plants and the jobs at the tower and blade factories.
- 2. *Indirect effect:* It refers to the increase in local economic activity that happens when a contractor, vendor or manufacturer receives payment for goods or services and in turn is able to pay others who support their business economy cycle. For instance, this impact includes the banker who finances the contractor; the accountant who keeps the contractor's books; and the steel mills and electrical manufacturers and other suppliers that provide the necessary materials on-site.
- 3. *Induced effect:* It is a reflect effect and usually refers to the change in wealth and income that is induced by the spending of those economic agents (workers, companies, public services, etc.) directly and indirectly employed by the wind project. This would include spending on food, clothing, or day care by those directly or indirectly employed by the project, retail services, public transit, utilities, cars, oil, property & income taxes, medical services, and insurance, for example.

# 3.5 SUMMARY AND CONCLUSIONS

Now is the time to reform the energy system, since it was created during the growth phase in a highly industrialized society. Our society is on the verge of an energy crisis and various global environmental problems. These are influences that our society presents great opportunities for technological innovation. To implement this effectively, it is important to conduct and promote energy conservation policies, recognizing the negative effects on the external economy. Wind power has advantages over current systems of high efficiency power production used today. The great advantage of wind power is the fact that energy can be produced from natural resources that are available and plentiful. However, the electrical energy produced wind power is influenced by natural conditions, which can disturb the stability and reliability. Any escape from this problem of root development cannot be expected. The relationship between the owners of independent wind energy business and its external environment is very difficult. Therefore, it is safe to assume that wind power cannot remain competitive in isolation, as individual business entity with less financial support from consumers of electricity at present. For this question, initially, the government policy and electricity consumers should share the additional costs associated with all aspects of wind energy. As wind production becomes more widespread, the cost will be reduced through "learning by doing." The more traders contribute to the production of wind energy that will reduce some of the main disadvantages of the interaction between technology and markets. The advantages that accrue to the consumer as a result of greater penetration of wind power far outweigh the disadvantages of the initial costs.

The analysis of diffusion in the wind energy industry in terms of efficiency, effectiveness and development criteria reveals the following:

- Internal technological innovation has solved the technological imbalance between the subsystems that constitute a system, thus increasing the performance of wind turbines. These technologies were used in large equipment, improving the efficiency of wind turbines and ensuring economies of scale of this type of equipment in large scale wind farms or wind farms.
- 2) For the system of energy businesses, this analysis demonstrated that there is no balance between incentives and contributions from business owners of wind energy, electric energy companies, and consumers. The system is therefore not effective enough now.
- 3) The system began to evolve in order to complement each other, with systems of other technological products (solar, photovoltaic, etc.) as well as micro-networks.

To highlight these three aspects can be divided into technological trajectory and interaction between technology and markets. Analysis of the criteria of efficiency and technological development shows the trajectory, as described below, in technological innovation. In the first phase, innovations occurred in the subsystems of a product system. Pitch control was adopted in the original draft of Denmark, who became the dominant design. An approach permits the performance of a generator with increasing conversion efficiency of the turbine blades in a complementary relationship. In other words, in a complex product system consisting of interrelated

subsystems, it is necessary to increase the integrated action with the parties taking into account the interdependencies with the system, when there is an innovation in a product system. The internal logic of the technology itself defines technological innovation, as stated in the model of Rosenberg's technological imbalance. This case study indicates that not only increases the performance of technological equipment for the imbalance itself, but also creates new technological opportunities to make projects more wind turbines (Rosseger, 1996; TPWind, 2010b).

In the second stage, the innovation has occurred at the unit level of a modular product system by adopting a function of change of speed. When a product system has nonlinear characteristics with respect to the external environment, each party within the modular unit is quite capable of improving the technological imbalances in the face of nonlinear characteristics. For this reason, researchers have turned interference from the external environment in non-interference, which cannot be performed alone, but only through cooperation within the product system with which there was a mutual relationship. Near linear characteristics were obtained, resulting in an increase in the overall performance of the product. In other words, there was awareness of the range in which the imbalance was resolved technological expanded from working out in the modular unit, in search of mutual cooperation and integration has improved the performance of the whole technology (Hobday, 1998; Inoue & Miyazaki, 2008).

In the third stage, the innovation has occurred at the system level and micro-emerging networks. When a disturbance occurs as a frequency shift of power in the electrical system, there are limits that govern the performance improvement, improving the relationship because of the mutual dependence of modular units. For further performance improvement, an alternative means or other technology option is necessary (Heier, 1998). One such measure is to continue with the system decomposition approach in an attempt to stabilize the networks in small groups, ensuring a balance between supply and demand at connection points, and avoid disruptions that occur on the grid in general. It is interesting to note that the evolutionary trajectory of this technology tends to lead to higher levels of the hierarchy of the system for stability (Tidd, Bessant, & Pavitt, 2005). This is the reverse, and in contrast to the process by which cars in general and other industries are going to lower levels, apparently due to the fact that the wind carries the full burden of social charges, while production technologies existing power are not subject to external economic factors. Micro-grids can be expected to affect the diffusion of wind power ∴ If the demand for wind energy grows, the opportunities for technological innovation will emerge as well, which make it possible to eliminate factors that inhibit the rate of technological evolution of wind power (Clark, 1985).

Related to wind resources worldwide, many studies deal with wind speeds geographical distribution and most of them converge that characteristic parameters of the wind profile, orography, topography and local wind flow and measurement of the wind speed are very necessary in wind resource evaluation for a successful and safe application of wind turbines (de Castro, Mediavilla, Miguel, & Frechoso, 2011). The potential availability of wind power can change over time and among locations. This variation is not only caused by the resource characteristics (wind regime and profile, soil, humidity, etc.) but also by geographical (land use and land cover), techno-economic (scale, labor cost, inflation, time horizon, etc.) and institutional (policy regime,

legislation specialized) factors. Some of these factors cannot or can only approximately be quantified or estimated.

In respect to global wind energy situation we can say about 2011 was a tough year for wind energy industry, and although cumulative market growth was around 20%, the annual market decreased for the first time in the last twenty year. The financial crisis in medium term brought some consequences and the global economy had to slowdown, and very low orders in OECD countries at the end of 2008 and the beginning of 2009 made themselves felt in the 2010 installation totals, particularly in the USA. Amazingly approximately 40.5 GW of new wind power capacity was added around the world last year, and for once the majority of that new capacity was in developing countries and emerging economies; driven mainly by the booming wind sectors in China and India, but also with strong growth in Latin America, where we believe that macroeconomic situation and wind resource-rich will make the wind energy industry jumps much forward in those regions which we have been waiting for and expecting for so many years (GWEC, 2012).

The growth of wind power outside of the OECD has been essential driven by the continuing boom in China, which is now the top country in installed wind power capacity in the world (see Figures 3.13, 3.14 and Table 3.2). There is also a great change of attitude by government towards wind power in many countries. First of all wind technology was considered too expensive by many developing country energy planners just a couple of years ago, the progressive success of the technology in much more countries have changed that attitude to one of dramatically increased knowledge about wind energy and how could wind energy technology improve the country's power mix.

Economic impacts from wind energy industry are clearly positive in a macroeconomic terms, because its impacts on employment, incomes and taxes and production of goods and services in general. First of all, it is necessary to emphasize that wind energy industry represent an important source of employment in many countries in the globe. There are some activities like operation and maintenance (O&M), research and development (R&D), manufacturing and construction which are able to create jobs in wind industries. The electric power industry is a strongly regulated industry and, in the case of RE technologies, the role of governments' incentive to bring these young technologies (related to fossil fuel technologies) to market adds to the importance of politics. Looking at the growth of wind turbine capacity over the past ten years, some conclusions can be taken. Among all renewable energies, wind energy is certainly the one that is closest to making the transition from niche to mass market. It is strongly linked with long-term prosperity. For Pablo (2008) *investment* explains the productive capacity of an economy. Investments made in the renewable energy industry have in addition a strong influence on the degree of dependence among economies, their competitiveness, sustainability, and on all kinds of environmental issues including climate change.

Wind power technology must be understood with its nature, working principle of WECS, innovation and technology trends, in summary, the Chapter 4 is made a compilation of WECS in order to establish a context for better understanding the current wind energy conversion systems, for a comprehensive cost production analyzes of a wind farm.

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God gave the wind its weight. Job 28:25.

# **CHAPTER 4**

# WIND ENERGY CONVERSION SYSTEM

- 4.1 Introduction
- 4.2 History of wind energy
- 4.3 Wind energy technology
  - 4.3.1 Wind energy conversion system
  - 4.3.2 Wind energy converters
  - 4.3.3 Technical design of converters
    - 4.3.3.1 The design with gearbox
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- 4.4 Physical basics applied to WECS
  - 4.4.1 Energy extracted from wind
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      - 4.4.2.1 Betz' law and the power coefficient  $(C_p)$
      - 4.4.2.2 Tip speed ratio
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- 4.5 Wind farm planning
  - 4.5.1 Wind farm layout
  - 4.5.2 Requirements for land area
  - 4.5.3 Types of wind farm layout
- 4.6 Summary and conclusions
- 4.7 References

This chapter discusses about wind energy conversion system (WECS). It is discussed about wind energy history, technological aspects; types of wind energy converters are also presented. There is a summary of physics basics applied to WECS. Wind farms layouts with their own aspects are shown. Summary and conclusions are shown with respective references at the end.

## 4.1 INTRODUCTION

Wind energy systems have a multidisciplinary aspect and various perspectives to be analyzed. Any perspective approached, regardless of its background, will feel large gaps in its knowledge, areas where it does not even know what the question is, let alone where to go look for the answer. For Herbert, Iniyan, Sreevalsan, and Rajapandian (2007) wind energy system has a unique technical identity and unique demands in terms of the methods used for design. Remarkable advances in the wind power design have been achieved due to modern technological developments. Wind energy systems convert the kinetic energy<sup>27</sup> of moving air into electricity or mechanical power. Wind turbines are commercially available in a vast range of sizes. The kinetic energy in the wind is a promising source of renewable energy with significant potential in many parts of the world (see Figure 3.11).

The energy that can be captured by wind turbines is highly dependent on the local average wind speed. Regions that normally present the most attractive potential are located near coasts, inland areas with open terrain or on the edge of bodies of water. Some mountainous areas also have good potential. In spite of these geographical limitations for wind energy project sitting, there is ample terrain in most areas of the world to provide a significant portion of the local electricity needs with wind energy projects. Wind turbines are getting larger because of the desire to increase the power output and the associated economy of scale. The power output is directly proportional to the swept area of the rotor (larger blades equal larger swept area, which results in higher power output). Costs are also decreased when using larger turbines because fewer turbines are needed to make up the wind farm, which means that; less roads to the turbines are required, less interference with agriculture (when compared to having several smaller wind turbine units in the same area producing the same power).

This chapter makes a compilation of wind energy conversion systems (WECS) in order to establish a context for better understanding the current wind energy conversion systems. It begins with a bit of history about wind energy and its milestones and application by human civilization until nowadays time (section 4.2). Section 4.3 refers to the technological aspects of wind energy technology by describing system parts or elements (section 4.3.1) within its conversion processes and types of wind energy converters (section 4.3.2) and the design of converters (section 4.3.3) used in actual power energy market. Section 4.4 is related to physical basics applied to wind energy conversion system, especially emphasis on energy extracted from wind (section 4.4.1); power coefficients (section 4.4.2.1), *tip speed ratio* (sub-section 4.4.2.2) and *power efficiency* (subsection 4.4.2.3). For a question of economy scale, wind power is more and more presented as an aggregated form, in a wind farm configuration, that is why we discuss about wind farms layout (section 4.5). Finally, the summary and conclusions of the whole chapter (section 4.6) and all references used are present at the end of this chapter.

<sup>&</sup>lt;sup>27</sup> According to Rosa (2009) wind is a kind of simple air motion. It is caused by the unequal heating of the earth surface. Since the earth surface is made of different kinds of continents and oceans, it absorbs the sun heat at different rate, and the different temperature could cause the different pressure. The wind's kinetic energy can be converted into other forms of energy, either mechanical energy and/or electrical energy.

## 4.2 HISTORY OF WIND ENERGY

The power of the wind has been utilized for at least 3,000 years. Wind energy first used for boat navigation on the Nile River 5,000 BC. During the same period, windmills pumped water in China. The first written information on wind turbines is based on a simple structural horizontal axis wind turbine during the region of Alexander the Great. It is known that the Persians used vertical axis wind turbines during 700 BC. Windmills are introduced to the western world at the beginning of the 12th century from Islamic world. Until the early 20th century wind power is used to provide mechanical power to pump water or to grind cereals (Şahin, 2004). According to Kaldellis and Zafirakis (2011) it was centuries ago when the technology of wind energy made its first actual steps - although simpler wind devices date back thousands of years ago — with the vertical axis windmills found at the Persian-Afghan borders around 200 BC and the horizontal-axis windmills of the Netherlands and the Mediterranean following much later (1300-1875 AD).

The wind has been used to power sailing ships for many centuries. Many countries owed their prosperity to their skill in sailing. The New World was explored by wind powered ships. Indeed, wind was almost the only source of power for ships until Watt invented the steam engine in the 18th Century. On land, wind turbines date back many centuries. It has been reported that the Babylonian emperor Hammurabi planned to use wind turbines for irrigation in the seventeenth century B.C. Heron of Alexandria<sup>28</sup>, who lived in the third century B.C., described a simple horizontal axis wind turbine with four sails which was used to blow an organ (see Figure 4.1). The Persians were using wind turbines extensively by the middle of the seventh century A.D. Theirs was a vertical axis machine with a number of radially-mounted sails (Johnson, 2001).



**Figure 4.1** Concept of the windmill-device, or organ described by Heron of Alexandria. Source: Shepherd (1990, p. 5)

<sup>&</sup>lt;sup>28</sup> *Heron of Alexandria* was a mathematician, a physicist and an engineer who wrote many books on Mathematics, Geometry and Engineering, in use till the medieval times. His devices were powered by single humans, water, steam or the wind, and contained many simple mechanisms (Papadopoulos, 2007, p. 23).

For Johnson (2001) these early machines were rightly simple and mechanically inefficient, but they served their purpose well for many centuries. Maintenance was probably a problem which served to keep many people at work. Their size was probably determined by the materials available. A need for more power was met by building more wind turbines rather than larger ones. The earliest recorded English wind turbine is dated at 1191. The first corn-grinding wind turbine was built in Holland in 1439. There were a number of technological developments through the centuries, and by 1600 the most common wind turbine was the tower mill. This application was so common that all wind turbines were often called *windmills*<sup>29</sup> even when they actually pumped water or performed some other function. The tower mill had a fixed supporting tower with a rotatable cap which carried the wind rotor. The tower was usually built of brick in a cylindrical shape, but was sometimes built of wood, and polygonal in cross section. In one style, the cap had a support or tail extending out and down to ground level. A circle of posts surrounded the tower where the support touched the ground. The miller would check the direction of the prevailing wind and rotate the cap and rotor into the wind with a winch attached between the tail and one of the posts. The tail would then be tied to a post to hold the rotor in the proper direction. This process would be repeated when the wind direction changed. Protection from high winds was accomplished by turning the rotor out of the wind or by removing the canvas covering the rotor latticework (Sorensen, 1995).

The optimization of the rotor shape probably took a long time to accomplish. It is interesting to note that the rotors on many of the Dutch mills are twisted and tapered in the same way as modern rotors and appear to have nearly optimized the aerodynamic parameters necessary for maximum efficiency. The rotors presently on the tower mills probably do not date back to the original construction of the tower, but still indicate high quality aerodynamic engineering of a period much earlier than the present. Dutch settlers brought this type of wind turbine to America in the mid-1700's. A number were built but not in the quantity seen in Europe. Then in the mid-1800's a need developed for a smaller wind turbine for pumping water. The American West was being settled and there were wide areas of good grazing lands with no surface water but with ample ground water only a few meters under the surface. With this in mind, a distinctive wind turbine was developed, called the American Multibladed wind turbine. It had high starting torque and adequate efficiency, and suited the desired water pumping objective very well. If the wind did not blow for several days, the pump would be operated by hand. Since this is a reasonably good wind regime, hand pumping was a relatively rare occurrence (Bellarmine & Urquhart, 1996).

An estimated 6.5 million units were built in the United States between 1880 and 1930 by a variety of companies. Many of these are still operating satisfactorily. By providing water for livestock, these machines played an important role in settling the American West (Kaldellis & Zafirakis, 2011). For Brown (2003) the energy future belongs to wind. The world energy economy became progressively more global during the twentieth century as the world turned to fossil fuels. It promises to reverse direction and become more local during the twenty-first century as the world turns to wind.

<sup>&</sup>lt;sup>29</sup> The word *mill* refers to the operation of grinding or milling grain. The study of wind machines is called *molinology*. It is related to several fields including Meteorology, Aerodynamics, Machine Design, Structural Design, Materials Technology, Power Engineering, Reliability Engineering, Instrumentation and Controls Engineering (Hills, 1996).

Wind power will shape not only the energy sector of the global economy but the global economy itself. Some milestones in the history of wind machines are summary up in Table 4.1.

Period	Machine	Application
640 AD	Persian wind mills	Grinding, etc.
Before 1200 AD	Chinese sail type wind mill	Grinding, water pumping,
12th century AD	Dutch wind mills	Grinding, water pumping, etc.
1700 AD	Dutch wind mill to America	
1850 to 1930 AD	American Multi-bladed	Water pumping, 35 VDC power
1888 AD	Brush wind turbine; dia.17m, Tower 18.3m	12 kW Electric power
1925 AD	Jacob's 3 bladed propeller; Dia.5m, 10-20m/h, 125 to 225 rpm	0.8 to 2.5 kW at 32 VDC
1931 AD	Yalta Propeller, Russia; 2 bladed, dia.100 ft.	100 kW
1941 AD	Smith-Putnam Propeller 2 bladed, dia.175ft, 30 m/h, 28 rpm	1250 kW
1925 AD	Savonius Machine	Mechanical or Electrical
1931 AD	Darrius	Electrical power
1980s AD	2 bladed propeller (Commercially available)	225 kW
2000 AD	HAWT, VAWT	400-625kW, 1.2-3.2 MW

**Table 4.1** Historical development of wind energy conversion system

Source: adapted from Spera (1994) and Sorensen (1995)

Over more than 2,000 years, water and windmills powered the world's first industries with new technology and materials. Modern wind turbines are used to generate the clean electricity needed for lighting, heating, refrigeration and other uses. Wind energy is a rather young industry, but one which already makes good economic sense. It is a proven success and its use is increasing and the downward trend in its costs is expected to continue (Şahin, 2004). According to Leung and Yang (2012) currently, wind energy is a mature renewable energy source that has high potential to become a major primary source of energy in the future. Over the last decade, wind energy has developed by leaps and bounds∴ During this period, the world wind power producing capacity has grown rapidly, with an average annual growth of 29%. The history of wind energy has grown from humble sails and simple mills, to become one of the most important renewable energy sources in the energy markets. While the history of wind energy is already a long one, we believe the biggest part is not written yet! The history of wind energy is still in its childhood, and we will see many changes over the coming decades.

### 4.3 WIND ENERGY TECHNOLOGY

#### 4.3.1 WIND ENERGY CONVERSION SYSTEM

The wind energy technology is a system (called "Wind Energy Conversion System" — WECS) developed to capture the power in the wind (see section 4.4.1). The working principle of a wind turbine involves two main conversion processes, which are carried out by its main components: the rotor, which extracts kinetic energy from the wind and converts it into a mechanical torque, and the producing system, which converts this torque into electricity. This general working principle is depicted in Figure 4.2. Although this sounds rather straightforward, a wind turbine is a complex system in which knowledge or expertise from the areas of aerodynamics, mechanical, civil, electrical and control engineering comes together. Depending on the focus given to the WECS it can be includes economics and management sciences (e.g. wind farm management, economic evaluation of wind farms, etc.).



Figure 4.2 Wind energy conversion system (WECS). Source: Kim and Lu (2010, p. 120)

Susman and Glasmeier (2009) has divided wind energy systems into four major components. Each major component contains several sub-components, some of which are mentioned in the paragraphs below and in Figures 4.2 and 4.3.

1. *Nacelles.* The nacelle<sup>30</sup> is the external shell or structure that houses all of the producing components, i.e., gearbox, shaft, generator, etc. Turbine size ranges from 1 kW to 7 MW. A rotor aerodynamically converts wind energy into mechanical energy on a slowly turning shaft. A gearbox increases the rotor-shaft speed for the generator, which converts shaft speed into electrical energy. Most turbines have gearboxes, but generators can run at rotor-shaft speed and not require a gearbox (e.g., Enercon). The yaw drive<sup>31</sup> turns the turbine horizontally on its tower toward angles that maximize advantage of wind direction.

<sup>&</sup>lt;sup>30</sup> Term derived from old French *nacelle* which means small boat or dinghy, which is derived from the Latin *navicella*. The term is used generally in aviation project, nautical and space. In the case of wind power, the nacelle is the part that houses the main components of the wind turbine, gear box, electric generator, gearbox, controllers, cooling system, among others (Jenkins, 2001).

<sup>&</sup>lt;sup>31</sup> The yaw drive is a mechanism used to keep the rotor facing into the wind as the wind direction changes. The yaw system has a motor, which turns the wind turbine to align it with the wind, is nearly always included on large turbines, resulting in active yaw control (Hau, 2006, p. 146).

- 2. *Rotors/Blades.* Rotors typically have three blades that are secured to a hub by extenders. The dominant design for large wind turbines (above 100 kW) is variable speed and variable pitch<sup>32</sup> control. Also, the, rotor is located on the wind side (upwind) of the tower. In such systems, a pitch drive turns the blades to optimal angles for wind speed and desired rotation speed, e.g., perpendicular to the wind at low speeds and parallel at high speeds. Rotor diameter generally increases with turbine size for application in low and medium wind locations.
- 3. *Towers*. For lighter wind power classes<sup>33</sup>, turbines need to be raised to heights where the average wind speed is greater and the effects of local obstructions are fewer. Utility scale towers are 60-100 meters in height. Towers can be made of rolled tubular or lattice-structured steel or cement. Most towers in the current world are made of rolled steel tube sections that are bolted together (Paredes, Barbat, & Oller, 2011).
- 4. Balance of System Components. These components include transformers to step up voltage for transmission to electrical grids, underground cables, circuit breakers, power substations, supervisory control and data acquisition (SCADA<sup>34</sup>), fiber optic cables, a control station, crane pad, access roads, and maintenance buildings. It can also include *miscellaneous* items such as training, interest during construction and contingencies (Magoha, 2001).

According to Cheng, Lin, Bao, and Xue (2009) generally, a wind turbine producing system can be divided into two parts: mechanical section and electrical section (see Figure 4.3). Early development is focused on mechanical section with multistage gearbox; then it changed to more electrical part and less mechanical part, such as direct-drive and one-stage gearbox (see Figure 4.10). The trend is due to reduce the system mass and cost, mechanical loss and potential to wear out; increase the aerodynamic efficiency and control flexibility, then enhance the power quality. When we consider the WECS into these two main parts, it really makes sense to measure its working by the *electromechanical efficiency*, so it express a reduce way to analyze its electrical and mechanical power.



# **Figure 4.3** Main components of a wind turbine system. Source: Zhe, Guerrero, and Blaabjerg (2009, p. 1860)

<sup>&</sup>lt;sup>32</sup> Pitch control is the active regulation of the rotor blades' angle by a machine control system (pitch control mechanism). Turbine blade pitch control has a significant impact on the dynamic behavior of the system. This type of control only exists in horizontal axis machines. Variable pitch turbines operate efficiently over a wider range of wind speeds than fixed pitch machines (Şahin, 2004).
<sup>33</sup> For more details, please see page 54, Chapter 3, footnote 14 of this Ph.D. research work.

<sup>&</sup>lt;sup>34</sup> The SCADA system typically provides the ability to manage the wind plant remotely and locally. SCADA system also consists of databases to manage both real-time and historical information updated from the turbines typically done once every second, while the SCADA system aggregates and compiles the raw data into meaningful information (Badrzadeh et al., 2011).

The main components of a wind turbine system are illustrated in Figure 4.3, including a turbine rotor, a gearbox, a generator, a power electronic system, and a transformer for grid connection. Wind turbines capture the power from wind by means of turbine blades and convert it to mechanical power. It is important to be able to control and limit the converted mechanical power during higher wind speeds. The power limitation may be done either by stall control<sup>35</sup>, active stall<sup>36</sup>, or pitch control (Blaabjerg, Chen, & Kjaer, 2004).

For Hoffman and Molinski (2009) wind turbines are getting larger because of the desire to increase the power output and the associated economy of scale. The power output is directly proportional to the swept area of the rotor (larger blades equal larger swept area, which results in higher power output). Costs are also decreased when using larger turbines because fewer turbines are needed to make up the wind farm, which means that; less roads to the turbines are required, less cabling between wind turbines is required, less maintenance (fewer turbines) is required, and there is less interference with agriculture (when compared to having several smaller wind turbine units in the same area producing the same power).

Wind turbines are large structure and so weight is very important. Blade weight is especially important, as savings in rotor weights allow related reductions in the weight of the hub, nacelle and tower structure. A wide range of blade materials have been used for blade manufacture, including aluminum, steel, wood epoxy and glass-reinforced plastic (E-glass) (Griffin, 2002; Griffin & Ashwill, 2003). The two last materials are now most common as they have the best combination of strength, weight and cost. It is essential to keep weights to the minimum, as the weight of a wind turbine has a strong influence on its overall cost (Oliveira & Fernandes, 2012; Şahin, 2004). Dalili, Edrisy, and Carriveau (2009) studied about ice, insects, and erosion and conclude that these issues represent significant economic impact for commercial wind turbine operation, as they can decrease the aerodynamic efficiency of wind turbine blades, make happen shutdowns, and contribute to unscheduled maintenance requirements.

Towers are the other main component of WECS. They are as integral to the performance of the wind system as the wind turbine itself. The tower must be strong enough to withstand the thrust on the wind turbine and the thrust on the tower. The tower must also support the weight of the wind turbine. Tall towers are preferred as they minimize the turbulence induced. Tall towers allow more flexibility in sitting. The most important factor is the ability of a tower to withstand the forces acting on it in high winds. Towers are rated by the thrust load they can endure without buckling. The thrust on the tower at high speeds depends on the rotor diameter of the wind turbine and its mode of operation under such conditions (Jenkins, 2001; Söder, 2001).

WECS can be classified is many aspects, so we consider broadly criteria used for wind energy conversion system technology (size of electrical power output; rotational speed of wind turbines and orientation of wind turbines). Table 4.2 presents the current classification of WECS.

<sup>&</sup>lt;sup>35</sup> *Stall control* is a passive system that reacts to wind speed. The rotor blades are fixed in their pitch angle and cannot rotate around its longitudinal axis. The pitch angle is chosen so that wind speeds higher than the rated speed; the flow around the rotor blade profile takes off from the surface of the shovel (stall), reducing the support forces and increasing the drag forces. Under all conditions of winds in excess of rated speed, the disposal around the profiles of rotor blades is, at least partially, taken off the surface, producing a minors lift forces and high drag forces (Jenkins, 2001).

<sup>&</sup>lt;sup>36</sup> According to Manwell, McGowan, and Rogers (2002) *active stall* is the combination of *stall* and *pitch control* options. This kind of control is being used on an increasing number of large wind turbines usually greater than 1 MW.

Criteria	Classification	Application
<ol> <li>Size of useful electrical power output</li> </ol>	(1) Small size (up to 2 kW)	These may be used for remote applications, or at places requiring relatively low power.
	(2) Medium size (2–100 kW)	These turbines may be used to supply less than 100 kW rated capacity to several residences or local use. They are used to generate power for distribution in central power grids.
	(3) Large size (100 kW and up)	
2. Rotational speed of wind turbines	(1) Constant Speed Constant Frequency (CSCF)	For large scale electrical energy to feed-in directly into electrical grids with pitch and stall controls active with a simple design and low cost of capital; Frequency limitation by grids connection for power produced
	(2) Variable Speed Constant Frequency (VSCF)	distribution. When it is necessary to low the initial cost, leading to an overall reduction of 5–10% in total system capital cost, and are maintenance free and most reliable; Higher annual energy yields per rated installed capacity.
	(3) Variable Speed Variable Frequency (VSVF)	Stand-alone wind power applications; Off-grid applications.
3. Orientation of wind turbines	(1) Horizontal Axis Wind Turbines (HAWT)	Electricity production; Pumping water; Purifying and/or desalinating water by reverse osmosis; Heating and cooling using vapor compression heat pumps; Mixing and aerating water bodies; Heating water by fluid turbulence; Research, development, and demonstration (RD&D) initiatives.
	(2) Vertical Axis Wind Turbines (VAWT)	Research, development, and demonstration (RD&D) initiatives; Electricity production; Pumping water.
4. Location of wind turbines (cluster, e.g. wind farm)	(1) Onshore	When there is availability of lands without objections by the public or other stakeholders; Budget restrictions; RE policy. etc.
	(2) Nearshore	Few people live near the coast; when the distance out to sea, and a range of difficulties to do not overcome the difficulties of an offshore site for the wind farm; wind resources are better than off and on-shore sites available.
	(3) Offshore	When exist higher and more constant wind speeds and, consequently, higher efficiencies; The mobility of technicians and goods for O&M routines are not a problem.
istribution of electrical power output	(1) Off-grid applications	Pumping water and providing smaller amounts of electricity for stand-alone battery; Charging applications; Research, development, and demonstration (RD&D) initiatives.
	(2) On-grid (grid-connected) applications	Remote windy areas with high cost of transporting
	(2.1) Isolated-grid	diesel fuel to these isolated sites; Research, development, and demonstration (RD&D) initiatives.
5. D	(2.2) Central-grid	For windy areas, larger scale wind turbines clusters together (wind farm) for multi-megawatt output power

Table 4.2 General criteria, classification and some applications of WECS

Source: based on Bansal, Bhatti, and Kothari (2002); Bansal, Zobaa, and Saket (2005), Haggett (2008) and RETScreen® International Clean Energy Decision Support Centre (2008, 2009)

As we could see in Table 4.2 it is possible to classify WECS into broadly criteria categories, so, that is, (1) Size of useful electrical power output; (2) Rotational speed of wind turbines; (3) Orientation of wind turbines; (4) Location of wind turbines and (5) Distribution of electrical power output. The first category, size of useful electrical power output, the small, medium and large size, there is a range from 2 kW to 100 kW per turbine. This classification is usually applied to wind turbine alone, not to wind turbine cluster together (wind farms).

The second category, *rotational speed of wind turbines*, the wind turbines has developed since its first conception. The technological evolution has been pushing forward by nature of innovation process. The wind turbines typologies represent phases of wind industry evolution, in the beginning the CSCF machines were used for the implantation phase, after we can notice such a technological evolution in electronics aspects of wind turbines as VSCF and VSVF. These concepts have been improved in function, essentially, to avoid *harmonics*<sup>37</sup> and *flicker*<sup>38</sup> emissions on the grids (Chen & Blaabjerg, 2009; Georgilakis, 2008). It is important to say that each of these typologies depending on grids requirements or connection, in case of on-grids applications. Most of the current grid connections are still in constant frequency situations. According to Polinder (2011) wind turbines are mostly connected to a 50 or 60 Hz grid.

The third category is usually when it is considered the direction of the axis of wind turbines in relation to the air flow; they can be classified as *Horizontal Axis Wind Turbines (HAWT)* and *Vertical Axis Wind Turbines (VAWT)*. We must highlight into the history of wind energy technology the first steps were done with VAWT principle by the Persian people. During the technology evolution special emphasis was given to HAWT due to its applicability in different and better windy sites for this kind of technology.

The fourth category is related to the location of wind turbines, it is clear to understand the difference among onshore, nearshore and offshore. According to Mathew (2006) when a wind farm is about three kilometers away from the nearest shoreline it is regarded as an *onshore* wind farm. They are normally installed in the mountainous areas as the higher you go the faster the wind blows. The cliffs and mountains also contribute to speeding up the wind. Before setting up a wind farm much research has to be done because the smallest difference of placement could even double the turbines' output (Petersen, Mortensen, Landberg, Højstrup, & Frank, 1998). If a wind farm lies on land within three kilometers to the nearest shore line or staying on the water within ten kilometers from the shore it is considered as *nearshore* wind farm. Sea shores tend to be very windy as the land and sea heat up and cool down at different rates, creating strong winds. The wind from the sea is also denser and therefore carries more energy than the same speed wind in mountainous terrain (Söder, 2001). If a wind farm is more than ten kilometers into the sea form a shore then it is considered to be *offshore*. Offshore turbines are found in deep sea waters and are usually much larger than their land-based siblings. The wind over the open sea is considerably faster and stronger than that of land because they have no obstacles in their way such as trees and

<sup>&</sup>lt;sup>37</sup> Harmonic emission is another crucial issue for grid connected wind turbines cause it may result in voltage distortion and torque pulsations, which consequently causes overheating in the generator and other problems (Kim & Lu, 2010, p. 127).

<sup>&</sup>lt;sup>38</sup> Fluctuations in the system voltage (in terms of rms value) may cause perceptible light flicker depending on the magnitude and frequency of the fluctuation. Fast variations in the power output from a wind turbine, such as generator switching and capacitor switching, can also result in variations in the rms value of the voltage. At certain rate and magnitude, the variations cause flickering of the electric light. Thus, this type of disturbance is called *voltage flicker* (Zhe et al., 2009).

buildings to affect the wind speed. Their distance from land allows companies to create larger ones and they do not need to worry about any noise factors as they are a considerable distance from the shore (Haggett, 2008). The offshore wind farms are the most expensive to build as they need to be set in the open ocean where they are subjected to all the earth's elements, therefore raising the maintenance cost of offshore wind farms. The cost involved in transferring the electricity from the turbine to the land could be large as there is a large distance to be covered (Beurskens, Andersen, Petersen, & Garrad, 1996). Offshore wind farms are much larger than the onshore counterparts as there is much more space in the open sea as opposed to land.

The fifth category, *distribution of electrical power output*, it is related to the distribution of the electrical production by wind turbine or wind farm. The main criterion is the grid connection of the power system. If the WECS is not connected to any grid, it is named *off-grid* applications. This has been applied to remote sites when the connection to an electrical grid is too much expensive to the whole system, considering the power output of this same power system. But if the wind power system must be connected into a grid for power distribution, it can be classified into *isolated-grid* and *central-grid*. The main differences between isolated-grid and central-grid applications

We must clarify that these categories of WECS classification can be expanded due to its evolutive nature and applications. It is not a rigid classification and it is far of being concluded. More categories can be added, it depends on the way we want to analyze the power system as a whole or as its parts. So what it is shown in Table 4.2 is the most common and useful classification of current WECS, as we know it. Some aspects of WECS configuration must be known as essential technical aspects of the power system, as *swept area of blades*, *rotor diameter*, *rotor blade (2 or 3 blades)* and *hub height* (see Figure 4.4).



**Figure 4.4** HAWT system schematic. Source: RETScreen® International Clean Energy Decision Support Centre (2009, p. 8)

#### 4.3.2 WIND ENERGY CONVERTERS

A wind turbine is a rotating machine which converts the kinetic energy in wind into mechanical energy. If the mechanical energy is then converted to electricity, the machine is called a *wind generator, wind turbine, wind power unit (WPU), wind energy converter (WEC), or aerogenerator.* Today there are various types of wind energy converters in operation as shown in Figure 4.5. The most common device is the horizontal axis wind energy converter, also named as Horizontal Axis Wind Turbine (HAWT). The main aspect of this type of system is the rotor blades optimized by few aerodynamics controls, which its function is primary make the regulation of the position of their long axis (pitch-regulation). Another less expensive way to control and regulate it is related to the design of the blades in such manner that the air streaming along the blades surface will go into turbulence at a certain speed (stall-regulation). Therefore, it is only applied for electricity production projects purpose which needs *"high speed engines"* to keep the gear transmission and the generator small and cheap (Hau, 2006, p. 102; Mathew, 2006, p. 34).



Figure 4.5 Different types of WECS. Source: Wagner and Tryfonidou (2005, p. 192)

The multiblade wind energy converter is another type of horizontal axis rotor. As windmills in the beginning of wind power history utilization have a high starting torque which makes them suitable for driving mechanical water pumps. The number of rotations is low, and the blades are made from simple sheets with an easy geometry. For pumping water, a rotation regulating system is not necessary, but there is a mechanical safety system installed to protect the converter against storm damage. In order to increase the number of rotations, this type of converter had been equipped with aerodynamically more efficient blades facilitating the production of electricity, where the area of a blade is smaller. The mechanical stability of such *"slow speed converters"* is very high; some have had operation periods of more than fifty years (Shepherd, 1990).

A third type of converter is known as Darrieus, they are a type of vertical axis rotor engines. Their main advantage is that they do not depend on the direction of the wind. To start working, they need the help of a generator working as a motor or the help of a Savonius rotor installed on top of the vertical axis. In the 80's and 90's years, a reasonable number of Darrieus-converters had been installed in US, especially in California, but in the rest of the world does not happen the same. One possible reason could be the noise produced when they were working in comparison with horizontal axis converters. It is important to highlight the disadvantage about the increasing nature of wind speed with height, which possible makes horizontal axis rotors on towers more attractive at economical point of view. Amazingly this type of rotor is extensively applied for R&D activities, pumping water, and other related purpose for conversion of kinetic power into mechanical ones (Eriksson, Bernhoff, & Leijon, 2008).

The Savonius rotor is used only for research activities, e.g. as a measurement device especially for wind speed, it is not used for power production. In fact, the Savonius rotors can be said to be high productivity and low technicality wind machines  $\therefore$  It is probably the reason why they are often used for water pumping, especially in poor countries and in isolated sites (Menet, 2004). Therefore it will not be discussed in detail here. There have been many designs of vertical axis windmills over the centuries and currently the vertical axis wind turbines can be broadly divided into three basic types, namely (1) Savonius type, (2) Darrieus type, and (3) H-Rotor type. Take a look in Figure 4.6 below.



**Figure 4.6** Modern VAWT types. Source: Islam, Ting, and Fartaj (2008, pp. 1091-1095) (a) Savonius-type VAWT; (b) Curved-blade (or "Egg-beater" type) Darrieus VAWT; (c) Straight-bladed Darrieus VAWT; (d) H-Rotor-type VAWT.

The last technique is known as *up-stream power station*. The up-stream power station's principle working is a scheme of sequential power conversion inter-connected. The air is heated by solar radiation under a low circular transparent or translucent roof open at the periphery; the roof and the

natural ground below it form a solar air collector. In the middle of the roof is a vertical tower with large air inlets at its base. The joint between the roof and the tower base is airtight. As hot air is lighter than cold air it rises up the tower. Suction from the tower then draws in more hot air from the collector, and cold air comes in from the outer perimeter. Continuous 24 hours-operation can be achieved by placing tight water-filled tubes or bags under the roof. The water heats up during day-time and releases its heat at night. These tubes are filled only once, no further water is needed. Thus solar radiation causes a constant updraft in the tower. The energy contained in the updraft is converted into mechanical energy by pressure-staged turbines at the base of the tower, and into electrical conventional generators (Schlaich, Bergermann, Schiel, & Weinrebe, 2003).

Two major technological developments have recently occurred in the field of wind energy. First, a substantial extension which in turn made further reducing the cost of wind energy turbine: individually become bigger and so has typical dimensions. For modern wind turbines of multi-MW class, both the height of the rotor diameter and nacelle are on the order of 100 m. Hence, upright, the tip of the blade can reach heights of up to 150 m. development of scale of individual wind turbines placed on the market is represented in Figure 4.7.



**Figure 4.7** Growth in size of commercial wind turbine designs. Source: Morthorst and Shimon Awerbuch (2009, p. 39)

The second important development in wind turbine technology is the change of production constant speed for a variable speed system of production. Of course, the difference in wind speed constant turbine, the rotor rotates at a constant speed while in a variable speed wind turbine; the rotor rotation speed can vary and be controlled, of course within a certain limit projected. In recent years,

many manufacturers have the concept of conventional speed constant to the variable speed concept. Variable speed systems are technically more advanced than the constant-speed systems. Consist of more components require additional control systems and, therefore, a higher cost. However, also have several advantages compared to systems of constant speed, as greater energy efficiency, a reduction in noise emission and mechanical loads and better controllability of active and reactive power (Jenkins, 2001; Manwell et al., 2002).

According to Amirat and Benbouzid (2007) the fixed and variable speed for WECS has its own peculiarities. In a fixed speed WECS, the turbine speed is determined by the grid frequency, the generator pole pairs number, the machine slip, and the gearbox ratio. A change in wind speed will not affect the turbine speed to a large extent, but has effects on the electromagnetic torque and hence, also on the electrical output power. With a fixed speed WECS, it may be necessary to use aerodynamic control of the blades to optimize the whole system performance, thus introducing additional control systems, complexities, and costs : As for the producing system, nearly all wind turbines installed at present use either one of the following systems: squirrel-cage induction generator<sup>39</sup> (SCIG), doubly-fed (wound rotor) induction generator<sup>40</sup> (DFIG), direct-drive synchronous generator<sup>41</sup> (DDSG). The variable speed production system is able to store the varying incoming wind power as rotational energy, by changing the speed of the wind turbine, in this way the stress on the mechanical structure is reduced, which also leads to that the delivered electrical power becomes smoother. The control system maintains the mechanical power at its rated value by using the Maximum Power Point Tracking Technique<sup>42</sup> (MPPT). These WECS are generally divided into two categories: systems with partially rated power electronics and systems with full-scale power electronics interfacing wind turbines.

For Li and Chen (2008) WECS can be classified considering the rotation speed, into *fixed speed*, *limited variable speed* and *variable speed*. For variable speed wind turbines, based on the rating of power converter related to the generator capacity, they can be further classified into wind generator systems with a partial-scale and a full-scale power electronic converter. In addition, considering the drive train components, the wind turbine concepts can be classified into *geared-drive* and *direct-drive* wind turbines. In geared-drive wind turbines, one conventional configuration is a multiple-stage gear with a high-speed generator; the other one is the multibrid concept which has a single-stage gear and a low-speed generator. In the last decade, many power converter techniques have been developed for integrating with the electric grid. The use of power electronic converters allows for variable speed operation of the wind turbine, and enhanced power extraction. In variable speed operation, a control method designed to extract maximum power from the turbine and provide constant grid voltage and frequency is required. A wide range of control schemes, varying in cost

<sup>&</sup>lt;sup>39</sup> According to Solyali and Redfern (2009) a squirrel-cage rotor is the rotating part used in the most common form of AC induction motor. In overall shape, it is a cylinder mounted on a shaft. Internally it contains longitudinal conductive bars (usually made of aluminum or copper) set into grooves and connected at both ends by shorting rings forming a cage-like shape.

<sup>&</sup>lt;sup>40</sup> Doubly fed electric generators are electric motors that have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and electrical system. Doubly fed machines are used in applications that require varying speed of the machine's shaft for a fixed power system frequency (Baroudi, Dinavahi, & Knight, 2007).

<sup>&</sup>lt;sup>41</sup> The rotor of direct-drive generator for wind turbine is directly connected to the rotor hub. The synchronous machines have as a work principle to operate at synchronous speed (speed of rotor always matches supply frequency). One of the most important types of electrical rotating machines is the *synchronous generator*, this machine is capable of converting mechanical energy into electricity when operated as a generator and power mechanics when operated as a motor (Bang, Polinder, Shrestha, & Ferreira, 2008; Cheng et al., 2009).

and complexity, have been investigated for all the previously considered conversion systems. All control schemes integrated with the power electronic converter are designed to maximize power output at all possible wind speeds (El-helw, Tennakon, & Shammas, 2006). The wind speeds range from the *cut-in speed*<sup>43</sup> to the *rated wind speed*<sup>44</sup>, both of which are specific to the size and type of generator used in the WECS. There is a continuing effort to make converter and control schemes more efficient and cost effective in hopes of an economically viable solution to increasing environmental issues (Hau, 2006; Li & Chen, 2008).

The wind turbine generators can be classified into four categories well known by the electronics market. These categories are: Induction Generators (IG), Doubly-Fed Induction Generators (DFIG), Field-Excited Synchronous Generators (FESG) and Permanent Magnet Synchronous Generators (PMSG). It is not the focus of this thesis explains each one in details, but we try to explain broadly the main differences of each category. We start with the Induction Generator. It can be called Asynchronous Generator (AG), is a type of alternating current electrical generator. The generator's rotor is placed within a rotating magnetic field, and the rotor is then spun by an external source of mechanical energy so that it rotates more rapidly than the magnetic field. Induction generators are less complex and more rugged than other types of generators and can continue effectively producing power if their rotor speed changes. An induction generator needs an external supply of electricity to create its rotating magnetic field and start operating, but once it has started producing power it can continue running on its own provided it has a source of mechanical energy (Cheng et al., 2009; de Freitas, Menegaz, & Simonetti, 2011).

Meanwhile, the DFIG are electric motors that have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and electrical system. Doubly-fed machines are used in applications that require varying speed of the machine's shaft for a fixed power system frequency. The DFIG producing principle is widely used in wind turbines. It is based on an induction generator with a multiphase wound-rotor and a multiphase slip-ring assembly with brushes for access to the rotor windings. It is possible to avoid the multiphase slip-ring assembly (e.g. with brushless doubly-fed electric machines), but there are problems with efficiency, cost and size  $\therefore$  A better alternative is a brushless wound-rotor doubly fed electric machine (Muller, Deicke, & De Doncker, 2002).

The FESG are able to effectively convert mechanical energy applied to its axis, but it is necessary that the field winding located in the rotor of the machine is powered by a voltage source so that by rotating the magnetic field produced by the rotor poles can move on to the drivers of the stator windings. The electric current used to power the field is called the *excitation current*. When the generator is operating in isolation from an electrical system (i.e., off-grid applications), the excitement of the field will control the voltage produced.

<sup>&</sup>lt;sup>42</sup> This technique is encountered in the literature under its acronym, MPPT. Its goal is to operate the WECS around the maximum power (within safety limits), using information from the static power characteristic and a minimum of information from the system (Munteanu, Cutululis, Bratcu, & CeangĂ, 2008, p. 110).

<sup>&</sup>lt;sup>43</sup> *Cut-in speed* is the minimum wind speed at which the wind turbine will generate usable power. For more information, please see Johnson (2001, p. 155).

<sup>&</sup>lt;sup>44</sup> The *rated (nominal) wind speed* is the lowest wind speed at which a wind turbine can generate its nominal output power. The rated wind speed usually corresponds to the point at which the conversion efficiency is near its maximum. At wind speeds between *cut-in* and *rated*, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs, called *"power curves"*, showing how their wind turbine output varies with wind speed. Please see Manwell et al. (2002) and/or Rosa (2009).

In the case of PMSG, they are electrical generators where the excitation field is provided by a permanent magnet instead of a coil<sup>45</sup>. In a PMSG, the magnetic field of the rotor is produced by permanent magnets. Other types of generators use electromagnets to generate a magnetic field in a rotor winding. The direct current in the rotor field winding is fed through a slip-ring assembly or provided by a brushless exciter on the same shaft.



**Figure 4.8** Categorization of electrical generators applied to WECS. Source: based on Hansen, Helle, et al. (2001); Hansen, Madsen, et al. (2001) and Yao and Harley (2009)

Due to the nature of technology's evolution, the future is difficult to predict. However, one issue is certain; the demand of renewable energy technologies keep growing vertically and WECS is an important RETS in any energy portfolio. Innovations are the results of market needs, push demand nature. Many concepts and protypes will be considered and even applied but only those that fulfill market demand and show significant performance will survive. There have been great developments in WECS, but this has not finished yet.

Many WECS with different generators and power electronic converters have to be analyzed in function of the lowest cost of energy produced and best electromechanical efficiency reached. Different types of WECS have quite different performances and controllability, which theoretically results into different costs per kWh produced, which is the main priority. Table 4.3 shows the advantages and disadvantages of generator types studied.

<sup>&</sup>lt;sup>45</sup> The simplest coil is an electrical wire wrapped in. As usual in electricity the wire has to be the electrical conductor, but must have an electrical insulation to clothe it (for example, an insulating varnish or a plastic coating). If not, it won't work as expected and may even burn. A *coin* (or an *"electromagnetic coil"*) is formed when a conductor (usually an insulated solid copper wire) is wound around a core or form to create an inductor or electromagnet (Ohsaki, Terao, & Sekino, 2010).

Types	Advantages	Disadvantages
Permanent magnet synchronous generator	<ul> <li>☆ Eliminates the need for separate excitation or cooling systems.</li> <li>☆ Flexibility in design allows for smaller and lighter designs.</li> <li>☆ Generator speed can be regulated without the need for gears or gearbox.</li> <li>☆ Higher output level may be achieved without the need to increase generator size</li> <li>☆ Lower maintenance cost and operating costs, bearings last longer.</li> <li>☆ No significant losses produced in the rotor</li> <li>☆ Very high torque can be achieved at low speeds.</li> </ul>	<ul> <li>☆ High temperatures and sever overloading and short circuit conditions can demagnetize permanent magnets.</li> <li>☆ Higher initial cost due to high price of magnets used.</li> <li>☆ Permanent magnet costs restrict production of such generators for large scale grid connected turbine designs.</li> <li>☆ Use of diode rectifier in initial stage of power conversion reduces the controllability of overall system.</li> </ul>
Asynchronous generator	<ul> <li>Excellent damping of torque pulsation caused by sudden wind gusts.</li> <li>Higher availability especially for large scale grid connected designs.</li> <li>Known as rugged machines that have a very simple design.</li> <li>Lower capital cost for construction of the generator.</li> <li>Relatively low contribution to system fault levels.</li> </ul>	<ul> <li>☆ Generator requires reactive power and therefore increases cost of initial AC-DC conversion stage of converter.</li> <li>☆ Increased control complexity due to increased number of switches in converter.</li> <li>☆ Increased converter cost since converter must be rated at the full system power.</li> <li>☆ May experience a large in-rush current when first connected to the grid.</li> <li>☆ Results in increased losses through converter due to large converter size needed for IG.</li> </ul>
Doubly fed induction generator	<ul> <li>Allows converter to generator or absorb reactive power due to DFIG used.</li> <li>Control may be applied at a lower cost due to reduced converter power rating.</li> <li>Improved efficiency due to reduced losses in the power electronic converter.</li> <li>Reduced converter cost, converter rating is typically 25% of total system power.</li> <li>Suitable for high power applications including recent advances in offshore installation.</li> </ul>	<ul> <li>☆ Increased capital cost and need for periodic slip ring maintenance.</li> <li>☆ Increased control complexity due to increased number of switches in converter</li> <li>☆ Increased slip ring sensitivity and maintenance in offshore installations.</li> <li>☆ Is not direct drive and therefore requires a maintenance intensive gearbox for connection to wind turbine.</li> <li>☆ Stator winding is directly connected to the grid and susceptible to grid disturbances.</li> </ul>
Wound field synchronous generator	<ul> <li>Allow for independent control of both real and reactive power.</li> <li>Allow for reactive power control as they are self-excited machines that do not require reactive power injection.</li> <li>Direct drive applicable further reducing cost since gearbox not needed.</li> <li>Minimum mechanical wear due to slow machine rotation.</li> <li>Readily accepted by electrically isolated systems for grid connection.</li> </ul>	<ul> <li>☆ Magnet tends to become demagnetized while working in the powerful magnetic fields inside the generator.</li> <li>☆ Magnet used which is necessary for synchronization is expensive.</li> <li>☆ Requires synchronizing relay in order to properly synchronize with the grid.</li> <li>☆ Typically have higher maintenance costs again in comparison to that of an IG.</li> </ul>

**Table 4.3** Advantages and disadvantages of generator types

Source: adapted from Baroudi et al. (2007, p. 2382)

Hansen and Hansen (2007) the wind turbine technology has matured during the last ten years. Wind turbine technology objectives have changed the drives philosophy from convention to optimization issues, and taking into consideration the operating regime and market environment. In addition to wind turbines are increasing their sizes (see Figure 4.7). Wind turbine design concepts are progressing from fixed speed, stall control and drive trains with gearboxes to variable speed, pitch control and drive trains with or without gearboxes  $\therefore$  The present general availability of low-cost power electronics increasingly supports the trend towards variable speed wind turbines. Table 4.4 is a list of some technology improvements and the implementation of best practices from related products and industry sectors that have helped to reduce the cost of wind energy during the last decade.

Feature	Comments
Advanced airfoils	Driven by the wind industry to meet its special needs. A key accomplishment for the industry.
Direct electrical drive	Adapted initially from the hydro electric industry (large low speed multi-pole generators) and advanced electric rail technology (linear inductive) with significant wind industry innovation and commercialization to meet large and small turbine requirements.
Fiber glass RTM methods	Advances driven by wind power needs.
Full span pitch control	Adapted from the helicopter industry.
Large diameter pitch bearings	Adaptation of commercial bearings driven by specific wind turbine needs.
Large scale manufacture	Large HAWTs are a multi-billion \$ industry and must use modern manufacturing techniques.
Numerical simulation techniques	Significant wind industry advances and adaptations of commercial software for other rotating structures.
Power electronics	Adapted from the variable speed drive product sector with some wind industry innovation. The power electronics sector is a vital industry sector and the wind industry continues to benefit from technology improvements and cost reductions.
Spherical cast hubs	Adopted for all large HAWT rotors.
Steel welding quality control	Adoption of high quality steel fabricating industry <i>"best practices"</i> . Important for fatigue strength.
Tower feedback in controls	Part of a system approach to controls. Software and hardware costs for sophisticated controls are now more affordable.
Variable speed	Wind industry driven. Reliable operation of turbines at variable speed with full-span pitch control to limit power output is a major accomplishment for the industry.

Table 4.4 Examples of technological improvements in the wind industry in the last decade

Source: adapted from Malcolm (2003) and Oliveira and Fernandes (2011a)

The wind turbine generators can be also distinguished by whether there is a gear box between the turbine and the generator. These aspects are present at section related to technical design of converters.

#### 4.3.3 TECHNICAL DESIGN OF CONVERTERS

#### 4.3.3.1 THE DESIGN WITH GEARBOX

The wind energy conversion systems have changed so much since the beginning of the utilization on wind power as a way to substitute man power in humankind activities. So gearbox had to walk together its (r)evolution. The design was adapted according to its necessity. The efficiency and safety are the main drive of converter's design. The first to be shown in general aspects is the design with gearbox (see Figure 4.9), also called the *Danish* design as this is where the history most developed.



Figure 4.9 The classic design. Source: Wagner and Tryfonidou (2005, p. 197)

This design is characterized by the split shaft system. A wind turbine gearbox must be robust enough to handle the frequent changes in torque caused by changes in the wind speed. The gearbox requires a lubrication system to minimize wear. The gearbox converts slow rotating into high torque power which gets from the wind turbine rotor — and high speed, low torque power, which is use for the electric generator (Ragheb & Ragheb, 2010). The transmission of torque to the generator is shut off by means of a large disk brake on the main shaft. A mechanical system controls the pitch of the blades which can also be used to stop the operation of the wind turbine. There is a hydraulic system for pitch mechanism control. This system requires a yearly basis maintenance and constant pressure monitoring, along with the gearbox which is lubricated with oil (Arabian-Hoseynabadi, Tavner, & Oraee, 2010). A small electric motor is used for each blade pitch angle controlled in the case of applications without a main brake disk. Wind speed and direction measuring devices are located at the back of the hub head. The Danish concept is well-known design in the wind power industry worldwide (Tavner, Xiang, & Spinato, 2007).

#### 4.3.3.2 The design without gearbox

In wind power industry is more and more necessary to reduce weight and cost for wind turbine components — so a right way is develop another working mechanism to WECS as a producing system. The design without gearbox, usually called *gearless* wind turbine. This design has just one stationary shaft. It is important to say that rotor blades and the electric generator are mounted on the same shaft. The electric generator is in the shape of a large spoked wheel with a certain number of pole pairs<sup>46</sup>, around the outer circumference and stators fixed on a stationary arm around the wheel. The wheel is fixed to the blade support, so it rotates slowly with the blades (Gandy, 2009). So, it becomes unnecessary a gearbox, rotating shafts or a disk brake. These omissions of mechanical parts simplify and reduce the cost of the maintenance and production of the WECS as a whole. This design as a typical minimized converter system (compared to others) needs to be automated, in this exact case; a central computer controls the pitch control and hub direction, which operates the small directional motors. DD wind turbine is an answer by Enercon manufacturer, which adopts an annular multiple poles generator. This type of generator significantly reduces the number of moving parts, lowering the amount of maintenance work/cost and associated turbine downtime, which increases the availability in general (Hansen, Helle, et al., 2001; Ragheb & Ragheb, 2010).



**Figure 4.10** Scheme of a nacelle without gearbox (Model Enercon 1.5 MW). Source: Ackermann and Söder (2002, p. 93)

As we can see in Figure 4.10 the rotor shaft is directly connected to the generator stator, which can reduce the electromechanical losses, or in other words, increases the overall efficiency of the WECS.

<sup>&</sup>lt;sup>46</sup> The number of pole pairs determines the synchronous speed of the three phases motor.

#### 4.4 PHYSICAL BASICS APPLIED TO WECS

#### 4.4.1 ENERGY EXTRACTED FROM WIND

The quantity of power captured from a wind turbine is specific to each technical features of wind energy conversion system but we can generalize by:

$$P_w = \frac{1}{2} \rho A v_w^3$$
 [W/m<sup>2</sup>] Eqn (4.1)

Where  $P_w$  is the turbine power,  $\rho^{47}$  is the air density, A is the swept turbine area and  $v_w$  is the wind speed. The air density ( $\rho$ ) is calculated by the formula (Rehman & Al-Abbadi, 2005):

$$\rho = \frac{P}{R \times T} \qquad [kg/m^3] \qquad \text{Eqn (4.2)}$$

Where *P* is the air pressure (Pa or N/m<sup>2</sup>); *R* is the specific gas constant for air (287 J/kg K); and *T* is the air temperature in Kelvin ( $^{\circ}C$  +273).

As we can notice in Eqn 4.1 the output power is directly proportional swept area by rotor and the air density. Regarding to wind speed, the output power is just the cube of it!!! So we can sure highlight the importance of wind resource. Currently, to be cost-competitive, wind farms must be sited in high quality wind regimes, normally a wind power class of 4 or higher, preferably 5 or higher. Figure 4.11 shows a graph with the comparison of wind speed/power classes to capacity factor.

The capacity factor of a wind power plant is the percentage of a year it would need to run at rated power to generate its annual output. As power output, and therefore production, is related to the cube of the wind speed, slightly higher average wind speeds, or wind regimes with a higher variability in the high speed range, can generate significantly more power. The very best wind sites tend to be class 6, according to Figure 3.11. A class 4 site is considered marginal by economic point of view, especially when the wake effects of other wind turbines within a wind farm are taken into account. The cost of wind-produced electricity is driven by several factors. The cost of wind power changes as assumptions regarding to capacity factor, capital cost, financing terms, and operation and maintenance routines. Therefore, in today's market, a capacity factor of about 25% can be considered a lower bound, unless the combined capital and operating costs of wind turbines drop down (Khatib, 2003).

<sup>&</sup>lt;sup>47</sup> It is important to know that "P" and "T" change according the site analyzed.


**Figure 4.11** Comparison of average wind speed and wind power class to capacity factor. Source: McGowan and Conners (2000, p. 152)

Wind speed and power class where the WECS is installed have a great influence on the system overall. That is why the wind resources analysis is so important for a better or lowest cost of energy produced by a wind power plant. According to Georgilakis (2008) wind power plants generate electricity when the wind is blowing, and the plant output depends on the wind speed. Wind speeds cannot be predicted with high accuracy over daily periods, and the wind often fluctuates from minute to minute and hour to hour. Consequently, electric utility system planners and operators are concerned that variations in wind power plants output may increase the operating costs of the electrical system as a whole (taking into consideration on-grid applications). The energy production from WECS is highly dependent on the wind speed at hub height. Usually, the wind speed measurements are made at heights much lower than the hub height is calculated using the  $1/7^{\text{th}}$  wind power law that may underestimate or overestimate the wind speed, which ultimately will provide wrong estimates of energy production (Rehman & Al-Abbadi, 2005).

### 4.4.2 POWER COEFFICIENTS

As we understand, the WECS is a conversion chain processes by a wind mechanical and electrical parts. The power coefficients are so important in order to analyze the WECS performance as a whole. It is necessary for wind farms management and ensures a safety and profitable range for cost of energy produced by the power plant. So we easily can conclude that during this process we have to face its limitations (electromechanical and Physics` laws). The next sub-sections (4.4.2.1, 4.4.2.2 and 4.4.2.3) discuss about these key issues.

### 4.4.2.1 Betz' LAW AND THE POWER COEFFICIENT $(C_P)$

A German physicist called Albert Betz concluded in 1919 that no WECS can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor. Nowadays this is known as the *Betz Limit* or *Betz' Law*<sup>48</sup>. The theoretical maximum power efficiency of any design of wind turbine is 0.59 (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine). This is called the "maximum power coefficient" and is defined as:

$$C_{p_{\text{max}}} = \frac{16}{27} P_w \cong 0.593 P_w \qquad [W/m^2]$$
 Eqn (4.3)

The power coefficient  $(C_p)$  is defined as the power extracted by rotor  $(P_{w_{out}})$  to power available in the wind  $(P_w)$  is given by:

$$C_{p} = \frac{P_{w_{out}}}{\frac{1}{2}\rho A v_{w}^{3}}$$
 [%] Eqn (4.4)

The power coefficient must consider the mechanical  $(\eta_m)$  and electrical  $(\eta_e)$  transmission efficiency. So the electrical power output is defined by Yao, Bansal, Dong, Saket, and Shakya (2011):

$$P_{w_{(e)}} = C_p \eta_m \eta_e P_w \qquad [W_{(e)}/m^2]$$
 Eqn (4.5)

Also, wind turbines cannot operate at this maximum limit or nominate rated power in term aerodynamically. There is only one  $C_p$  value to each turbine type and it is a function of wind speed that the turbine is operating in. When are inputted many as often engineering requirements of a wind turbine — strength and durability in particular — the real world limit reached is much less than the Betz Limit with values in the range of 0.35–0.45 common even in the best designed wind turbines (Mathew, 2006). Whereas other factors in a complete WECS — e.g. the gearbox, bearings, generator and so on — only 10–30% of the power of the wind is ever actually converted into usable electricity. Hence, the power coefficient needs to be factored in Eqn 4.1 and the extractable power from the wind is given by:

$$P_{w_{avail}} = \frac{1}{2} \rho C_{p_{max}} A v_w^3 \eta_m \eta_e \qquad [W_{(e)}/m^2] \qquad \text{Eqn (4.6)}$$

<sup>&</sup>lt;sup>48</sup> The energy conversion systems in general are driven by the *First Law of Thermodynamics (Conservation)* which states that "energy can be changed from one form to another, but it cannot be created or destroyed. The total amount of energy and matter in the Universe remains constant, merely changing from one form to another. For more explanations related to Physics applied to WECS, please read the chapter about *Physical Principles of Wind Energy Conversion* in Hau (2006, p. 81).

If we consider the mechanical  $(\eta_m)$  and electrical  $(\eta_e)$  transmission efficiency into the overall efficiency of WECS  $(\eta_{wecs})$  and rewriting the Eqn 4.6, we must have:

$$P_{W_{avail}} = \frac{1}{2} \rho C_{p_{\text{max}}} A v_{w}^{3} \eta_{wecs} \qquad [W_{(e)}] \qquad \text{Eqn (4.7)}$$

Rosa (2009) explains the difference among power density ( $P_w$ ), available power density ( $P_A$ ) and power delivered ( $P_D$ ). When it is necessary to analyze the performance of WECS these aspects must be well-defined (see Figure 4.12).

The symbol, $P$ , in this chapter stands for both <i>power</i> and <i>power density</i> —that is, power per unit area, depending on the context. The lower case, $p$ , is reserved for <i>pressure</i> . The following subscripts are used:			
$P_W = \frac{1}{2}\rho v^3$	"Power density in the wind." This is the amount of energy transported across a unit area in unit time.		
$P_A = \frac{16}{27} \frac{1}{2} \rho v^3$	"Available power density." This is the theoretical maximum amount of power that can be extracted from the wind.		
$P_D = \frac{16}{27} \frac{1}{2} \rho v^3 A \eta$	"Power delivered." This is the power that a wind turbine delivers to its load.		

Figure 4.12 Principles of aerodynamics applied to WECS. Source: Rosa (2009, p. 730)

It is not the focus of this sub-section discusses about aerodynamics issues<sup>49</sup>, but when we talk about wind energy conversion system it becomes impossible not to discuss about something related to. Wind is the air in motion and it is a type of energy (kinetic energy), and rotational movement is *Physics Applied*, which means *Aerodynamics*.

### 4.4.2.2 TIP SPEED RATIO

The rotor is a rotate part of WECS, so the rotor efficiency is a function of the rotor turning rate. The tip speed ratio (*TSR*) is given by dividing the speed of the tips of the turbine blades ( $\pi DN_{rs}$ ) by

<sup>&</sup>lt;sup>49</sup> For more details, please see Snel (2003). Review of Aerodynamics for Wind Turbines. *Wind Energy*, 6(3), 203-211. doi: 10.1002/we.97.

the speed of the wind  $(v_w)$ . If the rotor turns too slowly, the efficiency drops off because too much wind unaffected by the wind turbine blades. However, if the rotor turns too fast, efficiency will reduce as the turbulence caused by one blade increasingly affects the following blades. The TSR can be calculated by Yao et al. (2011):

$$TSR(\lambda) = \frac{\pi DN_{rs}}{60v_w} \quad [-] \qquad \text{Eqn (4.8)}$$

Where  $(N_{rs})$  is rotor speed in rpm, (D) is the rotor diameter (m); and  $(v_w)$  is the wind speed (m/s) upwind of the turbine.

### 4.4.2.3 POWER EFFICIENCY

In a power plant is an important factor to be analyzed is the power efficiency of the entire system. A classical way to take this measure is through the power input into comparison with power output. In WECS, obviously, the wind farm efficiency is a function of the turbine type employed, the wind farm configuration and wind speed. Estimation of the overall efficiency of a wind farms of crucial importance to a wind farm design procedure since due to its explicit relation to total annual power converted; it is considered a vital trade-off between performance and cost analysis (Kiranoudis, Voros, & Maroulis, 2001).

According to Krokoszinski (2003) the efficiency and effectiveness of wind farms must be evaluated based on the losses which can be classified into *downtime losses, speed losses* and *quality losses*. Each of these losses affects the wind power plant in terms of power efficiency. In downtime is related to the availability of wind turbines' working or producing electricity. As much as downtime losses less electricity are produced. In the case of speed losses are linked to power curve of wind turbines and wind site profile. The quality losses are linked to electricity actual produced and useful. It is a relation of the valuable production time and net operation time. Grauers (1996) suggests a calculation method to find the power efficiency applied to wind power plants.

$$\eta_{wecs} = 1 - \frac{P_{w_{a_v}}}{L_{w_{a_v}}}$$
 [-] Eqn (4.9)

where  $(P_{w_{a_v}})$  is average power production by WECS and  $(L_{w_{a_v}})$  is the average losses of WECS.

### 4.5 WIND FARM PLANNING

The wind farm planning is a long term process and involves several *economic agents*<sup>50</sup> during the lifetime of the power plant. The planning process can be classified into five phases. These phases are: (1) Pilot study, (2) Site evaluation, (3) Planning, (4) Realization and (5) Operation (see Figure 4.13). The phases 1 and 2 can happen simultaneously what makes wind farm developers save time in the planning process as a whole. In the *pilot study* phase begins with site selection. The most important issues for this step are wind resources and access to the right site chosen. Due to these two *drivers*, the legal aspects and initial economics analysis within WEC technology are performance. In this phase is also suggested to be done a pre-feasibility study for economic evaluation.



Figure 4.13 Flowchart of wind power during the project lifetime. Source: WWEA (2011)

In the *site evaluation* phase the estimation of local wind conditions are especially crucial in the selection of the site. In addition to an evaluation of the wind speed based on general meteorological data, wind prediction also requires an analysis of the orography of the site selected, i.e. the structure of the terrain, the roughness of the surface, and the type and size of the terrain's

<sup>&</sup>lt;sup>50</sup> An institution, single person, company etc. that has an effect on the economy of a place (city, region and country), for example by buying, selling, or investing.

boundaries. Furthermore, any individual obstacles — such as rows of trees, buildings, and any other wind turbines — must be registered accurately (Meah & Ula, 2008). In this stage it is necessary to determine accurately the potential of local wind energy production. Several methods are commonly used to measure, simulate, and evaluate wind conditions. Depending on local conditions and the quality of any wind and data available for the region — such as from measuring stations — a methodology will be chosen, and a decision will be made as to whether additional wind measurements are required to confirm the initial findings (Al-Yahyai, Charabi, & Gastli, 2010).

For the *planning phase* a more in-depth analysis of the project's prospects is done which is driven by the feasibility study. The *feasibility study* must provide information about the physical characteristics, financial viability, and environmental, social, or other impacts of the wind power project, such that the proponent can come to a decision about whether or not to proceed with the project. It is characterized by the collection of refined site, wind resources, costs and equipment's data. It typically involves site visits, resource monitoring, energy audits, more detailed computer simulations, and the solicitation of price information from equipment suppliers. Also in this phase is defined the type of company to run the wind project related about financing operations and grid access, in case of on-grid applications.

In the *realization phase* all administrative aspects are carried out. First of all, it is given emphasis to the *Financing contract, Construction permit* or *licenses, Feed-in<sup>51</sup> contracts* and *Purchase Contract.* The *Financing* and *Feed-in* contracts are directly influenced by *Financing* terms and *WEC/Grid* conditions. The erection and commissioning steps will only be done when the legal and economics items are concluded. This step usually requires another or additional studies for installing and testing the wind farm as a new power plant. If it is a *repowering*<sup>52</sup> action it is necessary to check the last years of operation of the wind farm in order to notice how *WEC/Grid* conditions and what are possible impacts on the economic feasibility of the project, so the modifications, if it is possible, in the *Financing* and *Purchase* contracts.

Finally in the *operation phase* is the last of planning stage but the first and longest phase in a wind power project, a wind farm. The operation objective for a wind power plant (WPP) is to ensure that the system achieves the best energy yield from the prevailing wind conditions at the respective location. In addition to these commercial requirements, the operation of the WPP must also ensure that dangerous operating conditions are recognized early enough and that the WPP control system acts appropriately to avoid dangers to the environment and the WECS that could arise from malfunctions. If necessary, the system behavior can be continuously monitored via remote data and on-site monitoring and interventions implemented in the WPP control system. A wind farm is usually designed for 20 to 25 years of operation, which is planned for 175,200 to 219,000 full hours, excluding the downtimes for maintenance or repairs. After 20-25 years-operation it is time to decide to *removal*<sup>53</sup> or repower the power plant.

<sup>&</sup>lt;sup>51</sup> The central principle of *feed-in tariff* policies is to offer guaranteed prices for fixed periods of time for electricity produced from Renewable Energy Sources (RES) (Couture & Gagnon, 2010).

<sup>&</sup>lt;sup>52</sup> The expression *"repowering"* refers to power plant in general and includes all measures which improve the efficiency and capacity by means of retrofit to the latest technology.

<sup>&</sup>lt;sup>53</sup> The expression "*removal*" is used when a wind power plant shutdown the operation definitely.

### 4.5.1 WIND FARM LAYOUT

Lundberg (2003, 2006a) a wind farm is a set of elements, such as wind turbines (WT), local wind turbine grid, collecting point, transmission system and wind farm interface to the point of common connection (PCC). The energy is then transmitted to the wind farm grid interface over the transmission system. So to discuss about wind farms layout is a complex issue and exciting due to its nature and importance for a better performance of the whole power plant. The wind farm layout can be so different from wind farm to wind farm, from site to site and from type of wind turbine used.

As stated in the specialized literature "*rule of thumb*" is applied 10 ha/MW for land requirement of wind farms, including infrastructure (Bansal et al., 2002). The spacing of a cluster of wind turbines in a wind farm depends on the terrain, the predominant wind direction and speed, and the turbine size. According to Patel (1999), the optimal spacing is found in rows 8–12 rotor diameters apart in the windward direction, and 1.5–3 rotor diameters apart in the crosswind direction. According to Ammara, Leclerc, and Masson (2002) and Grady, Hussaini, and Abdullah (2005) discussed about this intuitive spacing scheme resulted in sparse wind farms that were inefficiently using the wind energy potential of the site. A dense, staggered sitting scheme was proposed that would yield production similar to the sparse scheme, but would use less land. While this approach successfully reduced the land mass required for a given amount of wind turbines, the method of placement was still intuitive.

According to Samorani (2010) the way or criteria used to choose the number and the model of the wind turbines to install depends on a variety of factors. First, it is important to note that a more powerful wind turbine is usually preferred to a less powerful one since both the cost of a turbine and the energy it generates is usually proportional to its nominal power. So when we in the phase of project development there is a trend to choose a more powerful wind turbine in order to have a lowest cost per wind power installed and consequently a lowest cost of energy produced. But it is also such a *"trick"* because as bigger as the size of wind turbines as more expensive are the initial investment cost formed by civil works, electrical works and the rest of the installations and maintenance costs impacted by the size of the wind turbine.

The actual consultancy market practice is design a preliminary layout used for discussions with the relevant local economic agents and other affected parties. This process is iterative due to its nature because this preliminary layout is a tool for engineering, economics, environmental studies and common can be changed in function of the results reached. As many researcher states the most factors that usually affect wind turbines location are: (1) optimization of energy production output; (2) turbines loads; (3) noise emissions and (4) visual impact (Gonzalez, Rodriguez, Mora, Santos, & Payan, 2009; Payan, Gonzalez, Rodriguez, Mora, & Santos, 2011; Zhang, Chowdhury, Messac, & Castillo, 2012). In the wind power industry we frequently identify as "Balance of Plant (BOP)" the civil and electrical works and are generally have been done by a contractor or contractors separate from the wind turbine supplier. The major influence on the economic success of a wind farm is the energy production, which is principally determined by the wind regime at the chosen site, the wind farm layout and the choice of wind turbine technology applied.

#### 4.5.2 REQUIREMENTS FOR LAND AREA

The utilization of the land depends on several aspects but one of most important is wind turbine model to be used in the power plant. If the wind power plant is the type of on-grid application, the area must be design to the access roads, buildings support and the power station. When we have useful (in terms of electricity production) wind resources and land enough, the wind farm design process begins. The central objective is to maximize energy production, minimize capital cost and operating costs, take into account the constraints imposed by the site. The constraints and costs are all subject to some level of uncertainty in terms of a project conception; the optimization process also seeks to minimize risk.

The land area required for wind power projects varies significantly from project to project. The goal of a project plan is to distribute the wind turbines in order to maximize power production. Wind turbines are usually distributed in lines perpendicular to the prevailing wind direction. The direction of the prevailing winds and the complexity of the terrain are two of the most important aspects that guide the placement of turbines in a project. The distance between the wind turbines (between lines and between the wind turbines in a same line) is commonly described in terms of the diameter of the rotor. For example, if a plant is described as having a spacing 3x10, this means that the turbines are distributed with an equivalent spacing for three rotor diameters within the same row, and the lines have a spacing equivalent to 10 rotor diameters. For a project that uses a rotor with 60 meters in diameter, this means spacing between the turbines of a same line of 180 meters, and 600 meters between the rows. Figure 4.14 shows a typical wind farm layout and so the land area changes according to its layout defined.



Figure 4.14 Wind farm layout according to the rule of thumb. Source: Samorani (2010, p. 12)

The interference of a turbine on another positioned towards the wind turbine is called *interference effect* (*wake effect or array effect*)<sup>54</sup>. The turbines are positioned too close to each other will suffer a loss of greater energy-induced effect of interference. As a large spacing between turbines usually

<sup>&</sup>lt;sup>54</sup> Whereas a wind turbine generates electricity from wind energy, the wind flow after passing through the turbine must contain a lower potential energy than the wind flow reaching turbine first.

maximizes power production output, but increases the need for infrastructure (e.g., land area, network and roads), the cost must be parsed before defining the location of the turbines. For example, there is a replacement of the costs between the optimization of layout of turbines for power production (increasing the spacing) while trying to keep a compact design to have reasonable costs with network and roads, which tend to grow with increased spacing between turbines (Samorani, 2010). A wake effect of one wind turbine on another decides the spacing between the wind turbines in a wind farm. Typical spacing between the machines in a wind farm is shown in Figure 4.13 and effect of spacing on energy loss is shown in Figure 4.15. Grid connectivity, accessibility are important considerations in selection and design of wind turbines site. Other considerations are reducing noise, transmission disturbance and visual disturbance (Hau, 2006).



Figure 4.15 Effect of spacing on energy loss. Source: Hau (2006).

The distance between lines in a complex terrain is typically determined by the characteristics of the terrain (e.g., the turbines will be arranged linearly in a mountainous relief to take advantage of better exposure to the wind, and the layout is determined by the location of mountain ranges). In a relief plane, the rows are spaced turbines depending on the spacing between the turbines of a same line. The goal is to optimize the balance between the increased interference effect and the lower cost associated with a narrow spacing. Regard to the lines, the spacing is determined by the direction of the wind. Unidirectional environments (mostly wind power production comes from the same direction), the turbines can be placed closer together in a same line. In the case of multidirectional winds (ex., half the time it comes from the North and the other half he comes from East), you need a larger spacing (Ozturk & Norman, 2004; Petersen et al., 1998).

The typical spacing for wind uni-directional or a location with strong winds in two opposite directions predominant (180°) is three rotor diameters between the turbines in a same line and 10 diameters between rows. The typical spacing for omni-directional wind or wind with two predominant directions of 90° is five to six diameters between turbines and seven to eight diameters between the lines. The turbine manufacturer may require or allow a narrower spacing depending on the characteristics of the turbine and wind characteristics of local.



(a) Typical spacing for wind farms

(b) Optimum spacing of towers in wind farm

**Figure 4.16** Comparison of suggested spacing for wind farms. Source: based on Hau (2006, p. 586) and Yao et al. (2011, p. 14)

As we can notice the distances change from author to author (see Figures 4.14 and 4.16), but all of them have as the main concern the optimization of the wind power plant, in other words, the wind farm electricity output production. For example, Emami and Noghreh (2010) have studied the optimum wind turbines distances in flat terrains. Hau (2006) and Yao et al. (2011) have studied the best positions for maximizing wind power capture by the wind farms reducing the wake effect. The great question is not what size are the precise distance among turbines and the rest of facilities in the power station because it is so variable. This variability is due the technical features of the wind farm in general. That is why it is necessary to analyze the wind farm array in terms of production, called the *array efficiency*, given by Pao and Johnson (2009):

$$\eta_A = \frac{E_A}{E_T N_{WT}} \qquad [\%] \tag{4.10}$$

Where  $(E_A)$  is the annual energy of the array,  $(E_T)$  is the annual energy of one isolated turbine and  $(N_{WT})$  is the number of turbines in the wind farm. Array efficiencies of greater than 90% have been shown to be achievable when downwind distances of 8-10 rotor diameters and crosswind distances of 5 rotor diameters are used (Lissaman, Zaday, & Gyatt, 1982).

### 4.5.3 TYPES OF WIND FARM LAYOUT

A wind farm is an industry in essence with special aspects related to its configuration. We called "*power plant*" because it is a unit that produces something, electricity, in this case. An industry only produces if there is *raw material*, in other words, *wind resources* available in economic terms. As an industry it must be the machinery to transform raw materials in products, similarly we mean, *electricity energy sold*. The arrangement of this power producer machinery in the wind power plant is the *layout of the wind farm*.



Figure 4.17 Wind farm array schematic. Source: Asif and Muneer (2007, p. 1411)

Figure 4.17 shows a general schematic of the layout of a wind power plant that may be situated either *onshore* or *offshore* applications related to the most important thing in a wind farm, the wind turbines sites. Many authors have shown that for turbines that have downward and crosswind spacing of up to 10- and 5-rotor diameters, respectively, the array losses are typically less than 10% (Manwell et al., 2002). According to Lundberg (2003, 2006a) a wind farm is usually composed by:

- $\Rightarrow$  Local wind turbine grid
- ✿ Collecting points
- $\Rightarrow$  Electrical transmission system and
- $\Rightarrow$  Wind farm interface to the point of common connection

All these elements reflects on the wind farm layout and performance, so it must be evaluated and optimized as we could notice in most of studied done in order to optimize the wind farms performance and cost of energy produced. We cannot forget the investment cost is impacted

directly by the type of layout used, so it is necessary to run an economic analysis and always try to reduce the amount of capital invested in the wind farm. For a better visualization we can see Figure 4.18 and understand that we must face technical and economical challengers for optimizing a wind farm and get the most competitive cost of energy.



Figure 4.18 General wind farm layout. Source: Lundberg (2003, p. 5)

In Figure 4.18, the layout is formulated considering such aspects: (1) the wind turbines (WT) are in linear configuration, each row is composed by four WT inter-connected; (2) the collecting point is the same to all WT which can represent a risk for the wind farm, because if there is some problem with a single WT, it is necessary to stop the whole wind power plant. Although it has an advantage in initial investment, usually lower than other configurations which require more than one or central collecting point. According to Lundberg (2006b, p. 27) "in the collecting point, the voltage is increased to a level suitable for transmission. The energy is then transmitted to the wind farm grid interface over the transmission system. The wind farm grid interface adapts the voltage, frequency and the reactive power of the transmission system to the voltage level, frequency and reactive power demand of the grid in the PCC".

The distance to the nearest road access and the complexity of the terrain will substantially influence the capital cost of the project. It is important to say, the layout configuration of a wind farm must be analyzed considering each project is a *unique project*. It can change so much its analysis in function of the site, legal aspects, economic feasibility, WECS technology installed, and other aspects related to wind farm direct and indirectly, such as renewable energy policy.

When we discuss about wind farm layout, in other words, it is related to the position of wind turbines, providing the overall form or configuration of the wind energy development and its perceived density or complexity. In Figure 4.19 is shown some typical layout topologies applied in wind farms, both *onshore* and *offshore* applications, excepting the Figures 4.19 (f) and (g) because they are especially designed for *onshore* and *nearshore* applications. Generally, wind farm layout should be of a uniform type, whether a single line, staggered line, splayed line, random or grid, rather than a mixture. The creation of a "*visual stacking*" effect from a sensitive viewpoint should be avoided.



**Figure 4.19** Typical layout topologies applied in wind farms. Source: adapted from Farrell Farrell (2006, p. 44). (a) Plan and view of single line layout; (b) Plan and view of staggered line layout; (c) Plan and view of splayed linear layout; (d) Plan and view of random layout; (e) Plan and view of grid layout; (f) View of linear layout on a peak and (g) View of linear layout in response to a road, shoreline or cliff.

All layout options are usually acceptable. However, the best solutions would either be a random layout, and clustered where located on hills and ridges (Figure 4.19 (f)), or a grid layout on sweeping and continuously even areas of moorland or plateau (Figure 4.19 (c) and (d)). Where a wind energy development is close to a linear element, such as a river, road or long escarpment, a corresponding linear layout (Figure 4.19 (a), (g)) or staggered line (Figure 4.19 (b)) might be most desirable.

It is important to empathize that terrain conditions, so the *topography*<sup>55</sup>, impact directly on wind farm layout and performance in general, not only related to wind turbines, but in the rest of wind farm's facilities and operation. That is the case of the access roads, supporting buildings, electricity collecting points, and so on. The final arrangement also impacts on costs of installations or capital costs, operation & maintenance costs, other costs and expenses which will reflect on the cost of energy produced by the power plant as a whole.

<sup>&</sup>lt;sup>55</sup> The wind close to the earth's surface is strongly influenced by the nature of the terrain surface, the detailed description of which is called *topography* (Petersen et al., 1998).

### 4.6 SUMMARY AND CONCLUSIONS

Humankind evolution is closely linked to energy resources, since the beginning of time man has to know it and seeking it ever more on the environment. He began to enjoy and benefit from their potential. Thus obtained a better and continuing adaptation to the environment questions and needs, which was often hostile and consequently sparsely inhabited. Respecting the means and knowledge of each period of evolution, man became sovereign in the environment, acquired with so much more responsibility, while that on the environment imposed serious changes to meet its development. In general, wind power can provide an important contribution to reducing fossil fuel consumption and meet international environmental commitments. However, interconnection capacity, the combination of the existing capacity of production and characteristics of the wind power system to have a significant effect on how the variable production is assimilated by the system and on the extent of their contribution to meet the needs of modern society.

A WECS is a rotary system that extracts the energy from the wind. The mechanical energy from the wind turbine is converted to electricity (wind turbine generator). The wind turbine can rotate through a horizontal (HAWT) or vertical (VAWT) axis. Most of the modern wind turbines fall in these two basic groups: HAWT and VAWT. For the HAWT, the position of the turbine can be either upwind or downwind. For the horizontal upwind turbine, the wind hits the turbine blade before it hits the tower. Significant differences between wind turbines depending on the direction of their axis of rotation have been presented in this chapter. Many comparative studies have shown that VAWTs are advantageous to HAWTs in several aspects. Furthermore, common misjudgments about VAWTs have been discussed in the wind power literature.

The tower shadow has a great importance in HAWTs due to the tower interference. This problem is not as big for upwind turbines as for downwind turbines. The turbine dynamics is affected by the tower shadow gives power fluctuations and increases noise production. VAWTs do not experience tower interference as the distance between blades and tower is much larger in comparison to HAWT (Eriksson et al., 2008). It is important to say that these two types of WECS must be analyzed considering its application. Generally, the green investors try to maximize its return of capital invested, which is one of the reasons the HAWT has developed more than VAWT in the last decades. Table 4.5 makes a comparison between HAWT and VAWT.

 Table 4.5
 Comparison between HAWT and VAWT concept

Types	Ad	vantages	Dis	advantages
	✡	Variable blade pitch, which gives the turbine blades the optimum angle of attack. Allowing the angle of attack to be remotely adjusted gives greater control, which results in the maximum amount of wind energy collected during the period of operation.	∞	The tall towers and blades up to 90 meters long are difficult to transport. Transportation can now cost 20% of equipment costs. Tall HAWTs are difficult to install, needing very tall and expensive cranes and skilled operators. Massive tower construction is required to
	¢	High efficiency, since blades always moves perpendicularly to the wind,	·	support the heavy blades, gearbox, and generator.
HAWT	⋩	receiving power through the whole rotation. In contrast, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring aerofoil surfaces to backtrack against the wind for part of the cycle. Backtracking against the wind leads to inherently lower efficiency. The tall of the tower allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up, the wind speed can increase by 20%	☆	Downwind variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow (for this reason, the majority of HAWTs use an upwind design, with the rotor facing the wind in front of the tower). HAWTs require an additional yaw control mechanism to turn the blades toward the wind. Reflections from tall HAWTs may affect side lobes of radar installations creating signal clutter, although filtering can suppress it.
	✡	and the power output by 34%. A massive tower structure is less	¢	Most VAWTs generate energy at only 50% of the officiency of HAWTs in large part because
VAWT	⋩	frequently used, as vAw1s are more frequently mounted with the lower bearing mounted near the ground. Designs without yaw mechanisms are possible with fixed pitch rotor designs,	✡	of the additional drag that they have as their blades rotate into the wind. While VAWTs' parts are located on the ground, they are also located under the weight
	✡	which low the initial investment. A VAWT can be located nearer the ground, making it easier to maintain the		of the structure above it, which can make changing out parts nearly impossible without dismantling the structure if not designed
	✡	moving parts. VAWTs have lower wind start-up speeds than HAWTs. Typically, they start creating electricity about 3 m/s	✡	properly. Having rotors located close to the ground where wind speeds are lower due to wind share VAWTs may not generate as much
	✡	VAWTs may have a lower noise signature.		energy at a given site as a HAWT with the same footprint or height.

Source: Malcolm (2003) and Dang (2009)

Because VAWTs are not commonly deployed due mainly to the serious disadvantages, they appear novel to those not familiar with the wind industry. This has often made them the subject of wild claims and investment scams over the last 50 years. The development of a wind energy system requires the integration of many disciplines and resources. The necessary elements in the development of a wind power plant include wind resource evaluation and sitting, project development and financing, engineering, manufacturing and construction, and operations and maintenance. All these elements must be balanced in order to get the most competitive performance and cost of energy produced. The wind power technology has achieved the maturity in 2000 years, as we could notice at Table 4.4, but this history and such evolution keep going forward, in function of new application and the improvement of efficiency and reliability of wind energy conversion systems. For McGowan and Conners (2000) the advances in wind energy system technology during the 1990s have produced major successes in the following three areas:

- 1. Cost of delivered energy. This success has occurred as a result of continued technology improvements, increased size and number of sales, and increased financial confidence.
- 2. Flexibility of wind technology. Because wind energy systems represent a modular technology, it can be added in relatively small steps, making it easier to speed up or slow down introductions to meet immediate economic circumstances. Also, wind technology is relatively easy to transfer, making it attractive to developers in expanding international markets.
- 3. Availability. The availability, or fraction of time that a wind turbine is available to generate power has increased to the point where values of 98% to 99% are typical for established wind farms. This high level of availability represents values that are higher than many conventional utility scale power production systems.

The working principle of a wind turbine encompasses two main conversion processes, which are carried out by its main components: the rotor that extracts kinetic energy from the wind and converts it into generator torque and the generator that converts this torque into electricity and feeds it into the electrical grids (Slootweg & Kling, 2003). The power in the wind is proportional to the air density  $(\rho)$ , the intercepting or rotor swept area (A) and the wind speed  $(V_w)$  to the third power relation, as shown in Eqn 4.1. The air density is a function of air pressure and air temperature, which both are functions of the height above sea level (Ackermann & Söder, 2002).

The calculation of the annual theoretical production of electrical power from a wind farm is resulting from the product of electrical power installed, total hours of production for one year and capacity factor of the wind farm. The capacity factor is due to production losses, stops for maintenance and periods where the wind speed is not suitable for the production of electricity by wind turbines. The capacity factor is also referred to as system utilization factor of production (Kreith & West, 1997; NREL, 1995).

The wind farm planning is a long and complex process which each phase is remarkable for the whole wind power plant lifetime. A major issue in the planning of a wind farm is to identify the optimal rating and design of the installation. Several phenomena will limit the maximum possible capacity of wind farms. According to Oliveira and Fernandes (2011b) renewable energies have generally lower emissions than conventional power stations, making them strongly favored by the environmental regulations for the energy sector. However, renewable energy technologies are not free of negative impacts, although the public attitude in relation to renewable energy is generally positive, local people may react negatively to specific projects. In the particular case of wind energy impacts on the ecosystem, noise pollution (noise) and negative impacts on the landscape have been reported.

As we can see at Figure 4.13 the planning process of a wind farm has been made by four stages or phases: (1) Pilot study, (2) Planning, (3) Realization or Execution and (4) Operation. In the Pilot study are checked legal and economic aspects, site selection and type of WEC/grid technology will be used for the project. All the licenses necessary for the project goes are taken in this phase. This first step usually takes from 1 to 2 years to be concluded.

The *Planning* phase is longer than the first one. This stage can take from 2 to 3 years of duration. This phase several and important aspects related to the project economic feasibility are done such as financing planning and WEC chosen to be installed in the power plant. A quick and initial examination by the pre-feasibility analysis determines whether the proposed project has a good chance of satisfying the proponent's requirements for profitability or cost-effectiveness, and therefore merits the more serious investment of time and resources required by a feasibility analysis. It is also analyzed the type of company and building application and environmental impact review to complete a the final feasibility analysis that is a more in-depth analysis of the project's prospects, the feasibility study must provide information about the physical characteristics, financial viability, and environmental, social, or other impacts of the project. The *Planning* phase is done in order to be used as decision tool about whether or not to proceed with the project by the developer.

In the *Realization or Execution* phase, the project get out from papers and computers and starts be materialized. This phase can take from 1 to 2 years to be done. The *Financing*, *Feed-in* and *Purchase* contracts are concluded. If the feasibility study is positive, then engineering and development will be the next step. Engineering includes the design and planning of the physical aspects of the wind power plant. Development involves the contracts and other regulatory aspects of the project. Even following significant investments in engineering and development, the project may be halted prior to construction because financing cannot be arranged, environmental approvals cannot be obtained, the pre-feasibility and feasibility studies "*estimates*" important cost items, or for other reasons.

Finally, the project is built and put into service in the *Operation* phase. This phase represent the longest part of the project lifetime and start from the year 5<sup>th</sup> to 25<sup>th</sup> of the wind power project. This phase includes control, monitoring and maintenance activities that must be performed precisely to keep downtime to a minimum. The main objective for a wind farm is to ensure that the system achieves the best energy yield from the prevailing wind conditions at the respective location. In addition to these commercial requirements, the operation of the wind farm must also ensure that dangerous operating conditions are recognized early enough and that the wind farm control system acts appropriately to avoid dangers to the environment and the WECS that could arise from malfunctions.

At the end of the Operation phase a great decision must be taken: *removing* or *repowering* the wind power plant. *Removing* or *Decommissioning* is a process of inactivating a wind power plant and trying to remove the most the environmental impacts caused by the previous power plant existence. The purpose of the removing plan is to identify the methodology to be used to mitigate potential impacts resulting from the cessation of operation of the facility at the end of the project's useful

life. The removal action-plan identifies the specific project components that will be removed; the nature of the costs associated with the removal of the components and associated scrap value.

In the other hand, if the power plant will going on, improved its efficiency it is necessary to make a repowering process. Also known as replanting, *Repowering* is the process we go through to replace older first-production wind turbines with modern, more efficient wind turbines. The process is carried out in a timeframe that allows us to replace an older wind farm, by the time it comes to end of its typical 20-25 year lifetime. Many wind farms have permission to operate for up to 25 years. If a site has proved to be a good and efficient site, we consider whether there is merit in continuing to operate a wind farm at this location.

It is important to say about WECS in relation to GHG emissions, especially  $CO_2$  considering wind power be market-ready (mature technology), and the price of power is broadly competitive to other types of RETs production, depending on the location. In terms of energy and carbon balance, about 3–7 months of turbine operation are required to recover the energy spent in the full life cycle of the wind power plant (including removal and disposal), and the technology can avoid  $CO_2$  emissions ranging from 391 to 828 g  $CO_2/kWh$  (GWEC, 2010).



Figure 4.20 CO<sub>2</sub> emissions saved by WECS deployment from 2008–2030. Source: GWEC (2010)

The success of wind power as a renewable energy sources is obviously a direct function of the economics of production of WECS. In this regard, the role of improved power output through the development of better aerodynamic performance offers some potential return; however, the focus is on the cost of the entire system. For this reason in the Chapter 5 is discussed about *economic measures and optimization models* applied to renewable energy technology with emphasis on wind energy technology.

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# **CHAPTER 5**

# **ECONOMIC MEASURES AND OPTIMIZATION MODELS**

### 5.1 Introduction

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This chapter discusses about economic measures and optimization models applied to RETs, with focus on wind power technology in order to establish a framework for a better utilization in economic engineering evaluation at a microeconomic view. Summary and conclusions are presented at the end, with the respective references.

# 4.1 INTRODUCTION

The objective of economic measures is to provide the information needed to make a judgment or a decision in economic issues related to a certain project. The most complete analysis of an economic measure of a renewable technology project requires the analysis of each year of the lifetime of the same project, taking into account relevant aspects, such as direct costs, indirect and overhead costs, taxes, and returns on investment, plus related externalities, such as environmental impacts, that are relevant to the decision to be made. However, it is important to consider the purpose and scope of the particular economic measures used in economic analyzes because this will drive the course to follow. The perspective of the analysis is important, often dictating the approach to be used. Also, the ultimate use of the results of an economic measure will influence the level of detail undertaken.

The modern world is moved by ways to generate and consume energy, especially into electricity form. Electricity is accepted as one of the driving forces of the economic development of all the nations. The challenge of continuously producing electricity and meeting the growing demands is great concern for both developed and developing countries. The high costs of delivered electricity can be attributed to strong dependence on centralized energy systems which operate mostly on fossil fuels basis and require huge investments for establishing transmission and distribution grids that can be available anywhere for everybody. Furthermore, the fossil fuel utilization results in the emission of greenhouses gases rising concerns about the climate change and other health hazards (Oliveira & Fernandes, 2011c).

In order to face these problems there is a strong need for renewable energy systems of power producing and distribution. Unlike the centralized energy systems, on the other hand, decentralized energy systems, the case of WECS, both in the presence and absence of grids, and easily accessible to remote locations because of production and consume of power can happen in the same place, considering the demand site. The Renewable Energy Technologies (RETs) must be optimized in function of its own nature capital-intensive and its production output is expectable not plannable due to the forces of nature, in terms of intensity, frequency, availability of the natural resources.

This chapter discusses about economic measures and optimization models applied to RETs, with focus on wind power technology in order to establish a framework for a much better utilization in economic engineering evaluation of a project in a microeconomic view. It starts presenting economic measures principles and costs categorization to be considering into analysis (section 5.2). Section 5.3 refers to the models of projects economic evaluation by describing the most used economic measures indicators (section 5.3.1) within its particularities and hurdles. Section 5.4 is related to models for costs evaluation applied to energy power projects, especially emphasis on monetary costs indicators for wind power projects (section 5.4.1); Peculiarities in the cost analysis of wind energy projects (section 5.4.2). Section 5.5 discusses about optimization models applied to REPs, in this particular issue, we show some algorithms applied to technical-economic analyses of power plant. It is important to say that our purposed model of optimization (Chapter 6) is built considering these models extensively studied. Finally, the summary and conclusions of this chapter (section 5.6) and all references (section 5.7) used are present at the end of this chapter.

# **5.2** ECONOMIC MEASURES

The success of a project finance transaction depends on the project's capacity to generate sufficient cash during its operating phase so that it matches the cash needed for debt service (interest and principal repayment) and dividends paid to the project sponsors. Project finance is usually associated with large capital-intensive ventures (for example, power plants, transportation infrastructure, telecom projects) with low ratability values and limited recovery values in case of project defaults (Borgonovo, Gatti, & Peccati, 2010). Under these circumstances, lenders pay particular attention to project performance on a going concern basis because the possibility to repay principal and interest depends on the project's ability to generate sufficient cash flows.

Opportunities to use sun, wind, water, wood as energy sources are numerous. Renewable energy sources are naturally replenished energy in a relatively short period and produced by natural processes. While conventional sources of energy are finite (in human dimensions of time). Each case must be evaluated is the project economically. If the present high cost of energy produced compared to classical sources, the use of new technology is discredited by final consumers (and public opinion behind it). When there are different technical solutions, or when you offer multiple investment opportunities is necessary to evaluate the projects to decide what or who should be executed. This chapter focuses on the economic and financial evaluations for renewable energy projects (REPs). The REPs can be of different sizes and can extend over different time horizons. But always involve technical, financial and human resources that must be combined to create the expected result. The REPs share the typical characteristics of all other projects (Cleland, 1991):

- 1. The project begins and ends that determine the "*project's life*" that differentiates it from other activities of a permanent nature in existing organizations or companies (who may be involved in the project).
- 2. The financial and human resources available for project implementation are limited (usually pre-determined at the beginning of the project).
- 3. The project is a set of tasks and activities that are separate from other activities undertaken by the parties involved in a repeating basis (*"the day-to-day"*).

When we use economic measures for cost analysis of the electricity supplied by wind energy conversion systems (WECS) is a rather difficult task requiring the estimation of output power production as well as the cost of the WECS, in addition to the analysis of the wind distribution parameters. Power production of the WECSs is closely related not only to the system's performance but also to operating conditions, which means the wind characteristics of the site, as well as (Gökçek & Genç, 2009). The economic-financial models comprise many more factors influencing these key variables, such as macro-economic variables (inflation rates, interest rates, economic growth rates, etc.), market variables (overall demand, development of input and output prices) or technology variables (price developments due to technological change). Setting up the economic and financial model is typically done by applying standard investment appraisal techniques (discounting future cash flows, computing net present value (NPV), etc.) (Oliveira & Fernandes, 2011a).

Efficient planning and resource management is the key to the success of an energy project. The REPs require a specific organization that unites all parties together, regardless of other (existing permanent) organizational ties or relational boundaries between the parties involved, as shown in Figure 5.1.



Financial and economic management of RETs projects

**Figure 5.1** Evaluation process and financial management of REPs. Source: adapted from NREL (1995)

As we can see Figure 5.1, evaluation and economic management applied for RETs projects, is a process or a cycle. In order to differentiate the project and project management it is necessary to develop distinct definitions for the two terms. A project can be considered to be the achievement of a specific objective, which involves a series of activities and tasks which consume resources (*Project identification, Project evaluation* and *Project planning*). It has to be completed within a set specification, having definite start and end dates. In the other hand, project management can be defined as the process of controlling the achievement of the project objectives (*Project control*). Utilizing the existing organizational structures and resources, it seeks to manage the project by applying a collection of tools and techniques (*Management accounting, cost control*), without adversely disturbing the routine operation of the company (Munns & Bjeirmi, 1996), in the case of wind power, the wind farm manager.

The evaluation measures the investment attractiveness of investment or potential project (here more specifically: a REP, wind onshore) for the investor and/or manager. A project is attractive, the consequences of that lead to the expected result of attractive economically, financially by the investor (Lapponi, 2000). This chapter discusses the main methods of economic evaluation applied to the energy industry with a discussion of the topics of greatest interest to economists, engineers and other professionals related to analysis of economic and financial viability of investments in power of decentralized production of electricity. However the issue is important: the economic and financial viability of the enterprises is a necessary condition for the gradual deployment of new energy technologies to do so solid and convincing.

### 5.2.1 CLASSIFICATION OF COSTS CATEGORIES

### 5.2.1.1 COST STRUCTURE OF WIND ENERGY PROJECTS

Although we have not made any distinction between different technologies in renewable energy, the cost structure of a REP is dependent on the technology used. The "*Renewable Energy*" covers a diverse set of technologies ranging from small photovoltaic solutions for roofs of individual houses to large wind farms onshore and offshore  $\therefore$ . Most of the costs parameters and definitions used in this sub-section are characterized costs related to the onshore wind power made the analysis from production to the mains distribution.

The following are the major cost components for onshore wind power are presented and briefly described (see Table 5.1). The emphasis is on description of these elements are not in exact figures. The cost values are dependent on circumstances of individual projects and are altered at a rapid pace due to technological advances and economies of scale. The main cost elements are proving to be quite stable in the technological nature of particular projects to generate electricity from wind, so you should be familiar with them, to make a complete and consistent assessment of attractiveness of the project (Harrison & Jenkins, 1993; Kaltschmitt, Streicher, & Wiese, 2007).

Depending on the nature and reflects the behavior of the final cost of power produced by wind farm, the typical elements of cost are grouped by cost category. The listing does not tend to be exhaustive, as wind power, by experience and technological maturity has become easier to identify these costs. It is important that classification of the cost structure to facilitate financial and economic analysis of projects (EWEA, 2009). A plant for producing electricity from wind energy uses the principle of conversion of kinetic energy<sup>56</sup> contained in flowing air masses (wind) into electrical energy. The wind turbine consists of tower equipped with rotor blades and (the concept of *"windmill"*) connected to the electrical generator that converts rotational mechanical energy into electrical energy. Wind power can be used for both connected to the mains system (usually *"wind farms"*), as well as for applications independent of electrical grids (Heier, 1998).

According to IEA (1991), NREL (1995) and RETScreen® International Clean Energy Decision Support Centre (2008), the individual elements of project costs of wind power for electricity production can be grouped into four distinct categories of costs (investment costs, operational costs, maintenance cost and financial cost). This classification is used for monetary costs evaluation and excludes other types of cost, such as, the invisible costs usually present in sustainable renewable energy systems (wind energy conversion systems, wave energy, solar power systems, biomass, nuclear power, geothermal power systems, and others), like externalities costs, social costs and environmental costs.

<sup>&</sup>lt;sup>56</sup> In *Physics*, the principle of converting kinetic energy is the amount of work that must make an object to change its speed (either from the rest - *zero speed* - either from an initial speed). For an object of mass *m* speed *v* kinetic energy in an instant of time, is calculated as  $KE = \frac{mv^2}{r^2}$  (Rosa, 2009).

**Table 5.1** Classification of costs into categories for wind energy projects

Also called the *"capital cost"* or *"initial investment"*, this group of costs reflect all cost elements that occur only once at the beginning of the project. Investment cost includes cost of purchase and installation of equipment, site preparation, acquisition of necessary licenses or permissions, planning and professional advice necessary to connect the wind farm system facilities or construction of public grids.

Refers to the cost elements that occur during regular operation mode of the system after being put into production. The operating cost can be cost of raw materials or operating personnel, as well tax payments and insurance, land lease, or cost to supply energy to the public network (access fee). Part of the cost of operations is independent of capacity utilization of the production system, so, they are fixed. Other operating costs vary with the load supplied to the grid. The split between fixed and variable operating costs differ among renewable energy technologies. The ratio of fixed operating costs to revenue (per period) is called *"project self-financed"*. In a system with self-finance the project uses a greater proportion of revenue on systems with low self-financing. The self-finance the project reduces the flexibility of the cost of the system during operation.

It includes all cost elements that occur in order to maintain or ensure the production capacity (system operational availability). Can be achieved through preventive maintenance (system check before being damaged) or repair (arranged in the system after it was damaged). Maintenance measures may be small and frequent (replacement of small parts such as lamps and air filters, periodic verification procedures), or large and infrequent (unscheduled repair of significant damage, change of principal components).

This category of costs is included in all financial expenditures caused by financing transactions within the lifetime of the project. The most important element of cost is the interest payment to lenders of the project. Other elements are typical costs resulting from banking to venture capital acquisition, construction consortium, the cost of financial guarantees. The financial cost can be cost elements related to a specific period during the life of the project (similar to the cost of capital) or elements of recurrent costs (similar to the operating cost). Different from the capital costs and operations, as are not due to technical or operational characteristics of the project, but are influenced by the nature of funding.

Source: IEA (1991)

**Dperating cost** 

It is important to differentiate the wind farm costs in terms of installed capacity (total capital costs and variable costs) and cost of wind energy per kWh produced. Fuel costs for wind farm cost is zero. This is the fundamental difference between electricity produced by wind power and other options of conventional power production. For example, in a power plant to natural gas has been 40 to 60% of the costs related to fuel and O&M, compared with about 10% for onshore wind farm. Moreover, the fact that wind energy projects require substantial capital investment affects the financial viability of projects. Become essential to the investor or manager to have most of the funds needed at the time that the wind farm is built. To have access to the rest of the capital financed in good condition for a refund. Some projects cannot be executed due to the necessary funding process during this initial phase, although, over time, may become a less expensive option (Blanco, 2009).

The great advantage of wind power after the installation process and wind measurements calculated correctly, the production cost of this technology is predictable, which reduces the overall risk to the power company. The cost of capital projects for offshore wind power is higher than for onshore wind energy projects (Neij, 1999). The higher cost is due to increased investments (foundations of

the tower under the sea) and transport costs, on the other hand the need for high reliability and low maintenance routine (accessibility of the wind farm). The additional protection to physical facilities more effectively against corrosion and accumulation of harmful materials is necessary for marine offshore installations. All these factors orientates the initial investment (Bergmann, Hanley, & Wright, 2006).

Wind energy is a capital intensive technology, so that majority of cash outflows occur in this phase. The cost of capital can reach 80% of the total cost of the project during its lifetime, with variations between models, and local markets. The wind turbine is the major cost component, followed by the network. Even after more than two decades of consistent reductions, the capital cost of proposed wind energy has increased by 20% over the past three years. The results show that in the range of 1100-1400  $\epsilon$ /kW for new projects in Europe. The costs are smaller in some emerging markets, especially in China and the United States of America. There are also variations in the European Union (Milborrow, 2008).

Figure 5.2 illustrates the complexity of sub-components that make up a wind turbine, and helps explain why these elements are higher costs of initial investment. Note that the value refers to the exceptionally large size in the current market (5 MW, as opposed to 2-3 MW machines being installed in most onshore wind farms). The relative weight of sub-components varies depending on model. Other elements of cost, besides the wind turbine, are needed at the beginning of the project and represent about 18 to 32% of the total capital cost for onshore wind energy projects.



**Figure 5.2** Example of the main components of onshore wind turbine with distribution of the overall cost of the 5 MW Repower. Source: Blanco (2009).

Variable costs of production in wind energy projects are directly related to the cost of annual operations and maintenance (O&M) that are relatively high, accounting for 5-8% of initial

investment (capital cost). The cost of O&M is particularly high in offshore systems. A distinctive feature of wind energy is the importance of the cost of insurance due to increased risk of equipment damage, downtime and damage to third parties. Wind energy (offshore wind farms in particular) can also involve considerable repair costs : Although the overall lifetime of the project could be 20-25 years, major repairs may be needed after 10 years of operational wind farm (Milborrow, 2008). Currently, one of the priorities for wind turbine manufacturers is to reduce variable costs, especially those related to operations and maintenance (O&M) through the development of new projects for wind turbines, which require less service visits, resulting in higher productivity of the turbine. It is important to note that the downtime of the turbines is less than 2% per year (George & Schweizer, 2008).

According to BWEA (2006), AEE (2006); Morthorst (2007); Milborrow (2008), DTI (2007a), a prudent level of variable costs would be between 1-2 c $\in$ /kWh over the life span of the wind turbine. This would mean 10 to 20% of total costs (about 10% in O&M activities). As with other cost categories, the percentages are only indicative.

Finally, the future development of variable costs should be careful when interpreting the results presented previously. First, wind turbines have economies of scale in terms of reducing the investment per kW with an increase in turbine capacity, economies of scale similar may happen with O&M. Secondly, new and larger wind turbines have reduced the requirements for O&M in relation to older turbines and smaller∴Other costs, including replacement of components, monitoring and insurance may increase due to increases in material costs and risks associated with certain models of large capacity wind turbines (Blanco, 2009).

The local wind resource is the most important factor affecting the profitability of investments in wind and also explains most of the differences in cost per kWh between countries and projects. Wind turbines are useless without adequate wind resource. The correct location of each individual wind turbine is crucial to the economy of any proposed wind energy. In fact, it is widely recognized that during the initial phase of the modern wind industry (1975-1985), the development of the *European Wind Atlas Methodology*<sup>57</sup> was more important to productivity gains that advances in design in wind turbines (Troen & Petersen, 1989).

The size and characteristics of the turbines are adapted according to wind patterns observed, being located after careful computer modeling, based on local topography and meteorological measurements. The average number of hours of full load varies from place to place and from country to country<sup>58</sup>. The range of facilities for onshore wind farms ranges from 1700-3000 hours/ year (average of 2342 in Spain, 2300 in Denmark and in 2600 in the UK, to name a few in Europe). In general, good sites are first to be exploited, although they may be located in areas of difficult access (European Commission., 2007).

<sup>&</sup>lt;sup>57</sup> The European Wind Atlas Methodology developed by Erik Petersen and Troen Lundtang Erik which was later formalized in the WAsP software for wind resource assessment by Risø National Laboratory, Denmark. For more information, see <u>http://www.wasp.dk/</u>. <sup>58</sup> The full load hours are calculated as average annual production of wind turbine, divided by the nominal power.

The theoretical energy production, based on the power curves of wind turbines and wind regime estimates is reduced by a number of factors, including losses in matrix production (occurring due to wind turbines shadowed each other within the wind farm), losses due to dirt or freeze in spades, mechanical friction losses, losses in transformers and electrical cabling and downtime of wind turbines for scheduled maintenance or technical failure ∴ The net energy output is usually estimated at 10-15% below the energy calculation based on power curves of wind turbines (Welch & Venkateswaran, 2009).

Wind turbines are designed to generate maximum power at certain wind speed. This power is known as the rated power and wind speed at which it is reached is called the rated speed of the wind. The speed is adjusted according to the local wind regime, with values common to find between 12 to 15 m/s. For the same reason, to values above the rated wind speed is not increasing economic power, it would require the largest of all equipment with a corresponding increase in initial investment, which would draw only a few hours during the year, thus turbine is set at above nominal wind speed and operate at constant power, leading to artificially decrease the efficiency of conversion (Marafia & Ashour, 2003). When the wind speed becomes dangerously high (above about 25-30 m/s), the turbine is switched off for safety reasons (the aerodynamic loads increase with the square of wind speed). Today's turbines in the adaptation of the system of production to wind speed at each instant it is set by adjusting the angle of attack of the blades (pitch control) and solution set through mechanical or electrical that has in some cases associated solutions for electronic power control, as well as for controlling the rotation speed. However, in certain situations, is limited to the operating power of the wind turbine (Jenkins, 2001).

A variety of models that analyze the trend of long-term costs of wind and other renewable, have been developed over the last decade, many supported by the European Union<sup>59</sup>. The European Commission. (2007) in the 2007 Strategic Energy Review presents a set of key results, as part of the assessment of impact on renewable energies. This shows that the capital cost of wind power will drop to around  $826 \in kW$  in 2020, 788  $\in kW$  in 2030 and 762  $\in kW$  in 2050. A similar pattern is expected for offshore wind energy, as shown in Table 5.2.

	€/kW in2020	€/kW in 2030	€/kW in 2040	€/kW in 2050
Onshore	826	788	770	762
Offshore	1274	1206	1175	1161

**Table 5.2** Trends in the cost of capital assumed by PRIMES project for wind energy

Source: European Commission. (2007)

Likewise, the British Department for Business, Enterprise and Regulatory Reform (DTI, 2007b) commissioned a study by Ernst & Young to examine current and future costs of renewable

<sup>&</sup>lt;sup>59</sup> For example, TEEM, SAPIENT, SAPIENTIA, CASCADE-MINTS, co-funded by DG Research.

technologies. Wind energy onshore and offshore provide upward trend until 2010. This will be followed by a decrease, since bottlenecks in the supply chain are addressed. Using specific costs of energy as the basis (cost per kWh produced), the estimated rates of progress in specialized publications are from 0.83 to 0.91, corresponding to learning rates from 0.17 to 0.09. Then, when the total installed capacity of wind energy doubles, the cost per kWh for new turbines decrease between 9-17%. The recent study by the DTI (2007b) estimates the cost savings of 10% when the total installed capacity doubles. Tables 5.3 and 5.4, have been short of capital costs, energy production and variable costs with their studies and values.

Study	Capital cost per kW installed	Cost per kWh	
Morthorst (2007); Morthorst and Chandler (2004)	900€/kW to 1,175€/kW	n.a	
Milborrow (2006)	869€/kW to 1,559 €/kW	n.a	
AEE (2006)	971.67€/kW to 1,175.10€/kW	n.a	
EER for Vestas (EER, 2007)	1,050€/kW to 1,350€/kW	n.a	
BWEA (2006)	1,520€/kW	n.a	
IEA (2005) projected costs of producing electricity, 2005 update, IEA publications	1,000–1,600US\$ onshore (850–1,360€) and 1,600–2,600 US\$ offshore.	n.a.	
IEA (2007) annual report, draft-data provided by Governments	1,365€/kW in Canada; 979€/kW in Denmark; 1,289€/kW in Germany; 1,050€/kW in Greece; 1,200€/kW in Italy; 1,209€/kW in Japan; 1,088€/kW in Mexico; 1100 €/kW in the Netherlands; 1,216€/kW in Norway; 1,170€/kW in Portugal; 1,220€/kW in Spain; 1,242€/kW in Switzerland; 1,261€/kW in the UK; 1,121€/kW in the U.S.	n.a.	
UKERC (2006)	n.a.	5.9 c€/kWh with a standard deviation of 2.5 c€/kWh 9.3– 11.5c€/kWh (high and low)	
DTI (2007a)	1,633€/kW (medium scenario); 1,850€/kW (in the high scenario); 1,422€/kW (in the low scenario).		
DTI (2007b)	n.a.	8.1 c€/kWh to 15 9c€/kWh	
Bano, Lorenzoni for APER (Blanco, 2009) 1,400 €/kW		9.4 c€/kWh	
Wiser, Bolinger for US DOE (Blanco, 2009)	1,480 US\$/kW (1,200 €/kW approximately) projects in 2006; 1680 US\$/kW (1,428€/kW) for proposed in 2007.	n.a.	

Table 5.3 Summary of some sources about capital costs and production costs of wind power

Study	O&M costs	Other variable costs
Morthorst (2007); Morthorst and Chandler (2004)	1.2 to 1.5c€/kWh	n.a. (not clear)
Milborrow (2006)	15 to 40c€/kW; 1 to 1.5c€/kWh	n.a. (not clear)
AEE (2006) EER for Vestas (EER, 2007)	1.02c€/kWh 2.5 to 4c€/kWh; 0.25 to 0.40c€/kWh	1.03 c€/kWh n.a
BWEA (2006) IEA (2005)	23.25c€/MWh 12.50 to 33.8c€/kW	(check) n.a.
DTI (2007b) Bano, Lorenzoni for APER (Blanco, 2009)	61.5c€/kW 1.8c€/kWh	n.a. n.a.
Wiser, Bolinger for US DOE (Blanco, 2009)	Partial data; 0.68c€/kWh for the most recent projects; 1.7 c€/kWh for older projects.	n.a.

Table 5.4	Summary	of some	sources about	variable	costs in	producing	wind	energy
								( ) . /

## 5.3 MODELS OF PROJECTS ECONOMIC EVALUATION

### 5.3.1 ECONOMIC BASICS OF PROJECTS EVALUATION

An "investment" in the broadest sense is any occasion where financial resources (capital) are put to productive purposes. This money could then be invested in new product development, acquisition of a competitor or to build new plant to generate electricity. In a narrower sense, an investment is limited to cases where financial resources are applied to acquire or build tangible capital assets ("capital cost"). The purchase of government securities (investments) or project financing to develop new products (intangible investment) is not characterized as an investment in this sense. REPs are typically capital-intensive investments, as mentioned earlier (Damodaran, 2001).

The investments have important consequences for the investor, because a considerable amount of capital is needed and is linked to long and not available for other purposes, equally attractive, if applied (time of operation or life of the project). The consequences of a wrong investment decision can be large, and endangering the investor. It is natural that investment decisions are preceded by long and extensive analysis of the potential attractiveness of investment. The analysis of investment attractiveness are called *"economic evaluation of investment"* (Dixit & Pindyck, 1995).

Appropriate setting for the opportunity cost of investment (discount rate or cost of capital), the cost of capital is an appropriate discount rate to be applied in the economic evaluation of projects. Note that in business practice, often we use the average cost of capital (measured in all forms of capital currently used). The most appropriate measure would be the marginal cost of capital (cost of additional capital investment in employee analysis). The marginal cost and average cost are not
equal. However, the most common is the "Weighted Average Cost of Capital" (WACC). It is calculated using the following formula (Damodaran, 2001):

$$r_{WACC} = (1 - W_D)r_E + W_D r_D (1 - t_x)$$
 [%/yr] Eqn (5.1)

where  $r_{WACC}$  = Weighted Average Cost of Capital;  $W_D$  = Capital Structure;  $r_E$  = Equity cost;  $r_D$  = Debt cost before tax and  $t_x$  = taxes.

The assets of a project are financed by debt and equity. The *WACC* allows calculation of weighted average cost of funding sources, in which the weight of each is considered in each funding position. This weight is defined as the ratio:

$$W_D = \frac{Equity}{(Equity + Debt)} \qquad [\%] \qquad Eqn (5.2)$$

The interest rate for working capital loan is simple (since it is known from the interest payment to creditors). The interest rate to be applied to equity is less obvious. In finance theory suggests alternative methods for estimating the cost of equity, the most prominent are the opportunity cost methods, methods based on Discounted Cash Flow (DCF) and methods based on Capital Asset Pricing Model (CAPM). Both approaches have a disadvantage because they are applicable in open capital markets (sale of shares through stock exchanges). In these cases, the opportunity cost approach must be taken when the investor is evaluating alternative investment options with equity and/or obvious to the expected return on investment as "cost of capital" for the planned project.

An analysis or economic evaluation of investment involves activities undertaken before an investment decision in order to assess the potential of attracting investment by the investor. These evaluations may be limited to purely monetary parameters, which in most cases also include non-monetary parameters (NREL, 1995). This section discusses about economic evaluations methods for REPs, especially wind farms in order to accomplish the objectives of this same section.

### 5.3.1.1 SIMPLE PAYBACK

The Simple Payback (SPB) is defined as the time (number of periods) required for the project's cash flow<sup>60</sup> refinance the initial investment. In other words, the SPB is required to recover the initial investment through positive cash flows of the project. Before that moment, the project has recovered all the initial investment or at least part of the invested capital is still at risk (if the project fails).

The SPB is used as a measure of project risk: the higher the return time, the greater the risk for investors, because (in part) the invested capital cannot be recovered. In a typical project, the negative cash flow early in the project (initial investment) is followed by positive cash flows (return) in subsequent periods. Mathematically, SPB can be expressed as the smallest t that satisfies the condition:

$$(Ci - Co)_{l+}(Ci - Co)_{2+...+}(Ci - Co)_t = \sum (Ci - Co)_t \ge Co_0$$
 [yrs] Eqn (5.3)

where  $C_i = Cash$  inflows;  $C_o = Cash$  outflows;  $C_{o0} = Initial$  Investment and t = Number of periods.

Since *t* is an integer, the sum (Eqn 5.5) is likely to be lower or higher than the initial investment ( $C_{o0}$ ), but not exactly equal to  $C_{o0}$ . The value (decimal) exactly the SPB (where the sum corresponds exactly to the initial investment) can be calculated by linear approximation by using the following formula (Brealey & Myers, 1997):

$$t' = t - \sum (Ci - Co)_t \times \frac{1}{\sum (Ci - Co)_{t+1} - \sum (Ci - Co)_t}$$
 [yrs] Eqn (5.4)

with

$$\sum (Ci - Co)_t < Co_0 \text{ and } \sum (Ci - Co)_t > Co_0$$
 [yrs] Eqn (5.5)

<sup>&</sup>lt;sup>60</sup> In finance, cash flow (known in English as "*cash flow*"), refers to the amount of cash received and spent by a company during a period, sometimes linked to a specific project. There are two types of streams: - outflow exit, which represents cash outflows, underlying the investment costs - inflow of entry, which is the result of the investment. The value that balances with the outputs and translates into increased sales or represents a reduction of production costs, among others (Brealey & Myers, 1997).

For investment projects in renewable energy, wind energy onshore case, to determine the best project is necessary to consider the cash inflows or revenues uniform (which actually does not happen) during the lifetime of the project. For energy projects, the *SPB* must be calculated using the following equation (Fingersh, Hand, & Laxson, 2006):

$$SPB = \frac{ICC}{AAR}$$
 [yrs] Eqn (5.6)

where ICC = Initial Capital Cost and AAR = Average Annual Revenue based on hourly production.

Importantly, this model assumes that the wind farm (project) will generate the same amount of electricity per year to the same sales price during the years of operation under review. As a result, this analysis assumes constant revenue stream. This method does not consider the discount rate or life of the project, so, the analysis of the Simple Payback is not dependent on these values. The SPB is often preferred as a measure of investment merit due to its simplicity. However, there are several other aspects of economic merit. These methods are discussed and compared below; the discussion is in relation to the needs of this particular study. There is a general discussion on the economic values of merit.

Before the occurrence of the *SPB*, the project has not recovered all the initial investment, or at least part of the capital invested is still at risk (if the project fails). The *SPB* has disadvantages that limit its use in business practice in renewable energy:

- 1. SPB ignores the value of economic resources over time. The positive net cash flows for subsequent periods are treated as if they were carried out at present. Future cash flows are as overweight which leads to SPBs too optimistic.
- 2. SPB ignores cash flows that occur after the recovery period. It may be that a project has shorter payback, but smaller NPV (Net Present Value) over the life of the entire project. Decide based solely on the SPB, the investor chooses the wrong alternative.

The *SPB* represents the length of time that it takes for an investment project to recover its own initial cost, from the cash receipts it generates. A shorter payback period means a desirable investment. In the case of implementation of a wind energy project, a negative payback period would be an indication that the annual costs incurred are higher than the annual savings produced (Rehman, 2005). For this situation it is necessary try to reduce the production cost by renegotiation with the wind farm's suppliers. That is why *cost control* and *management accounting* stages as shown in Figure 5.1 is part of the evaluation process of RETs.

#### 5.3.1.2 DISCOUNTED PAYBACK

The Discounted Payback (*DPB*) considers the value of capital over time by discounting net cash flows of each period before sum them and compare them with the initial investment. *BDP*, therefore, can be expressed by the following formula (Brealey & Myers, 1997):

$$\frac{(Ci - Co)_1}{(1+i)^1} + \frac{(Ci - Co)_2}{(1+i)^2} + \dots + \frac{(Ci - Co)t}{(1+i)^t} = \sum \left(\frac{(Ci - Co)t}{(1+i)^t}\right) \ge Co_0 \qquad \text{[yrs]} \qquad \text{Eqn (5.7)}$$

where  $C_i = Cash$  inflows;  $C_o = Cash$  outflows;  $C_{o0} = Initial$  Investment and i = Discount rate.

When investment projects relate to renewable energy, e.g. wind energy power projects, to determine the time of return on investment of the project is necessary to consider the cash inflows or revenues uniform (which actually does not happen) during the period project life. For energy projects, the DPB should be calculated using the following equation (Fingersh et al., 2006):

$$DPB = \frac{ICC}{\left[AAR - \left(O \& M + LLC\right)\right]} \qquad [yrs] \qquad Eqn (5.8)$$

where ICC = Initial Capital Cost; AAR = Average Annual Revenue based on hourly production; O&M = Operations and Maintenance cost and LLC = Land Lease Cost.

As *DPB* is discounting the future cash flows (positive), this takes longer periods of recovery that the *SPB*. For any project will exceed the typical *SPB*. Linear interpolation can be used to determine the exact decimal value of *BDP*. According to Eqns 5.4 and 5.5. Unlike *PBS*, which is simplified, the *BDP* believes the discount rate (interest rate) and the fact that not always the expected flows are constant.

The electricity production project from renewable primary energy sources, wind energy project case highlights the importance given to the costs of operations and maintenance as well as lease

cost of the land where the wind farm is deployed, if leased. Thus the analysis of investment risk is minimal considering the changing market. This method reveals some weaknesses among other models of investment appraisal. The main limitations of this method are:

- 1. It has total focus on the variable time, not worrying about possible cash flows after the payback time.
- 2. Does not discount cash flows properly, because it considers "surplus" of investment.
- 3. Determine the payback period is somewhat arbitrary, because the *DPB* can be expected to take interest or discount rates that are not practiced by the financial market.

For Bhandari (2009) in a project with normal or conventional cash flows the *DPB* is a unique number. The *DPB* based decision rule also provides an objective rule for decision making because accepting project if *DPB* is less than expected life of a project involves no subjectivity. In many instances the lifetime of a project itself is uncertain due to change in technology (case of repowering in wind power industry, consumer preference, competing products, regulatory environment etc.

#### 5.3.1.3 NET PRESENT VALUE

The Net Present Value (*NPV*) is a method of economic evaluation of projects very well-known also. *NPV* takes into account the capital value over time. The value of capital in time refers to the fact that this value is now worth more than the present in time future. This is because an amount placed in time may be invested and getting a return above the rate of inflation. Therefore, future earnings should be discounted. *NPV* has become more widespread and accepted as a measure of financial performance of the project (Brealey & Myers, 1997).

NPV is the direct application of the concept of present value<sup>61</sup> and the difference of present value of cash inflows (inflows) between the present values of cash outflows (outflows). NPV is the sum of all discounted cash flows associated with the project. The general equation can be written as (Kaltschmitt et al., 2007):

$$NPV = (Ci_0 - Co_0) + \frac{(Ci_1 - Co_1)}{(1+i)} + \frac{(Ci_2 - Co_2)}{(1+i)^2} + \dots + \frac{(Ci_t - Co_t)}{(1+i)^T} = \sum \left(\frac{(Ci_t - Co_t)}{(1+i)^T}\right)$$
[\$M] Eqn (5.9)

<sup>&</sup>lt;sup>61</sup> It denotes the number of periods elapsing between now and when the payment occurs *i* denotes interest rate or discount period, then the general formula to discount future cash flow is given as:  $K_0 = \frac{K_t}{(1+i)^1} = K_t \times (1+i)^{-t}$ , and  $K_0$  is called "present value" of future payment  $K_t$ . (Brealey & Myers, 1997)

where  $C_i = Cash$  inflows;  $C_o = Cash$  outflows;  $C_{o0} = Initial$  Investment, i = Discount rate and T = Number of periods.

When investment projects refer to wind projects, to determine the time for return on investment of the project is necessary to consider the entries of cash receipts as uniforms (which actually does not happen) during the lifetime of the project.

For energy projects, the *NPV* is defined as the present value of benefits less the present value of costs. The present value of costs is the cost of initial capital, *ICC*. It is assumed that the distribution of wind speed remains constant from year to year, resulting in uniform amount of electricity produced from year to year (Kaltschmitt et al., 2007). It is assumed that the annual revenue would be uniform. This uniform cash flow must be discounted, since it occurs in the future. The *NPV* of a uniform cash flow is given by Eqn 5.10.

$$NPV = AAR\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] - ICC \qquad [\$M] \qquad \text{Eqn (5.10)}$$

where AAR = Average Annual Revenue based on hourly production; i = Discount rate; N = Lifetime of wind farm and ICC = Initial Capital Cost.

For independent projects, the investment decision occurs when *NPV* is greater than zero. If the investor decides between two mutually exclusive projects, then the project with higher *NPV* should be chosen. In optimization analysis, the choice is mutually exclusive. It is important to remember that, unlike the Simple Payback, the financial assumptions that count in determining the discount rate and lifetime for *NPV* of the investment can change engineering aspects of the wind farm under consideration.

Once the rotor diameter is the single parameter of the project to be variable, *AAR* and *ICC* can be generalized as functions of rotor diameter, *i* and *N* are chosen, the value of the term  $\left[\frac{(1+i)^N - 1}{i(1+1)^N}\right]$ will remain constant and then Eqn 5.10 can be generalized as:

$$NPV = C \times AAR(D) - ICC(D) \qquad [\$M] \qquad \text{Eqn} (5.11)$$

Where C is a constant. The maximum NPV is found by differentiating Eqn 5.11 with respect to the rotor diameter, D, and equating to zero, as shown below.

$$\frac{dNPV}{dD} = C \frac{dAAR(D)}{dD} - \frac{dICC(D)}{dD} = 0$$
 [\$M] Eqn (5.12)

Rearranging the Eqn 5.12, we have:

$$\frac{dNPV}{dD} = C \frac{dAAR(D)}{dD} - \frac{dICC(D)}{dD} = 0$$
 [\$M] Eqn (5.13)

Eqn 5.13 shows that the constant, C, has no effect on the rotor diameter that maximizes the *NPV*. The financial assumptions that go into determining the discount rate and lifetime of the investment will change the optimal design of engineering of the wind farm.

*NPV* approach involves assigning a rate of return that is reasonable for, and specific to, the project and then computing the present value of the expected stream of payments. Since the investment is initially expended, it is counted as negative revenue. An appropriate rate of return must be identified (Khatib, 1996). The rate of return is a problem, mostly because of risk associated with the payoffs to the investment, but also because of the incentives of project managers to inflate the payoffs and minimize the costs to make the project look more attractive to upper management (Khatib, 2003).

*NPV* has disadvantages that may limit the use in the evaluation and management of projects in renewable energy, particularly in wind energy projects:

- 1. The need to know the actual capital cost of the project. As the interest rate that measures the cost of capital for an investment should include the risk of the project, the task of defining the real value of capital cost is not always easy to accomplish.
- 2. The discount rate or cost of capital remains unchanged throughout the period under review the project, which is not as fixed as well as the cost of capital depends on financial market behavior and risk of new developments in the analysis.
- 3. The type of response in money instead of being a percentage, for the assessment of monetary values incurs no assessment of the real purchasing power, if it were in percentage terms; it would make it easier to compare projects in different currencies.

### 5.3.1.4 INTERNAL RATE OF RETURN

The method of Internal Rate of Return (*IRR*) is to calculate the rate that cancels the net present value of cash flow in investment analysis. Investment which will be attractive internal rate of return is greater than or equal to the rate expected by the investor attractiveness. In comparison of investment, the best is one that has the highest internal rate of return (Kreith & West, 1997).

According to Newnan and Lavelle (1998) the rate is not easily calculated, since it must be determined by *trial and error* or the *least squares method*. We try to rate a likely value and thereafter to make successive approximations. The level of precision in the result of IRR is 0.01%, and should be obtained for a maximum of 10 000 interactions. As the calculations of present value, IRR is used to bring the current date all the cash flows of the project, according to Eqn 5.14.

$$NPV = \sum \left( \frac{\left(Ci_t - Co_t\right)}{\left(1 + i\right)^t} \right) = 0 \Longrightarrow i = ? = IRR \qquad [\%] \qquad \text{Eqn (5.14)}$$

where  $C_{it} = Cash$  inflows in period t;  $C_{ot} = Cash$  outflows in period t; i = Discount rate and t = Number of periods.

In most cases, this equation is a polynomial of degree t that cannot be solved in closed form. Instead, different types of successive approximation should be applied to solve i. The software (MS Excel and RETScreen) offer this functionality as a modern tool inserted in their functions.

*IRR* is expressed as a percentage ("*return*") and is easily interpreted as "*return of a project*". The *IRR* represents the maximum rate of interest that *i* can still take the project to create the NPV equals zero. If *NPV* is zero means that the project finances the capital invested, plus interest, an *IRR* of 10% means that the project could re-finance the capital invested, plus interest at a maximum of 10% of this capital. At any rate above 10%, the same project creates surplus value (*NPV*> 0) for the investor. At any interest rate below 10%, the project would not be able to refinance the capital invested and pay interest. The investor would have to add extra capital to pay the amount invested, plus interest, and thus reduces your assets. Only 10% would be indifferent to the investor, and neither gain nor loses from the project (Dixit & Pindyck, 1995).

*IRR* is the discount rate that sets the *NPV* equal to zero (Newnan & Lavelle, 1998). *IRR* of a wind energy project, with uniform revenue is found by solving the equation for the *IRR*. The project *IRR* is greater chosen as best. If *IRR* is maximized, the financial assumptions required to determine the duration of the project, *N*, have no effect on the ideal project. Maximize *IRR* result in the same design when *SPB* is minimized. This is shown below (Kaltschmitt et al., 2007).

$$NPV = AAR \left[ \frac{(1 + IRR)^{N} - 1}{IRR(1 + IRR)^{N}} \right] - ICC = 0 \qquad [\%] \qquad \text{Eqn (5.15)}$$

where AAR = Average Annual Revenue based on hourly production; N = Lifetime of wind farm and ICC = Initial Capital Cost.

The Eqn 5.15 can be rearranged to:

$$\left[\frac{\left(1+IRR\right)^{N}-1}{IRR\left(1+IRR\right)^{N}}\right] = \frac{ICC}{AAR} = SPB \qquad [yrs] \qquad Eqn (5.16)$$

By increasing *IRR*, the left side of the Eqn 5.16 decreases for any N value. The relationship *ICC/AAR*, which is equivalent to *SPB*, it must also decrease with the increase in *IRR*. This proves that maximize the IRR have the same effect of minimizing *SPB*, no matter what is assumed for the lifetime of the project. Despite its intuitive nature, *IRR* has some drawbacks, therefore, must be applied with care:

- 1. Depending on the structure of cash flows of the project, a project can have more than one *IRR*. The equation to be solved generates multiple solutions (for example, depending on the value from the iterative approach). So, no clear decision can be made.
- 2. The IRR implicitly assumes that all cash flows can be reinvested at the *IRR*. *NPV* does not have this disadvantage, since it assumes that cash flows are reinvested in the *i* defined as the discount rate (which is the average cost of capital and represents a more realistic assumption for reinvestment).
- 3. *IRR* does not take into account the different sizes of investment. An alternative could provide an internal rate of return, but with a smaller initial investment. The absolute gain in wealth for the investor may still be more different with *IRR* that offers a slightly lower *IRR*. *NPV* does not have this limitation.

It is important to highlight that Certified Emission Reductions  $(CERs)^{62}$  can impact directly on *IRR* results, due to extra revenues made by the wind power project. It is supposed to performance the *IRR* analysis with and without CERs impact.

<sup>&</sup>lt;sup>62</sup> According to Bode and Michaelowa (2003) the credited emission reductions are commodities that can be sold and thus provide additional revenues and increase the economic attractiveness of a REPs.

### 5.3.1.5 REQUIRED REVENUES

Required Revenues (RR) is the appropriate concept and applies only to regulated sectors (consumers and producers of electricity are regulated by specific taxes or burdens of government action). The REPs can fit into this profile, because the market power electrical distribution system in a certain region (for large wind farms), which access to the public grids is regulated by tariffs (Tahvanainen, 2010). The method *RR* is the analysis of total revenues (cash inflows), the project received from clients to compensate for all costs associated with the project during its lifetime (NREL, 1995).

$$RR = TLCC = \Sigma \left( \frac{Co_t}{(1+i)^t} \right)$$
 [\$M] Eqn (5.17)

where TLCC = Total Life-Cycle Cost;  $C_{ot} = Cash outflows in period t$ ; i = Discount rate and t = Number of outflows periods.

This comparison is not made with absolute (nominal), but with discounted values. The method determines the level annual returns required to cover the cost of the entire project (with discount) (Finnerty, 2007):

Levelized RR = TLCC × UCRF = 
$$\sum \frac{Co_t}{(1+i)^t} \times \frac{i(1+i)^n}{(1+i)^n - 1}$$
 [\$M] Eqn (5.18)

where *UCRF* = *Uniform Capital Recovery Factor* and *n* = *Number of periods*.

The UCRF converts the current value in the flow of equal annual payments over a specified period of time t, i the rate specified discount (interest). The Eqn 5.19 shows UCRF calculation, where i = discount rate and t = number of periods in years.

$$UCRF = \left[\frac{i(1+i)^{t}}{(1+i)^{t}-1}\right]$$
 [-] Eqn (5.19)

The main purpose of economic regulation is to achieve competitive results in an environment where competition is (for various reasons) not feasible, case of wind power industry. Traditional tariff setting is based on RR that should allow a company to cover its expenses and have a reasonable rate of return on its invested capital (Lesser & Su, 2008).

This is an inverse measure: the lower level RR is the project more attractive because it can cover costs of the project (including interest), with lower revenues. When revenues are fixed (i.e., defined by the regulator), the investor or manager of the project (i.e., wind farm manager) will chose an alternative that can maximize the difference between RR level per unit of energy and administered prices per unit produced and marketed the electrical distribution network needed to ensure the smallest level of revenues required (Phung, 1980). RR has disadvantages that limit their application in the evaluation and management of projects in renewable energy, particularly in wind energy projects:

- 1. The capacity factor is considered constant throughout the life of the project. In wind energy projects this may fluctuate resulting in annual electricity production variable, so revenue and costs also vary.
- 2. The financial indicators considered over the life of the project (inflation, discount rate, taxes) also remain constant throughout the analysis period of life of the project.
- 3. Costs are projected to lifetime of the project, which makes the financial cycle equal to the operational cycle of investment, a fact that the classical rules of accounting does not always coincide.

### 5.3.1.6 BENEFIT-TO-COST RATIO

The Benefit-to-Cost Ratio (*BCR*) of a project is another application of the principle of the capital in time. BCR analyzes the discounted cash flows. Unlike the *NPV*, cash flows are positive (*"benefits"* of the project) and negative cash flows (cost of the project) are discounted and accumulated separately. The sum of the discounted cash flow positive is placed over the sum of all negative cash flows discounted (NREL, 1995):

if 
$$PV_{ci} = \sum \frac{Ci_t}{(1+i)^t}$$
 [\$M] Eqn (5.20)

and 
$$PV_{co} = \sum \frac{Co_t}{(1+i)^t}$$
 [\$M] Eqn (5.21)

then,

$$B/C = \sum \frac{\sum \frac{Ci_t}{(1+i)^t}}{\sum \frac{Co_t}{(1+i)^t}} \qquad [-] \qquad \text{Eqn (5.22)}$$

where  $PV_{ci}$  = Present Value of Cash Inflows and  $PV_{co}$  = Present Value of Cash Outflows.

In order to better illustrate the application of this method, using a discount rate of 8% per year returns the discounted cash flow or updated, according to Table 5.5.

In 000 CSD, interest rate= $8\%$ year0123TotalCash outflows (-)-100,0-30,0-30,0-30,0-30,0Cash inflows (+)0,0 $80,0$ $80,0$ $80,0$ Discounted cash outflows-100-27,8-25,7-23,8-177,3Discounted cash inflows0,074,168,663,5206,2	Le "000 LICD" internet and 200//		T = 4 = 1				
Cash outflows (-)-100,0-30,0-30,0-30,0Cash inflows (+)0,080,080,080,0Discounted cash outflows-100-27,8-25,7-23,8-177,3Discounted cash inflows0,074,168,663,5206,2	In 000 USD , interest rate = $8\%$ year	0	1	2	3	Total	
Cash inflows (+)0,080,080,0Discounted cash outflows-100-27,8-25,7-23,8-177,3Discounted cash inflows0,074,168,663,5206,2	Cash outflows (-)	-100,0	-30,0	-30,0	-30,0		
Discounted cash outflows-100-27,8-25,7-23,8-177,3Discounted cash inflows0,074,168,663,5206,2	Cash inflows (+)	0,0	80,0	80,0	80,0		
Discounted cash inflows         0,0         74,1         68,6         63,5         206,2	Discounted cash outflows	-100	-27,8	-25,7	-23,8	-177,3	
	Discounted cash inflows	0,0	74,1	68,6	63,5	206,2	

**Table 5.5** Example of typical cash flow for BCR analysis

Source: NREL (1995)

*BCR* analysis is 206.2/177.3 = 1.16. Each currency (at current values) generates returns of 1.16 currency units (at current values). The relation B/C above 1 represents attractive investment options in absolute terms  $\therefore BCR$  analysis is not a useful measure to compare mutually exclusive alternatives; since the ratio does not measure the relative attractiveness can be misleading the decision maker. Not necessarily lead to the same result when assessing the attractiveness of a project because the *NPV* is not a widely used measure.

*BCR* analysis is the ratio of current value of the sum of benefits divided by present value of the sum of costs. It is used as a selection criterion for all eligible projects that have independent cost-benefit ratio, calculated the relevant discount rate (opportunity cost of capital) equal to or greater than

unity. Cannot be used to choose between mutually exclusive alternatives (Boardman, Greenberg, Vining, & Weimer, 1996).

*BCR* compares benefits to costs and is a dimensionless number that indicates how many money of benefit are returned per monetary unit invested beyond the required rate of return expressed by the discount rate. It is computed by dividing total discounted benefits by total discounted costs. A ratio greater than one means that benefits exceed costs. A ratio of 10 to 1, for example, means that, on average, \$10 in benefits are produced for every monetary unity of costs incurred, after adjusting for the time-value of money. (Generally, investment costs for the denominator and other costs are deducted from benefits in the numerator) (Prasad & Bansal, 2011).

*BCR* has disadvantages that limit its application in the evaluation and management of projects in renewable energy, particularly in wind energy projects:

- 1. The main disadvantage of ratings based on *BCR* is that ignoring non-monetary impacts. Attempts were made to mitigate these limitations through a combination of *BCR* with information regarding these impacts are not likely to denomination, as the approach proposed by the New Approach to Appraisal, used in the  $UK^{63}$ .
- 2. Another difficulty refers to the *BCR* precise definition of benefits and costs, due to variability in the criteria for more realistic analysis is required a distinction between perfect and total operating costs and investment.
- 3. The pre-operational wind energy project, (studies, construction and equipment installation, testing and technical adjustments) and the fact considers the costs of O&M constant over the lifetime of the project makes the phase of exploration / production project is different from the life of the project. This interferes with the production time and consequently the entrances and exits of cash flow, which makes the analysis imprecise *BCR* in terms of monetary values.

There are many other microeconomic methods for measuring investment in REPs derived from the ones studied on this chapter, such as Life-Cycle Cost (*LCC*), Net Benefits (*NB*) or Net Savings (*NS*), Savings-to-Investment Ratio (*SIR*), Overall Rate-of-Return (*OOR*). The variety of methods to evaluate the economic performance of (renewable) energy systems serves as a "tool" to be chosen by the analyst. A good start point for the evaluation process is to define the problem and the objective of the evaluation (Kreith & West, 1997).

For Ramakumar, Butler, Rodriguez, and Venkata (1993) economic considerations are among the primary factors that influence the evolution of energy systems. Unless the "cost of energy" obtained using a particular technology is competitive with the alternatives, that technology will not be viable. However, the "cost" considerations should be comprehensive and should include prospecting, collection, conversion, transportation, distribution, storage and reconversion, end use, and the management of power system analyzed.

<sup>&</sup>lt;sup>63</sup> For further information, see on <u>www.environment-agency.gov.uk</u>.

### 5.3.2 PECULIARITIES IN THE INVESTMENT ANALYSIS OF WIND ENERGY PROJECTS

The investment analysis can be considered as a set of techniques that allow the comparison between the results of making decisions regarding the different alternatives in a scientific manner. In this comparison, the differences that mark the alternatives should be expressed in quantitative terms. To express in quantitative terms the differences between the alternatives for decision-making uses economic engineering principles.

*IRR* and *NPV* based on the same principles of equity capital<sup>64</sup> and lead to the same decision. The key difference among the two techniques is that the *NPV* assumes reinvestment at the same cost of capital (discount rate), while the IRR assumes reinvestment will be the actual internal rate of return of the project.

In the case of wind energy projects *NPV* is a function of *AAR* and the *ICC*. As a result, to maximize *NPV* also maximizes the absolute wealth created by investment. Because of this, *NPV* is biased toward larger investments. While on return is greater than the discount rate. The analysis of the *NPV* will push the decision to bigger projects, even if the relative profitability is smaller.

The *SPB*, *DPB* and *IRR* are functions of *ICC/AAR*. Minimizing *ICC/AAR* will maximize the wealth of the equity invested. For the optimization of wind farm, should be determined to maximize the wealth obtained from the absolute wind farm or to maximize the relative wealth produced by the project. As the wind turbine is modular, it is more convenient to choose the size of the rotor, which maximizes the relative ability of the wind turbine to generate wealth. In case you decide to minimize the *SPB* because of the method is simpler as shown before, to minimize *SPB* will result in the same optimal design to maximize the *IRR*. An example is when you want to maximize absolute wealth would be if the land available for development of wind farms were limited. In this case, the absolute wealth produced by the wind farm can be maximized by selecting a turbine capable of producing greater.

It is worth being aware of some of the other methods of investment analysis and expresses a wind power project in economic terms. The preferred indicator depends on the exact nature of the project being evaluated, the cash flow profiles and the requirements of the investment analysis to be done (Boyle, 1997). These methods and techniques can be used to decide whether or not to invest in a given wind farm; to determine which system design or size is economically efficient; find the combination of components and systems that are expected to be cost-effective; to estimate how long before a project will break even; and to decide which WECS-related investments are likely to provide the highest rate of return to the investor.

<sup>&</sup>lt;sup>64</sup> The principle of equity capital is the financial situation at that given rate of return of capital or update makes a series of future values, regardless of their nominal values and terms, when the current values are equal. Thus, to effect any transactions involving securities held in the future you need to know how much currently worth, or what are the current values (Damodaran, 2001)

# 5.4. MODELS FOR COSTS EVALUATION

### 5.4.1 Specific measures of economic performance for energy projects

The costs levelized (or revenue  $\rightarrow$  revenues levelized) is a technique to compare investment alternatives (such as REPs), involving different amounts of capital (i.e., different sizes) and/or different time periods with different life-cycles. Applying *NPV* method is done implicitly on assumptions necessary reinvestment in REPs. These implicit assumptions can be avoided by smoothing of cash flows: even involves the calculation of steady cash flow, net present value (*NPV*) is equal to a given cash flow variable (NWCC, 1997). Suppose that two investment alternatives for REPs have the following net cash flow per period, as shown in Table 5.6.

Cash Flows	Period (years)						NDV
Cash Flows	0	1	2	3	4	5	IVF V years
Alternative 1 Net Cash Flow	-100	20	40	30	50	10	14,1
Alternative 2 Net Cash Flow	-50	20	25	30	-	-	11,4

**Table 5.6** Example of net cash flow for economic performance in energy projects (NPV method)

Source: NREL (1995)

The alternative 1 implies a higher initial investment (capital requirements) and provides higher absolute return than alternative 2. Alternative 2 has only a small initial investment, but also shorter lifetime (3 versus 5 years). It is difficult to make a direct comparison between the two projects. In calculating *NPV* of the project (with a discount rate of 10%) results in *NPV* = 14.1 for an alternative 1 and *NPV* = 11.4 to alternative 2. For *NPV* rule suggests that an alternative 1 is chosen. The levelizing of cash flows (net) is to find a constant amount *g* during the life of the project *NPV* with this flow in equal amounts *g* to become equal to *NPV* of the original project, as shown in Figure 5.3.

Carrying out a *NPV* analysis essentially requires two things. First, investment and revenues must be estimated. This is a challenge, especially for new products where there is no direct way of estimating demand, or with uncertain outcomes like wind power projects. Second, an appropriate rate of return must be identified. The rate of return is a problem, mostly because of risk associated with the payoffs to the investment, but also because of the incentives of project managers to inflate the payoffs and minimize the costs to make the project look more attractive to upper management (Salles, Melo, & Legey, 2004).



Figure 5.3 Scheme of the cash flows levelizing process for REPs. Source: IEA (1991)

This amount g (also called "annuity") is calculated using the Eqn 5.23 below:

$$g = NPV \times UCRF = NPV \times \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \qquad [-] \qquad \text{Eqn} (5.23)$$

The Uniform Capital Recovery Factor (*UCRF*), is the factor by which *NPV* must be multiplied to reach the constant value g given discount rate i for a series of n periods. In the example in Table 5.6, the alternative creates an annuity of 3.73 (in monetary units). The five cash inflows of 3.73 are equal to a *NPV* of 14.1, exactly equal to *NPV* of cash flows of the project plan (including initial investment). Alternative 2 generates annuity of 4.58 (in monetary units). By comparing the potential of their projects to generate stable cash flows, the alternative 2 should be higher than the alternative 1.

Annuities are not specific to REPs. The concept *LCOE* is used to compare the different alternatives of energy production. Revenues are fixed and equal between these alternatives (e.g., because the price is set by the regulator and does not depend on the technology used to generate energy, then the alternatives differ only in their costs (cash flows of revenues are equal to all alternatives) (NREL, 1995).

The above concept is applied only to cash outflows (costs). The sum of all costs involved in the project during its full life cycle — Total Life Cycle Cost (*TLCC*) are discounted to present value and converted into a stream of equal cash outflows for each year of the project (*"annuity*")

*negative"*). If the value is divided by the annual amount of energy produced, the result is called the *Levelized Cost of Energy (LCOE)*. *LCOE* is assigned each unit of energy produced (or saved) by the project during the analysis period is equal to the *TLCC* when discounted to the base year (period 0). *LCOE* can be used to rank different alternatives for production (or consumption) of energy, as shown in Figure 5.4.



**Figure 5.4** Values in \$/kWh LCOE in 2005 for various conventional and renewable technologies. Source: NREL (1995)

## 5.4.1.1 LEVELIZED COST OF ENERGY

The Levelized Cost of Energy (*LCOE*) is the real cost of production of kilowatt-hours (kWh) of electricity. This measure includes the total construction phase costs, central production costs of the power station during its economic lifetime, financing costs, return on capital and depreciation. Costs are levelized in current monetary values, or adjusted to eliminate the impact of inflation (Friedman, 2010).

*LCOE* is what it would cost the owner of the facility to generate one kWh of energy. Most of the wind power projects have a lifetime for 20-25 years, a long period, so the inflation impact can sufficiently change and economic evaluation of the same project, which is why to take into consideration the inflation during the lifetime of the project (Sevilgen, Erdem, Akkaya, & Dağdaş, 2005). For electricity production, *LCOE* is a method to compare renewable energy technologies adopted to generate electricity. The model *LCOE* most known and used in energy projects by the *National Renewable Energy Laboratory* (Cohen, 1989). The calculation method is defined below.

$$LCOE = \frac{FCR \times ICC + LRC}{AEP_{net}} + O\&M + PTC \qquad [\$/kWh] \qquad Eqn (5.24)$$

where FCR = Fixed Charge Rate; ICC = Initial Capital Cost; LRC = Levelized Replacement Cost; O&M = Operations and Maintenance; PTC = Production Tax Credit and  $AEP_{net} = Net$  Annual Energy Production.

The calculation of *LRC* can be accomplished with the Eqn 5.25, where MR = Machine Rating (NREL, 1995).

$$LRC = \frac{\$}{kW}MR$$
 [\$/kW] Eqn (5.25)

For correct analysis of the levelized cost of energy, the net annual energy production of the wind farm is given by Eqn 5.26. The *availability* is defined as the ratio of hours the wind system is capable of producing energy relative to the number of hours during the study period and losses represent loss of matrix, dirt on the blades and ice formation, the central production downtime for maintenance and miscellaneous system losses in production and distribution of energy to the electric grid (RETScreen® International Clean Energy Decision Support Centre, 2008).

$$AEP_{net} = AEP_{gross} \times Availability \times (1 - losses)$$
 [kWh] Eqn (5.26)

where  $AEP_{gross} = Gross Annual Energy Production$ .

*LCOE* was adopted by the United States Department of Energy in the Low Speed Wind Turbine Program (LWST) and makes reasonable approximation of the Cost of Energy (*COE*), which is estimated by the potential investor to consider the reliability of the equipment to determine *AEP*, *O&M* and *LRC*. *AEP* is affected by the availability of equipment due to the shutdown of wind turbines due to scheduled and unscheduled maintenance. The costs of *O&M* consist of programmed costs (preventive) and costs unscheduled (repair) maintenance, including costs for replacement parts, supplies, manpower, leases (royalties) of land, among other expenses arising from the operation of a wind farm.

## Fixed Charge Rate

The capital cost component of *COE* is determined by the spread of installed capital cost over the lifetime of the project done in a linear basis over the years through *FCR*. *FCR* is a percentage of the cost of installed capital costs including debt service (financing costs) allocated to each year of the project (for more analytical detailed, see Tegen et al. (2012)). The component of the cost of capital is analogous to a payment of fixed rate mortgage of a house, or fixed amount per pay period during the term of the debt. The analysis period may be the life of a physical plant for the production or lifetime for accounting purposes. The lifetime of a wind farm ranges from 20 to 30 years, while lifetime used for financial accounting purposes may be smaller (Harper, Karcher, & Bolinger, 2007; NREL, 1995). *FCR* is the annual value for each monetary unit of initial capital cost needed to fully cover the initial capital cost, return on equity and debt, and other overheads. The fee is charged from a hypothetical project, spread over cash flow. The current base model, *FCR* must include funding for construction, financing rates, return on equity and debt, amortization of equipment and facilities, tax revenue and profits all on an annual basis (Cohen, 1989).

## Initial Capital Cost

The Initial Capital Cost (*ICC*) is the sum of the cost of wind power system and the cost structure of the wind farm. Not included is cost of financing the construction or financing rates, as they are calculated and added separately through *FCR*. Nor does it include the costs of the reserve fund for debt service (charges for financing costs). This cost measure includes all the planning, equipment acquisition, construction and installation costs of the wind system, leaving the wind farm ready to operate. This cost includes wind turbine towers and delivered and installed on site along with all maintenance, electrical system and other infrastructure support. For a wind farm, the cost of installed capital should include the system of collection of electricity which extends from each wind turbine to the substation and point of interconnection with the grid. Depending on the policy and practice of grid administrator and distributor, the electrical system may or may not be included in the cost of capital (NREL, 1995). *ICC* includes costs for buildings to support the operation and maintenance, the initial stock of spare parts and maintenance of diagnostic equipment. Other costs should be included as costs of pre-construction planning, including assessment and analysis of wind resources, surveying, and consultancy for obtaining financing. The installed capital cost of a wind farm includes the following elements (NWCC, 1997):

- 1. Assessment and analysis of wind resources;
- 2. Construction of service roads;
- 3. Construction of foundations for wind turbines, infrastructure to mount transformers and substations;
- 4. Purchase of wind turbines and towers with local delivery and installation;
- 5. Construction and installation of wind sensors, able to communicate wind turbine units for controls;
- 6. Construction of the power reception system, including wiring of each wind turbine for the mounting of the transformer and deck mount transformers for the substation;

- 7. Construction of facilities needed for operations and maintenance during the regular operation of the wind farm;
- 8. Construction and installation of the communication system of wind farms to support the command and control data flow from each wind turbine to a central facility operations;
- 9. Integration and verification of all systems for proper operation of the wind farm;
- 10. Commissioning for wind farm period of decommissioning.

## Levelized Replacement Cost

The *Levelized Replacement Cost (LRC)* is a cost component used as a saving account for the wind power project. Depending on the details of the project, the major review of the wind turbine occurs every 5, 10 or 15 years. The review focuses on the large gears, bearings, seals and other moving parts. Usually the nacelle and its machinery are removed from the tower and transported to the plant maintenance garage of the wind farm. Often, removal of the nacelle and equipment is replaced immediately by all already rebuilt (NREL, 1995). The replacement of the blades of wind turbines is an example of this category of frequent replacement of subsystems. Since these costs occur at intervals of several years and infrequent during each year, correct accounting for these costs requires annual exercise of funds (working capital). The aim is to make funds available when needed to repair or total replacement of occurrence. The exercise involves calculating the net present value or even to allocate costs for review and replacement on an annualized basis consistent with other cost elements (NWCC, 1997).

## **Operations and Maintenance Cost**

The costs of *Operations and Maintenance* (O&M) include costs normally associated with recurrent routine operation of the plant installed. O&M costs do not include overtime worked or infrequently, such as major repairs of wind turbines and other systems. These costs are included in the cost component *LRC*. Most of O&M costs is associated with maintenance and generally grouped into three categories (Christopher, 2003):

- 1. Cost of unscheduled visits, but statistically predictable, routine maintenance visits to troubleshoot the operation of wind turbines;
- 2. Scheduled preventive maintenance costs for wind turbines and energy collection system;
- 3. Costs of major repairs and replacements scheduled subsystems of wind turbines.

The first two costs occur during the course of a year in operation and are included in the cost component of *O&M*. The third occurs at intervals of 5, 10 or 15 years and involves financial year over the next few years, therefore, is included in the cost component *LRC*. The purpose of preventive maintenance is to replace components and reform systems that have finite lifetime, generally smaller than the projected life of the turbine. Tasks include periodic inspections of equipment, lubricating oil and filter changes, calibration and adjustment of sensors and controllers, replacement of consumables such as brake pads. The cleaning of the blades in general, fits into this category. The specific tasks and frequency are usually explicitly defined in the maintenance manuals provided by the manufacturer of the turbine. The costs associated with planned

maintenance can be estimated with reasonable accuracy, but may vary according to labor costs location, location and accessibility. The scheduled maintenance costs also depend on the type and cost of consumables used (IEA, 2005). The unscheduled maintenance should be anticipated in any proposed wind energy production. Commercial wind turbines contain a variety of complex systems that must function correctly for the turbine work and get best possible performance. Failure or malfunction of the smaller component (subsystem), it often shuts down the turbine and require the attention of maintenance professionals. Unplanned costs can be separated into direct and indirect costs. Direct costs associated with labor and equipment needed for repair or replacement and consumables used in the process. The result of the indirect costs associated with the revenue lost due to stop the turbine. Depending on the details of ownership and location of the wind farm, there may also be costs associated with negotiating land use agreements, contracts, power purchase agreements and access to transmission and distribution of energy produced (Blanco, 2009). Besides the cost of operations and maintenance, spare parts and other maintenance items in the cost element of O&M may also include:

- 1. Taxes on property where the wind farm operates;
- 2. Payment of land use;
- 3. Miscellaneous insurance;
- 4. Access to transmission and distribution rates;
- 5. Management fees and general and administrative expenses.

The values of cost of operations vary with the situation. The tax structure is where the wind farm contract, land use, insurance rates and other fees vary from location to location and installation of wind farms to another. In comparison to maintenance costs, operating costs are typically very small relative to the cost of production of a central power production (Christopher, 2003).

### Production Tax Credit

The *Production Tax Credit (PTC)* is a type of public incentive, usually granted by the Governments for the renewable energy sector. This incentive is offered in the form of tax credits for producing energy for a certain period of operation of the central production of energy. *PTC* is adjusted for inflation rate prevailing in the country concerned, within 10 to 15 years, falling on each MWh of renewable energy produced and sold to the distribution grid. For the production of wind power in Portugal, *Decree-Law No. 33-A/2005*<sup>65</sup> stipulates that farms that have already obtained permission to establish the date of entry into force of the law or they may obtain the license for establishment within one year after the entry into force, maintaining the current tariff of 88.20€/MWh from 2005, progressing at the rate of inflation, for a period of 15 years from the date of entry into force of that legislation. At the end of this period, the rate will converge to market price plus the premium for the sale of green certificates.

<sup>&</sup>lt;sup>65</sup> Available in <u>http://www.edpdistribuicao.pt/pt/produtor/renovaveis/EDP%20Documents/DL33A-2005.pdf.</u>

The cost of energy produced by a wind farm represents an indicator for economic efficiency of the wind power plant. The LCOE/NREL methodology is assumed as one of the most complete ways to calculate and compare the monetary production cost by renewable energy technologies. The levelized cost of electricity (*LCOE*) is one of the most important indicators for evaluating fiscal performance of power supply systems such as WECS. *LCOE* is a technique applied by the techno-commercial analysts to calculate the unit cost throughout the economic life of the project. The levelized cost for WECS can be describe as the ratio of the total annualized cost of the WECS to the annual electricity produced by the system.

According to Roth and Ambs (2004, p. 2127) *LCOE* can be interpreted as *''a constant level of revenue necessary each year to recover all expenses over the life of a power plant''*. So it is useful for wind power plant management and economic evaluation process. We must remember that wind power plant is a non-conventional industrial unit, in case of production output, it only can be expected not programmable, it means, the level of revenues is function of the production and sales levels. The capacity factor of the power plant will vary during the project's lifetime.

The calculation of *LCOE* provides a common way to compare the cost of energy across renewable technologies because it takes into account the installed system costs and other associated costs such as financing, land, insurance, transmission, operation and maintenance, and depreciation, among other expenses. Carbon emission costs and wind farm efficiency can also be taken into account.

The Levelized Cost of Energy method has drawbacks that limit its application in the assessment and management of projects in renewable energy, particularly in wind energy projects:

- 1. The technical and economic parameters directly impact the method *LCOE* and should be carefully considered in the analysis of the final cost of energy produced. The dramatic reductions in *LCOE* occur when the wind farm wind resource is above average, or when we obtain improvements in capacity factor. This suggests that the increase in capacity factor from values below the levels of average capacity factor can lead mainly to large reductions in *LCOE* (Cory & Schwabe, 2009).
- 2. *LRC* that matches the costs for equipment replacement in the long term, it has been reported to be increasingly significant component to the annual cost of wind power and if it is overvalued, can inflate the cost of energy currently produced. The technological improvement in wind power can make the cost of capital is smaller in the coming years.
- 3. *LCOE* is a methodology for determining and analyzing the cost of energy production restricted to certain period of time. The fact that the analysis is for one year of production (a single unit of time) ignores gains economies of scale throughout the project life.

We can see one difficulty in evaluation of the cost of wind power — the average cost depends on the scale, and can vary greatly, and the marginal cost is very low. Presumably we want to compare average costs, and for this we need a sense of scale. The usual cost measure in the power industry is *LCOE*. This is defined as the constant cost at which electricity would have to be sold for the production facility to break even over its lifetime, assuming that it operates at certain capacity factor.

### 5.4.1.2 TOTAL LIFE-CYCLE COST

The evaluation method Total Life-Cycle Cost (*TLCC*) method is derived from *NPV*, as it takes into account only items of costs (cash outflows). *TLCC* evaluates the differences in cost (and time of occurrence of costs) between project alternatives over the life cycle. Cash outflows associated with the project (alternatives) are evaluated for each period and are then discounted to present value using a discount rate as defined in *NPV* approach (Kreith & West, 1997). *TLCC* calculate the present value of all cash outflows (cost items), but no cash inflows (revenues). This only makes sense if:

- 1. There is no revenue produced by the project (Note that the cost saved are recorded as revenue) or,
- 2. Revenues are independent of the investment decision (e.g., because revenues are fixed, no matter what the investment decision is chosen).

The analysis may focus only on cash outflows. Soon *TLCC* takes no account of the project incomes, which makes this indicator not adequate to evaluate absolute attractiveness of an investment alternative. It can be used to evaluate the relative attractiveness of alternative investments when considering the cost per unit of output as a factor of choice. By definition, the calculation of *TLCC* is defined by the following Eqn 5.27 (Cory & Schwabe, 2009):

$$TLCC = \frac{Co_1}{(1+i)} + \frac{Co_2}{(1+i)^2} + \dots + \frac{Co_t}{(1+i)^t} = \Sigma \left(\frac{Co_t}{(1+i)^t}\right)$$
 [\$M] Eqn (5.27)

where  $C_{ot} = Cash$  outflows in period t; i = Discount rate and t = Number of periods.

According to Lu et al. (2010) life cycle cost estimate of power system planning, provides a new idea and effective way to enhance the cost management business for the enterprises. However, it is worth noting that the accuracy of *LCC* model is dependent on the data for calculation and the uncertainties. *TLCC* is a derivation of *LCC* and have to be distinguishing as well as possible. For Asiedu and Gu (1998) it is necessary separate the cost of the production components and the production cost of a plant. These are different things, in the case of the wind power plants the costs of machines and other facilities/equipment are summer up into Initial Capital Costs (*ICC*), described in sub-section 5.4.1.1. The rest of the costs (operation and maintenance, financial, taxes, interests, etc.) are incorporated into *FCR*, *LLC* and *O&M*, as follow as LCOE/NREL methodology.

*LCC* is an economic method to get the whole cost of production. It is a special approach that examines all the parts of the cost. It is used to produce a spend profile of the goods or service over

its all lifetime. The results of *LCC* analysis are used to help managers in the decision-making process. *LCC* analysis sees projects further into the future. It is very valuable as a comparative tool when long term investment in some goods is considered (Lee, An, Cha, & Hur, 2010).

For Woodward (1997) the costs can be classified or considered into different categories during the lifetime of a project. These costs can be divided into the three categories of: *engineering and development*; *production and implementation*; and *operation* (see Figure 5.5).



Figure 5.5 Cost categorization during the phases of LCC. Source: Woodward (1997)

We have to pay attention to the external factors for a better economic evaluation of wind farm which mainly include electricity price, taxes, repayment load and time of wind power plant. All these factors can influence directly on the cost of the wind power project (Tai & Wen-rui, 2009).

*TLCC* has disadvantages that limit its application in assessing and managing projects in wind energy projects:

- 1. The need to know the actual capital cost of the project. As the interest rate that measures the cost of capital for an investment should include the risk of the project, the task of defining the real value of capital cost is not always easy to accomplish.
- 2. The failure to consider the project's revenues, there is interference by the revenue costs, because there are costs that are directly influenced by income, as is the case of taxes on income in energy projects that may or may not be supported by incentive programs governments on renewable energy.
- 3. Costs are projected for the life of the project, which makes the financial cycle equal to the operating cycle of the investment, which by classical rules of accounting does not always match.

### 5.4.1.3 NET PRESENT COST

The Net Present Cost (*NPC*) of a REP is the sum of the current value of all costs during the project's interest period (generally considered its lifetime), including residual values<sup>66</sup> as costs. The net present cost of a project is the sum of all cost components, including (Blackler & Iqbal, 2006):

- 1. The investment of capital or initial capital cost;
- 2. O&M costs, excluding fuel (in case of wind);
- 3. Costs of major replacements;
- 4. Energy costs (fuel costs, including other associated costs);
- 5. Any other costs such as fees and legal fees, among others.

If a series of projects or investment options are being considered, the lowest net present cost will be the best option. By definition, the formula for calculating *NPC* is defined as Eqn 5.28 (George & Schweizer, 2008; NREL, 1995):

$$NPC = \frac{Co_1}{(1+i)} + \frac{Co_2}{(1+i)^2} + \dots + \frac{Co_t}{(1+i)^t} + \frac{D_v}{(1+i)^N} = \sum \left(\frac{Co_t}{(1+i)^t} + \frac{D_v}{(1+i)^N}\right)$$
 [\$M] Eqn (5.28)

where  $C_{ot} = Cash$  outflows in period t; i = Discount rate; t = Number of periods of outflows; N = Lifetime of wind farm and  $D_v = disinvestment$  value.

*NPC* is one of the principal economic indicators for the cost-benefit analysis. All quantities and costs are expressed as present worth cost. There are many ways to calculate the economic cost of production, distribution of renewable energy and/or efficiency projects. The capital and replacement costs, the operation and maintenance costs must be combined in some manner so that a comparison may be made with the costs of not doing the project (Hakimi & Moghaddas-Tafreshi, 2009).

We must highlight the conception of "*costs*" considered for this method. It is the *private* conception, but there are other conceptions that we could include in this method, such as *environmental* and *social* costs. Costs of industrial activity are always included in the price paid by the consumers and the unpaid costs also called "*external environmental and costs*" (Frangopoulos & Caralis, 1997).

<sup>&</sup>lt;sup>66</sup> It is understood by residual values, the difference between the book value of the commercial value of a fixed asset after the project lifetime. (Newnan & Lavelle, 1998)

For Dekker, Nthontho, Chowdhury, and Chowdhury (2012) *NPC* can be calculated within HOMER<sup>67</sup> using Eqn 5.29:

$$NPC(\$) = \frac{TAC}{CRF}$$
 [\$M] Eqn (5.29)

where TAC = total annualized cost (which is the sum of all annualized costs of each system component). The *Capital Recovery Factor* (*CRF*) is the same *Uniform Capital Recovery Factor* (*UCRF*), so is given by Eqn 5.19, already described.

It is assumed that all prices escalate at the same rate, and uses "*annual real interest rate*" rather than the "*nominal interest rate*", which makes the inflation effect be factored out of the analysis. That is a way to reduce to performance and economic analysis within the most real values as possible.

It is also important to explain the difference between *price* and *cost*. The price includes all costs and *expected return* by investor or producer. The *cost* only includes the outflows (expenses) related to the product/service production/supply (Tai & Wen-rui, 2009).

*NPC* has disadvantages that limit their application in the evaluation and management of wind energy projects:

- 1. The discount rate or cost of capital remains unchanged throughout the period under review the project because the cost of capital depends on the behavior of the risk of the activity that tends to be decreasing with the years of operation and technological maturity.
- 2. The financial indicators considered over the life of the project (inflation, discount rate, insurance, taxes, among others) also remain constant throughout the period analyzed what makes the NPC not to be influenced by the uncertainties of the economic scenario where the projects are inserted.
- 3. The fact of considering the value of disinvestment, especially for wind energy projects, because it is capital intensive project, makes the value of the divestment is high compared to other renewable technologies. In the case of wind energy projects return higher net present cost.

<sup>&</sup>lt;sup>67</sup> HOMER is a software developed by NREL that simplifies the task of designing distributed generation (DG) systems - both on and offgrid. HOMER's optimization and sensitivity analysis algorithms allow to evaluate the economic and technical feasibility of a large number of renewable energy technologies options and to account for variations in technology costs and energy resource availability. For more details, please check on <u>https://analysis.nrel.gov/homer</u>.

### 5.4.1.4 LEVELIZED ELECTRICITY PRODUCTION COST

The *Levelized Electricity Production Cost (LEPC)* per kW is the proportion of the total cost over the lifetime of the project from anticipated results expressed in equivalent terms by the current value. This cost is equivalent to the average cost being paid by consumers to cover production costs included capital costs, operations and maintenance, fuel, rate of return equivalent to the discount rate. The Eqn 5.30 is used for calculating *LEPC* for one unit of electricity production is defined by IEA (1991):

$$LEPC = \frac{\sum \left[ (I_t + M_t + F_f) (1 + r)^{-t} \right]}{\sum \left[ AAR (1 + r)^{-t} \right]} \qquad [\$/kWh] \qquad \text{Eqn (5.30)}$$

where  $I_t$  = Investment expenditures in the year t;  $M_t$  = Operations and maintenance expenditures in the year t;  $F_t$  = Fuel expenditures in the year t; AAR = Average Annual Revenue based on hourly production and r = Discount rate; t = Number of outflows periods.

By comparing *LEPC* for wind energy projects in different sites, it is important to define the limits of "*production system*" and costs that are included in it. For example, transmission lines and distribution systems should be included in the cost? Usually only connection costs to the production source for the transmission system is included as cost of production. One must be careful to delimit the border of cost analysis, what should or should not be included in the cost of energy (IEA, 2005).

According to Elkinton, Manwell, and McGowan (2008); Elkinton, Manwell, and McGowan (2005); Elkinton, Manwell, and McGowan (2006) to analyze the cost of one unit of electricity produced by a renewable power system is a great challenge. First of all we have to collect accurate and current data. In the case of wind power projects, for onshore applications, there are many researches done and real data are available for this kind of analyzes. For a broader understanding of the WECS Elkinton et al. (2008; 2005; 2006) studied the impact of Offshore Wind Farm Layout Optimization (OWFLO) on the cost per kW using *Levelized Production Cost (LPC*).

LPC is a similar method of LEPC, but the last one has a structure routine for OWFLO which is analyzed with the following criteria: (1) as lower as the LPC as better as OWFLO and (2) as higher as the LPC as worst as OWFLO. So it is an inverse economic measure. We must consider the fact that is not useful with excluding or different projects. This analyzes must be undertaken with the same project in different options or configurations. This assumption is also applied to LEPC method, remember that different wind power projects, different results we get it from it!





Figure 5.6 Flowchart for LPC Calculation. Source: Elkinton et al. (2008; 2005; 2006)

*LEPC* has disadvantages that limit application in the evaluation and management of projects in wind energy projects:

- 1. The discount rate or cost of capital remains unchanged throughout the period under review the project because the cost of capital depends on the behavior of the risk of the activity that tends to be decreasing with the years of operation and technological maturity.
- 2. Capital costs are regarded as a lump sum at the beginning of the analysis; however there are other capital costs as major equipment installations and replacements that occur in other periods of the plant's lifetime production.
- 3. All recurrent costs begin to accumulate from the first period and are grouped together and considered to occur at the end of the current period. By using the discount rate to update and add costs in different periods, one runs the risk of this rate is different from the rate at which raise costs and other current expenditure over the life of the project.

### 5.4.1.5 UNIT PRESENT AVERAGE COST

The Unit Present Average Cost (UPAC) is significant for each year. However it is less meaningful if the evaluation period extends from the investment decision until the end of the lifetime of the plant production. The average annual cost per unit calculated for the two solutions, both technically and financially different, may be the same and be different than the interest of such solutions. To obtain the average unit cost updated, update separately charges (investment, operations and maintenance, fuel, and others) and total output during the lifetime of the plant production. Assigning charges generally updated by  $PV_{Co}$  and annual accumulated and updated by  $PV_{sAEP}$ , UPAC (\$/kW), is given by (NREL, 1995):

$$UPAC = \frac{\sum PV_{Co}}{PVs_{AEP}} \qquad [\$/kW] \qquad \text{Eqn (5.31)}$$

where  $PV_{Co}$  = Present value of cash outflows and  $PV_{SAEP}$  = Present value of cumulated annual energy production.

The update is to calculate the amount as payments and receipts made on various dates if made at time t = 0. To set the model to consider is necessary to establish precisely what is expected escalation for the exits and entries for cash. A fairly general model can admit that both the inputs (energy sales) and cash outflows (investment, operating costs) are irregularly spread over a period of n years of life. Although payments and receipts are distributed more or less irregularity over time, can be assumed:

- 1. Expenditure is done on the first day of the year during which it is paid;
- 2. Revenues go into the last day of the year in which they actually receive it.

The interest and depreciation depend on the conditions of financing, accepted the same for all projects being compared. The following calculation is the average cost to date, considers itself neither interest nor amortization. Invested capital and its depreciation could never be considered simultaneously, it would be a duplication (Damodaran, 2001). In this model of assessment of costs, cash outflows are classified as investment costs and operating expenses. The investment costs include all cash outflows arising from the physical structure of the central production (machinery and equipment, civil works, roads and access, control systems, among other things of that nature). As operating costs we should include O&M costs, fuel and other charges related to the regular operation of the power plant. The calculation of *UPAC*, starting of the Eqns 5.31 and 5.32, it is assumed the following parameters:

- 1. Investment (*ICC*) focuses on the initial moment of the project (t = 0).
- 2. The annual use of power (capacity factor for wind projects) installed is constant throughout the lifetime of the project.
- 3. *O&M* costs are constant over the useful lifetime and equal to  $C_{O\&M}$ .
- 4. There are no charges for fuel, will be the case of small hydroelectric plants, wind farms and photovoltaic cells.
- 5. The various charges are void or may be included in the *O&M* costs.

Accordingly, *UPAC* is defined by Eqn 5.32:

$$UPAC = \frac{ICC(1 + \alpha C_{O\&M})}{(\alpha AEP)} = \frac{ICC(\beta + C_{O\&M})}{AEP_s} \qquad [\$/kW] \qquad \text{Eqn (5.32)}$$

where ICC = Initial Capital Cost;  $C_{O\&M} = Operations$  and Maintenance costs and  $AEP_s = Cumulated$  annual energy production.

For those factors 
$$\alpha = \left[\frac{(1+i)^t - 1}{i(1+i)^t}\right]$$
 and  $\beta = UCRF = \left[\frac{i(1+i)^t}{(1+i)^t - 1}\right]$ , where:  $i = interest \ rate$  and  $t = interest$ 

number of outflows or lifetime of the project.

UPAC has disadvantages that limit its use in evaluating and managing projects in wind energy:

- 1. Capital costs (*ICC*) are considered as a fixed sum at the beginning of the project; however there are other capital costs as major equipment installations and replacements that occur in other periods of the plant's lifetime production.
- 2. The capacity factor is not fixed throughout the period of operation of the project (lifetime), which makes the wind production variable over the years. By oscillating energy production, there is also fluctuation in wind energy revenues and costs.
- 3. *O&M* costs are not fixed over the lifetime of the project. The maintenance contracts for wind farms are defined according to the warranty period given by equipment manufacturers. The duration of maintenance contract outside the manufacturer's warranty is 5 to 12 years, yet the life of the wind farms are for at least 20 years.

### 5.4.2 PECULIARITIES IN THE COST ANALYSIS OF WIND ENERGY PROJECTS

The adoption of standardized methodology for calculating the cost of wind energy projects is necessary in the efficient management of a wind farm. Some approaches can be used for economic assessment in various contexts, to reflect the criteria and priorities of different economic agents involved in the venture. The choice of wind power system has the greatest impact on the cost of wind power produced. The link between wind turbine production capacity and production cost stems partly from technical economies of scale. In addition to technical economies of scale, there are production economies of scale that reduce the cost of wind power. However, this does not guarantee that a specific wind project will generate power at a competitive cost level. The capacity to optimize production costs depends on a number of other factors (Valentine, 2011).

According to Dicorato, Forte, Pisani, and Trovato (2011) the cost analysis of a wind power plant must be done by *cost centers*, classified into *wind turbines cost center*, *electrical system cost center* and *grid interface cost center*. These cost centers change its costs and sub-divisions depending on the kind of application of wind power plant. If it is related to an Offshore Wind Farm (OFWF), the costs of foundations and electrical system and grid interface are higher. In the case of a Nearshore Wind Farm (NWF) the same costs are less than the OFWF, especially, the costs with electrical system and grid interface. Then, for an Onshore Wind Farm (OWF), most of the costs are less expensive, but the wind resources are also less intense, so this fact requires a much better efficiency in wind turbine technology. In the power industry in general, the more efficient more costly, that is why in OWF applications, most of the costs are for *wind turbines cost center* (Milligan, 2004).

For the correct definition and calculation of the cost of one unit of energy produced by a central production is essential to characterize the boundaries of the project under study. It is important to compare the power plants meet the cost of energy produced in isolation, but may not reflect the total economic impact of new power when connected to the network within an existing electrical system. It is important from the standpoint of the producer to estimate the cost of producing one unit of energy for the management and evaluation of the project as a business unit must ensure that economic return for the investor/manager (Johasson, 1993).

The average cash cost methodology for the series of costs to present values at a given base year by applying the discount rate. The discount rate considered appropriate for the energy sector may differ from country to country, and in the same country, from technology to technology. Applying the discount rate takes into account the time value of money, or an amount earned or spent in the past or future, has the same value as the same amount (in real terms) gained or spent on this. The discount rate may be related to rates of returns that can be earned on typical investments, which may be a fee required by regulators incorporating the provision for financial risks and /or derived from national macroeconomic analysis. Despite the investment option not to depend entirely on how it is financed, as it should be profitable by itself, funding may influence the attractiveness of the project. This is especially true for REPs. How often it is very capital intensive and require large amount of initial debt and equity. The financial conditions for such a loan, becoming an important factor in the project evaluation (Harper et al., 2007).

# 5.5 OPTIMIZATION MODELS APPLIED TO REPS

## 5.5.1 CONCEPTS OF SIMULATION AND OPTIMIZATION

In a wide variety of economic, political, scientific, and social situations often arise in that if you want to maximize or minimize a certain amount that is a measure of the efficiency of the activity. This amount can be, for example, the total production in a certain period of time, or the cost of the operation, these problems are optimization problems that are known as *mathematical programming* problems. The mathematical optimization models find an optimum expansion plan by using a calculation procedure that solves a mathematical formulation of the problem (Latorre, Cruz, Areiza, & Villegas, 2003).∴Specific classes of these problems are those involving only *linear equations* and *inequalities*. And, the most popular method to solve *linear programming* problems is the *simplex* method (Nocedal & Wright, 1999).

The objective of simulation optimization process is *minimizing the resources* spent while maximizing the information obtained in a simulation experiment (Carson & Maria, 1997). In mathematics, the term optimization, or *mathematical programming*, refers to the study of problems in that search minimizing or maximizing a *function* (mathematical model) through systematic choice of whole or real variable values within a set feasible (optimization strategy). In engineering, administration, logistics, transport, economy, biology or other sciences, when it manages to build *mathematical models* quite representative of their dynamic systems under study, it is possible to apply the mathematical techniques of optimization to *maximize* or *minimize* a *function* previously defined as *performance index (PI)*, or *index of performance (IP)*, in order to find an optimal solution of the problem, that is, that results in the *best* possible performance of the system, according to this previously defined *performance criteria (PC)* (Christodoulos & Panos, 2009).





According to Figure 5.7 we can discuss about *inputs*, *simulation process (mathematical model and optimization strategy)* and *outputs*. In the *systemic theoretical*<sup>68</sup>approach, the broadest conception, a "system" may be described as a complex of interacting components together with the relationships among them that permit the identification of a boundary-maintaining entity or process. The *inputs-process-outputs* relation must work as an organism. The optimization strategy can be understood as a continuum interaction for improving the whole system, which can be a power plant.

So the concept of *optimization* can be taken as a way or technique to improve the efficiency of a system in general (for an optimal condition). For this precise and complex duty the optimization process have to be measure anyway. The method adopted for measuring the optimization process depends on the nature of *inputs-process-outputs* relation. In the Figure 5.8 is displayed the six major categories of simulation optimization methods. In the literature on energy systems, the word *optimization* is often used in cases where the proper word is *improvement*. The two words do not have the same meaning and care should be exercised in their use.



**Figure 5.8** Simulation & optimization methods. Source: Nocedal and Wright (1999) and Christodoulos and Panos (2009)

<sup>&</sup>lt;sup>68</sup> The General Systems Theory (GST) was developed by biologist Von Bertalanffy, to search for an explanatory scientific model of the behavior of a living organism. A system is defined as a whole organized consisting of interdependent elements, which is surrounded by an external environment; If the system interacts with the outside environment is called *open system*; System relations with the exterior render themselves through exchanges of information and energy which is called *input* or *output*; the channels that convey the input-output information or energy called *communication channels* (Von Bertalanffy, 1972).

### 5.5.2 AN OVERVIEW OF SIMULATION AND OPTIMIZATION METHODS

The simulation is one of the most powerful tools available to decision makers responsible for the design and operation of complex systems and processes. Throughout the study on this topic, prior to work, met some definitions found in articles of authors with research in the area. Then are given two of these settings found, so the *"simulation"*:

- 1. According to Banks (1999) is "the imitation of the functioning of a real-world system or process over time. Involves the creation and observation of an artificial history so the system can draw conclusions about the nature of the real system represents."
- 2. For Shannon (1992) is "the process of designing a model of a real system, conduct experiments using this same model with the purpose of understanding the behavior of the system and/or evaluate various strategies for its functioning. Thus, it is crucial that the template is designed so that its behavior mimics the behavior of the real system events that occur over time."

These two definitions it is concluded that both authors agree that simulate is the act of imitating the behavior of a model of a real system. This conclusion leads to the need to define the terms "model" and "system". Also for these two terms there are in the literature various definitions. For Carson and Maria (1997), a model is a representation of a system or process, and a simulation model is a representation that changes within time and a system is a group of interconnected elements that cooperate in order to achieve a defined objective.

The *optimization* is process the improvement of a system functioning in its best outputs as possible. The simulation and optimization models can be classified as *continuous or discrete*, *static or dynamic* and *stochastic or deterministic* (Andradóttir, 2007):

- 1. Continuous the simulation time progresses continuously at intervals of equal times;
- 2. *Discrete* the simulation time is based on the occurrence of events, namely advances in event;
- 3. Static the state of the system is described only to given time and usually the time variable is not important;
- 4. *Dynamic* the state of the system is described based on a time variable, this evolves over time.
- 5. *Deterministic* the values entered in the simulation are constant;
- 6. *Stochastic* the values entered in the simulation are constant; for stochastic models, the entered values are random.

The simulation and optimization problems are often driven by maximization or minimization expected values of the objective function designed to represent the system behavior∴This, however, does not have to be always the objective of the simulation and optimization problems. On other situations, one might be interested in minimizing the dispersion of the values rather than its expected values (Azadivar, 1999).

The simulation and optimization problems consist of a determination of the extreme (minimum or maximum) of an objective function under certain constraints or restrictions. It is usually mathematically shown as follows:

*Minimize* 
$$f(x)$$
 [-] Eqn (5.33)

considering

$$x = (x_1, x_2, \dots, x_n)$$
 Eqn (5.34)

$$a_i(x) = 0$$
  $i = 1, 2, ..., m$  Eqn (5.35)

$$b_k(x) \le 0$$
  $k = 1, 2, ..., n$  Eqn (5.36)

where x = set of all the independent variables;  $a_i = \text{equality constraint functions ("strong constraints")}$ , which constitute the simulation model of the system and are derived by an analysis of the system (energetic, exergetic, economic, etc.);  $b_k = \text{inequality constraint functions ("weak constraints")}$  corresponding to design and operation limits, state regulations, safety requirements, etc.

When we refer to power systems analysis, independent of the type of power system, it is usually helpful to classify the independent variables into three categories (described in Table 5.7):

 Table 5.7 Classification for independent variables for power system optimization analysis

Variable	Category	Meaning
0	Operation	Load factors components, mass flow rates, pressures and temperatures of
		streams, etc.
d	Design	Nominal capacities of components, mass flow rates, pressures and
		temperatures of streams, etc.
S	Synthesis	There is only one variable of this type for each component, indicating
		whether the component exists in the optimal configuration or not; it may
		be a binary (0 or 1), an integer, or a continuous variable such as the rated
		power of a component, with a zero value indicating the non-existence of a
		component in the final configuration.

Source: Frangopoulos (2003)

As we could understand about the definitions of the terms "*simulation*" and "*optimization*" adopted in this research, it is also necessary to discuss about the most common methods used in simulation and optimization process for power systems evaluations. In Figure 5.8 are shown the six most used methods of simulation and optimization.

The Gradient Based Search Methods (GBSM) estimate the response of the gradient function  $(\nabla f)$  to assess the shape of the objective function and employ deterministic mathematical programming techniques. The most used gradient techniques are (1) Finite Difference Estimation (FinDE); (2) Likelihood Ratio Estimators (LR); (3) Perturbation Analysis (PA) and (4) Frequency Domain Experiments (FDE) (Fu, 1994).

The Stochastic Optimization (SO) methods are optimization methods that generate and use random variables. For stochastic problems, the random variables appear in the formulation of the optimization problem itself, which involve random objective functions or random constraints, for example. Stochastic optimization methods also include methods with random iterates. Some stochastic optimization methods use random iterates to solve stochastic problems, combining both meanings of stochastic optimization. Stochastic optimization methods generalize deterministic methods for deterministic problems (Spall, 2003).

For Kleijnen (2008) the Response Surface Methodology (RSM) explores the relationships between several *explanatory variables*<sup>69</sup> and one or more *response variables*<sup>70</sup>. The method was introduced by G.E.P. Box and K.B. Wilson in 1951. The main idea of RSM is to use a sequence of *designed experiments*<sup>71</sup> to obtain an optimal response. Box and Wilson suggest using a *second-degree polynomial*<sup>72</sup> model to do this. They acknowledge that this model is only an approximation, but use it because such a model is easy to estimate and apply, even when little is known about the process.

An Asynchronous Team (A-Team) is a scale efficient network of distributed computer agents working together to solve a difficult problem. An A-team is a process that involves combining various problem solving strategies so that they can interact synergistically. A-Teams, which are biologically inspired, are characterized by autonomous agents and cyclic data flow (Carson & Maria, 1997).

The Statistical Methods for simulations and optimization procedures related to power systems reflect the deterministic optimization models *via* statistical frequency analysis, probability distributions, multiple regression and inference analysis (Frangopoulos, 2003). The statistical methods and techniques aim to find existing relations between the historical data production, explanatory variables and information collected in real time. These models have the advantage that they do not need physical modeling. However, for the process of parameters estimation is necessary to possess a wide range of historical data and measurements in real time. The most used statistical techniques are (1) Importance Sampling (IS); (2) Ranking and Selection (RS) and (3) Multiple Comparison (MC).

<sup>&</sup>lt;sup>69</sup> This categogy is also classified as *"independent variables"* represents those ones that intentionally are introduced (by the researcher) to verify the relationship between their variations and the behavior of other variables, it corresponds to what in function of which to achieve what was predicted and/or get results (Montgomery, 2008).

<sup>&</sup>lt;sup>70</sup> *Response variables* or *dependent variables* are those whose behavior if you want to check in function of the oscillations of the *independent variables*, it corresponds to what you want to predict and/or get as a result. It happens depending on the completion of the experiment in a research (Montgomery, 2008).

<sup>&</sup>lt;sup>71</sup> For Montgomery (2008)"a designed experiment is a test in which some purposeful changes are made to the input variables of a process or system so that we may observe and identify the reasons for changes in the output response. Experimental design methods play an important role in process development and process improvement."

<sup>&</sup>lt;sup>72</sup> A *second-degree polynomial* model should be formulated by an equation in which one or more of the terms is squared but raised to no higher power, having the general form  $ax^2 + bx + c = 0$ , where *a*, *b*, and *c* are constants.
#### 5.5.3 Types of optimization models for energy systems

In the last 20 years we could see a great improvement of renewable energy technologies, especially wind and solar energy technologies worldwide that can also be seen as an answer to several energy related environmental problems. The renewable energy systems (power plants and individual applications) are complex systems (Oliveira & Fernandes, 2011b) and one of the most important issues is the efficiency of the systems or *coefficient of performance (COP)*. So this hard duty to make the energy systems work in the best COP as possible, which is a complex problem to solve.

Energy systems have been evoluting jointly with energy demand of humankind, so these systems have to generate more and more energy. This necessity brings up the concept of system optimization in energy systems. In a conventional design procedure (in the earlier times), the objective is to reach an opertationable system (system had to work), i.e. a system that performs as was designed within the imposed constraints or technical limitations. However, in general, there will be more than one operationable design; and, in fact, there may be any number of improved designs that the conventional procedure may not identify. The role of optimization is to reveal the best (under certain criteria and constraints) design and the best operational point of the system automatically, with no need for the designer to study and evaluate one by one among several others possible designs.

The objective of the optimization can change depending on the objective of the designer or analyst. The optimization process of an energy system can be considered at three levels (Frangopoulos, 2003):

- 1. *Design optimization.* The word *design* here is used to synonym of technical features of the systems components and the working properties of each component at the nominal load of the system. The *design point* of the system is nominal load or operational conditions of the energy system. However in order to distinguish the various levels of optimization and due to the lack of a better term, the word *design* will be used with the particular meaning given here.
- 2. *Synthesis optimization*. The term *synthesis* refers the components that work in a power system and their interconnections or relations. After the synthesis of an energy system has been successfully composed, the flow diagram of the system can be drawn.
- 3. *Operation optimization.* For a given energy system (i.e. one in which the synthesis and design are known) under specified conditions, the *optimal operating point* can be known, as it is defined by the operating properties and interconnections of components in the system (speed of revolution, power output, mass flow rates, pressures, temperatures, composition of fluids, etc.).

Of course if complete optimization is the objective, each level cannot be considered separately from the others. So, afterwards, the complete optimization problem can be stated by the following question: What is the synthesis of the system, the design features of the components and the operating strategy that lead to an overall optimum situation of the whole power system?

The following aspects show the necessity of applying optimization procedures in the design and operation of energy systems: (1) Increasing the quality and capacity of the power plants while reducing costs in order to be competitive, case of wind power; (2) Fulfilling ever increasing specification as well as considering reliability and safety conditions, observing strict pollution regulations, and saving energy and material resources and (3) Saving time and spending less money in the initial power plant's lifetime.

As we can notice, optimization algorithms fit as a *suitable tool* for solving complex problems in the field of renewable energy systems. Figure 5.9 shows an exponential evolution in the number of optimization algorithms using for solving complex problems in renewable energy systems. Some authors have reviewed different types of models such as *renewable energy models*, *emission reduction models*, *energy planning models*, *energy supply-demand models*, *forecasting models*, and *control models* using optimization methods (Jebaraj & Iniyan, 2006), but many researchers are continuously proposing and applying new or *hybrid methods* applied into different renewable energy technologies simultaneously (Castronuovo & Lopes, 2004; Deshmukh & Deshmukh, 2008).



Figure 5.9 Evolution of optimization algorithms solutions in RETs. Source: Baños et al. (2011)

The great expansion and diffusion of optimization algorithms for solving complex problems in RETs is a clear response for the "boom" of renewable energy industry globally. When we match the global annual installed capacity for wind power (see Figure 3.12) with the utilization of optimization algorithms as shown in Figure 5.9, there is clear positive evidence between them. We must remember that renewable energy technologies and sources have as a central common aspect, the *uncontrollability*, and the outputs are expectable, case of electricity produced by a wind farm or a solar central power or still some other RETs.

In order to classify in groups of optimization, taking into consideration the objective of the algorithm, we can organize them into two big groups (see Tables 5.8 and 5.9). The first one is *EConomic Optimization Algorithm (ECOA)* and the second is *ENgineering Optimization Algorithm* (*ENOA*). Both groups are inter-linked because any effect in each of them will reflect in the other, consequently.

Group		Subgroup	Algorithm			
	1.1 E	Economic Models				
	1.1.1	Huang (2007); Huang, Fu, and Guo (2009)	$\cos t_{tot} = \cos t_{gy} N \left( \frac{2}{3} + \frac{1}{3} e^{-0.00174N^2} \right)$ and			
			$profit = \left[s - \left(\frac{\cos t_{tot}}{E_{tot}}\right)\right] E_{tot}$			
	1.1.2	Lundberg (2006)	$E_{\cos t} = \frac{Invest}{P_{out,AVG^T}} \times \frac{r(1+r)^N}{(1+r)^N - 1} \times \frac{100}{100 - PR} = K \frac{Invest}{P_{out,AVG^T}}$			
	1.1.3	Hetzer, Yu, and Bhattarai (2008)	$C_{w,i}(w_i) = d_i w_i$			
	1.1.4	Salcedo-Sanz, Saavedra-Moreno, Paniagua-Tineo, Prieto, and Portilla- Figueras (2011)	$\cos t = N\left(\frac{2}{3} + \frac{1}{3}e^{-0.00174N^2}\right)$			
OA	1.1.5	Zhang, Chowdhury, Messac, and Castillo (2010, 2012)	$C_t = \frac{1}{n}C_{in} + C_{O\&M}$			
	1.1.6	Fuglsang and Madsen (1999); Fuglsang and Thomsen (1998)	$C = \sum_{i=1}^{N_{COM}} C_i,  C_i = R_i (b_i + (1 - b_i)m_i)$			
	1.1.7	Sisbot, Turgut, Tunc, and Camdali (2010)	$TotalCost = \ell C_{cp} + C_{op}$			
	1.1.8	Elkinton et al. (2008)	$LPC = \frac{CC}{a.E_{a}} + \frac{C_{O\&M,a}}{E_{a}}$			
1. EC	1.1.9	Emami and Noghreh (2010)	$g = w_1 \cos t_m + w_2 \frac{1}{P_{total}},  w_1 + w_2 = 1$			
	1.1.10	Habib, Said, El-Hadidy, and Al- Zaharna (1999)	$C_{i,t} = C_{i,PV} + C_{i,W} + C_{i,Q}, C_{i,PV} = AC \times A_{PV} \times X_{i},$ $C_{i,W} = WC(1 - X_{i}) \text{ and } C_{i,Q} = BC \times Q$			
	1.1.11	Ozturk and Norman (2004)	$profit_{\max} = \left[k - \left(\frac{\cos t_{tot}}{P_{tot}}\right)\right]P_{tot}$			
	1.1.12	Yang, Lu, and Zhou (2007)	$LCE = \frac{\frac{(CO_{PV})}{Y_{PV}}}{\frac{Y_{PV}}{Y_{PV}} + \frac{(CO_{W})}{Y_{W}} + \frac{(CO_{Bat})}{Y_{Bat}}}$			
	1.1.13	Yang, Wei, and Chengzhi (2009)	$ACS = C_{acap} (P_V + W_{ind} + B_{at} + T_{ower}) + C_{arep} (Bat) + \dots$ $\dots + C_{arep} (P_V + W_{ind} + B_{at} + T_{ower})$			
	1.1.14	Zhao, Chen, and Hjerrild (2006)	$OBJ = LPC + \beta \times R_s$			
	1.1.15	Koutroulis, Kolokotsa, Potirakis, and Kalaitzakis (2006)	$system_{\cos t} = c_s \times \alpha_s + c_w \times \alpha_w$			
	1.1.16	Benitez, Benitez, and van Kooten (2008)	$TC_{\min} = \sum_{i=1}^{N} \left( F_i C_i + \sum_{t=1}^{T} \left( pf_i E_{t,i} + c_i Q_{t,i} \right) \right)$			
	1.1.17	Jong-Bae, Ki-Song, Joong-Rin, and Lee (2005)	$C = \sum_{j \in J} F_j(P_j) \qquad F_j(P_j) = a_j + b_j P_j + c_j P_j^2$			

**Table 5.8** Economic models of optimization algorithms for wind and hybrid power system

Source: own construction. Note: The nomenclature of these formulas is in Appendix A.

Group		Subgroup	Algorithm
	2.1	Engineering Models	
	2.1.1	Rašuo and Bengin (2010)	$f(x_1) = \frac{P_{total}}{P_{max}} \qquad f(x_2) = \frac{\cos ts}{P_{total}}$
	2.1.2	Marmidis, Lazarou, and Pyrgioti (2008)	$Obj = \frac{\cos t}{P_{tot}} u_i = u_0 \left[ 1 - \sqrt{\sum_{i=1}^{N} \left( 1 - \frac{u}{u_0} \right)^2} \right]$
	2.1.3	Gonzalez, Rodriguez, Mora, Santos, and Payan (2010)	$E_{WF} = T \sum_{j=1}^{N_{t}} \int_{v_{ci}}^{v_{co}} P_{gen} j(v) p_{j}(v) d_{v}$
	2.1.4	Mustakerov and Borissova (2010)	$P = h_y \eta N P_{wt}, N = N_{row} N_{col}, N_{row} = \frac{L_x}{SD_x} + 1,$
			$SD_x = k_{row}D_{and}$ $N_{col} = \frac{L_y}{k_{col}D} + 1$
	2.1.5	Diaf, Diaf, Belhamel, Haddadi, and Louche (2007)	$P_{tot}(t) = P_{PV}(t) + P_{WD}(t)$
	2.1.6	Ashok (2007)	$P_{tot}(t) = \sum_{h=1}^{N_h} P_h + \sum_{w=1}^{N_w} P_w + \sum_{s=1}^{N_s} P_s$
. ENOA	2.1.7	RETScreen® International Clean Energy Decision Support Centre (2008)	$e_{base} = \left(e_{CO_2}GWP_{CO_2} + e_{CH_4}GWP_{CH_4} + e_{N_2O}GWP_{N_2O}\right)\frac{1}{\eta}\frac{1}{1-\lambda}$
0	2.1.8	Huang (2007)	$P_{tot} = \sum_{i=1}^{N} P_i$
	2.1.9	Moran and Sherrington (2007)	$E_{windfarm} = IC \times CF \times h_{vear}$
	2.1.10	Diveux, Sebastian, Bernard, Puiggali, and Grandidier (2001)	$E_{AP} = \frac{8760}{1000} \frac{\rho_{air}}{2} \times S_R \times \int_{V_i}^{V_f} V^3 f(V) C_P(V) \eta_{GB}(V) \eta_G(V) dV$
	2.1.11	Flores, Tapia, and Tapia (2005)	$P_{opt} = k\omega_r^3$
	2.1.12	Vallée, Lobry, and Deblecker (2011)	$MAWPC = (1 - FOR_t) \cdot IWPC$
	2.1.13	McWilliam, Van Kooten, and Crawford (2012)	$N = \frac{4n\pi\pi^2}{\sqrt{3X_p^2}}$
	2.1.14	Maki, Sbragio, and Vlahopoulos (2012)	$V = V_{ref} \left( \frac{Hub_{Ht}}{H_{ref}} \right)^{0.34}$
	2.1.15	Szafron (2010)	$E_{y} = \left[ \left( E_{i} - (w_{ake})_{i} - (coll_{ection})_{i} \right) \cdot (a_{vail})_{i} \right] - (trans_{mission})$
	2.1.16	Habib et al. (1999)	$P_{i,j} = P_{sj}X_i + P_{wj}(1 - X_i)$
	2.1.17	Kiranoudis, Voros, and Maroulis (2001)	$C_p = C_{pr} \exp\left[\frac{\left(\ln u - \ln u_r\right)^2}{2(\ln s)^2}\right]$

**Table 5.9** Engineering models of optimization algorithms for wind and hybrid power system

Source: own construction. Note: The nomenclature of these formulas is in Appendix B.

The optimization models applied to wind power system in the last decade started to increase in the same rhythm as wind power industry has increased. According to Yin and Wang (2012) the most common three types of WECS problem can be categorized into: (1) Integrate power conversion; (2) Structural system design and (3) Wind turbine placement.

The *integrate power conversion* refers to technical issues such as wind intermittency and grid reliability. The conventional management of transmission and distribution operation is challenged by electricity market restructuring, security of supply concerns and the integration of newer production technologies such as wind power.

The WECS transform kinetic energy of the air motion into mechanical and electrical. It is a chain conversion process which starts by wind turbines. So, the *structural system design* of a WECS must include the blades, engines, and the tower structure  $\therefore$  All these elements represent a critical factor for maximizing energy production. To maximize the power production per unit of cost, the number of *installed turbines and the spacing* between them should be optimized. As we can see in Figure 5.10, there is an obvious correlation between the layout optimization and energy production cost.



Figure 5.10 The layout optimization and its relationship. Source: adapted from Lundberg (2006)

The cost per kWh from a power plant, a wind farm, must be understood as a result from a systemic components interlinked. A wind farm depends on directly the physical and environmental conditions. The physical refer to the system configuration (layout, technology employed, local terrain configuration, etc.) and environmental conditions refer to the local weather such as wind intensity and speed, air humidity, *flora* and *fauna* aspects (specially flying animals as bats, birds, etc.). The system configuration has impacts on investment and O&M costs, which reflects on energy production cost by a wind farm. Also, we can see the system configuration has influence on loss model and power performance model, we mean, the energy produced by the same wind farm. The relation of energy production cost and (net or available) energy production is finally the *cost per kWh*.

## **5.6.** SUMMARY AND CONCLUSIONS

As far as investment decisions when dealing with uncertainty of future events that may not be totally avoided. The decision is based on estimates and assumptions about future developments and future states (prices, volumes, market sizes, regulations, etc.). The reality may eventually be less favorable than the original estimate of project. It is not a productive strategy for evaluating investments working hypotheses, very negative. The objective of the investment should not be too pessimistic, but to evaluate adequately the uncertainties involved in analyzing and quantifying this uncertainty in some analytical way. One rule applies to all methods of economic evaluation of projects and costs for the private view, if two projects generate the same results in the future, but are associated with different degrees of uncertainty, the more uncertain project will be considered less attractive. There is an inverse relationship between uncertainty and attractiveness of the project. Like any other project, the REPs should ensure financial returns to investors and managers. The evaluation is not limited to assessment of financial attractiveness, but should include several other factors.

As we explained in this chapter, the attractiveness of an investment project should be quantified in an analytical way. Methodologically, to arrive at this result it is necessary to sort and organize items in the project cost. In the case of wind energy projects, the costs are classified and structured investment costs, operating costs, maintenance costs and financial costs. All these classes and cost structure have their own characteristics depending on the location, size, types of financing and regulations. These costs behave differently from project to project, from country to country (region), from author to author, in summary, we present estimates for these costs, as shown in Tables 5.3 and 5.4.

Although the crucial important aspect for classifying and structuring the cost of wind energy projects used to the proper application of existing models for economic evaluation of projects, considering the objectives of the evaluation itself. For this research, the purpose and scope of the theme, we studied the main methods of economic evaluation of projects and their applicability in wind energy projects. The indicators studied were *SPB*, *DPB*, *NPV*, *IRR*, *RR* and *BCR*.

*SPB* and *DPB* measure the return time of investment, although *BDP* discounting project costs (usually operating costs). *NPV* analysis measures the level of wealth that the investor receives the bet on any one project with its own capital and/or others. In *IRR* analysis, which refers specifically rate the investment can pay for the capital (the higher the rate, the better the project). For models of economic evaluation of projects studied were identified limitations or weaknesses of each.

However, for sectors where there is strong government regulation of economic activity, if the renewable energy sector, we need to analyze, also what level of minimum income that the project in question needs. This response is given by *RR* analysis. For a *RR* analysis, the smaller the need for revenue, better the project is. The analysis of *BCR* is the ratio of the current value of the sum of the project benefits divided by present value of the sum of project costs. *BCR* analysis is used as a criterion for selection of independent projects that have benefit-cost ratio greater than or equal to

unity. It cannot be used to choose between mutually exclusive alternatives. For wind energy projects, methodologies were also analyzed with emphasis on analysis of the cost production per MWh: Among the indicators studied were *LCOE*, *TLCC*, *NPC*, *LEPC* and *UPAC*. These indicators of attractiveness and cost of projects are for specific REPs. Together with other indicators of financial attractiveness of the project is a set of tools that can be used selectively to evaluate and project management. They were also pointed out factors that limit each type of cost analysis. It is comparative analysis of methodologies studied in Table 5.10, considering the main aspects that impact on economic assessment of wind energy projects and their costs.

		Λ	1ethods of	<sup>e</sup> econom	ic evaluat	ion of pro	jects and co	osts	
	NPV	IRR	TLCC	SPB	DPB	BCR	LCOE	RR	UPAC
Significant investments (negative net cash flow) after first return	Possible	Not useful	Possible	Possible	Possible	Possible	Possible	Possible	Not useful
Investment subject to regulation	Possible	Possible	Possible	Possible	Possible	Possible	Possible	Preferred	Possible
Project-specific debt- financing needed	Possible	Possible	Possible	Not useful	Not useful	Possible	Possible	Possible	Not useful
Social costs (externalities)	Preferred	Possible	Possible	Possible	Possible	Preferred	Possible	Possible	Possible
Taxes	Possible	Possible	Possible	Not useful	Not useful	Possible	Possible	Possible	Possible
Select from mutually exclusive alternatives	Preferred	Not useful	Possible	Not useful	Not useful	Not useful	Not useful	Possible	Possible
Ranking (Limited budget)	Possible	Possible	Possible	Not useful	Not useful	Preferred	Preferred	Possible	Possible
Risks	Possible	Possible	Possible	Preferred	Preferred	Possible	Possible	Possible	Possible

 Table 5.10
 Overview of economic measures applying to specific investment features and decision

Source: adapted from IEA (1991).

The methodologies for economic evaluation of projects and costs are summarized in Table 5.10. Economic measures are suggested which better suited for each specific analysis. Different economic measures apply to different situations and it is believed to be preferable to use several methodologies to evaluate an investment project in the energy area. Sometimes the objective of economic evaluation is to find the most appropriate combination of each method available in engineering economics.

After analysis of these economic models applied to wind energy projects, we highlight that:

- 1. The attractiveness of the proposed wind energy can vary considerably between evaluation of the private and public sector. The public sector takes into account additional factors such as externalities, public authorities for tax purposes or long-term effects that are beyond the horizon of private investors.
- 2. The financing structure is very important influencing factor for the attractiveness of wind energy project. In many cases, economic agents practice their actions by means of financing the project in order to earn sufficient income to meet the demands from investors and other economic agents involved.
- 3. The project's economic attractiveness of wind energy is influenced by government intervention through regulatory actions. Common tools of public intervention are *tax incentives, direct subsidies, regulated tariffs (revenue) or subsidized loans (low interest loans).*

The REPs can be analyzed using essentially the "tool kit", presented in this chapter. The financial attractiveness is an integral part of any project. The economic agents involved must offer sufficient guarantees to the financial return in order to make it attractive. There are a number of other factors and peculiarities that make the evaluation of REPs little more difficult than in "normal" projects. So far, possible investments in REPs have been treated as if the consequences were entirely predictable. In reality, the consequences are still very uncertain. This situation applies to projects of all types and especially for wind energy projects (Gottschalk, 1996).

In order to improve the reliability of projected and REPs already in operation the key players of renewable energy industry, case of wind energy sector, more and more adopt simulation and optimization methods. The simulation and optimization methods since the end of nineties decade, as shown in Figure 5.9 have increased exponentially. This growth as an answer for complex problems that has appeared related to renewable energy systems design and operation. It is a way to explain and understand system behavior and improves it as a whole, so consequently, spent less money and until lower the cost of energy produced. For a wind farm that the occupies a given land area, if the *wake effect*<sup>73</sup> of wind turbines is ignored, more wind turbines lower the unit average cost, and the better the economic efficiency of the whole wind farm.

 $<sup>^{73}</sup>$  Wind energy converser systems produce electricity by extracting the energy in the wind. Consequently, the air mass leaving the turbine must have lower energy content and by implication lower speed than the air arriving in front of the turbine. In other words, the turbine positioned upstream in the wind direction influences the wind speed at turbine locations on its downwind (Jiang, Yan, & Feng, 2009).

Techniques for simulation and optimization of RETs vary greatly depending on the exact problem setting. The case of RE projects the local conditions such as orography, (micro) climate, local population and government must be taken into consideration. Many systems simulation and optimization in areas such as *manufacturing, distribution, financial evaluations*, are too complex to be analyzed discretely. Discrete event simulation and optimization has long been a useful *tool* for evaluating the performance of such systems. However, a simple evaluation of performance is often insufficient and a more exploratory process may be needed in the manner of simulation and optimization situations. Simulation and optimization is the process of finding the best values expected of some decision variables for a system where the performance is evaluated based on the output of a simulation model of this system (Olafsson & Jumi, 2002).

There has been many work on simulation and optimization procedures (techniques) in the specialized literature, and more recently optimization routines has been incorporated into several *commercial simulation package and softwares*<sup>74</sup>. The choice of the procedures (software) to use in the simulation and optimization study depends on the analyst or researcher and the problem itself to be solved.

The success expansion of WECs worldwide is obviously a direct response of economic scale phase this *industry* has entered during the last decade. From now and on, the great challenger is maintain this rhythm of growth by improving the power output through the development of better aerodynamic performance offers some potential economic return; however, the focus is on the cost of energy produced of the entire system. The main objective of this Chapter has been discuss about economic measures and optimization models applied to RETs, with focus on wind power technology in order to *establish a framework* for a much better utilization in *economic engineering evaluation of a project in a microeconomic view*.

In Table 5.8 and 5.9 are summarized the economic and engineering models of optimization algorithms for WECS and hybrid power systems. We could conclude that the economic view is given an emphasis on cost and profit produced by the system, however in engineering view the emphasis is addressed to cost/production, electricity production and wind farm capacity. There is a question we try to understand as how these two aspects are linked and which is more important in determine the cost of energy produced. That's why is necessary to do simulation and optimization procedures through a new reread of the *economic measures and optimization models* applied to wind energy projects.

For this reason in the Chapter 6 is discussed and presented the *methodology proposed* by this Ph.D. research work related to the scientific field of Economics developed in the Department of Economics, Management and Industrial Engineering of the University of Aveiro, applied to Renewable Energy, case of WECS. The simulation and validation of the proposed methodology is performance in Chapter 7 and the results and discussions with conclusions and implications are presented in Chapters 8 and 9.

<sup>&</sup>lt;sup>74</sup> For more details, please see Connolly, Lund, Mathiesen, and Leahy (2010); Quaschning, Ortmanns, Kistner, and Geyer (2001); RETScreen® International Clean Energy Decision Support Centre (2008, 2009).

## 5.7 **References**

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## **CHAPTER 6**

# **Research Methodology**

- 6.1 Introduction
- 6.2 Epistemological and methodological research issues
- 6.3 Rationale of the study
- 6.4 Research framework and design
  - 6.4.1 Literature review
  - 6.4.2 Methodological procedures
  - 6.4.3 Theoretical framework and hypotheses development
    - 6.4.3.1 Research objectives
    - 6.4.3.2 Research approach
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    - 6.4.3.4 Research hypotheses and limitations
  - 6.4.4 Research design
    - 6.4.4.1 Relation of variables and research boundary
    - 6.4.4.2 Mathematical model structuring
    - 6.4.4.3 Numerical simulation and validation process
- 6.5 Summary and conclusions
- 6.6 References

This chapter explains about the research methodology aspects used in this Ph.D. research work. The epistemological and methodological research issues, rationale of the study, research framework and design are explained in details. Summary and conclusions are presented at the end, with the respective references.

## 6.1 INTRODUCTION

Humanity has always tried to understand and solve the questions and challenges that have emerged over time, not only to overcome his own reason, but also for the sake of survival. And the extent to which these challenges were getting increasingly complex tools to address them failed to follow the same rhythm, until the mathematics began to be developed as an aid to science and used to understand observations in nature and solve their problems.

Finally, in the process of creating a model, we have, as a first step the definition of objective(s), we can start with the following question: *what we want to achieve with this model?* Then define what will be the *model decision variables*: cost, size or quantity? And so how these variables are related to each other and with the constraints of the problem (often *"resources"*) or method used to do the modeling, which gets its name from its *restrictions*.

In wind energy conversion systems, as it is expressed in its name, productive process occurs in a system operative conception and engineering and economic architectures. So it is possible to be reduced to a mathematical model by formula within its variables and relationships. In other words, we can simulate it as in a real world situation. We have to follow some criteria related to its own scientific nature, that is why in Chapter 4 was reviewed the *Wind Energy Conversion Systems* (WECS) in details and Chapter 5 also reviewed issues about economic measures and optimization/simulation models for better understanding the economic variables and relations of this interesting production system.

In this chapter we present the mathematical model that was developed and used in the *economic optimization model for wind farms in function of the cost of energy produced.* First, it is explained the development of each of the variables and constraints that make up the model and the objective function, after this, the ratings used are presented, and so the model is presented.

This chapter discusses and summarizes the way in which the research process was performance. It begins with an epistemological and methodological conceptualization (section 6.2) and introduces a brief overview about operational research and optimization methods. The rationale of the study is discussed with current data about wind power worldwide, is also shortly discussed some researches about economic analysis approach and our motivation for this research. The research framework and design is detailed (section 6.4), some literature statistics is shown in Table 6.1 where is explained thematic areas present in literature review process (see Figure 6.4) and the relationship within this research. Methodology procedures and phases of this research (section 6.1.2) are discussed and present some difficult found during the elaboration of this study. The theoretical framework and hypotheses development steps are justified in section 6.4.3, which results in the objectives (section 6.4.3.1), approach adopted (section 6.4.3.2), concepts and variables analyzed (section 6.4.3.3) and hypotheses and limitations (section 6.4.3.4) considered for this Ph.D. research work. In the research design (6.4.4) we can see the relation of variables and research boundary (6.4.4.1), mathematical model structuring (6.4.4.2) and the numerical simulation and validation process (6.4.4.1) are detailed and justified. Finally, in the section 6.5 presents the summary and conclusions of the whole chapter as well as section 6.6 the references used.

## 6.2 EPISTEMOLOGICAL AND METHODOLOGICAL RESEARCH ISSUES

Epistemology concerns what constitutes acceptable knowledge in a field of study. The central problem of epistemology is to decide how we can acquire knowledge which Plato and others following him have defined as "*justified true belief*". This definition of knowledge creates three substantive issues: *the nature of belief, the basis of truth* and *the problem of justification* Phillips (1974). This definition of knowledge is widely accepted, but the definition brings us some implications such as "*what is the source of our belief*", "*how we determine what is true*" and "*how we justify our belief*"? These weighty issues each have their own branch of philosophical enquiry.

The implications about "what is the source of our belief", "how we determine what is true" and "how we justify our belief" are driven by the research process. Research is a process of intellectual discovery, which has the potential to transform our knowledge and understanding of the world around us. The word research is composed of two syllables, "re" and "search". The "re" is a prefix meaning again, a new or over again and "search" is a verb meaning to examine closely and carefully, to test and try, or to probe. Together they form a noun "describing a careful, systematic, patient study and investigation in some field of knowledge, undertaken to establish facts or principles" (Kothari, 2009).

The research philosophy is a belief about the way in which data about a phenomenon should be gathered, analyzed and used. The term *epistemology* (what is known to be true) as opposed to doxology (what is believed to be true) encompasses the various philosophies of research approach. The purpose of science, then, is the process of transforming things *believed* into things *known*: *doxa* to *episteme*. Two major research philosophies have been identified in the Western tradition of science, namely positivist (sometimes called scientific) and interpretivist (also known as antipositivist).. The research problem should determine the choice of methods — not the researcher's knowledge or experiences of different research methods. The nature of our research is interdisciplinary as we could notice during the literature review phase explained in section 6.4.

This Ph.D. research work needed to be driven methodologically (section 6.4.3.2) by an interdisciplinary branch of applied mathematics and social applied science that uses mathematical modeling methods and algorithms to arrive at optimal or near optimal solutions to complex practical problems, known as *"operations research"*. Operations research helps the manager/investor to achieve its goals using scientific methods and can be used in particular for wind farm design decisions. It is often concerned with optimizing of some objectives (maximum of profit, performance, etc. or minimum of loss, risk, cost, etc.) at limited resources. The majority of real-world optimization problems are multiobjective by nature — they have more than one and usually conflicting objectives that must be satisfied simultaneously. Instead of aiming at a single solution finding, the multiobjective optimization methods try to generate a set of good trade-off solutions (Pareto-optimal solutions) from which the decision maker could select∴Nevertheless, there exist some practical problems where the single criterion optimization would be able to get an optimal solution with less calculation difficulties. One of the questions that should be answered when using optimization methods for the wind farm design is the effectiveness and advisability of single or multicriteria optimization application (Mustakerov & Borissova, 2010).

## 6.3 **RATIONALE OF THE STUDY**

The availability of electrical energy is a precondition for the functioning of modern societies. It is used to provide the energy needed for operating information and communication technology, transportation, lighting, food processing and storage as well as a great variety of industrial processes, all of which are characteristics of a modern society. Because the energy for many of the technologies, systems and possibilities that are a property of the developed world is provided as electricity, it can be presumed that there is a link between the level of penetration and consumption of electricity on the one hand and various properties of a society on the other. The relation between economic and societal development and electricity consumption is bidirectional. The availability of electricity greatly facilitates industrialization, because electricity is a convenient way to replace human power by other sources of energy, which are converted into electricity for transmission, distribution and consumption (Slootweg, 2003).

There are other electricity production technologies using renewable primary energy sources that do hence not involve the disadvantages of nuclear and thermal production. Examples are wave and tidal power, solar power and wind power. In wave and tidal power plants, energy are extracted from the waves and from the water flows caused by the tide. In solar power plants, consisting of solar panels, sunlight is converted into electricity, whereas in wind turbines, the energy contained in flowing air is converted into electricity (Rosa, 2009).

One technology to generate electricity in a renewable way is to use wind turbines that convert the energy contained in the wind into electricity. The wind is an infinite primary energy source. Further, other environmental impacts of wind power are limited as well. Although they affect the landscape visually and emit some noise, the consequences of this are small and ecosystems seem hardly to be affected. Further, once removed, their noise and visual impact disappear immediately and no permanent changes to the environment have occurred. A wind turbine generates the energy used to generate and install it in a few months so that the energy balance over the life cycle is definitely positive (Kennedy, 2005; Oliveira, 2010). According to Global Wind Energy Council (2012) the growth of wind power during the last decade in the world. The global cumulative installed of wind power capacity is growing approximately exponential over the past five years, annual growth has been above 30%.



Figure 6.1 Global cumulative installed wind capacity 1996-2011. Source: Global Wind Report 2011 (GWEC, 2012)

Wind was even more dominant as a destination for investment in 2009 than in the previous year. In 2008, it accounted for \$59 billion or 45% of all financial investment in sustainable energy, but in 2009, its share rose to 56%. Total financial investment in wind last year was \$67 billion, compared with \$119 billion for all sustainable energy technologies (SEFI, 2010).

Wind	07	Growth:
VVIIId	67	14%
UNEP Solar	24	-27%
Global Trends Biomass & Waste	11	14%
Investment Biofuels	7	-62%
Energy smart technologies	4	34%
Small Hydro	4	-9%
Geothermal	2	-28%
Low carbon services & support*	0.3	-40%
Marine	0.2	110%

**Figure 6.2** Financial new investment (\$bn) and growth by technology (2008-2009). Source: SEFI (2010)

The strength of wind reflected several developments. One was the financial go-ahead for a number of large offshore wind farms in the North Sea, notably the 1GW London Array, the 317 MW Sheringham Shoal project and the first, 165 MW phase of Belwind∴ Another was that, in uncertain economic and financial circumstances, wind was seen as a relatively mature and therefore lower risk, sub-sector of clean energy than some others (SEFI, 2010).

According to Wagner and Epe (2009) to promote wind energy, the research needs must be identified and the research work carried out. Initially, there are such environmental and social challenges as integration into the landscape, noise impact, bird flight paths, life cycle analysis and sustainability. And of course, wind turbine and component design have to be improved continually, *i.e.* basic research in aerodynamics, structural dynamics, dynamic forces, new materials, feasibility studies into new systems, generators using permanent magnets, gear boxes, etc. For planning and building wind turbines and wind farms, commonly accepted certification procedures must be formulated and standardized. For an optimized grid integration of wind energy, especially in great quantities, power quality can be supported by better forecasts of wind resources and by the use of storage sites.

El-Kordy, Badr, Abed, and Ibrahim (2002) the evaluation of the economics of energy systems strongly depends on the four cost factors: *capital cost; maintenance cost; fuel cost; and external cost*, when considered. Fuel and external costs are sensitive to fuel type and efficiency of the used system. Economic parameters such as discount, inflation and escalation rates, deeply affects the evaluation. Future sums of money must be discounted because of the inherent risk of future events

not turning out as planned, the present worth method being considered as a suitable tool for comparing the different alternatives. The IEA (1991) developed a guidelines for the economic analysis of renewable energy technology applications that can be summarized as in the Figure 6.3.



**Figure 6.3** Diagram of recommended economic analysis approach. Source: IEA/Guidelines for the economic analysis of renewable energy technology applications IEA (1991, p. 12)

The IEA's recommended methodology represents a consistent, structured, generalized approach which is appropriated for feasibility analysis for both public and private sector. The Figure 6.3 shows the relationship between the inputs, costs, performance formats and sector analysis models. The entire economic indicator will be discussed ahead.

For Gökçek and Genç (2009) the calculation of the electrical energy production cost, all payments required for the installation of the power plant must be known. The cash flow for the project includes the expenditures such as land, construction, fuel and operating and maintenance. In general, in power plants, cost per unit energy is calculated by dividing the amount of energy produced to the total expenditures made along the certain time interval. The levelized cost of electricity (*LCOE*) is one of the most important indicators for evaluating fiscal performance of power supply systems such as wind energy conversion system (WECS). *LCOE* is a technique applied by the techno-commercial analysts to calculate the unit cost throughout the economic life

of the project. The levelized cost for WECS can be describe as the ratio of the total annualized cost of the WECS to the annual electricity produced from the system.

A techno-economic analysis of electricity production from wind energy made by Arslan (2010) discuss about Life-Cycle Cost analysis for onshore wind farm connected to a grid which essentially includes two main components, which are the investment and operations and maintenance (O&M) costs. The investment cost includes the costs of the turbine, foundation, grid connection, and civil work. The environmentalist economists maintain that the real cost of a process must be calculated by adding to the investment and operational costs the cost of the damages to both human health and nature.

Zhang, Chowdhury, Messac, and Castillo (2010) introduce a new concept for economic evaluation of wind farms. Its formulation is based on *cost of energy* (*COE*) optimization. The result showed that (*i*) the profitability is particularly sensitive to changes in the capital cost, the capacity factor, the electricity escalation rate, and the initial installation cost; (*ii*) the profitability is slightly less sensitive to changes in the O&M cost; and (*iii*) the impact of the turbine rated power and the inflation rate is limited.

Nouni, Mullick, and Kandpal (2007) developed the levelized unit cost of electricity (*LUCE*). *LUCE* is one of the commonly used indicators for financial performance evaluation of renewable energy based decentralized power supply systems. Total annualized cost is calculated by taking into consideration the capital costs of the different sub-systems of the SWEG project and its annual operation and maintenance cost.

The NREL (1995) compiled a *Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies* that provides guidance on economic evaluation approaches, economic measures, while offering a consistent basis on which analysts can perform analyses using standard assumptions for each case∴ It not only provides information on the primary economic measures used in economic analyses and the fundamentals of finance but also provides guidance focused on the special considerations required in the economic evaluation of renewable energy projects.

Oliveira (2010) makes an overview about the indicators of attractiveness and risks like *simple* payback (SPB), discounted payback (DPB), net present value (NPV), internal rate of return (IRR), benefit-to-cost ratio (BCR) and required revenues (RR). Also are discussed about some indicator of cost analysis in energy projects just like LCOE, total life-cycle cost (TLCC), net present cost (NPC), levelized electricity production cost (LEPC) and unit present average cost (UPAC). A simulation studied with these indicators concludes that they must be used as tool kit for wind energy project economic evaluation. The indicator studied is not recommended to be applied alone, better combine the indicators in function of the evaluation objective.

There are many software available in the market that can be possible to make a sophisticated economic evaluation of an energy project for both renewable and efficiency application. We can cite the *RETScreen*<sup>®</sup> *International Clean Energy Project Analysis* used as an investment tool decision, *the HOMER energy software* applied to determinate the size of a power system with all

its features for the system works as it must be. It is possible to make a list of software used professionally by engineers, designers, economists and related professions.

The cost of the renewable technology can be evaluated by its cumulative production, research, development aspects. Many authors such Kobos, Erickson, and Drennen (2006), Ibenholt (2002), Lund (2006), Neij (1999, 2008), Pan and Köhler (2007) and Sorensen, Org Econ, Dev, and Dev (1997). For onshore and offshore wind energy technological aspect and its improvements have a great impact on cost reduction of wind energy project analysis. It is an important aspect to be considered.

Efficiency planning and resource management is the key to the success of an energy project. Wind is one of the most potent alternative energy resources; however the economics of wind energy is not yet universally favorable to place wind at a competitive platform with conventional energy (fossil fuels) (Zhang et al., 2010). The *optimization model for economic evaluation of wind farms*, developed in this research, would allow investors and managers to better plan their projects, as well as provide valuable insights into the areas that require further development to improve the overall economics of wind energy.

As we can notice there is an exhaustive list of authors, institutions about economic evaluation methodologies and approaches applied to energy projects. Each methodology and approach has its own objective, although they usually highlight economic merits only — in an energy project it is also interesting engineering and physics variables. In economics view it is necessary that the project could remunerate its costs and create profits for investor as well as any other economic agent involved. In the other hand, in engineering aspects, the project must be size according to its equipment, utilities and machinery used in the power station. How is it possible to optimize a wind farm, in a project conception or in a real system, in both economical and engineering point of view?

Both onshore and offshore wind energy has a growth during the last decade in the world and the importance of renewable energies technologies is more and more emphasized by public authorities because climate change and global warming is a concern for modern world, so methodologies which could become investment in this kind of technology more safe with simulation and optimization analysis will be welcome. Wind energy is one of the renewable technologies that is becoming more and more competitive at the global level, but has not received enough attention on optimization process for economic evaluation of wind farms by the researchers in both economic and engineering aspects. Indeed, most of the optimization models reflects aspects of Engineering and Physics sciences, but in the economic view has not been analyzed in the depth that it deserves.

So, try to develop an economic optimization procedure of wind farms in function of the cost of energy produced using algorithm is a step ahead for economic evaluation methodologies, and I hope to apply it my professional life as Project Finance and Management Consultant in a few years for better decisions and make the alternative investment in renewable energy projects rightly and securely way to explore the resources from nature, help the economy growth and the environment protection. It is a way to join my professional experience and background with the new knowledge acquired during my Ph.D. in Economics in a specialized and scientific area, *Energy Economics*.

## 6.4 **Research framework and design**

## 6.4.1 LITERATURE REVIEW

During the research, the literature review (1<sup>st</sup> phase of the research work) was undertaken from primary, secondary and tertiary sources comprising books, websites, and reports from companies operating in the wind energy sector and public organizations and papers published in scientific journals. The objective was to gain an understanding of the problem and possible approaches, building up a theoretical framework of this research work. In the Table 6.1 details a summary of literature review main sources.

	Type of source	Number	Percentage (%)
✡	Books or books sections	100	11.0
✡	Conference proceedings	83	9.1
✡	Government documents	34	3.7
✡	Journal articles	558	61.3
✡	Magazine articles	10	1.2
✡	Others <sup>(*)</sup>	21	2.3
✡	Thesis	21	2.3
✡	Web pages	83	9.1
	Total	910	100.0

 Table 6.1
 Literature review statistics

Source: Own elaboration

<sup>(\*)</sup> Pamphlet, patents and reports.

It is important to highlight that most of journal articles reviewed is related to energy economics scientific field, such as, *Energy, Renewable and Sustainable Energy Reviews, Energy Conversion and Management, Energy Policy, Wind Energy Conversion, Energy Economics, Renewable Energy, Renewable & Sustainable Energy Reviews, Renewable Energy, Wind Energy, Electric Power Systems Research, Journal of Wind Engineering and Industrial Aerodynamics, Journal of Energy and Development, Applied Energy, Energy Problems and Environmental Engineering, Resource and Energy Economics, Global Journal of Researches in Engineering, Energy and the Environment, Energy Sources, Power Systems, Wind Engineering, Ecological Economics, Climate Policy and others.* 

The work also included an extensive wind turbine data analysis, which focused mainly on the maximum power curve available on *Product Database of RETScreen Software*. The technical characteristics of the existing wind farms were obtained from official reports of specialized public and private organizations related to wind energy technology (sources as government documents, magazines articles and web pages). It is relevant to emphasize the self-constructed approach taken during the research project, because research on renewable power system optimization is encouraged by R&D priorities.



Figure 6.4 Thematic areas in literature review process. Source: Own elaboration

There are five main thematic areas in which this research is related to (see Figure 6.4), which detailed discussions were done in previous chapters. An analysis of literature on *economic measures* applied for renewable power systems, aiming to introduce and confront the different techniques of economic evaluation, in a microeconomic view. Also, a review on WECS was important to undertake, specially the identification of the rule and routine of wind energy systems operate. In WECS thematic was examined the wind energy converters types, physics basics, describes how energy is extracted from the wind, explain about power coefficients and its limitations on wind power systems and what problems must be considered.

The *energy policy* and *renewable energy* thematic areas were analyzed altogether into the global status of wind energy market. The energy policy and renewable energy thematic areas address the wind energy situation worldwide in order to establish a context for understanding the contemporary wind energy industry. It was explored the global character of wind energy sector, describing its R&D trends, technological evolution and diffusion process, investment focus, global market share and the global drivers for the expansion of this renewable technology.

The *simulation/optimization* thematic area was involved in this research due to its nature and the research object requires an interdisciplinary approach. In this thematic was introduced the concept of simulation and optimization, the objective of this process, model framework, main methods and techniques currently used. During the literature review in this thematic we could classify the most used economic and engineering models of optimization algorithms for wind and hybrid power system (Tables 5.8 and 5.9). The costs of energy produced from RETs/WECS could be understood as a combination of components interlinked. A wind farm depends on directly the physical and environmental conditions. As shown in Figure 5.10 the system configuration has impacts on investment and O&M costs, which reflects on energy production cost by a wind farm. Also, we can see the system configuration has influence on loss model and power performance model.

#### 6.4.2 METHODOLOGICAL PROCEDURES

The research problem should determine the choice of methods — not the researcher's knowledge or experiences of different research methods. As we established in Chapter 1, the research was driven by the central research question:

What is the minimum difference between maximum power production and minimal total costs based on LCOE/NREL methodology proposed for a wind farm? If any, which possible strategies could be followed?

This question led us to a research trajectory which should be classified in phases. Each phase of the research is shown in Figure 6.5. The research methodology is structured in three phases: 1) *Literature Review*; 2) *Database Analysis* and 3) *Simulation and Optimization*.



Figure 6.5 Research methodology overview. Source: Own elaboration

In the first phase of this research, literature review was undertaken on economic measures for Renewable Energy projects and optimization models (studies) for wind energy projects and the research question and objectives formulation. It was necessary to engage in different approaches, but complementary, microeconomic project evaluation methods and optimization methods applied to engineering solutions in renewable power systems, as detailed in Chapter 5. For this reason, and considering the objectives of each study, different approaches were followed in order to understand what could be complemented for an optimization model, both in economic and technical issues, as detailed in Chapters 4 and 5.

For the second phase of this research, database analysis, the choice of *RETScreen Product and Climate Database* was made by the worldwide recognition and scientific application in renewable energy projects economics analysis∴ The key items checked in *RETScreen Product Database* were

capacity per unit, hub height, rotor diameter per turbine, swept area per turbine and power curve. For RETScreen Climate Database were "annual wind speed", "air temperature" and "atmosphere pressure", because both technical and climate aspects influence directly on wind energy production (see Figure 6.7). In RETScreen Software it is possible to choose and change these inputs, so for simulations analysis it is useful (Himri, Stambouli, & Draoui, 2009; RETScreen® International Clean Energy Decision Support Centre, 2008). According to Connolly, Lund, Mathiesen, and Leahy (2010) RETScreen Software can be applied for scenario and investment optimization/simulation analysis, but not for operation optimization of power plants.

According to RETScreen® International Clean Energy Decision Support Centre (2008)"the product data incorporated directly into the RETScreen Software provides access to over 6,000 pertinent product performance and specification data needed to describe the performance of the proposed clean energy system in the first step of the RETScreen analysis", as the research is focused in WECS due to the objective, the technology chosen to be analyzed is wind turbine.

ystem	Pov	ver			- Pow	ver curve data	
Fechnology	Win	d turbine			Wind	Power	
					speed		
					mvs ol	<u>KVV</u>	
					- 1	0.0	
Manufacturer	Vestas			•	2 2	0.0	
Model	VESTAS V90-2	2.0 MW - 10	)5m	•	- 3	0.0	
model	,				- 4	56.0	
Capacity per unit			kW	2,000	- 5	165.0	
Number of units			,	25	▲ 7	570.0	
			_	25	- 8	863.0	
Capacity			kW	50,000	9	1215.0	
			,		10	1606.0	
Hub height: 105 m					11	1878.0	
Rotor diameter per turbine:	90 m				12	1974.0	
Swept area per turbine: 6	5361.7 m²				14	2000.0	
					15	2000.0	
					16	2000.0	
					17	2000.0	
					18	2000.0	
					19	2000.0	
					20	2000.0	
					21	2000.0	
					22	2000.0	
					23	2000.0	
					24	2000.0	
					201	2000.0	

**Figure 6.6** RETScreen Products Database information for wind energy projects models. Source: RETScreen® International Clean Energy Decision Support Centre (2009)

The *power curve*<sup>75</sup> of a wind turbine is one of the most important aspects to be check in this technology when the objective is optimizing the power system. We must notice that each turbine

<sup>&</sup>lt;sup>75</sup> The *power curve* is a graph that indicates what the electric power output available in the wind turbine at different wind speeds.

has each own features and will condicionate the technical operation of the power plant at  $all \therefore Apply$  the best equipment is crucial for a lower cost of electricity produced from a wind farm!

The last phase of this research, *simulation and optimization*, it was firstly necessary develop an *energy model*<sup>76</sup> with technical features as the best performance as possible. It is possible only because the *RETScreen Product and Climate Database* analysis and chosen the optimized conditions. For developing the economic model it was necessary an exhausted analysis of feasibility and evaluation indicator for renewable energy projects. The optimization model was based on the combination of two fundamental methods: *i) maximize the total power output* and *ii) minimize the cost per unit power produced*. The mathematical formulation is based on the block diagram of the wind farm simulation and optimization algorithm developed during this research (see Figure 6.16). The models were then implemented in a computational language and solved using MS Excel-MATLAB<sup>®77</sup>, as detailed in section 6.4.4 and Chapter 7.

The *energy model definition* has to take into consideration the variables shown in Figure 6.8, reflecting technical and local climate features of wind farm location. The optimization model developed is going to maximize the equipment used (wind turbines) with the actual climate site conditions (*wind speed, air temperature and atmosphere pressure*). Figure 6.7 shows the meteorological site information available at RETScreen Software databases fed by NASA's satellite.



**Figure 6.7** Site reference conditions used for wind energy projects models. Source: RETScreen® International Clean Energy Decision Support Centre (2009)

<sup>&</sup>lt;sup>76</sup> In this case, the *energy model* means features or specific parameters describing the location of the energy project, the type of system used, the type of technology for the power plant, the loads demanded, and the renewable energy resource (for RETs).

<sup>&</sup>lt;sup>77</sup> For more information, please see at <u>http://www.mathworks.com/products/matlab</u>.

The economic model definition also has to take into consideration the variables shown in Figure 6.8, reflecting economic and financial features of a typical wind farm project. The cost optimization algorithm developed is going to minimize the cost of energy produced from the power plant (wind farm).



Figure 6.8 Variables influencing on COE in a wind power plant. Source: based on Morthorst and Shimon Awerbuch (2009)

As we can see, the lifetime of the project, cost of capital, price of wind turbines (with foundations and others auxiliaries infrastructure) reflect directly on capital cost per year in a wind power project. According to Milborrow (2008) the cost of capital can reach 80% of the total cost of the project during its lifetime, with variations between models, and local markets : O&M costs depend on technical features of the wind power plant (e.g. rotor diameter, hub high and other physical features of the BOP<sup>78</sup>). The configuration of the wind farm and climatic conditions (see Figures 6.7 and 6.8) determine the expected wind farm production and also the annual emissions of greenhouse gases<sup>79</sup> (GHG). The *cost of energy (COE)* per kWh is a result from total cost per year in relation to annual energy production of a wind power plant. That is why in the economic model definition we must consider the variables and their relationship and influence ones each other.

<sup>&</sup>lt;sup>78</sup> The BOP is the acronym of "Balance Of the Plant" and refers to the infrastructure of a wind farm project, in other words all elements of the wind farm, excluding the turbines. It includes civil works, SCADA and internal electrical system. It may also include elements of the grid connection. For more details, please see WindFacts (2010). <sup>79</sup> The gases whose absorption of solar radiation is responsible for the greenhouse effect, including carbon dioxide, methane, ozone, and

the fluorocarbons.

#### 6.4.3 THEORETICAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

Many issues related to renewable energy project analysis are truly interdisciplinary in their nature. Therefore, research within the field should reflect that fact and should; if possible, it is used more than one scientific discipline or method. Thus, model results and insights become supported by not just one but several scientific disciplines. The optimization model for economic evaluation of wind farms can be as an efficient planning and resource management, which is the key to the success of an energy project. Wind energy is one of the most potent alternative energy resources; however the economics of wind energy is not yet universally favorable to place wind at a competitive platform with coal and natural gas (fossil fuels). Economic evaluation models of wind projects developed would allow investors to better plan their projects, as well as provide valuable insight into the areas that require further development to improve the overall economics of wind energy projects.

According to Benatiallah, Kadia, and Dakyob (2010) the economic model should be made while attempting to optimize the size of integrated power production systems favoring an affordable unit price of power produced. The economic analysis of the wind system has been made and the cost aspects have also been taken into account for optimization of the size of the systems. For Baños et al. (2011) some of these optimization methods are based on traditional approaches, such as *Mixed-Integer and Interval Linear-Programming*<sup>80</sup>, *Lagrangian Relaxation*<sup>81</sup>, *Quadratic Programming*<sup>82</sup>, and *Nelder–Mead Simplex Search*<sup>83</sup>, while a growing number of research papers tackle these problems using *heuristic optimization methods*<sup>84</sup>, especially *Genetic Algorithms*<sup>85</sup> and *Particle Swarm Optimization*<sup>86</sup>. Besides purposes and approaches of models used, the models can also be distinguished according to their structure, more specific the assumptions on which the structure is based. For each type of model, a decision has to be made on which assumptions will be embedded in the model structure (the internal assumptions) and which are left to be determined by the user (i.e., external assumptions). In this research, the model proposed followed by the research objectives and approach which influence directly on internal and external assumptions considering in the analytical model resulted from this Ph.D. research work.

<sup>&</sup>lt;sup>80</sup> Mixed Integer Programming (MIP) is actually an extension of Linear Programming which allows for greater detail in formulating technical properties and relations in modeling energy systems. Decisions such as *Yes/No* or (0/1) are admitted as well as nonconvex relations for discrete decision problems. MIP can be used when addressing questions such as whether or not to include a particular energy conversion plant in a system. By using MIP, variables that cannot reasonably assume any arbitrary (e.g., small) value — such as unit sizes of power plants — can be properly reflected in an otherwise linear model (World Bank, UNDP, & ESMAP., 1991).

<sup>&</sup>lt;sup>81</sup> Lagrangian Relaxation consists in removing some of the restrictions of the original formulation, but attempts to embed these inequalities in the objective function. The idea is to penalize the objective function when the restrictions removed are violated. The *"weight"* of these penalities is controlled by coefficients called Lagrangian multipliers (Fisher, 2004).

<sup>&</sup>lt;sup>82</sup> It is the problem of optimizing (minimizing or maximizing) a quadratic function of several variables subject to linear constraints on these variables (Nocedal & Wright, 1999).

<sup>&</sup>lt;sup>83</sup> It is also called *"Simplex Search"* which uses the concept of a simplex, which is a special polytope of N + I vertices in N dimensions. Examples of simplices include a line segment on a line, a triangle on a plane, a tetrahedron in three-dimensional space and so forth. The method approximates a local optimum of a problem when the objective function varies smoothly (Carson & Maria, 1997).

<sup>&</sup>lt;sup>84</sup> Heuristic optimization is the process that adopts methods beginning with an initial solution and utilizes types of operations to modify this solution. This gives these methods the flexibility to move to another solution and continue the improvement process (Ozturk & Norman, 2004).

<sup>&</sup>lt;sup>85</sup> Genetic Algorithms (GAs) are computer imitation of a simplified and idealized evolution. DNA is represented as a string where each position in the string may take on one of finite sets of values. The fitness of the organism is determined by a fitness function; the function decodes the string and returns a real scalar value (Carson & Maria, 1997).

<sup>&</sup>lt;sup>86</sup> Particle Swarm Optimization (PSO) mimics the behavior of individuals in a swarm to maximize the survival of the species. In PSO, each individual makes his decision using his own experience together with other individuals' experiences. It is the representation of a metaphor of social interaction, searches a space by adjusting the trajectories of moving points in a multidimensional space (Jong-Bae, Ki-Song, Joong-Rin, & Lee, 2005).

#### 6.4.3.1 RESEARCH OBJECTIVES

As discussed before in this chapter the main objective of this thesis is to verify how concepts derived from the Theory of Simulation and Optimization can be helpful to *develop an algorithm for Economic Optimization of Wind Farms in Function of the Cost of Energy Produced.* Particularly, it intends to maximize wind farm's production, mainly in terms of power delivered and the lowest production cost, and what its relationships. More specifically it aims to:

- 1. Apply a combination of methodologies and approaches of optimization procedures according to a microeconomic point of view for economic evaluation applied on wind farms, in an investment and management context, determining the best option that results in the best decision-make for an optimization model.
- 2. Review and systematize methods and techniques of economic evaluation applied to renewable energy projects, specific to wind energy projects. Both project and cost methodologies of economic evaluation are reviewed for a model optimization construction for a proposed optimization model with its objective function most appropriated.
- 3. Propose a methodology based on assumptions of *Theory of Simulation and Optimization* that could develop the best solution for investment and management decisions with a different approach, non-deterministic nature, for validating the new concepts of economic project evaluation, supported by the analysis process, design and objective function developed with its constraints.

The overall model must recognize the multiple and conflicting objectives involved in energy decisions, dealing with the large economic and engineering costs involved and also eliciting the priorities variables. The process must combine simultaneously efficiency with investment planning, assessing whether incremental investment should be met through existing economic advantage or through the addition of new production capacity, in order to maximize its production.

Based on accomplishing of these three objectives, it is expected as contribution of this thesis:

- 1. Development of a new methodology able to inform the investor or manager of a wind energy project what its size, initial investment, *O&M* costs (including frequency of maintenance routines), replacement cost, annual energy production, maximum losses expected, how many turbines, high hub, minimum wind speed, as well as its maximum variation;
- 2. Make an integration of methods applied to economics and engineering sciences in function to the multivariable problem and create a planning and managing tool for energy projects, special to onshore wind energy that could be used in the future for new methodologies and approaches of economic evaluation for renewable energy projects.
- 3. Create a tool applied to competitiveness ranking for wind farms in a place, region and district considering the cost of energy produced. It is important to classify economically the land or areas and gives an idea of competitiveness' measurement.

## 6.4.3.2 RESEARCH APPROACH

The overall approach taken to reach the research objective was to investigate the formulation and logics of the various evaluation models/indicators, each model has its own variables and relations to explain the results and objectives for each model studied. At first, it checks only the economic models and then engineering evaluation models are analyzed with its objectives too. According to the central question or this research, it is an industrial problem and the steps to follow might be considered as follows (Hillier, Lieberman, & Hillier, 1995):

- 1. Define the problem of interest and gather relevant data why is there dissatisfaction with the present operations and what alternative courses of action appear to hold most promise of being effective solutions to the problem, relative to a set of pertinent objectives. The size of a wind farm project and the size of the wind turbine itself will vary depending on the amount of electricity the developer intends to produce. Costs of components per unit size tend to decrease as size increases, and through economies of scale, the construction costs per unit manufactured decreases as more wind turbines are manufactured (at least to the point where equipment and personnel are adequate). However, because the mass of the wind turbines' materials increases at a cubic rate to its rotor diameter, and the power rating increases with the square of its rotor diameter, there will be a critical size that increases the cost per kW of maximum power (Johnson, 2001). As wind energy is an intermittent source of power, this fact gives rise to extra costs in production, distribution and transmission, as well as the cost associated with the intermittency of wind.
- 2. Determine a suitable "measure of effectiveness" (often called the "objective function") to be optimized the wind energy industry is capital intensive, so wind farms' investment must be returned at an expected rate at investor point of view. Usually, the wind farm promoter (manager) needs to overcome some technical and economic issues about sub operation which has to be maximized or certain costs minimized. Thus, most optimizations are economic optimizations.
- 3. Elaborate a model to represent the system whose optimization is desired a model may be defined as a device, physical or symbolic. Models are almost always necessary in industrial work since experimentation with full-sized industrial equipment disrupts production and is very costly in money and time. And sometimes industrial equipment is only contemplated in design or as replacements. Usually, the most desirable model is the mathematical model, which employs mathematical statements to represent the system and enables responses to be calculated rather than be measured. The measure of effectiveness is expressed as a function of a set of variables at least one of which is subject to control. (The variables involved are often functionally interrelated so that they behave similarly to the active variables in the realistic system simulated). As the variables are manipulated; their effectiveness in optimizing the objective is changed. Often there are restrictions imposed on the values of the independent variables, or functional restraints involving these variables, and such restraints are expressed by supplementary equations and/or inequations.

- 4. *Solve the problem* determine the values of the independent (controllable) variables which optimize the objective (*i.e.*, maximize the effectiveness of the system) subject to any restraints imposed on the system (equipment limitations, rigid management policy, operating limitations, minimum quality characteristics, market restrictions, legal limitations, etc.).
- 5. *Test the model and calculated solution obtained from it* if adjustment is indicated, readjust the model, determine a new solution, and check again. A carefully chosen initial model may eliminate difficulties here.
- 6. *Establish controls* the lack of effective control over certain variables might seriously invalidate the appropriateness of the original model.. The need for a change in the original controllable variables to offset changes in uncontrollable variables must be recognized and a new optimum solution found.
- 7. *Implement the suggested solution* through appropriate organizational channels, and establish a set of operating procedures so that those concerned with control of the operation can attain the optimum as easily as possible.

It proved necessary to investigate the various aspects of a microeconomics view, as a power station unit, because when it is studied separately, it is necessary to understand the wind system conversion, its electro-mechanical, layout and economical restrictions. As it has been said about wind farms, the intermittency must be considered into economic evaluation methodologies, fundamental difference can be found when the intermittency is not considered. It was hence impossible to draw conclusions with respect to the isolated impact of the intermittency effect, because it was made simulation and the conclusions had to be qualified for the minimum cost of energy and other economic indicators being used.

The widely used *RETScreen software*, version 4, a tool for analyzing the technical and financial viability of potential renewable energy projects is now being used by more than 35,000 people in over 196 countries around the globe (RETScreen® International Clean Energy Decision Support Centre, 2008) was also used for the research. At the start of the research project, it was quickly found that there was not a unique methodology or optimization procedure model included in the standard libraries (products and projects database) of this software. Further study showed that at that time, this also needed to other simulation packages, and that wind technologies available are based only on manufactures' information. It was therefore inevitable to adopt another methodology for optimization process and try simulation by nonlinear algorithms.

Finally we studied extensively the *Theory of Simulation and Optimization* and take advantage of practical aspects of the simulation approach, as well as the manipulation of variables and its results. Then, we developed an optimized technology and calculated the best economics results for a hypothetical wind energy project. A preliminary validation of the developed model was carried out using different combinations of wind technologies available in the *RETScreen Products Database*. It is important to say again, the software does not make simulations, only deterministic and probabilistic calculations.
## 6.4.3.3 CONCEPTS AND VARIABLES

As we already discussed about philosophical, epistemological, methodological issues and paradigms of research in function of the research object — economical optimization of a wind farm *via* cost of electricity produced — the next step is determine the *concepts* and *variables* to be analyzed through a research. Figure 6.9 shows the inter-relations of these aspects in the research process.



**Figure 6.9** Epistemological tree for research concepts and variables integration. Source: adapted from Smyth and Morris (2007)

As we can notice in Figure 6.9, concepts, variables and hypotheses constitute the links between theory and practical (empirical) analysis. Concepts are terms that refer to the characteristics of events, situations and individuals that are studied. In order to apply the theory or preposition; we make the operationalization of the main definitions adopted for this research (see Table 6.2) through quantification of them. According to Magoha (2001) for economic analysis of wind energy, a variety of methods can be adopted: their accuracy is strictly related to the type of the WECS technology and its application for each power plant (*e.g.* whether it is for remote autonomous use or for grid connection).

The conceptualization is based on the *LCOE/NREL methodology*<sup>87</sup> presented and explained in Chapter 5, through the Eqn (5.24), with the following formula:

$$LCOE = \frac{FCR \times ICC + LRC}{AEP_{net}} + O\&M + PTC \qquad [\$/kWh]$$

We understand that this equation can be analyzed into two aspects: the one is "economics" and the other is "engineering". The economic nature of the formula is related to FCR, ICC, LRC, O&M and PTC elements. AEP<sub>net</sub> represents the power output (production), so the "engineering" part.

<sup>&</sup>lt;sup>87</sup> *NREL/LCOE* is the acronym of National Renewable Energy Laboratory/Levelized Cost Of Energy. For more details about this methodology, please see Cohen (1989); Cory and Schwabe (2009); George and Schweizer (2008); Milligan and Graham (1997); NREL (1995); Tidball, Bluestein, Rodriguez, and Knoke (2010).

We must highlight that *PTC* element add to this economic part the public influence on cost of energy produced from RETs. In other words, *LCOE/NREL* methodology is a comprehensive economic metric for cost of energy production and also can be applied to WECS. We possible compare different technologies or the same technology in different places.

Table 6.2 Conceptual and operational definitions used for the Ph.D. research work

	Conceptual definition	Operational definition
Economic Optimization	In economics, the term <i>economic optimization</i> means that resources are being used in the best possible way to meet the needs of people's desires. In other words, the existence of <i>optimization</i> is synonymous with absence or minimal losses. In micro-economic terms, <i>economic optimization</i> in terms of production means that, given the available technology and the prices of production factors, determined agent was able to generate as many goods with minimal production costs (Griffiths & Wall, 2000).	It was run the algorithm developed during this Ph.D. research for economic optimization of wind farms (see Eqn 6.2). $LCOE_{ww} = \frac{LCCCM_{WF} + LRCM}{LCPM_{WF}} + O\&M_{WFCM} + RCM_{WF} - REPIM$
Simulation Model	It is a descriptive model based on a logical representation of a system, and it is aimed at reproducing a simplified operation of this system. A simulation model is referred to as static if it represents the operation of the system in a single time period; it is referred to as dynamic if the output of the current period is affected by evolution or expansion compared with previous periods (Van Beeck, 1999).	Run the <i>objective function</i> ( $LCOE_{wso}$ ) which represents the real system through a computational language and solved using commercial and/or academic softwares (e.g. MS Excel-MATLAB <sup>®</sup> ).
Levelized Cost of Energy (LCOE)	<i>LCOE</i> is the real production cost of kilowatt-hours (kWh) of electricity. Includes the total construction, central production costs of the power station during its economic lifetime, financing costs, return on capital and depreciation. Costs are leveled in current monetary values, or adjusted to eliminate the impact of inflation (Oliveira, Fernandes, & Gouveia, 2011).	<i>LCOE</i> methodology was based on <i>LCOE/NREL</i> . Each element was changed by the formulas present in section 6.4.4.2. $LCOE = \frac{FCR \times ICC + LRC}{AEP_{ner}} + O\&M + PTC$
Annual Energy Production (AEP)	The calculation of theoretical production of electricity by the wind farm is result of the product among installed electricity capacity $(P_c)$ , capacity factor $(C_F)$ and total hours of production (24 hours x 365 days <sup>88</sup> ) of the wind farm. The capacity factor is in function of production losses, maintenance stops and periods when the wind speed is not suitable for electricity production by the aerogenerators. The capacity factor is also named utilization factor of the production system (Tidball et al., 2010).	We also make the equivalence to the <i>Annual Energy Production Net</i> $(AEP_{nel})$ for annual production electricity by the wind farm. The wind farm production for this Ph.D. research work is measure by the <i>LCPM</i> <sub>WF</sub> variable. <i>LCPM</i> <sub>WF</sub> = $f(WF_{CM};WT_{LM};PC_{PM};P\&D_{LM})$
Cost of Energy (COE)	The ratio of the <i>total costs</i> (C) to the <i>annual energy</i> production (AEP). The <i>total cost per year</i> is the sum of capital costs and $O\&M$ costs per year (see Figure 6.8) (Fuglsang & Madsen, 1999; Fuglsang & Thomsen, 1998). It is usually measured in $\&$	We adopted the concept of unit cost for the <i>COE</i> . It has been considered the relation of <i>total costs</i> and <i>total output</i> , in our case, the <i>annual energy production</i> (Griffiths & Wall, 2000). $COE \Rightarrow Unit Cost = \frac{C}{C}$
Sou	rce: Own elaboration	AEP
200		

<sup>&</sup>lt;sup>88</sup> Some authors consider 365.25 days/year for annual production estimation by the wind power plant, so is added more six hours of production per year, in other words, 8 766 hours per year. In our research we consider what is the most hours of production used for wind power production estimation (8 760 hours per year).

# 6.4.3.4 RESEARCH HYPOTHESES AND LIMITATIONS

According to Figure 6.9, from the epistemological aspects of the research, research approach (paradigm) and conceptual and operational definitions already done the research hypotheses can be developed in order to check whether the new theory formulated (*Economic Optimization Algorithm Proposed*) is valid<sup>89</sup> or not. For Jensen and Bard (2003) the research hypotheses are fundamental and necessary and a scientific "*piece*" in a research work. One another important aspect is the relationships between the variables analyzed in a research work, these variables can be classified into univariate (related to a single variable), bivariate (the relationship between two variables, one dependent and other independent) and multivariate (relate more than two variables) (Kothari, 2009). In this research there were used multivariate variables and the systemic approach in an operational research context.

During the literature review (1<sup>st</sup> phase of the research work) we could map five thematic areas (see Figure 6.4) for a better and comprehensive understanding about the cost of energy produced from a wind farm, in economic terms, considering manufacturing nature of the WECS. It has been necessary to study the inter-relations among the variables which influence on *COE*, as shown in Figure 6.8. For resuming these thematic areas in Figure 6.10 is shown how was studied the cost of energy during the Ph.D. research work.





**Figure 6.10** Contributions of each thematic area during the literature review process. Source: Own elaboration

*COE* can be analyzed in many ways, but we focus on the producer point of view, in other words, what is the *real minimum cost* for the power producer in a wind farm? It is necessary to understand how the WECS works, what king of relation the wind power producer has within the electricity market and what renewable energy policies can influence on the power production cost. WE could see during the extensive literature review, the lifetime of the REPs is around 15 to 25 years, case of wind energy projects. Gökçek and Genç (2009) have made an economic analysis for long term (more than ten years), it is better consider the whole lifetime for the same analysis.

<sup>&</sup>lt;sup>89</sup> The term "*valid*" derives from "*validation*" that conveys a sense that a scientific effort must be justified in some logical, objective, and algorithmic way (Kleindorfer, O'Neill, & Ganeshan, 1998).

The research work was driven by *COE* minimization during the wind farm's lifetime that is why we consider *LCOE* more appropriate to our research objectives. The cost is the most important pledge for economic operation of wind farm. There are two theories for minimum of wind power cost: *economy of scale*<sup>90</sup> and *square-cube theorem*<sup>91</sup>. Many authors suggest we should develop great unit, and it emphasizes wind speed is proportionate to altitude; while other scholars consider the captured energy is proportionate to diameter of wind turbine, meantime, mass of wind turbine (i.e. cost) is proportionate to square of diameter (Tai & Wen-rui, 2009). It is assertive to use the two theories, however, cost of energy produced will not be totally proportionate to the production in a yearly basis, it must include other factors, and the cost function (*LCOE<sub>wso</sub>*) for the Ph.D. research work was developed considering the following hypotheses as shown in Table 6.3.

 Table 6.3 Research hypotheses considering for the Ph.D. research work

Hypotheses	Statement	Basis
$RH_1$	The WECS is dependent on the local wind resources. The better the local wind resources more electricity production.	The theoretical power output in the current wind technology is equal to the cube of the wind speed. However, the power production profile of a wind turbine is typically more proportional to the square of the average wind speed (Manwell, McGowan, & Rogers, 2002).
RH <sub>2</sub>	The higher the production of the wind farm, the less will be the unit cost of electricity, is an inverse relationship.	Considering the ratio between costs of the wind farm and power output (production), and if we keep constant the costs and increase the production, the cost per unit falls, taking into consideration some proportions (Fuglsang & Madsen, 1999; Fuglsang & Thomsen, 1998).
RH <sub>3</sub>	It is possible to determine the <i>break-even-point</i> of a wind farm from the wind speed and the minimum <i>LCOE</i> .	Wind power plants generate electricity when wind blows and the plant output depends on the wind speed (Georgilakis, 2008).
$\mathbf{RH}_4$	The layout of wind turbines has impact directly on <i>LCOE</i> . It can increase or decrease <i>LCOE</i> , depends on the design used.	The wind farm layout possible can lead to lower than expected wind power production, increased or decreased $O\&M$ costs, investment costs and in general the cost of energy produced (Kusiak & Song, 2010).
RH <sub>5</sub>	The smaller <i>LCOE</i> , more optimized is the wind farm, in economic terms.	The increasing in capacity factor from values below the levels of average capacity factor can lead mainly to large reductions in <i>LCOE</i> (Cory & Schwabe, 2009).

<sup>&</sup>lt;sup>90</sup> The *economy of scale* is a reduction in cost per unit resulting from increased production, realized through operational efficiencies. Economies of scale can be accomplished because as production increases, the cost of producing each additional unit reduces (Griffiths & Wall, 2000).

<sup>&</sup>lt;sup>91</sup> Discovered in the 16<sup>th</sup> century by Galileo, this *theorem* explains that no biological organism can suffer a change of size (consequently, in scale) without changing its shape or conformation: the volume of this organism will grow in a cubic reason, but the surface which contains itself increases into a square ratio only. In WECS, the output power is just the cube of wind speed (see Chapter 4, section 4.4.1).

Hypotheses	Statement	Basis
RH <sub>6</sub>	The maintenance program can be used as a strategy of optimization of the wind farm, in technical and economic terms.	Maintenance management for wind power production systems aims at reducing the overall maintenance cost and improving the availability of the systems. Since the operation and maintenance costs represent a substantial portion of the total life cycle costs of wind power production systems (Ding & Tian, 2012; Tian, Jin, Wu, & Ding, 2011).
RH <sub>7</sub>	The type of energy policy (EP) can influence directly on <i>LCOE</i> . It depends on the focus of the EP instrument adopted.	The renewables support instruments can be applied quite differently. Many of the available instruments can essentially be classified in grants about <i>investment costs</i> and <i>operation (production)</i> . As well as <i>investment</i> <i>incentives, incentives for operational costs</i> are subsidies to reduce the cost of energy produced (Wohlgemuth & Madlener, 2000).

Table 6.3 Research hypotheses considering for the Ph.D. research work (continuation)

Source: Own elaboration

According to the objectives and hypotheses research developed for this Ph.D. research work, we have to face some limitations. These limitations of this work should be mentioned. The studies included in this research focus on *cost of energy* (electricity) produced from a wind farm. So we can list the most important limitations of this research work:

- 1. *There is no standard LCOE to be reference for this kind of research.* There is not a single price and cost of energy for wind farms. Both depend on the location, size and number of turbines, in addition to being influenced by political incentives or subsidies granted by governments. These facts will affect the generalization done in the simulations which criterion is the *minimum LCOE* reached from the results in the studies done.
- 2. It is not possible to harmonize all input assumptions. A large number of assumptions have to be made before model simulations/optimization is carried out. Even though the input assumptions have been harmonized to an extensive degree in all sub-models, it has not been possible to reach full harmonization. The reason is that the sub-models are designed differently. Some of these differences make it impractical to fully harmonize model input without impacts the functionality of the sub-models inter-linked, and some of these differences significantly affect model results in general.
- 3. *Recognize the "locational" differences for the model proposed as universal methodology for economic optimization of wind farms.* As for *"locational"* differences may involve e.g. how are considered and practiced some rules, e.g. energy markets, policy instruments and taxation. This is strongly influenced by the *"energy history"* of a certain place. Models based on countries where a certain technology to the existing date has played an important role tend to look generously on the prospects for technology also in the future.

# 6.4.4 RESEARCH DESIGN

The research design is the conceptual structure and way within which the research work would be conducted. The function of research design is to provide for the collection of relevant scientific and valid information with intention to give an answer to the problem of the research work (Kothari, 2009). The research design was developed during the Ph.D. research work and adapted to its interdisciplinary nature, among the simulation and optimization theory, economic measures applied to RETs, WECS and energy policy.

We can summarize that a problem of optimization is formed by choosing variables, objective function and group of answers viable. The problem is choosing the best viable alternative. In General, the theory of simulation and optimization allows the representation of the problem in a search for the maximum or minimum of objective function in respect to the variables of choice and subject to restrictions. For this research work we have been considered the clusters of variables to be analyzed in the new LCOE methodology proposed:

- 1. Wind speed  $(v_w)$  the energy production cost is strongly dependent on the average wind speed. As an example, the energy production cost at an average wind speed of 6.5m/s was twice as high as the cost for an average wind speed of 10m/s. It was also found that the energy production cost decreases when the power output of the wind farm increases (Lundberg, 2006). There is clear evidence about the effect of the wind speed at the cost of energy produced in WECS.
- 2. Wind turbines layout  $(L_{wt})$  the wind turbines layout has direct impact on wind farm production and costs. As we have already discussed in Chapter 4, sections 4.5.1, 4.5.2 and 4.5.3 by many researcher the most factors that usually affect wind turbines location are: (1) optimization of energy production and COE output; (2) turbines loads; (3) noise emissions and (4) visual impact (Gonzalez, Rodriguez, Mora, Santos, & Payan, 2009; Payan, Gonzalez, Rodriguez, Mora, & Santos, 2011; Zhang, Chowdhury, Messac, & Castillo, 2012b). The Ph.D. research work has focused only on optimization of energy cost.
- 3. Operations and Maintenance management  $(O\&M_{manag}) O\&M$  management aims at improving the availability of the systems and reducing the overall maintenance cost (Ding & Tian, 2012). This variable can be also classified into *scheduled maintenance* and *unscheduled maintenance*, as already explained in Chapter 5, section 5.4.1.1.
- 4. Energy policy instruments  $(E_{pi})$  a strong focus on capacity installations might result in the construction of projects with little productive efficiency. Production incentives, in contrast, help to specially stimulate the development of efficient projects, resulting in a higher output of renewable energy per supporting capital involved (Enzensberger, Wietschel, & Rentz, 2002).

In order to test and understand the impact of these *clusters of variables* on  $LCOE_{wso}$  we have made several simulations. We have done 900 interactions within the *cluster of variables*, considering 3 different sites for a hypothetical wind farm, as detailed in Table 7.16.

One of the reasons for these sites (Brazil, Canada and Portugal) was based on *installed capacity of wind energy* at the end of 2011 of 1 509 MW, MW 5 265 and 4 083 MW, respectively, according to the GWEC (2012). The *annual mean of wind speed* was the determinant factor to choose the best site in these countries with geographies, climates, and structure, politics, technological development and different public perception about RETs. Table 6.4 shows these locations used for the simulations and optimization procedures.

Location	Criteria	Reason
1. Aracati, Ceara, Brazil	Local wind resources; Energy policy	The annual calculated mean of wind speed is 7.4m/s
<ol> <li>Cape Saint James, British Columbia, Canada</li> </ol>	Local wind resources; Energy policy	The annual calculated mean of wind speed is 12.5m/s
3. Corvo Island, Açores, Portugal	Local wind resources; Energy policy	The annual mean of wind speed is 9.1m/s

**Table 6.4** Locations chosen for simulations procedures within criteria and reasons

Source: RETScreen® International Clean Energy Decision Support Centre (2009)

For each site selected in the *RETScreen Climate Database* (2<sup>nd</sup> phase of the research work) we have gotten the following information about, as shown in Figures 6.11, 6.12 and 6.13.



**Figure 6.11** Site climate conditions used for simulation/optimization of the wind power plant in Aracati (Brazil). Source: RETScreen® International Clean Energy Decision Support Centre (2009)

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**Figure 6.12** Site climate conditions used for simulation/optimization of the wind power plant in Cape Saint James (Canada). Source: RETScreen® International Clean Energy Decision Support Centre (2009)



**Figure 6.13** Site climate conditions used for simulation/optimization of the wind power plant in Corvo Island (Portugal). Source: RETScreen® International Clean Energy Decision Support Centre (2009)

# 6.4.4.1 VARIABLES RELATIONSHIP AND RESEARCH BOUNDARY

The variables influencing on cost of energy produced from a wind farm are present at Figure 6.8, which for this Ph.D. research work were analyzed in certain conditions and relationships:

- The *lifetime of the project* is the period of working of the power plant. We have been considered 25 years of operation. The lifetime of the wind farm is driven by wind turbines 'lifetime. If it is chosen a wind turbine for 20 years of operation, so the lifetime of the wind farm will be the same period;
- 2. The *cost of capital* reflects how much the project finance operation is. It is also called *"financial cost"* of the project, as we have already explained in Table 5.1. Usually the cost of capital of a power plant is affected by the lifetime, the initial investment that is driven directly by the power system configuration;
- 3. The price of wind turbines, access roads, foundations and other facilities can be analyzed as *"capital cost"* or *"initial investment"*. The wind turbines chosen are driven by the local wind resources and terrain conditions : As higher the wind power class, more powerful and bigger the wind turbines have to be adopted;
- 4. For *power system configuration* (rotor diameter, hub high and other physical features) has been considered the data shown at Figure 6.6. The power system configuration is used to be conditioned to how capital the investor has available, the local wind resources profile and the cost of energy produced;
- 5. For *mean wind speed and site characteristics* have been considered the data shown at Figures 6.11, 6.12 and 6.13. We easily find a direct relation among wind speed, initial investment, and annual energy production. As higher as wind speed, much as initial investment and the annual production;
- 6.  $O\&M\ costs$  were classified into  $O\&M\ costs\ fixed\ (O\&M_{fixed})$  and  $O\&M\ variable\ (O\&M_{variable})$ .  $O\&M_{fixed}$  was determined by a number of fixed hours of work during the operation years of the power plant; however  $O\&M_{variable}$  was fit to the annual energy production of the power plant;
- 7. Annual Energy Production (AEP) has been calculated for each year by the  $LCPM_{WF}$ , which the *capacity factor* ( $C_F$ ) variable per year of power plant operation. It seems to be more realistic to the nature of operational aspect for the WECS;
- 8. For the *annual emissions of GHG*, we consider only  $CO_2$  *emissions* and it was compared with the same amount of electricity produced from fossil fuel technology considering the fuel type, region and P&D losses. The GHG emission of  $CO_2$  ( $GHG_{EF_{\# CO_2}}$ ) was calculated

for Brazil, Canada and Portugal.

When these variables have been considered for all lifetime of the power project how is the case of present Ph.D. research work (25 years), we could get *LCOE* of the power plant. The methodology

proposed for simulation and optimization of WECS projects was developed during this research work considering these variables and their relationships. It is important to understand in the new methodology proposed ( $LCOE_{wso}$ ) which is the most influencing variable(s) on cost of energy produced from the wind farm. It was also of great importance to define the research boundaries in order to make the results more measureable and transparent, in economic terms.

Economic optimization of wind farm *via LCOE* methodology is a combination of many different disciplines including operational research, economics, accounting, industrial engineering, production management, maintenance costs and others related to. In the present Ph.D. research work we have to consider as WECS boundaries for *LCOE* calculations and evaluations as shown in Figure 6.14.



Figure 6.14 Cost and production frontier considered in simulations for optimized  $LCOE_{wso}$ . Source: Own elaboration

For reasons of system delimitation for the research work, economic evaluation and annual energy production, all analysis done was related to the production and transmission phases<sup>92</sup> of the WECS. The *power plant*, including the *land*, *local wind turbines grid*, *collecting point*<sup>93</sup> and *transmission system* (to the grid of distribution) were included for costs and production analysis. This implies that the costs and other charges for distribution and commercialization of the electricity produced to the final consumer are not part of the proposed methodology of this Ph.D. research work.

<sup>&</sup>lt;sup>92</sup> When we refer to energy production in form of electricity, it is used to be analyzed as, *production, transmission, distribution* and *commercialization* phases. Each of these phases present its aspects and costs associated.

 $<sup>^{93}</sup>$  The *collecting point* for a wind farm is the same as an electrical substation. An electrical substation is a part of an electrical production, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions.

# 6.4.4.2 MATHEMATICAL MODEL STRUCTURING

As we have already discussed before, a "model" is a representation of a system or process of the real world into a theoretical manner (Carson & Maria, 1997). For the present research work, methodologically adopted and approach of operational research, because it is related to a real problem industrializing activity, case of wind power. So the WECS studied has to be analytical analyzed through the "mathematical modeling". Mathematical modeling is to establish a set of mathematical tools that allow making a theoretical analysis of a given situation. For Banks (1999) the real-world system under investigation is abstracted by a *conceptual model*, a series of mathematical and logical relationships concerning the components (variables) and the structure of the system.

Our conceptual model was based on *LCOE/NREL*, considering the conceptual and operational definitions explained in Table 6.2. The conceptualization of this Ph.D. research work was also driven by the hypotheses formulation (see Table 6.3), which variables were grouped in clusters (see section 6.4.4) to be better studied and mathematically formulated. The most important relationships were briefly described in section 6.4.4.1 and the size or structure of the system (see Figure 6.14) to be modeling.



Figure 6.15 Modeling process flowchart. Source: Own elaboration

As we can see in the Figure 6.15 the modeling process is dynamic. The present research modeling process was built since the first and second phases of this research due to the nature of the present Ph.D. research work. It is related to engineering economic analysis of wind power, so the *mathematical model*<sup>94</sup> was developed through the block diagram structure for wind farm economic optimization (see Figure 6.16) considering these two aspects, the economic and engineering one.

 $<sup>^{94}</sup>$  In this section of this Ph.D. thesis a *mathematical model* is defined as a mathematical description — usually in the form of a computer algorithm — of a real system and the ways that phenomena occur within that system, and an energy model is a model with its focus on energy issues, according already explained in the footnote 76 on this same Chapter.

The Economic Optimization Algorithm Proposed ( $EOAP = >LCOE_{wso}$ ) developed during this research work was built in models. There are six main modules: Wind Farm Life-Cycle Capital Cost Model ( $LCCCM_{WF}$ ); Wind Farm O&M Cost Model ( $O&M_{WFCM}$ ); Levelized Replacement Cost Model (LRCM); Wind Farm Removal Cost Model ( $RCM_{WF}$ ); Renewable Energy Public Incentive Model (REPIM) and Wind Farm Life-Cycle Production Model ( $LCPM_{WF}$ ). Each of them was integrated into sub-models, as shown in Figure 6.16.



**Figure 6.16** Block diagram of the wind farm simulation and optimization algorithm proposed. Source: Own elaboration

Now we have detailed our proposed methodology and new approach for *LCOE* calculations. The following Eqn 6.2 has shown the Ph.D. research algorithm:

<sup>&</sup>lt;sup>95</sup> In " $O\&M_{fixed}$ " we have been considered all expenses about insurances, taxes not incidents of revenue, land rents and other expenses related, but not directly to *AEP*, revenue or operational nature in the wind farm. <sup>96</sup> For " $O\&M_{variable}$ " we have been considered all expenses and costs related directly proportional to the hours of working and to the

<sup>&</sup>lt;sup>96</sup> For " $O\&M_{variable}$ " we have been considered all expenses and costs related directly proportional to the hours of working and to the operational revenues of the wind farm.

$$LCOE_{wso} = \frac{LCCCM_{WF} + LRCM}{LCPM_{WF}} + O\&M_{WFCM} + RCM_{WF} - REPIM \qquad [\$/kWh] \qquad \text{Eqn (6.2)}$$

where  $LCCCM_{WF}$  = Wind Farm Life-Cycle Capital Cost Model; LRCM = Levelized Replacement Cost Model;  $O&M_{WFCM}$  = Wind Farm O&M Cost Model;  $RCM_{WF}$  = Wind Farm Removal Cost Model; REPIM = Renewable Energy Public Incentive Model and  $LCPM_{WF}$  = Wind Farm Life-Cycle Production Model.

### Wind Farm Life-Cycle Capital Cost Model (LCCCM<sub>WF</sub>)

*LCCCM*<sub>WF</sub> is an important aspect for the formulation of the *initial investment* (capital cost) of the wind power project, even for onshore or offshore installations. As we already discussed before, these projects are capital-intensive and a great part of the costs were driven to this term. This item represents the sum of the cost of wind power system and the cost structure of the wind farm. This cost measure includes all the planning, equipment acquisition, construction and installation costs of the wind system which makes the wind farm ready to operate. For our proposal methodology, *LCCCM*<sub>WF</sub> was built considering the wind turbines, towers, local wind turbines grid, transmission system, collecting point<sup>97</sup>, supporting infrastructure (builds and other facilities), pre-operational costs (consulting, surveys, permitting, etc.), financing costs and other contingencies capital costs. The wind turbines and towers have been delivered and installed on site of the wind farm with all maintenance, electrical system and other infrastructure support for the whole wind farm installations. We also emphasize the utilization of *Uniform Capital Recovery Factor*<sup>98</sup>

 $UCRF = \left[\frac{WACC_{proj}(1 + WACC_{proj})^{N}}{(1 + WACC_{proj})^{N} - 1}\right]$  for cost items which represents the power system (equipment and

facilities) of the proposed methodology.  $LCCCM_{WF}$  is shown in Eqn 6.2.1.

$$LCCCM_{WF} = WT_{CM} + T_{CM} + LWTG_{CM} + CP_{CM} + TS_{CM} + SI_{CM} + PO_{CM} + F_{CM} + CCC_{CM}$$
 [\$/kW] Eqn (6.2.1)

where  $WT_{CM} = Wind Turbines Cost Model$ ;  $T_{CM} = Towers Cost Model$ ;  $LWTG_{CM} = Local Wind Turbines Grid Cost Model$ ;  $CP_{CM} = Collecting Point Cost Model$ ;  $TS_{CM} = Transmission System Cost Model$ ;  $SI_{CM} = Supporting Infra-structure Cost Model$ ;  $PO_{CM} = Pre-operational Cost Model$ ;  $F_{CM} = Financing Cost Model$  and  $CCC_{CM} = Capital Costs Contingencies Cost Model$ .

<sup>&</sup>lt;sup>97</sup> In case of *system of transmission* and *collecting point* of electricity which extends from each wind turbine to the substation and point of interconnection with the grid of distribution.

 $<sup>^{98}</sup>$  UCRF converts the current value in the flow of equal annual payments over a specified period of time "t", "i" the rate specified discount (interest). For  $LCOE_{wso}$  model "t" is the lifetime of the wind farm (t=N) and "i" is the weight average costs of capital of the project ( $i=WACC_{proj}$ ) for UCRF calculation. In Eqn 5.19 shows UCRF calculation, where "i" = discount rate and "t" = number of periods in years.

The wind turbines investment costs ( $WT_{CM}$ ) were developed considering the wind turbine cost for manufacturer ( $CM_{WT}$ ), number of turbines in the wind farm ( $N_{WT}$ ), market cost adjustment ( $MC_A$ ) and uniform capital recovery factor (UCRF). For George and Schweizer (2008) market cost adjustment "reflects a number of factors, which are not believed to be fundamentally technology-related to the turbine cost estimate". Then,  $WT_{CM}$  can be calculated with the Eqn 6.2.1.1:

$$WT_{CM} = [N_{WT}(CM_{WT} + MC_A)]UCRF$$
 [\$/kW] Eqn (6.2.1.1)

where  $CM_{WT}$  can be calculated within the *percentage cost for the wind turbine component*, with the *total relative cost* ( $RC_{WT}$ ), *cost of kW installed* ( $C_{kW}$ ) and *industrialized product taxes* (*IPT*). This formulation was shown in Eqn 6.2.1.1.1 as follows:

$$CM_{WT} = (RC_{WT}C_{kW})(1-IPT)$$
 [\$/kW] Eqn (6.2.1.1.1)

Another important element of capital cost for wind projects is the wind turbine tower. We called "*Towers Cost Model*". According to Oliveira and Fernandes (2012a) towers figure 30-65% of WECS weight and 10-25% of the costs.  $T_{CM}$  model was based on Fingersh, Hand, and Laxson (2006) which have been considered the scalar relation among, *rotor diameter (D)*, *swept area (A)* and *hub height* ( $H_h$ ). For a given wind farm, the total towers cost is also the product of the *percentage cost for the wind tower component (RC<sub>T</sub>)*, with the *wind turbines investment costs (WT<sub>CM</sub>)*, mass of each tower ( $T_{mass}$ ), cost of steel ( $C_{steel}$ ) and uniform capital recovery factor (*UCRF*). The cost of the towers often depends on fluctuations in the cost of steel, which is the main production material for the modern towers (Jamieson, 2011).  $T_{CM}$  was written in Eqn. 6.2.1.2:

$$T_{CM} = \left[ RC_T \left( T_{mass} C_{steel} \right) \right] UCRF \qquad [\$/kW] \qquad \text{Eqn (6.2.1.2)}$$

The cost of connections for a wind farm is an important initial cost item which has been considered as "Local Wind Turbines Grid Cost Model"<sup>99</sup> (LWTG<sub>CM</sub>). The internal electrical grid installation of the wind farm comprises the medium voltage grid in the wind farm up to a common point and the necessary medium voltage switch gear at that point. The total costs for this item ranges from 3 to 10 % of the total costs of the complete wind farm. It depends on local equipment prices, technical requirements, soil conditions, the distance between the turbines, the size of the wind farm and

<sup>&</sup>lt;sup>99</sup> According to research boundary (section 6.4.4.1) was focused only on local (internal) grid of the wind farm, but the costs for grid connection can be split up in two. The costs for the local (internal) electrical installation and the costs for connecting the wind farm to the electrical grid for distribution.

hence the voltage level for the line to the connecting point of existing grid (European Commission, 2001).  $LWTG_{CM}$  proposed was formulated as shown in Eqn 6.2.1.3:

$$LWTG_{CM} = \frac{\left[\left(L_g CAB_{cost}\right) + MC_A\right]UCRF}{WF_{cap}} \qquad [\$/m/kW] \qquad \text{Eqn (6.2.1.3)}$$

Then  $LWTG_{CM}$  could be understood as a product of the *local grid length* ( $L_g$ ) and *cables cost* ( $CAB_{cost}$ ) including skilled labor. It was also considered the *market cost adjustment* ( $MC_A$ ) for the cables materials` life-cycle and *uniform capital recovery factor* (UCRF) per *wind farm electric installed capacity* ( $WF_{cap}$ ). The length of the grid is affected by the wind farm and grid layouts, type of cables, orography and other electrical configurations of the power plant.

The Collecting Point Cost Model  $(CP_{CM})$  was developed considering the function of this investment item for the wind farm as a whole to the wind farm, as an *electrical substation* (already explained in footnote 93). The "collecting point" also called "integration system" manages the voltage from high to low, or the reverse, or performs any of several other important functions for the output power quality. That is why for our  $CP_{CM}$  proposed has been considered a fixed part for transformers, and other *electrical facilities*  $(EF_c)$  added the cost ( $\varsigma$ ) per wind farm electric installed capacity ( $WF_{cap}$ ) and uniform capital recovery factor (UCRF).  $CP_{CM}$  was formulated within Eqn 6.2.1.4:

$$CP_{CM} = \left(EF_c + \varsigma WF_{cap}\right)UCRF \qquad [\$/kW] \qquad \text{Eqn (6.2.1.4)}$$

The present methodology also has taken into consideration the transmission system. We have called "*Transmission System Cost Model*".  $TS_{CM}$  proposed was based on DeCarolis and Keith (2006) when have been considered the *transmission line cost* ( $TL_c$ ), *transmission line thermal rating*<sup>100</sup>( $TL_r$ ), *transmission line length* ( $L_t$ ) and *substation cost of transmitting* ( $SB_c$ ). It also has been considered the *market cost adjustment* ( $MC_A$ ) for the cables materials` life-cycle and *uniform capital recovery factor* (*UCRF*). The following Eqn 6.2.1.5 represents  $TS_{CM}^{101}$ :

$$TS_{CM} = \left[ \left( \frac{TL_c}{TL_r} L_t \right) + SB_c + MC_A \right] UCRF \qquad [\$/kW_e] \qquad \text{Eqn (6.2.1.5)}$$

<sup>&</sup>lt;sup>100</sup> The current carried by a given transmission line conductor which results in the maximum allowable conductor temperature for a particular set of weather parameters. <sup>101</sup> The transmission line cost (TL) transmission line thermal ratios (TL) transmission line length (L) and substation cost of

<sup>&</sup>lt;sup>101</sup> The transmission line cost ( $TL_c$ ), transmission line thermal rating ( $TL_r$ ), transmission line length ( $L_t$ ) and substation cost of transmitting ( $SB_c$ ) are measure in m; 1/kW; km and \$/kW, respectively.

A large and medium wind power plant will require a maintenance facility for storing trucks, service equipment, spare parts, lubricants, and other supplies. The maintenance facility may be located onor off-site. Some wind farms combine control and maintenance functions in one building (see Figure 4.16). The model developed during this research called "Supporting Infra-structure Cost Model" (SI<sub>CM</sub>) was based on building cost (Bld<sub>cost</sub>), building area (Bld<sub>area</sub>), per wind farm electric installed capacity (WF<sub>cap</sub>) for contingencies and uniform capital recovery factor (UCRF). We have also considered the wind turbine installation (WT<sub>inst</sub>) as the cost of RM<sub>WT</sub> added the RM<sub>CT</sub><sup>102</sup>. The variables<sup>103</sup> used for SI<sub>CM</sub> were organized as shown in Eqn 6.2.1.6:

$$SI_{CM} = \left[\frac{\left(Bld_{cost}Bld_{area}\right)}{WF_{cap}}UCRF + WT_{inst}\right] \qquad [\$/m^2/kW] \qquad \text{Eqn (6.2.1.6)}$$

The *pre-operational phase*<sup>104</sup> of the power plant is an important part for life-cycle cost analysis, especially in the case of wind projects. As we have discussed in section 4.6 of this Ph.D. research work, this phase could reach 4 years of activities and resources (see Figures 4.13 and 5.1) and obvious costs associated to the same period. We have developed the "*Pre-operational Cost Model*" (*PO*<sub>CM</sub>). *PO*<sub>CM</sub> was based on the *Feasibility Studies* (*FS*), *Development (DT)* and *Engineering (EG)* per *wind farm electric installed capacity (WF*<sub>cap</sub>) and *uniform capital recovery factor (UCRF)*. The variables used for *PO*<sub>CM</sub> were organized as shown in Eqn 6.2.1.7:

$$PO_{CM} = \left[ \left( FS + DT + EG \right) UCRF \right] \qquad [\$/kW] \qquad \text{Eqn} (6.2.1.7)$$

Wind projects with its capital-intensive nature, in general, are implemented with project financing operations in the beginning of project's lifetime. The capital structure of an analyzed wind power project has influenced on the finance cost. Capital structure refers to the mix of debt and equity in the power project. The "*Financing Cost Model*" ( $F_{CM}$ ) proposed was based on Damodaran (2001) which has been considered the *percentage* ( $w_{F_{CM}}$ ) of *Weighted Average Cost of Capital* calculation of weighted average cost of funding sources, in which the weight of each one is considered for each funding position during the *pre-operational phase* ( $n_{fin}$ ) of the wind project.  $F_{CM}$  was formulated as the product of  $w_{F_{CM}}$ , *WACC*<sub>proj</sub> and the sum of capital investment cost ( $WT_{CM}$ ,  $T_{CM}$ ,  $LWTG_{CM}$ ,  $CP_{CM}$ ,  $TS_{CM}$ ,  $SI_{CM}$  and  $PO_{CM}$ ). The following Eqn 6.2.1.8 represents  $F_{CM}$ :

$$F_{CM} = w_{F_{CM}} \left[ 1 + WACC_{proj} \right]^{n_{fin}} \left[ \sum \left( WT_{CM} + T_{CM} + LWTG_{CM} + CP_{CM} + TS_{CM} + SI_{CM} + PO_{CM} \right) \right] \quad [\$/kW] \quad \text{Eqn (6.2.1.8)}$$

<sup>&</sup>lt;sup>102</sup> The literature confirm that the same equipment and cost are similar, but considering the effect of time, so the *cost of wind turbine installation (WT<sub>inst</sub>)* is defined as analogous as the sum of *removal wind turbine (RM<sub>WT</sub>)* and *concrete (RM<sub>CT</sub>)*,  $WT_{inst} = RM_{WT} + RM_{CT}$ . <sup>103</sup>  $Bld_{cost}$  (\$/m<sup>2</sup>) and  $Bld_{area}$  ( $m^2$ ).

<sup>&</sup>lt;sup>104</sup> The *pre-operational phase* includes all of the activities required before production of the power plant. These activities are usually technical studies, construction and equipment installation, testing and technical adjustments.

The balance of system and miscellaneous costs typically includes a number of items such as building and yard construction, spare parts, transportation, training & commissioning, contingencies and interest during construction (RETScreen® International Clean Energy Decision Support Centre, 2009): "Capital Costs Contingencies Cost Model" (CCC<sub>CM</sub>) proposed was formulated with a *percentage* ( $\kappa$ ) of *capital costs* for contingencies of the power project. The following Eqn 6.2.1.9 represents CCC<sub>CM</sub>:

$$CCC_{CM} = \kappa \left[ \sum LWTG_{CM} + CP_{CM} + TS_{CM} + SI_{CM} + PO_{CM} + F_{CM} \right]$$
 [\$/kW] Eqn (6.2.1.9)

#### Levelized Replacement Cost Model (LRCM)

According to NREL (1995) the Levelized Replacement Cost (LRC) is a cost component used as a saving account for the wind power project. Depending on the technical details of the power plant, the major review of the power system occurs every 5, 10 or 15 years. The proposed "Levelized Replacement Cost Model" (LRCM) was formulated considering the "Annual Replacement Cost Model" (AR<sub>CM</sub>) and "Technological Obsolescence Cost Model" (TO<sub>CM</sub>).

$$LRCM = AR_{CM} + TO_{CM} \qquad [\$/kW] \qquad \text{Eqn (6.2.2)}$$

"Annual Replacement Cost Model" ( $AR_{CM}$ ) was developed within the principles: (a) as an economic reserve for future expendures; (b) the money cost is influenced by the time and (c)  $AR_{CM}$  is also affected by  $O\&M_{WFCM}$ . We have been considered for  $AR_{CM}$  wind turbines ( $WT_{CM}$ ) and towers ( $T_{CM}$ ) costs. It was also adopted the *inflation rate* ( $if_r$ ) to ensure the effect of time on investments and available funds within the present value of annual stream of reserve for major replacements and overhauls over the life of the wind power system when payments for event occurring in year needed ( $Y_{RC}$ )<sup>105</sup> have to be made.". When we refer to depreciation<sup>106</sup> of the equipment and installations, the proposed  $AR_{CM}$  has been considered the difference of depreciation of wind turbines with towers ( $Depr_{WT_{inst}}$ ) and the depreciation in the year ( $Depr_{Y_{RC}}$ ) when the major review of the power system was programmed.

$$AR_{CM} = Depr_{WT_{inst}} - Depr_{Y_{PC}}$$
 [\$/kW] Eqn (6.2.2.1)

<sup>&</sup>lt;sup>105</sup>  $O\&M_{WFCM}$  possible can affect the overall turbine availability as well as the downtimes during replacements and overhauls. Economically, if  $O\&M_{WFCM} > LCCCM_{WF}$  per kW we consider it is time to make the replacements and overhauls necessary to the power system becomes again economically interesting! <sup>106</sup> The accounting mechanism for the reduction in value of a capitalized item (tangible assets) due to utilization or loss of usefulness by

<sup>&</sup>lt;sup>106</sup> The accounting mechanism for the reduction in value of a capitalized item (tangible assets) due to utilization or loss of usefulness by utilization, action of nature or aging. The precise definition and the schedule of reduction will vary widely, depending on the use. Frequently associated with capital cost deductions for income tax purposes (NREL, 1995).

where  $Depr_{WT_{inst}}$  can be calculated by the Eqn 6.2.2.1.1 as follows:

$$Depr_{WT_{inst}} = \left[ \left( \frac{WT_{CM} + T_{CM}}{N} \right) \right] \left[ \left( 1 + if_r \right)^N \right] \qquad [\$/kW] \qquad \text{Eqn } (6.2.2.1.1)$$

and  $Depr_{Y_{pc}}$  can be calculated by the Eqn 6.2.2.1.2 as follows:

$$Depr_{Y_{RC}} = \left[ \left( \frac{WT_{CM} + T_{CM}}{N} \right) \right] \left[ \left( 1 + if_r \right)^{Y_{RC}} \right] \qquad [\$/kW] \qquad \text{Eqn (6.2.2.1.2)}$$

We also analyzed the *technological obsolescence effect* for the power system as a cost (view of investor), considering during the lifetime of the wind project, the technological option chosen for that specific power plant could not be changed easily, even when the investor decides to repower the system in the end of its lifetime, if it is worth it!! That is why we have aggregated the effect of technological obsolescence to *LRCM*. The technological obsolescence and improvement can be understood as an inverse relation, so, *LRCM* was formulated within the inverse of technology improvements (*TI*)<sup>107</sup> described by Lund (2006).

$$TO_{CM} = \left[ \left( \frac{WT_{CM} + T_{CM}}{N} \right) \right] \left[ \left( \frac{1}{TI} \right) (1 + if_r)^{v_{RC}} \right] \qquad [\$/kW] \qquad \text{Eqn (6.2.2.2)}$$

where TI can be calculated by the Eqn 6.2.2.2.1 as follows:

$$TI \Rightarrow cv = c_0 \left[\frac{V_0}{V}\right]^b$$
 [\$/kW] Eqn (6.2.2.2.1)

where "c" and "c<sub>0</sub>" are the current and initial costs (\$/kW); V and V<sub>0</sub> the current and initial cumulative volume (kW); "b" is the learning parameter. Moreover,  $b = \frac{\ln 2}{\ln PR}$ , where PR is the progress ratio<sup>108</sup>.

<sup>&</sup>lt;sup>107</sup> The unit cost drops by *1*- *PR* for each doubling of the cumulative volume. In the case of wind power, the cumulative volume is considered the cumulative installed capacity in a region. The learning curve describes the effects *of learning by doing* or by using the new technology and transforms the experiences gained through manufacturing and utilization into cost reductions (Lund, 2006). <sup>108</sup> According to Junginger, Faaij, and Turkenburg (2005) the progress ratio (*PR*) is a parameter that expresses the rate at which costs

<sup>&</sup>lt;sup>108</sup> According to Junginger, Faaij, and Turkenburg (2005) the progress ratio (PR) is a parameter that expresses the rate at which costs decline each time the cumulative production doubles.

As discussed by Pan and Köhler (2007) the learning effect (technology improvements) as described by a learning curve combines the effects of both real price and technological change. If a learning curve is measured at constant prices, the price effect is cancelled out and the curve reflects technological change only. This situation justified the adoption of *inflation effect* (*if<sub>r</sub>*) on the *TO<sub>CM</sub>* which usually both effects of real price change and technological change are included in the cost reduction — both effects imply or reflect the technology cost reductions as the number of physical installations has increased.

#### Wind Farm $O\&M Cost Model (O\&M_{WFCM})$

The *operations and maintenance* (O&M) of a wind farm is driven by its size, model of turbines, location and other technical and economic conditions. The objective of O&M is to enable desired component performance by maintaining or returning the component's ability to function correctly (Nilsson & Bertling, 2007). The *Wind Farm O&M Cost Model (O\&M\_{WFCM})* has been developed considering a *fixed (O\&M\_{fixed cu})* and *variable (O\&M\_{variable cu})* part, as shown in Eqn 6.2.3:

$$O\&M_{WFCM} = O\&M_{fixed} + O\&M_{variable_{CM}}$$
 [\$/kWh] Eqn (6.2.3)

 $O\&M_{fixed}_{CM}$  was oriented to those costs incurred during the operation phase of the project and are constant at all scales of production, even when the wind farm is stopped. We have proposed a *percentage* ( $\varpi$ ) of *wind farm life-cycle capital cost model* (*LCCCM<sub>WF</sub>*) and *land lease cost* (*LLC*) per kWh. We also have considered the *effect* (*rate*) of *inflation* (*if*<sub>r</sub>) during *the lifetime of the wind farm* (*N*).  $O\&M_{fixed}_{cu}$  was written in Eqn 6.2.3.1:

$$O\&M_{fixed_{CM}} = \varpi LCCCM_{WF} + LLC(1 + if_r)^{n} \qquad [\$/kWh] \qquad \text{Eqn} (6.2.3.1)$$

Meanwhile  $O\&M_{variable_{CM}}$  was driven to those costs incurred during the production phase and varies according to the scale of production. This part of  $O\&M_{WFCM}$  includes staffing, operations, planned (predictive) unplanned maintenance<sup>109</sup>, materials and other consumables, operation services, revenues taxes, and unforeseen expenses.  $O\&M_{variable_{CM}}$  was formulated based on Zhang et al. (2010), have been considered the costs covered by manufacturer ( $O\&M_{ccm}$ ), period of warranty  $(n_w)$ , maintenance labor cost (MLC) per hour, number of hours for maintenance labor  $(n_{mlh})$ , number of hours for technical labor  $(n_{tlh})$ , technical labor cost (TLC) per hour and revenue taxes

<sup>&</sup>lt;sup>109</sup> For more details about wind farm maintenance, please see at Endrenyi et al. (2001).

 $(R_{taxes})$ . We also have considered the *effect* (*rate*) of *inflation* (*if*<sub>r</sub>) during *lifetime of the wind farm* (*N*), as shown in Eqn 6.2.3.2:

$$O\&M_{variable_{CM}} = \left( \left( \frac{(MLC \times n_{mlh}) + (TLC \times n_{ilh})(1 + if_r)^{N-n_w}}{AEP_{avail}} \right) (1 - O\&M_{ccm}) + R_{taxes} \left( \frac{AAR}{AEP_{avail}} \right) \right) \quad [\$/kWh] \quad \text{Eqn (6.2.3.2)}$$

For Schreck and Laxson (2005) *O&M* costs for wind power plants shall include, and be supported by, a tabular listing of the following annual costs:

- ☆ Labor, parts and supplies for scheduled maintenance;
- ☆ Labor, parts and supplies for unscheduled maintenance;
- ✤ Parts and supplies for equipment and facilities maintenance;
- $\Leftrightarrow$  Labor for administration and support.

In the proposed  $O\&M_{WFCM}$  was done a separation of O&M costs because we believe that the costs for O&M could have two types of behavior, one related to the power plant itself (size, land area, and other administrative expenses) and other related to the production of the wind farm. Christopher (2003) has highlighted the effort to minimize wind turbine O&M costs must start with a better understanding of the current costs and other factors that drive these costs. This first step could allow development of a sound cost model for evaluating the performance of existing wind farms and enable estimating the cost of proposed projects with reasonable certainty. Some of the factors that have been driven the costs would be common to wind power projects in general, but other factors would be site specific. Detailed information about specific failure types, along with the operating conditions, would allow for an accurate model that could be adapted to different machine types and environments.

The maintenance and technical labor costs (MLC and TLC) could be determined considering the relation of Annual Failure Frequency (AFF) and Repair Costs (RC). Determining the maintenance costs of a wind farm could be similar to the approach for asset management and risk analyses have been used in many branches of industry in general. For Obdam, Braam, Rademakers, and Eecen (2007) this approach<sup>110</sup> could be written as:

Annual  $O\&M \cos ts = AFF \times RC$  [\$/kWh] Eqn (6.2.3.3)

<sup>&</sup>lt;sup>110</sup> In the proposed  $O\&M_{WFCM}$  this approach has not been considered because the focus and objective of the Ph.D. research work, therefore this approach is directly applied *corrective maintenance*, so in the case of wind power plants would not be enough for expressing the O&M costs totally.

### Wind Farm Removal Cost Model (RCM<sub>WF</sub>)

As we have already stated a wind farm as a project there must have an end of its economic lifetime of operation. The removal phase of WECS, when it was decided to repower the wind farm, is as important as the installation phase. There is not too much literature about uninstalling phase of WECS within its costs associated.

The wind farm removal costs depend a great deal on permit requirements and turbine and sitespecific aspects such as how deep the foundations are poured, capacity, and other. For wind developers the cost to remove a wind farm is usually an estimation during the planning stages, but rather assume that salvage value of the wind farm, specific the turbines, would really cover those expenses when the time comes at the end of the project operation phase<sup>111</sup>. The most common way to estimate removing costs is to assume that the future residual value of the turbines will be 5-10% of the initial equipment cost, or to guess what the value of steel and copper and the other metals in the turbine would be in 20-25 years (Botterud, 2003).

"Wind Farm Removal Cost Model" (RCM<sub>WF</sub>) was developed within the main principles: (a) assure funds enough at the end of operational phase to remove or repower the power plant and (b) reduce as most as possible the local microenvironment impact caused by the wind farm. We have been considered for  $RCM_{WF}$  the Wind Farm Decommissioning Cost Model ( $DCM_{WF}$ ) and Wind Farm Residual Value Model ( $RVM_{WF}$ ): For both sub-models were also adopted the inflation rate (if<sub>r</sub>) and UCRF to ensure the effect of time on investments and available funds within the present value of annual stream of monetary reserve.  $RCM_{WF}$  could be formulated by Eqn 6.2.4:

$$RCM_{WF} = DCM_{WF} - RVM_{WF} \qquad [\$/kW] \qquad \text{Eqn (6.2.4)}$$

 $DCM_{WF}$  was formulated per wind turbine, considering man-hour  $(M_{hr})$ , cost of man-hour  $(C_{Mhr})$ , number of machines/equipment  $(N_m)$ , time of utilization for machines/equipment in days  $(D_m)$ , cost per day  $(C_{md})$  and wind farm electric installed capacity  $(WF_{cap})$ . We have also considered the following activities: (1) Removal of wind turbines  $(RM_{WT})$ ; (2) Removal of concrete  $(RM_{CT})$  and (3) Seeding and re-vegetation  $(S\&RV)^{112}$ . RCM<sub>WF</sub> could be calculated by Eqn 6.2.4.1:

$$DCM_{WF} = RM_{WT} + RM_{CT} + S\&RV$$
 [\$/kW] Eqn (6.2.4.1)

then,

<sup>&</sup>lt;sup>111</sup> Many wind farms are not decommissioned, but are repowered. If a site is proven to have good wind resources, in many instances it makes more sense to replace turbines as needed rather than remove the entire facility. A decommissioning fund could be directed to repowering at the appropriate time.

Average of ~2 acres (0.8093712844 ha)/turbine including collection system.

$$RM_{WT} = \frac{N_{WT} \left[ \left( M_{hr_{RM_{WT}}} C_{Mhr_{RM_{WT}}} \right) + \left( N_{m_{RM_{WT}}} D_{m_{RM_{WT}}} C_{md_{RM_{WT}}} \right) \right]}{WF_{cap}} \left( 1 + if_r \right)^{N+1} \quad [\$/kW] \text{ Eqn } (6.2.4.1.1)$$

where  $M_{hr_{RM_{WT}}}$  is the man-hour for  $RM_{WT}$ ;  $C_{Mhr_{RM_{WT}}}$  is the cost of man-hour for  $RM_{WT}$ ;  $N_{m_{RM_{WT}}}$  the number of machines/equipment for  $RM_{WT}$ ;  $D_{m_{RM_{WT}}}$  time (days) of utilization for machines/equipment for  $RM_{WT}$  and  $C_{md_{RM_{WT}}}$  cost per day for  $RM_{WT}$ .

and,

$$RM_{CT} = \frac{N_{WT} \left[ \left( M_{hr_{RM_{CT}}} C_{Mhr_{RM_{CT}}} \right) + \left( N_{m_{RM_{CT}}} D_{m_{RM_{CT}}} C_{md_{RM_{CT}}} \right) \right]}{WF_{cap}} \left( 1 + if_r \right)^{N+1} \quad [\$/kW] \quad \text{Eqn (6.2.4.1.2)}$$

where  $M_{hr_{RM_{CT}}}$  is the man-hour for  $RM_{CT}$ ;  $C_{Mhr_{R_{CT}}}$  is the cost of man-hour for  $RM_{CT}$ ;  $N_{m_{RM_{CT}}}$  the number of machines/equipment for  $R_{CT}$ ;  $D_{m_{RM_{CT}}}$  time (days) of utilization for machines/equipment for  $RM_{CT}$  and  $C_{md_{RM_{CT}}}$  cost per day for  $RM_{CT}$ .

and,

$$S\&RV = \frac{N_{WT}A_{WT} \left[ \left( M_{hr_{S\&RV}} C_{Mhr_{S\&RV}} \right) + \left( N_{m_{S\&RV}} D_{m_{S\&RV}} C_{md_{S\&RV}} \right) \right]}{WF_{cap}} \left( 1 + if_r \right)^{N+1} \quad [\$/kW] \qquad \text{Eqn (6.2.4.1.3)}$$

where  $A_{WT}$  is the area per wind turbine;  $M_{hr_{S&RV}}$  is the man-hour for S&RV;  $C_{Mhr_{S&RV}}$  is the cost of man-hour for S&RV;  $N_{m_{S&RV}}$  the number of machines/equipment for S&RV;  $D_{m_{S&RV}}$  time (days) of utilization for machines/equipment for S&RV and  $C_{md_{S&RV}}$  cost per day for S&RV.

Wind Farm Residual Value Model ( $RVM_{WF}$ ) was formulated within the main considerations: (a) scrap value of wind turbine and (b) scrap value of steel tower. We have considered for  $RFM_{WF}$  the Wind Turbine Scrap Value Model ( $WTS_{VM}$ ) and Tower Scrap Value Model ( $TS_{VM}$ ).  $RVM_{WF}$  could be formulated by Eqn 6.2.4.2:

$$RVM_{WF} = N_{WT}(WTS_{VM} + TS_{VM})$$
 [\$/kW] Eqn (6.2.4.2)

where  $WTS_{VM}$  was formulated taking into consideration the *weight of a wind turbine* ( $WT_{weight}$ ) and the *cost of steel* ( $C_{steel}$ ). As we have thought about the wind farm lifetime, for  $RCM_{WF}$  was considered one more year for total removal process for the wind farm in question. It was also adopted the *inflation rate* (*if*<sub>r</sub>) during this period.  $WTS_{VM}$  can be written as Eqn 6.2.4.2.1:

$$WTS_{VM} = \left[\frac{\left(WT_{weight}C_{steel}\right)}{WF_{cap}}\right] (1 + if_r)^{N+1} \qquad [\$/kW] \qquad \text{Eqn } (6.2.4.2.1)$$

and  $TS_{VM}$  was also formulated taking into consideration the mass<sup>113</sup> of each tower ( $T_{mass}$ ) and the cost of steel ( $C_{steel}$ ). As we have thought about the wind farm lifetime, for  $RCM_{WF}$  was considered one more year for total removal process for the wind farm in question. It was also adopted the *inflation rate* (*if*<sub>r</sub>) during this period.  $TS_{VM}$  can be written as Eqn 6.2.4.2.2:

$$TS_{VM} = \left[\frac{\left(T_{mass}C_{steel}\right)}{WF_{cap}}\right] \left(1 + if_r\right)^{N+1} \qquad [\$/kW] \qquad \text{Eqn (6.2.4.2.2)}$$

If the wind farm was built with different wind turbines and towers in relation to the sizes, weights (both wind turbines and towers) and technologies, it will be necessary consider individually. We have to make the calculations for  $WTS_{VM}$  and  $TS_{VM}$  one-by-one and sum all for finding  $RVM_{WF}$ . Eqn 6.2.4.3 has expressed it:

$$RVM_{WF} = \sum \left( WTS_{VM_a} + ... + WTS_{VM_n} + TS_{VM_a} + ... + TS_{VM_n} \right) \qquad [\$/kW] \qquad \text{Eqn (6.2.4.3)}$$

But the most common situation is the wind farm has been settled-up with a homogeneous technology, both for wind turbines and towers, so the Eqn 6.2.4.2 can easily find  $RVM_{WF}$  for a specific wind farm.

<sup>&</sup>lt;sup>113</sup> The mass of a wind tower can be calculated by the relation  $A \times H_h$ , where A is the swept area and  $H_h$  the hub height. For more details, see at Fingersh et al. (2006).

## Renewable Energy Public Incentive Model (REPIM)

Globally, governments tend to appreciate the advantages of renewable energy production more than conventional energy production. Therefore, the support for expansion of production capacity of renewable energy in many ways, which basically aim to reduce the disadvantages of most technologies for renewable energy production: the cost and the lack of controllability. The disadvantage of the cost is in most cases decreased through the socialization of the burden by some form of subsidy or incentive. An example is forcing electricity companies to buy energy from renewable sources at a price that is not based on the actual cost of this energy, but it is calculated in such a way that the renewable energy project become profitable for the investor (Oliveira, 2010). In Figure 6.17 are briefly the main policy instruments for the promotion of renewable energy.



Figure 6.17 Typology of energy policy instruments. Source: Enzensberger et al. (2002)

We has followed the classification of Enzensberger et al. (2002) for *Renewable Energy Public Incentive Model (REPIM)* when we have considered the *market-based (economic)* instruments conception (see Figure 6.17). We have taken a look into the current market status and trends, e.g. electricity market liberalized<sup>114</sup> as result *REPIM* was orientated by *supply* and *demand-push approach*<sup>115</sup> into the following sub-models: (1) Renewable Energy Investment Credit Mode (*REI*<sub>CM</sub>); (2) Renewable Energy Production Credit Mode (REP<sub>CM</sub>); (3) Other REPs Credit Mode (*OREP*<sub>CM</sub>) and (4) GHG Reduction Credit Model (GHG.R<sub>CM</sub>). So, REPIM could be formulated as shown in Eqn 6.2.5:

<sup>&</sup>lt;sup>114</sup> For Menz and Vachon (2006) if the renewable energy market continuing rise fossil fuel prices, renewable energy technologies will become more economically attractive to consumers. In that context, market-based voluntary measures might play an increasingly important role in future wind power development.

<sup>&</sup>lt;sup>115</sup> For more details about *supply and demand-push approaches*, see at Grubb (2004); Jamasb (2007).

$$REPIM = REI_{CM} + REP_{CM} + OREP_{CM} + GHG.R_{CM} \quad [\$/proj] \qquad Eqn (6.2.5)$$

Then, as we have said *REPIM* and sub-models as  $REI_{CM}$  were also orientated by *supply-push approach* for initial investments in order to reduce the huge amount of capital in the initial life of the project, and consequently, reduce de final cost of energy produced from the wind power plant.  $REI_{CM}$  has been impacted on *investments* (*LCCCM<sub>WF</sub>*) and *overhaul expenses* (*LRCM*). Mathematically, Eqn 6.2.5.1 is shown this relation:

$$REI_{CM} = \frac{\psi_{total} \left( LCCCM_{WF} + LRCM \right)}{n_{\psi}} \left( 1 + ifr \right)^{n_{\psi}} \quad [\$/kW_e] \qquad \text{Eqn (6.2.5.1)}$$

where  $(\psi_{total})$  is the *total investment tax credit* given by government during the *time of policy energy instrument*  $(n_{\psi})$  and also considering the *inflation rate*  $(if_r)$  for the same time of instrument effect. It also must be calculated year by year, until be concluded the whole period of  $n_{\psi}$ .

For  $REP_{CM}$  were also orientated by *demand-push approach* for wind farm production in order to reduce the final *LCOE*.  $REP_{CM}$  have been impacted on  $AEP_{avail}/H_{prod}$  sold to the distribution grids per *wind farm electric installed capacity* ( $WF_{cap}$ ): Eqn 6.2.5.2 has been shown this instrument:

$$REP_{CM} = \varepsilon \left( \frac{AEP_{avail}}{H_{prod}} WF_{cap} \right) \qquad [\$/kW_eh] \qquad Eqn (6.2.5.2)$$

where ( $\varepsilon$ ) must be calculated considering *initial value paid by government* ( $\varepsilon_0$ ), *time of policy* energy instrument ( $n_{\varepsilon}$ ) and inflation rate (if<sub>r</sub>) for the same time of instrument effect. So, the *final* value paid by government ( $\varepsilon$ ) can be found by Eqn 6.2.5.2.1:

$$\varepsilon = \varepsilon_0 \left( 1 + i f r \right)^{n_{\varepsilon}} \qquad [\$/kW_{e}h] \quad \text{Eqn} (6.2.5.2.1)$$

Many types of energy policy instruments can be adopted by governments worldwide, but fundamentally these instruments are divided into *investment focused* and *production based* (Haas et

al., 2004). The Other REPs Credit Model (OREP<sub>CM</sub>) was developed considering a cover risk factor  $(CR_f)^{116}$ , time of policy energy instrument  $(n_{\psi})$  and discount given by the government  $(\psi_{total})$  for capital cost of the project (WACC<sub>proj</sub>). Eqn 6.2.5.3 has shown  $LCCCM_{WF_{OREGCM}}$  calculation:

$$LCCCM_{WF_{OREP_{CM}}} = \left[\frac{\left(LCCCM_{WF}WACC_{proj}\psi_{total}\right)\left(1 - CR_{f}\right)}{\left(1 + ifr\right)^{n_{\psi}}}\right] [\$/kW_{e}] \qquad \text{Eqn (6.2.5.3)}$$

where  $(CR_f)$  is the *financing risk*<sup>117</sup> for a given wind power project,  $(\psi_{total})$  is the *total investment tax credit* given by government during the *time of policy energy instrument*  $(n_{\psi})$  and also considering the *inflation rate*  $(if_r)$  for the same time of instrument effect. It also can be calculated year by year, until be concluded the whole period of  $n_{\psi}$ .

 $OREP_{CM}$  was developed to show how much the government incentive for this energy instrument is, we also could find it by the relation among the initial  $LCCCM_{WF}$ ,  $LCCCM_{WF}$ , and  $AEP_{avail}/H_{prod}$ , so the equation can be written as Eqn 6.2.5.3.1:

$$OREP_{CM} = \left[ \left( \frac{LCCCM_{WF_{OREP_{CM}}}}{LCCCM_{WF}} \right) \left( \frac{AEP_{avail}}{H_{prod}} \right) \right] \quad [\$/kW_e] \qquad Eqn (6.2.5.3.1)$$

Finally, to complete *REPIM* was developed *GHG*. $R_{CM}$  or *GHG Reduction Credit Model* for also associate the effect of GHG reduction in function of RET for producing green electricity. According to El-Kordy et al. (2002) external cost for electricity production are expressed by emissions from electric power plants which are generally evaluated based on the plant specifications, although, it could be hard to estimate a "*typical*" set of emissions for any resource type.

 $GHG.R_{CM}$  was developed considering Life-Cycle Emission Reduction for  $CO_2$  (LCER<sub>CO2</sub>) which can be found by the difference of GreenHouse Gas Emission of  $CO_2$  from fossil fuel ( $GHG_{EM_{ff}co_2}$ ) and GreenHouse Gas Emission of  $CO_2$  from WECS ( $GHG_{EM_{WECS}CO_2}$ ).

<sup>&</sup>lt;sup>116</sup> We have considered a risk factor for  $OREP_{CM}$  energy policy instrument in order to be more realistic to the wind power market and developed an instrument which associates the importance and impact of the risk in the projects, usually supported by government's actions. The *Cover Risk Factor* (*CR<sub>f</sub>*) can be classified into *price*, *technical* and *financial risks*. *CR<sub>f</sub>* works as a project security. For more details, please see at Gross, Blyth, and Heptonstall (2010); Gross, Heptonstall, and Blyth (2007).

<sup>&</sup>lt;sup>117</sup> If  $r_{debt} > WACC_{prof}$ , then  $CR_f = 100\%$ ; If  $r_{debt} \cong WACC_{prof}$ , then  $CR_f = 50\%$ ; If  $r_{debt} < WACC_{prof}$ , then  $CR_f = 25\%$ .

We have also considered the product from the difference from these  $CO_2 \ emissions^{118}$  and the sum of the whole lifetime of the wind farm production ( $\sum AEP_{avail}_{y_{T_{1+...+y_n}}}$ ). Eqn 6.2.5.4 has shown how  $LCER_{CO_2}$  was written mathematically:

$$LCER_{CO_2} = \left(GHG_{EM_{ff_{CO_2}}} - GHG_{EM_{wecs_{CO_2}}}\right) \sum AEP_{avail_{yr_1+\ldots+yr_n}} [tCO_2/MW_eh] Eqn (6.2.5.4)$$

so  $GHG.R_{CM}$  was created considering a carbon credit ( $\varepsilon_c$ ) for each MW<sub>e</sub>h of  $LCER_{CO_2}$  given to the producer within an annual basis. This credit must be updated within the same formula as shown in Eqn 6.2.5.2.1.  $GHG.R_{CM}$  was formulated as Eqn 6.2.5.4.1:

$$GHG.R_{CM} = \varepsilon_c LCER_{CO_2} \qquad [\$/tCO_2] \qquad \text{Eqn (6.2.5.4.1)}$$

It is important to highlight each of these energy policy instruments suggested by *REPIM* could be adopted more than one type for the same wind power project. In  $LCOE_{wso}$  we have considered four types of wind energy policy instruments (*REI*<sub>CM</sub>; *REP*<sub>CM</sub>; *OREP*<sub>CM</sub> and *GHG*.*R*<sub>CM</sub>).: Depend on specific legislation where wind farm is located or will be located, is crucial to understand what is acceptable, due to one of the fundamental condition is the public and local authorities to approve the wind farm operation and licenses. So, if we adopt more than one instrument for the same project, we could possible suggest a percentage<sup>119</sup> ( $\xi_n$ ) for each one, as shown in Eqn 6.2.5.5:

$$REPIM = \xi_1 REI_{CM} + \xi_2 REP_{CM} + \xi_3 OREP_{CM} + \xi_4 GHG.R_{CM} \quad [\$/\text{proj}] \qquad \text{Eqn} (6.2.5.5)$$

<sup>&</sup>lt;sup>118</sup> According to Hondo (2005) the life-cycle emission factor of CO<sub>2</sub> for wind power could be about 30 g CO<sub>2</sub>/kWh (29.5 g CO<sub>2</sub>/kWh) and for fossil fuel (Oil-fired) about 742 g CO<sub>2</sub>/kWh (742.1 g CO<sub>2</sub>/kWh) within both lifetimes of 30 years and capacity factor of 20% and 70%, respectively. It is also possible to calculate it through *Electricity Emission Factors* (*EF*<sub>el</sub>) specific by country. For more details, please see at IEA (2011).

<sup>&</sup>lt;sup>119</sup> The sum  $(\sum \xi_{1+.,+4})$  of  $\xi_n$  has to totalize 100%.

## Wind Farm Life-Cycle Production Model (LCPM<sub>WF</sub>)

When we have proposed to develop a different approach to calculate and simulate the electricity production of a wind farm, first of all it was necessary understand how a wind farm works. In other words, how WECS works, so we have understood according to what was discussed in Chapter 4 that wind has presents power in itself, so WECS extracts its kinetic energy into mechanical and finally into electricity. Therefore, *Wind Farm Life-Cycle Production Model (LCPM<sub>WF</sub>)* was based on Moran and Sherrington (2007) when were also considered the wind farm installed capacity which was called *Wind Farm Capacity Model (WF<sub>CM</sub>)*; wind turbines layout effect to be analyzed by *Wind Turbines Layout Model (WT<sub>LM</sub>)*; *Power Curve Production Model (PC<sub>PM</sub>)* in function of the full load hours of Production (*FLH<sub>wf</sub>*) and hours of effective Production (*H<sub>prod</sub>*) in a year and  $P\&D^{120}$  Losses Model ( $P\&D_{LM}$ ) for determination of wind farm capacity factor ( $CF_{wf}$ ). LCPM<sub>WF</sub> could be mathematically written by Eqn 6.2.6:

$$LCPM_{WF} = f(WF_{CM}; PC_{PM}; WT_{LM}; P\&D_{LM})$$
 [kWh/yr] Eqn (6.2.6)

The Wind Farm Capacity Model ( $WF_{CM}$ ) was developed considering the *electrical installed* capacity of a wind farm ( $WF_{cap}$ ). We can find  $WF_{cap}$  through the relation between the number of wind turbines<sup>121</sup> ( $N_{WT}$ ) and wind turbine rated capacity ( $WT_{rated}$ ). In other words, for a certain year a wind farm could be expressed its installed capacity as shown in Eqn 6.2.6.1:

$$WF_{CM} \Rightarrow WF_{cap} = N_{WT}WT_{rated}$$
 [kWe/yr] Eqn (6.2.6.1)

We have also considered the effect of layout for  $LCPM_{WF}$  development as a sub-model the *Turbines Layout Model* ( $WT_{LM}$ ) in a linear configuration as have already explained in Chapter 4, section 4.5.1. So we have determined  $N_{WT}$  based on Mustakerov and Borissova (2010) when was taken into consideration the total number of turbines  $N_{WT}$  as the result from a multiplication of rows ( $N_{row}$ ) and columns ( $N_{col}$ ) turbines number<sup>122</sup>. Mathematically,  $N_{WT}$  can be written as Eqn 6.2.6.1.1:

$$WT_{LM} \Rightarrow N_{WT} = N_{row}N_{col}$$
 [-] Eqn (6.2.6.1.1)

P & D = Production and Distribution

<sup>&</sup>lt;sup>121</sup> The number of wind turbines for  $WF_{CM}$  must be count with operationing ones, which can change from year to year, depending on  $O\&M_{manag}$ , natural disaster (e.g. earthquake, floods, etc.), repowering process and other. The number of wind turbines for a given wind farm could be variable during the wind power plant lifetime.

<sup>&</sup>lt;sup>122</sup> It is applied to layout configuration as shown in Figure 4.19.

As we could notice  $N_{row}$  and  $N_{col}$  must be calculated in function of the land area<sup>123</sup> available, *land lease cost (LLC)* and depending on orography of specific project. The predominant wind direction also has to be taken into consideration when positioning wind turbines. For  $WT_{LM}$  we have already considered wind-oriented turbines. For Johnson (2001)  $N_{row}$  can be found as Eqn 6.2.6.1.2:

$$N_{row} = \frac{L_{x_{row}}}{SD_{x_{row}}} + 1$$
 [-] Eqn (6.2.6.1.2)

where  $L_{x_{row}}$  is the area with length (for row) and  $SD_{x_{row}}$  the separation distances between wind turbines.  $SD_x$  can be calculated by the turbine rotor diameter. Then,  $SD_{x_{row}}$  can also be a result from the coefficients ( $k_{row}$  and  $k_{col}$ ) and rotor diameter (D). Eqn 6.2.6.1.2 has expressed this relation:

$$SD_x = k_{row}D$$
 [-] Eqn (6.2.6.1.3)

therefore, Eqn 6.2.6.1.2 can be rewritten as:

$$N_{row} = \frac{L_{x_{row}}}{k_{row}D} + 1$$
 [-] Eqn (6.2.6.1.3)

and then the same analogy can be taken into the *number of wind turbines in a column* with the  $(SD_{xcol} = k_{col}D)$ , as written in Eqn 6.2.6.1.4:

$$N_{col} = \frac{L_{x_{col}}}{SD_{x_{col}}} + 1 \qquad [-] \qquad \text{Eqn} (6.2.6.1.4)$$

Another important aspect for wind farm production is the *hours of production in a year* ( $H_{prod}$ ). The hours of production for a wind farm depend on several factors. First of all, as Krokoszinski (2003) has introduced the concept of *Layout Factor* (*LF*) as the difference between *theoretical electrical energy* ( $E_{theo}(park)$ ) and *available electrical energy* ( $E_{avail}$ ).  $E_{theo}(park)$  is result from *full load hours of production* which is the same of *theoretical production time*. Full load hours of production for a wind farm (*FLH*<sub>wf</sub>) are the total hours available for wind farm generate electricity. In general, *FLH*<sub>wf</sub> can be found by:

$$FLH_{wf} = 24_{hours} \times 365_{days} \Longrightarrow 8760_{hours/year} \quad [h/yr] \qquad \text{Eqn} (6.2.6.2)$$

<sup>&</sup>lt;sup>123</sup> According to Bansal, Bhatti, and Kothari (2002) 10 ha/MW is the "*rule of thumb*" for land area for wind power plants, including infrastructure.

So we have considered the difference between  $E_{theo}(park)$  and  $E_{avail}$  as Wind Farm Production Efficiency (WF<sub>PE</sub>) which is affected by human, climate and technological factor. Then, human factor refers how operations and maintenance of wind farm are ( $O\&M_{manag}$ ).  $O\&M_{manag}$  symbolized the frequency for scheduled maintenance ( $SC_{O\&M}$ ) and unscheduled maintenance ( $USC_{O\&M}$ ); within each repair duration (hours) and costs (&/kWh) associated. In other hand, the climate factor is associated to wind direction, intensity and speed; relative humidity, air pressure, site orography. So as we have considered the hours of effective production in a year ( $H_{prod}$ ) for wind farm production, we could write it as Eqn 6.2.6.2.1:

$$H_{prod} = FLH_{WF} - \sum SC_{O\&M} + USC_{O\&M} \qquad [h/yr] \qquad \text{Eqn (6.2.6.2.1)}$$

 $SC_{O\&M}$  and  $USC_{O\&M}$ <sup>124</sup> were developed based on Mabel and Fernandez (2008) when were considered the inclusion of hours for *wind turbine maintenance* ( $WT_{main}$ ), *turbine breakdown* ( $WT_{bd}$ ), grid maintenance ( $G_{main}$ ) and grid breakdown ( $G_{bd}$ ) to determine the effective hours of production of a wind farm. For  $LCPM_{WF}$  we have also taken into consideration the full (see Figure 6.18, *blue line*) and available load hours of production per month (see Figure 6.18, *red line*); different wind speed per period ( $v_{w_a}$ ), air density ( $\rho$ ), which resulted into the Power Curve

*Production Model (PC<sub>PM</sub>).* It was necessary to understand how the production could be fit to the wind turbine power curve. We have taken into consideration the hours of production per period (month) for determining the best period for  $O\&M_{manag} as$ :

- $\Leftrightarrow$  the frequency for *scheduled maintenance* (*SC*<sub>*O&M*</sub>) to be adopted in the wind farm (we have considered the period with less hours of production (*february, april, june, september* and *november*);
- $\Rightarrow$  the wind speed for each period  $(v_{w_p})$  was the main criteria for determining the period for  $SC_{O\&M}$  activities. If the mouth mean speed is lower than the annual mean wind speed, the loss of production would be reduced, in a contrary situation, the availability of the wind farm could be decreased;
- $\Rightarrow$  if both situation occurs, we have possible optimized the power curve of the wind farm in relation to *O&M* activities and *FLH*<sub>wf</sub>.

For WECS the local wind resources can determine the technical and economic viability for a power plant, although for any wind project, theoretically, we have the same time distribution for electricity production. If we have considered in a monthly basis, the wind resources could be represented by a graph as shown in Figure 6.18. The effect of  $O\&M_{manag}$  has influenced directly on wind farm *availability* (see Figure 6.18, *red line*).

<sup>&</sup>lt;sup>124</sup> When necessary, a possible way for calculation the total hours and costs for both  $SC_{O\&M}$  and  $USC_{O\&M}$ . For hours calculation we just do  $SC_{O\&M(h)} = freq. \times hours$  and for costs  $SC_{O\&M(h)} = SC_{O\&M(h)} \times \text{KWh}$ .



**Figure 6.18** *FLH*<sub>wf</sub> (blue line) and  $H_{prod}$  (red line) distribution during a year with  $O\&M_{manag}$  effect. Source: Own elaboration

For example, if we have considered an  $O\&M_{manag}$  for  $SC_{O\&M}$  and  $USC_{O\&M}$ . For  $SC_{O\&M}$  we have programmed 3 work days of downtime in *february*, *june* and *november* which resulted in 72 *hours* of downtime for the wind farm. And for  $USC_{O\&M}$  was considered a failure frequency of 1.5 per year, with 3 hours/wind turbine, which resulted into 112.5 hours and a total 184.5 hours of downtime per year. The availability has resulted into 97.9%, in other words, approximately 8 days/year of downtime. We must remember that the availability represents the hours able to be used for electricity production by WECS. As we could see the  $O\&M_{manag}$  is an important factor for wind farm electricity production. Technological factors are related to machinery and equipment for electricity production by WECS, e.g. power curve of wind turbines, cut-in and cut-off speeds (see Figure 6.19).



**Figure 6.19** Wind turbine VESTAS V90 - 2 MW power curve. Source: RETScreen® International Clean Energy Decision Support Centre (2009)

The production and distribution of electricity produced from WECS has influence due to the natural losses during the production and distribution of electricity. We have taken into consideration the same methodology adopted by RETScreen® International Clean Energy Decision Support Centre (2009) for losses categorization: array losses ( $\lambda_a$ ), airfoil soiling and icing losses ( $\lambda_{s\&i}$ ), downtime losses ( $\lambda_d$ ) and miscellaneous losses ( $\lambda_m$ )<sup>125</sup>. We have also taken into consideration the  $\eta_{wecs_{(factor)}}$  as the basis for losses calculation. So, P&D Losses Model factor (P&D<sub>LM factor</sub>) could be written as Eqn 6.2.6.3:

$$P\&D_{LM_{factor}} = \eta_{wecs_{(ref)}} \left[ (1 - \lambda_a)(1 - \lambda_{s\&i})(1 - \lambda_d)(1 - \lambda_m) \right] \qquad [-] \qquad \text{Eqn } (6.2.6.3)$$

then, the relation between  $AEP_{gross}$  and  $P\&D_{LM_{factor}}$  is  $LCPM_{WF}$  was developed for analyzing the wind farm production during the lifetime of the wind power plant. As we have developed for the whole lifetime of the wind farm, it was needed to calculate the *AEP* per year of operation. According to Albadi, El-Saadany, and Albadi (2009) *capacity factor* of a wind farm ( $CF_{wf}$ ), in general, *is defined as the ratio of the average output power to the rated output power*. As we can notice in Eqn 6.2.6.4:

$$CF_{wf} = \frac{AEP_{avail}}{WF_{cap} \times 8760} \Longrightarrow \frac{AEP_{avail}}{AEP_{rated}}$$
 [-] Eqn (6.2.6.4)

the Annual Energy Production Available ( $AEP_{avail}$ ). Downtime losses are influenced directly by the  $O\&M_{manag}$  program adopted by the wind farm manager. For  $LCPM_{WF}$  was considered the  $AEP_{avail}$  ( $AEP_{avail} = WF_{cap} \left(1 - \sum \lambda_{a;s\&i;d;m}\right)H_{prod}$ ), so we have taken into account  $H_{prod}$  for  $CF_{wf}$ , and possible rewrite the Eqn 6.2.6.4.1 as follows:

$$CF_{wf} = \frac{WF_{cap}H_{prod}(1 - \sum_{a;s\&idm})}{WF_{cap} \times 8760}$$
[-] Eqn (6.2.6.4.1)

then, if  $WF_{cap}$  is the same and constant during wind farm lifetime, Eqn 6.2.6.4.1 could be expressed mathematically as shown in Eqn 6.2.6.4.2:

<sup>&</sup>lt;sup>125</sup> According to RETScreen® International Clean Energy Decision Support Centre (2009) the typical values for a well designed wind farm for *array losses* range from 0 to 20% of  $AEP_{gross}$ , for *airfoil soiling and icing losses* range from 1 to 10% of  $AEP_{gross}$ ; for *downtime losses* range from 2 to 10% of  $AEP_{gross}$  and for *miscellaneous losses* range from 2 to 6% of  $AEP_{gross}$ .

$$CF_{wf} = WF_{cap}H_{prod} \left(1 - \sum \lambda_{a;s\&idm}\right) \frac{1}{8760}$$
 [-] Eqn (6.2.6.4.2)

As we have shown in Eqn 6.2.6.4, the product of  $WF_{cap}$  and  $FLH_{wf}$  is the maximum annual energy production (*AEP*<sub>rated</sub>). The relation between *AEP*<sub>avail</sub> and *AEP*<sub>rated</sub> can be understood as *Wind Farm Production Efficiency* (*WF*<sub>PE</sub>). We finally can obtain from Eqn 6.2.6.4, 6.2.6.4.1 and 6.2.6.4.2 an equivalent term related to  $CF_{wf}$  which was named as *Wind Farm Production Efficiency* (*WF*<sub>PE</sub>), considering the *Betz Limit*'s *coefficient of performance* (*C*<sub>PBetz</sub>). This generator indicator as closer to *Betz Limit* ( $\frac{16}{27}$  or 59.3%), better wind farm production efficiency the power plant is. *WF*<sub>PE</sub> was formulated as shown in Eqn 6.2.6.5:

formulated as shown in Eqn 6.2.6.5:

$$WF_{PE} = \frac{AEP_{avail}}{AEP_{rated}} \qquad [-] \qquad \text{Eqn} (6.2.6.5)$$

 $LCPM_{WF}$  can be rewritten from Eqn 6.2.6 into two parts when we have taken into consideration  $AEP_{rated}$  and  $WF_{PE}$ .

$$LCPM_{WF} = AEP_{rated}WF_{PE}$$
 [kW<sub>e</sub>h/yr] Eqn (6.2.6.6)

In order to make  $LCPM_{WF}$  more realistic we have decided to adopt the principles of aerodynamics applied to WECS from Eqn 4.7 and Figure 4.12 to calculate  $AEP_{avail}$  and consequently  $WF_{PE}$ . We have considered  $AEP_{avail}$  equivalent to *Power Delivered* ( $P_D$ ). So, if we have added the effective hours of production for each year ( $H_{prod}$ ) of wind farm lifetime, then, we found the Eqn 6.2.6.6.1:

$$AEP_{avail} \Leftrightarrow C_{PBetz} WF_{cap} H_{prod} = \left[\frac{16}{27} \frac{1}{2} 10^{-3} \rho v_w^3 A N_{WT} \eta_{wecs}\right] H_{prod_{yr_{1+\dots+yr_n}}} \quad [kW_eh/yr] \qquad \text{Eqn (6.2.6.6.1)}$$

As we could noticed  $AEP_{avail}$  for each year of the wind farm lifetime is variable due to annual mean wind speed  $(v_w)$ , air density  $(\rho)$ , wind power plant efficiency  $(\eta_{wecs})$  and hours of effective production  $(H_{prod})$ . The overall efficiency<sup>126</sup> for the power plant (equivalent to  $WF_{PE}$ ) can also be understood as a result from electrical transmission efficiency  $(\eta_e)$  and mechanical transmission efficiency  $(\eta_m)$ .

$$\eta_{wecs} = \eta_e + \eta_m$$
 [%] Eqn (6.2.6.6.1.1)

<sup>&</sup>lt;sup>126</sup> For Evans, Strezov, and Evans (2009) the efficiency of electricity production by WECS range from 24 to 54%.

# $6.4.4.3 \quad NUMERICAL SIMULATION \text{ and Validation Process}$

A simulation is a technique applied to systematic studies in order to understand *complex system*<sup>127</sup> and its interactions. The simulation process should follow some standard steps. For numerical simulation process we have found some common steps in the specialized literature (Andradóttir, 2007; Axelrod, 2003; Azadivar, 1999; Banks, 1999; Billinton, Hua, & Ghajar, 1996; Carson & Maria, 1997; Chang & Yu, 2009; Davis & Bingham, 2007; Delarue, Bouscayrol, Tounzi, Guillaud, & Lancigu, 2003; Fu, 1994; Fu, 2002; Hobbs, 2008; Law & Kelton, 2007; Olafsson & Jumi, 2002; Roberts, Andersen, Deal, Garet, & Shaffer, 1983; Shannon, 1992; Wang, Liu, & Zeng, 2009), for general proposals and applied to power systems, case of WECS. These steps are shown in Figure 6.20.



**Figure 6.20** Planning phase for simulations studies. Source: adapted from Shannon (1992) and Banks (1999)

<sup>&</sup>lt;sup>127</sup> We understand as a *complex system* when this same system has multiple interactions and one action implies into several responses from the system. It is the case of WECS and the LCOE approach.

For some researchers in simulation studies we must include more phases or steps, as the case of "*INPUT DATA PREPARATION*" (if the model to be simulated required several data) and "*FINAL EXPERIMENTAL DESIGN*". Meanwhile, we understand a simulation process possible never is totally concluded in function of its nature and the process could be in evolutive stages of improving. For Shannon (1992) the process for simulation studies could be classified into planning and operational phase, and the operational one must include the following steps (see Figure 6.21):



**Figure 6.21** Operational phase for simulations studies. Source: adapted from Shannon (1992) and Banks (1999)

The numerical simulation was run considering the variables and the impacts on the values of  $LCOE_{wso}$  found. Remember that there is no standard LCOE value for WECS, both onshore and offshore applications. Table 6.5 has summarized the variables and their variations expected in the numerical simulation done.

Table 6.5 Main variables within expected values for LCOE<sub>wso</sub> algorithm simulation

Variables	Variations
Annual mean wind speed calculated ( $v_{wc}$ )	7.4m/s; 9.1m/s; 12.5m/s
Operations and Maintenance management ( $O\&M_{manag}$ )	$O\&M_{manag(STD)}; O\&M_{manag(A);} O\&M_{manag(B)}$
Wind turbines layout $(L_{wt})$	5D/4D; 5D/7D; 5D/10D; 6D/12D
Energy policy instruments $(E_{pi})$	REPIM (all instruments)

Source: Own elaboration

As we could noticed the model proposed by this Ph.D. research work  $(LCOE_{wso})$  were needed many independent variables for running the algorithm developed. We have divided these variables into two large groups. The first group we reserve for economic variables and the second group is driven to engineering variables of the model (see Table 6.6).

Fauations Variables		Sources	
Equations	Economic	Engineering	Sources
Eqn 6.2.1.1; Eqn 6.2.1.1.1	$MC_A$ ; $RC_{WT}$ ; $C_{kW}$ ; IPT	$N_{WT}$	George and Schweizer (2008); Oliveira and Fernandes (2012a)
Eqn 6.2.1.2; Eqn 6.2.1.3	C <sub>steel</sub> ; CAB <sub>cost</sub>	$A; H_h; L_g$	Nandigam and Dhali (2008); Dicorato, Forte, Pisani, and Trovato (2011); Jamieson (2011); RETScreen® International Clean Energy Decision Support Centre (2009); Bolinger (2012); Bolinger
Eqn 6.2.1.4; Eqn 6.2.1.5	$EF_c$ ; $\zeta$ ; $SB_c$	$TL_r; L_t;$	and Wiser (2012) DeCarolis and Keith (2006); Hrayshat (2009); Alam, Rehman, Meyer and Al-Hadhrami (2011)
Eqn 6.2.1.6; Eqn 6.2.1.7	Bld <sub>cost</sub> ; WT <sub>inst</sub> ; FS; DT; EG	Bld <sub>area</sub>	Alam et al. (2011); Rehman, Ahmad, and Al-Hadhrami (2011); Himria, Boudghene, and Draouic (2009); Oliveira and Fernandes (2012b); Ozerdem, Ozer, and Tosun (2006)
Eqn 6.2.1.9; Eqn 6.2.2.1.1; Eqn 6.2.2.1.2	$if_r; Y_{RC}$	Ν	RETScreen® International Clean Energy Decision Support Centre (2009); Nilsson and Bertling (2007); Saidur, Islam, Rahim, and Solangi (2010)
Eqn 6.2.3.1; Eqn 6.2.3.2; Eqn 6.2.4.1; Eqn 6.2.4.1.1	$MLC; TLC; \\ R_{taxes}; C_{Mhr_{RM_{WT}}}; \\ C_{md_{RM_{WT}}}$	$M_{hr_{RM_{WT}}}; N_{m_{RM_{WT}}}; D_{m_{RM_{WT}}}$	Nilsson and Bertling (2007); Rademakers, Braam, and Verbruggen (2003); Martin- Tretton, Reha, Drunsic, and Keim (2012); Bolinger (2012); Bolinger and Wiser (2012)
Eqn 6.2.4.1.2; Eqn 6.2.4.1.3	$C_{Mhr_{RM_{CT}}};$ $C_{md_{RM_{CT}}};$ $C_{Mhr_{sdRV}};$	$M_{hr_{RMCT}}; N_{m_{RMCT}};$ $D_{m_{RMCT}}; A_{WT};$ $M_{hr_{S\&RV}}; N_{m_{S\&RV}};$	Zhang, Chowdhury, Messac, and Castillo (2012a) ;Martin-Tretton et al. (2012); Rehman et al. (2011)
Eqn 6.2.4.2.1; Eqn 6.2.4.2.2; Eqn 6.2.5.1; Eqn 6.2.5.2; Eqn 6.2.5.2.1	$\psi_{md s, \epsilon RV}$ $\psi_{total}; n_{\Psi}; \varepsilon; n_{\varepsilon}$	$D_{m_{S\&RV}}$ $T_{mass}$	Barradale (2010); Martinez, Sanz, Pellegrini, Jimenez, and Blanco (2009a, 2009b)
Eqn 6.2.5.3; Eqn 6.2.5.4.1; Eqn 6.2.5.5; Eqn 6.2.6.1.2; Eqn 6.2.6.1.4	$CR_{j}; \varepsilon_{c}; \xi_{n}$	$L_{x_{row}}; L_{x_{col}}; SD_{x_{row}};$ $SD_{x_{col}} k_{row}; k_{col}; D$	BNDES (2012); IEA (2011); Green and Schellstede (2007); Hondo (2005); RETScreen® International Clean Energy Decision Support Centre (2009)
Eqn 6.2.6.1; Eqn 6.2.6.3; Eqn 6.2.6.6.1		$\lambda_{a}; \lambda_{s\&i}; \lambda_{d}; \lambda_{m} \  ho ; v_{w}; A; \ oldsymbol{\eta}_{wecs(ref)}$	RETScreen® International Clean Energy Decision Support Centre (2009); IEA (2010)

**Table 6.6** Independent variables of equations for  $LCOE_{wso}$  algorithm

Source: Own construction
For Kleindorfer et al. (1998) the fundamental difficulty in warranting *simulation models* and scientific methodologies has to do with the problem of induction. Since a researcher has direct access only to his or her own peculiar and limited set of experiences and knowledge, how can be justified the generalizations beyond the particular and personal empirical domain? The same situation arises in *simulations researches*. How can we infer from our observations (experience) of a system that the model we have idealized captures its essential structure and parameters?

As we could see, the validation process could be a hard way to find it and be adequate to the model itself. First of all, the system to be simulated must be modeled, so, a conceptual model has to be formulated and applied by a computerized model. As shown in Figure 6.22 the real and simulation worlds are linked by system theories through the *hypothesizing* and *modeling* process. Create hypotheses about what is studied is the same as create conceptions about relation among things (parts) of a system functioning phenomena (Sargent, 2009). For WECS, as a system, was already discussed in Chapter 4, is a chain of energy conversion that results in a final product, *electricity*. So the conceptual model was developed considering WECS mechanism and laws.



**Figure 6.22** Relationship between real and simulation worlds through the verification and validation process. Source: Sargent (2009)

The *experimenting* and *specifying* process were done by adding the conceptual model (simulation model), which includes programming the conceptual model whose specifications are contained in the simulation model specification. The results obtained are compared within the data of the real world, taking into consideration "*mutatis mutandis*" condition in the comparison process done in the validation process.

For this Ph.D. research work we have chosen as validation technique the "*Comparison to Other Models*" and the other model to be compared with was *LCOE/NREL*. We also have considered the following possible equivalence for each part of the algorithm, as shown in Tables 6.7, 6.8, 6.9, 6.10 and 6.11.

Terms	Equivalent to	Values range	Sources/Notes
LCOE <sub>wso</sub>	LCOE/NREL	\$ 50/MWh <sup>(a)</sup> to \$ 150/MWh <sup>(b)</sup> \$ 71/MWh (mean)	Lantz, Wiser, and Hand (2012); <sup>(a)</sup> Wind class 5; <sup>(b)</sup> Wind class 2; IEA
LCCCM <sub>WF</sub>	ICC	869 €/kW to 1,559 €/kW	Milborrow (2006); IEA (2007); Ertürk (2012): See Table 5 3
WT <sub>CM</sub>		\$ 780,000 to \$ 1,326,600 <sup>(c)</sup> 700 to 1,600 cost/kW	Rehman et al. (2011); <sup>(c)</sup> Wind turbine cost represents 73.7% of wind turbine overall cost (Blanco, 2009); Adaramola Paul and Ovedeno (2011)
T <sub>CM</sub>		\$ 205,000 to \$ 473,400 <sup>(d)</sup>	Keith (2004); Rehman et al. (2011); <sup>(d)</sup> Tower cost represents 26.3% of wind turbine overall cost (Blanco, 2009)
$LWTG_{CM}$		3 to 10 % of the total costs of the complete wind farm	European Commission (2001)
CP <sub>CM</sub>	CAB <sub>cost</sub>	\$ 80,000/km to \$ 133,000/km \$ 608/kW <sup>(c)</sup>	Keith (2004); Rehman et al. (2011) Rehman et al. (2011); <sup>(c)</sup> This approximation was done excluding underground cable (4.5 km) and overhead line (5 km)
	$EF_c$	\$ 400/kW to \$ 500/kW	Rehman et al. (2011); IEA (2005, 2010)
$TS_{CM}$			
	$IL_c$ $Sb_c$	\$ 0.04 to \$ 0.07/kWh \$ 113/kW to \$ 200/kW	Keith (2004); IEA (2005, 2010)
$SI_{CM}$	Bld <sub>cost</sub> Bld <sub>area</sub>	\$ 500/m <sup>2</sup> 300 to 700 m <sup>2</sup>	Rehman et al. (2011)
$PO_{CM}$	urcu		
	FS	15 €/kW to \$ 97.60/kW	Himria et al. (2009); Oliveira and
	DI EC	\$ 87.22/KW to \$ 385.25/KW \$ 205.25/LW	Fernandes ( $2012b$ ); Ozerdem et al. (2006)
Far	EG FCR	\$ 505.25/KW calculated	Depending on capital structure and
I CM	W <sub>cc</sub>	estimated	project finance conditions
$CCC_{CM}$	Miscellaneous	3 to 5% of <i>ICC</i>	Harper, Karcher, and Bolinger (2007) figure based on industry review
	К	estimated	The estimation was done considering the final range from 3 to 5% of <i>ICC</i>

**Table 6.7** Numerical validation and reference parameters for  $LCOE_{wso}$  and  $LCCCM_{WF}$ 

Source: Own construction

Terms	Equivalent to	Values range	Sources/Notes
$LRCM \\ Y_{RC} \\ b$	LRC	\$ 10 to \$ 15/MWh 5 to 15 years calculated	Tegen et al. (2012) NREL (1995) $b = \frac{\ln 2}{\ln PR}$
$egin{array}{c} PR \\ c_0 \\ c \\ V \\ V_0 \end{array}$		0.7 to 0.9 1 100 €/kW to 1 400€/kW; \$ 1 700/kW to \$ 2 400/kW \$ 6 800/kW to \$ 9 600/kW 237 699 000 kW (2011) 6 100 000 kW (1996)	Lund (2006); Junginger et al. (2005) Blanco (2009); See Table 5.3 IRENA (2012); Lantz et al. (2012) Valentine (2011); Wiser (1997) GWEC (2012) GWEC (2012)
O&M <sub>WFCM</sub> O&M <sub>fixed</sub>	O&M Fixed O&M	3.5 to 6 cents/kWh 10 to 20% of <i>LCOE</i> 11.5 cents/kW-yr	Christopher (2003); Ertürk (2012); See Table 5.4 Harper et al. (2007)
CM	LLC	0.04 to 0.088 €/kWh \$0.00108/kWh	Fueyo, Sanz, Rodrigues, Montanes, and Dopazo (2011); Fingersh et al. (2006)
$O\&M_{variable_{CM}}$	Variable O&M	6 cents/MWh	(2000)
	Preventive maintenance	0,003 to 0,009 €/kWh	Rademakers et al. (2003)
	Corrective	0,005 to 0,010 €/kWh	
σ	maintenance	estimated	The estimation was done considering the final range from 10 to 20% of <i>LCOF</i>
MLC		54 €/h to 60 €/h	Nilsson and Bertling (2007); Rademakers et al. (2003)
Ν		20 to 30 years	RETScreen® International Clean Energy Decision Support Centre (2009)
$TLC^{128}$		94 €/h to 106 €/h	Nilsson and Bertling (2007); Rademakers et al. (2003)
<i>RCM</i> <sub>WF</sub>		30.43 \$/kW	According to Ferrell and DeVuyst (2012); they have considered \$ 70,000 for a 2 3MW capacity turbine
$DCM_{WF}$	ifr	\$ 27,285 to \$ 148,600/turbine 2.5 to 4.5%/year	Ferrell and DeVuyst (2012) IMF (2012)
$RM_{WT}$	$M_{hr_{RM_{WT}}}$	100 to 300 man-hour	Doyle (2008); LVI Environmental
	$C_{Mhr_{RM_{WT}}}$	\$ 85/h to \$ 90/h	Martin-Tretton et al. (2012); Rehman
	$N_{m_{RM_{WT}}}$	2 to 3 Cranes	ci al. (2011)
	$D_{m_{RM_{WT}}}$	3 to 5 days	
	$C_{md_{RM_{WT}}}$	\$ 4,000 to \$ 6,000/day	

**Table 6.8** Numerical validation and reference parameters for *LRCM*,  $O\&M_{WFCM}$  and *RCM*<sub>WF</sub>

<sup>&</sup>lt;sup>128</sup> Minor maintenance takes about *4h for two people* and major maintenance takes about *7h for two people* (Nilsson & Bertling, 2007).

		*			
Terms	Equivalent to Values range		Sources/Notes		
$RM_{CT}$					
	$M_{hr_{RM_{CT}}}$	100 to 150 man-hour	Doyle (2008); LVI Environmental Services (2009); Zhang et al. (2012a);		
	$C_{Mhr_{RM}_{CT}}$	\$ 85/h to \$ 90/h	Martin-Tretton et al. (2012); Rehman		
	$N_{m_{RMCT}}$	3 Equipment	ct al. (2011)		
	$D_{m_{RMCT}}$	2 to 3 days			
	$C_{_{md_{_{RM_{CT}}}}}$	\$ 2,500/day			
S&RV					
	$A_{WT}$	43 to 60 $m^2/wt$	Doyle (2008); LVI Environmental		
	$M_{hr_{S,eBV}}$	3 to 5 man-hour	Services (2009); Zhang et al. (2012a);		
	$C_{Mhr_{S\&RV}}$	\$ 85/h to \$ 90/h	et al. (2011)		
	$N_{m_{S\&RV}}$	3 Equipment			
	$D_{m_{S\&RV}}$	2 days			
DVM	$C_{md}_{S\&RV}$	\$ 3,500/day			
$RVM_{WF}$	WT <sub>weight</sub>	200 to 273 t <sup>(a)</sup>	Doyle (2008); LVI Environmental Services (2009); <sup>(a)</sup> We considered the proportional relation (kg/kW) as used by Bolinger (2012); Bolinger and Wiser (2012) for 2 MW wind turbine.		
TC	$C_{steel}$	\$190 to \$ 220/t	LVI Environmental Services (2009); Doyle (2008)		
$TS_{VM}$	T <sub>mass</sub>	138 to 143 t	LVI Environmental Services (2009); Martinez et al. (2009a, 2009b); Three sections		

**Table 6.9** Numerical validation and reference parameters for  $RCM_{WF}(cont)$ 

We have adopted general values for simulation and validation procedures. We have in mind that real values were obtained from specialized literature. A different methodology proposed for LCOE/NREL calculation only make sense for comparison reasons, if credible sources of data have be used for input and parameters for this different methodology ( $LCOE_{wso}$ ). All data related to monetary values in the model were considered the following aspects:

- 1. The effect of time on money, "*the inflation*", that is why all the values which mean "*money*" for the  $LCOE_{wso}$  were updated considering the inflation of the period until 2012 year.
- 2. As we have different currencies (US\$, CAD \$ and Euro), a standardization of currencies was applied through the exchange rates taking into consideration the published year and converted to year 2010. The currencies standardization was done for monetary values considered and shown in Chapter 7 and 8.

Terms	Equivalent to	Values range	Sources/Notes
REPIM			
REI	$\Pi C$ $\Psi_{total}$	30% <sup>(a)</sup> of initial capital cost;	<sup>(a)</sup> According to Bolinger (2009) and Kung (2012)
	$n_{arphi}$	6 years (5%/year)	
REP <sub>CM</sub>	$PTC$ $\mathcal{E}_0$	88.20 €/MWh <sup>(b)</sup> ; \$75.00/MWh <sup>(c)</sup> ; CAD \$10/MWh <sup>(d)</sup>	<sup>(b)</sup> For Portugal (DRE, 2012); <sup>(c)</sup> For Brazil (Azuela & Barroso, 2012); <sup>(d)</sup> For Canada (Saidur et al., 2010; Valentine, 2010)
ODED	n <sub>e</sub>	10-15 years <sup>(b)</sup> ; 15-20 years <sup>(c)</sup> ; 10-15 years <sup>(d)</sup>	valentine, 2010)
CHC P	$CR_{f}$	20 to 80%	BNDES (2012)
GHG.K <sub>CM</sub>	$GHG_{EF_{ff}}_{co_2}$	16 to 410 g/kWh; 689 to 890 g/kWh; 460 to 1234 g/kWh <sup>(e)</sup>	<sup>(e)</sup> Hydraulic, fuel oil and natural gas for Şahin (2004);
	$GHG_{EF_{wecsco_2}}$	11 to 75 g/kWh; 48 g/kWh <sup>(f);</sup> 12 to 83 g/kWh <sup>(g)</sup>	<sup>(f)</sup> Interpolation considering the lifetime effect (25 years) as Hondo (2005) has discussed; <sup>(g)</sup> Dolan and Heath (2012)
	$\mathcal{E}_c$	35 €/tCO <sub>2</sub> <sup>(h)</sup> ; \$13.00/tCO <sub>2</sub> <sup>(i)</sup> ; \$ 30.00/tCO <sub>2</sub> <sup>(j)</sup>	<ul> <li><sup>(h)</sup> For Portugal (Valles, Reneses, &amp; Campos, 2012); <sup>(i)</sup> For Brazil (Pereira, Reis, de Araujo, &amp; Gongalves, 2006);</li> <li><sup>(i)</sup> For Canada (Monahan &amp; van Kooten, 2010)</li> </ul>
	ζ <sub>n</sub>	0 to 100% ( <i>if applicable</i> )	The distribution depends on specific legislation, in case of the same wind project receives more than one incentive or subsidies by government.

 Table 6.10
 Numerical validation and reference parameters for REPIM

The *REPIM* was developed to represent the energy policy effect on wind power plant cost, but as Barradale (2010) has discussed about some other policy instruments used to encourage renewable energy investment include:

- ☆ Pricing or tariff mechanisms: Guaranteed prices for renewable energy. Favorable tariff mechanisms have been used to promote wind energy development in Germany and Denmark.
- *✿ Production cash subsidies*: These can be provided at the national, state, and local levels.
- ☆ Depreciation rules: Accelerated depreciation for capacity investment can reduce a company's tax expense during early years, providing a time-value-of-money benefit.
- ☆ Renewable portfolio standards (RPS): These require electricity suppliers to meet a certain percentage of their load from renewable energy sources.

Terms	Equivalent to	Values range	Sources/Notes
$LCPM_{WF}$	AEP <sub>avail</sub>	kW <sub>e</sub> h/yr	
WF <sub>CM</sub>	WT .	2 000 kW	RETScreen® International Clean
	vv 1 rated	2,000 KW	Energy Decision Support Centre (2009)
$WT_{LM}$	Wind farm geometry	5D/4D; 5D/7D; 5D/10D; 6D/12D	See Table 6.5
	$L_{x_{row}}$	1 800 to 4 680 m	Nandigam and Dhali (2008); Emami and Noghreh (2010)
	$L_{x_{col}}$	2 430 to 2 790 m	
	$SD_{x_{row}}$	calculated	Wind farm geometry impacts direct on
	$SD_{x_{col}}$	calculated	the values of these variables.
	$k_{row}$ and $k_{col}$	estimated	
	D	90 m	RETScreen® International Clean Energy Decision Support Centre (2009)
$PC_{PM}$	Cut-in	4 m/s	Vestas Wind Systems A/S (2013)
	Cut-out	25 m/s	
	ρ	calculated	It was calculated for Brazil, Canada and Portugal according to Eqn 4.2 within data shown in Figures 6.11, 6.12 and 6.13.
	${\cal V}_W$	5.3 m/s (Brazil); 9.0 m/s	<b>RETScreen®</b> International Clean
		(Canada) and 6.6 m/s (Portugal)	Energy Decision Support Centre (2009); See Table 6.4 and Figures
	Α	6,720.1 m <sup>2</sup> /turbine	RETScreen® International Clean Energy Decision Support Centre
			(2009); See Figure 6.6
	$SC_{O\&M}$	5 1 2 1 2 1	$O\&M_{manag(STD)}; O\&M_{manag(A)}; O\&M_{manag(B)}$
	Days/month Months	5 a; 2 a; 5 a Feb: Iun: Nov	Ding and $11an (2012)$ See Figure 6.18
	$USC_{O&M}$	100, 500, 100	See l'igure 0.10
	Freq. failure	1.5/yr; 1.0/yr; 1.8/yr	Rademakers et al. (2003)
	Duration	3 h/repair; 4 h/repair;	
	λĭ	2 h/repair	See Ean 6.2.6.1.1
	$H$ , $N_{WT}$	calculated	See Eqn 6.2.6.2.1
Р&Для	$\lambda_a$	0 to 20% of $AEP_{aross}$	RETScreen® International Clean
	$\lambda_{s,e_i}$	1 to 10% of $AEP_{gross}$	Energy Decision Support Centre
	$\lambda_d$	2 to 10% of $AEP_{gross}$	(2009)
	$\lambda_m$	2 to 6% of $AEP_{eross}$	
	$\eta_{_{wecs(ref)}}$	25%	Hansen, Bower, and Studies (2003)
$CF_{wf}^{129}$		21 to 41% (onshore)	IEA (2010)

 Table 6.11 Numerical validation and reference parameters for LCPM

All the variables from Tables 6.5 and 6.6 and data from Tables 6.7 to 6.11 were used for parameterization of the proposed  $LCOE_{wso}$  through the *simulations procedures* shown and explained in Chapters 7 and 8.

<sup>&</sup>lt;sup>129</sup> According to IEA (2010), the capacity factor of wind projects range from 21% to 41% for onshore and 34% to 43% for offshore.

# 6.5 SUMMARY AND CONCLUSIONS

This chapter started by briefly presenting some considerations on epistemological and methodological research issues in general, and focused on *operational research* and *optimization concerning*. The rationale of the study and the research framework was also discussed, followed by the outline of the research design, focusing on the main steps related to methodological procedures (section 6.4.2), theoretical framework and hypotheses development (section 6.4.3), research objectives (6.4.3.1), research approach (section 6.4.3.2).

The research design was build considered the *LCOE/NREL* methodology and the variables were grouped into four categories: (1) Wind speed  $(v_w)$ ; (2) Wind turbines layouts  $(L_{wt})$ ; (3) Operations and Maintenance management ( $O\&M_{manag}$ ) and (4) Energy policy instruments  $(E_{pi})$ . The reason for grouping these variables into these categories was based on research hypotheses presented at Table 6.3. The variables relationship and research boundary (see Figure 6.14) were explained in section 6.4.4.1 which driven the simulation procedures done and shown in Chapter 7.

During this Ph.D. research work a conceptual model was developed based on conceptual and operational definitions explained at Table 6.2. We defined the *Economic Optimization*, a *Simulation Model*, *LCOE*, *AEP* and *COE*. For this research work we considered as "model" the representation of a system or process of the real world into a theoretical manner (Carson & Maria, 1997). *LCOE* analyses, therefore, provide important insights into the main cost factors of alternative technologies for producing electricity, in our case, WECS. Since various cost components can vary considerably from place to place and from wind project to wind project, sensitivity analysis was adopted as the key in determining the impacts of changes in costs on the costs of producing electricity (Angevine, Murillo, & Pencheva, 2012).

For the mathematical model structuring we started by building a *Block Diagram* of the algorithm proposed. In Figure 6.16 is shown the six big groups of equations used for *Economic Optimization Algorithm Proposed (EOAP)*, which is equivalent to  $LCOE_{wso}$ . As we could notice, as wind power technology is capital-intensive, most of equations of this model figure that. So the first one is the *Wind Farm Life-Cycle Capital Cost Model (LCCCM<sub>WF</sub>)* with the sub-models as *Wind Turbines Cost Model (WT<sub>CM</sub>)*, *Towers Cost Model (T<sub>CM</sub>)*, *Local Wind Turbines Grid Cost Model (LWTG<sub>CM</sub>)*, *Collecting Point Cost Model (CP<sub>CM</sub>)*, *Transmission System Cost Model (TS<sub>CM</sub>)*, *Supporting Infrastructure Cost Model (SI<sub>CM</sub>)*, *Pre-operational Cost Model (PO<sub>CM</sub>)*, *Financing Cost Model (F<sub>CM</sub>) and Capital Cost Model (CCC<sub>CM</sub>)*.

For Tegen et al. (2012) *O&M* variables must be focused on understanding current and historical operation and maintenance (*O&M*) costs, including *major component replacement costs* (*LRCM*). A better understanding and more precisely analysis O&M costs trends and behavior go through the following aspects:

Analysis to estimate the impact of anticipated improvements to O&M for both *land-based* and *offshore* wind projects on *LCOE*. Simulation models can be improved and optimization procedures must be applied.

- ☆ Development of models to better represent *non-turbine driven project costs*, *e.g.*, foundations, electrical cabling, and installation, for a range of turbine and project sizes for both *land-based* and *offshore* wind technology.
- ☆ Analysis to quantify the impact of potential technology advances and obsolescence on wind power system reflect into *LCOE* for *land-based* and/or *offshore* wind technology pathways.

The model  $(LCOE_{wso})$  also took into consideration the *LRCM* or *Levelized Replacement Cost Model*, related to a cost item treated as "saving account" for the wind power project. It was designed two sub-models: the *Annual Replacement Cost Model* ( $AR_{CM}$ ) (see Eqn 6.2.2.1) and *Technological Obsolescence Cost Model* ( $TO_{CM}$ ) (see Eqn 6.2.2.2). This model was developed in order to guarantee at a certain period (5, 10 and 15 years) funds enough to make the necessary review in the producing power system.

The operation of a wind farm also needs funds to run the machinery and other facilities, so, we have included a model related to O&M named Wind Farm O&M Cost Model ( $O\&M_{WFCM}$ ).  $O\&M_{WFCM}$  was designed into two part, one is fixed ( $O\&M_{fixed}_{CM}$ ) and the other variable ( $O\&M_{variable}_{CM}$ ).  $O\&M_{fixed}_{CM}$  considered a percentage of initial capital cost ( $LCCCM_{WF}$ ) and the Land Lease Cost (LLC) within the inflation effect for the lifetime of the power plant (see Eqn 6.2.3.1). The variable part of O&M ( $O\&M_{variable}_{CM}$ ) was developed based on Zhang et al. (2010) and we took into consideration the number of wind turbines, annual energy rated production per turbine, labor cost and revenues taxes (see Eqn 6.2.3.2).

As  $LCOE_{wso}$  was designed for lifetime of the wind power project, we thought about the removal phase of the project (project shutdown, removal or repowering) as shown in Figure 4.13 and Figure 5.1. The *Wind Farm Removal Cost Model (RCM<sub>WF</sub>)* and sub-models *Wind Farm Decommissioning Cost Model (DCM<sub>WF</sub>) Model* and *Wind Farm Residual Value Model (RVM<sub>WF</sub>)* were developed in order to cover the main costs for *decommissioning process* and the *residual value of a wind farm at the end of its lifetime* (see Eqn 6.2.4.1; 6.2.4.1.1; 6.2.4.1.2; 6.2.4.1.3; 6.2.4.2; 6.2.4.2.1; 6.2.4.2.2; 6.2.4.2.3).

According to GWEC (2012) the wind power worldwide has increased exponentially as shown in Figures 3.12 and 6.1, this fact can be explained by the great attention the governments, enterprises and consumers in general put on RETs, case of wind energy. The hand of government in the renewable energy projects could be seen through the *incentives* given to the investors in this kind of project. That is why we have developed the *REPIM* for  $LCOE_{wso}$  for introduce the public incentives forms in order to reduce the cost of this technology. The *Renewable Energy Public Incentive Model* (*REPIM*) was created within the following sub-models: (1) Renewable Energy Investment Credit Mode (REI<sub>CM</sub>); (2) Renewable Energy Production Credit Mode (REP<sub>CM</sub>); (3) Other REPs Credit Mode (OREP<sub>CM</sub>) and (4) GHG Reduction Credit Model (GHG.R<sub>CM</sub>).

Each *REPIM* sub-model was explained and respective equation was developed as shown in Eqn 6.2.5.1, 6.2.5.2, 6.2.5.3, 6.2.5.5 and 6.2.5.5. The Eqn 6.2.5.5 could be used for the balance of the

incentive given to the same wind power project. The public inventive must consider that costs differ by geographic region to another. The incentive could be tailored to reflect differing costs to encourage locating wind farms throughout the region, according to the wind resources available, both *onshore* and *offshore*, so that wind energy is not just be concentrated in a few windy areas.

According to the *research question* and *LCOE/NREL methodology* used as the basis for the methodology proposed by this Ph.D. research work, the *power production* of the wind farm, in better words, *Annual Energy Production (AEP)* should be considered in our  $LCOE_{wso}$  developed and validated. We also called *Wind Farm Life-Cycle Production Model (LCPM<sub>WF</sub>)*. This model was developed with four sub-models: (1) *Wind Farm Capacity Model (WF<sub>CM</sub>)*; (2) *Wind Turbines Layout Model (WT<sub>LM</sub>)*; (3) *Power Curve Production Model (PC<sub>PM</sub>)* and (4) *P&D Losses Model (P&D<sub>LM</sub>)*, as shown in Eqn 6.2.6.

During the elaboration of  $LCOE_{wso}$  methodology we notice the necessity to verify if the model and sub-models would be a real *response* to the *research question* and *objectives* designed for this research work, so we have to make the *parameterization*<sup>130</sup> of the data for the *inputs* to feed the  $LCOE_{wso}$  calculations. As shown in Figure 6.22 we could compare the *real world* to the *simulation world* for validation if a conceptual model, in fact, represents a real system. In the case of this Ph.D. research work, could be able to calculate the nearest values for the cost of energy produced from 50 MW<sub>e</sub> onshore wind farm.

The parameterization process was done considering the data from Figure 6.6 (wind turbine technology used), Figure 6.11 (climate conditions for Aracati, Brazil), Figure 6.12 (climate conditions for Cape Saint James, Canada), Figure 6.13 (climate conditions for Corvo Island, Portugal), Table 6.4 (locations chosen with criteria and reasons), Table 6.5 (main variables), Table 6.6 (independent variables), Table 6.7 (parameters for  $LCOE_{wso}$  and  $LCCCM_{WF}$ ), Table 6.8 (parameters for  $LRCM,O\&M_{WFCM}$  and  $RCM_{WF}$ ), Table 6.9 (parameters for  $RCM_{WF}$ ), Table 6.10 (parameters for REPIM) and Table 6.11 (parameters for  $LCPM_{WF}$ ). All data used as inputs for each independent variable are from a variety of credible industry sources, as scientific journals and proceedings of the global wind energy industry.

The algorithm developed during this Ph.D. research work  $(LCOE_{wso})$  was solved in an environment MS Excel-Matlab<sup>®</sup>, with Matlab<sup>®</sup> we have retrieved data from Excel and have made the simulations considering the main variables, such as *wind speed*  $(v_{wc})$ , *operations and maintenance management*  $(O\&M_{manag})$ , wind turbines layout  $(L_{wt})$  and energy policy instruments  $(E_{pi})$ . The  $LCOE_{wso}$  proposed in this research can embody influences of WECS, financing and human factors on COE from the wind farm operation, and can be used to evaluate economic operation of wind farms with different wind resources, investing situations, installed capacities, maintenance situations and so on.

After discussing and justifying the methodological choices for this Ph.D. research work, the next two chapters present the numerical simulation and validation procedures (Chapter 7) with results and discussion (Chapter 8).

<sup>&</sup>lt;sup>130</sup> In this research work, the "*parameterization*" means the range of values of each independent variable can assume during a numerical simulation.

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# **CHAPTER 7**

# NUMERICAL SIMULATION AND VALIDATION

7.1 Introduction

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This chapter details the WECS and climate numerical parameters considered for simulations procedures. Economic and financial issues to a wind project are also analyzed, within O&M inputs, variables and strategies proposed. General simulations procedures within optimization criteria and sensitivity analysis. Summary and conclusions are presented at the end, with the respective references.

# 7.1 INTRODUCTION

After developing the  $LCOE_{wso}$  model for wind power and presented in Chapter 6, it is necessary to perform its testing. This is important as it will allow validating the  $LCOE_{wso}$  model and at the same time carrying out a comparison with other methodologies of basic wind power cost calculations. This chapter presents the test all tools developed and presented previously. In order to perform the *numerical modeling* and *simulations* we had used a set of *real data*, during the period of one year (see Figures 6.11, 6.12 and 6.13), for wind power energy production in three different sites.

Numerical modeling is an important phase of a simulation research work for designing, evaluation and implementation analysis of power systems. Several models for various types of WECS have been the subject of several studies (see Tables 5.8 and 5.9). We notice that improved analysis techniques are needed in two main areas: (1) evaluation of operational characteristics of a proposed WECS (technical performance), and (2) determination of the real economic cost of electricity production of a given power system at a right given site (economic performance) (Ibrahim, Lefebvre, Methot, & Deschenes, 2011). Numerical model is used as a strategy for validating the algorithm developed for representation of a real system.

As has stated Molenaar (2003, p. 111) validation is "the process of determining whether or not a computer simulation model is consistent with the underlying mathematical model to a specified accuracy level". We understand the validation in a research like this; it is a necessary procedure for a better comprehension of the relations among the set of variables used for the model proposed. We have checked the variable relations that affect each other simultaneously, which can be used for future research needs.

This chapter explains and shows the numerical simulation and validation process utilized in this Ph.D. research work, focused on wind power technology in order to be applied directly on economic evaluation of wind energy cost researches. *Power system parameters used for simulations* are shown in section 7.2. In this section, detailed *technical features of WECS* (section 7.2.1), within *assumptions, constraints, and limitations* (section 7.2.1.1) considered; *wind turbine technology* (section 7.2.1.2) and *wind farm layout* studied (section 7.2.1.3) are shown. The *climate data considered for simulations* are explained in section 7.2.2, focused on *wind speed* (section 7.2.2.1); *atmospheric pressure* (section 7.2.2.2) and *air temperature* (section 7.2.2.3) for three sites chosen.

Section 7.3 refers to the economic and financial aspects of the wind project by describing the assumptions, constraints, and limitations (section 7.3.1) and expected revenue, capital, O&M, and other costs (section 7.3.2). In section 7.4 O&M assumptions for wind project simulations are shown and inputs and variables (section 7.4.1) and O&M programs proposed (section 7.4.2). Section 7.6 is related to general simulations procedures within its steps fallowed (section 7.6.1), optimization criteria (section 7.6.2) and sensitivity analysis carried out (section 7.6.3). Finally, the summary and conclusions of this chapter (section 7.7) and all references (section 7.8) used are present at the end of this chapter.

# 7.2 POWER SYSTEM PARAMETERS USED FOR SIMULATIONS

#### 7.2.1 TECHNICAL FEATURES OF THE WIND FARM

The hypothetical wind farm will consist of up to 25 wind turbines with 2 MW rated power (see Table 7.3) which will be connected to the national electricity grid through *electrical cables*<sup>131</sup>. The operation of the wind farm will be closely monitored remotely through a sophisticated supervisory control and data acquisition (SCADA) system. A network of underground electrical cables will transmit the power from the individual turbines to the *point of common connection (PCC)*. The principal components of the onshore wind farm considered for simulations:

- ✿ 25 Vestas V90-2MW wind turbines;
- $\Leftrightarrow$  Access roads;
- ☆ Power cables between the turbines and from the wind farm to the connection point of the transmission public electricity grid;
- ☆ A substation required to house systems to control and monitor the operation of the wind farm as whole and electrical equipment needed to connect the wind farm to the electrical transmission grid.

The wind turbines chosen to be installed at power plant will be technologically updated and economically proposed. The turbines have minimum maintenance requirements and include the following features as shown in Table 7.1.

Long term corrosion protection	High quality paints are used to protect the turbine components from the corrosive environment experienced in sites close to the
✿ Low noise emissions	Aerodynamic blade and mechanical component design minimize noise emissions. Special control systems are embedded to mitigate noise emissions while maximizing energy production
<ul> <li>Safety and accessibility features for service engineers and technicians</li> </ul>	The turbines are normally fitted with navigational lights and aerial warning lights meeting the relevant safety standards
<ul> <li>Equipped with monitoring and control systems (SCADA)</li> </ul>	Predictive maintenance systems are embedded to detect potential technical problems at an early stage allowing for improved maintenance planning and reduced turbine downtime
✤ Lightning protection	A protection system protects the turbine blades and sensitive electrical components from damage caused by lightning strikes

Table 7.1	Wind turbines	systems	added-in
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Source: Own elaboration

<sup>&</sup>lt;sup>131</sup> The electrical cables are used for local wind turbines grid ( $LWTG_{CM}$ ) and transmission system ( $TS_{CM}$ ). The cables voltage are not detailed, due to the objective of this Ph.D. research work what discard the electrical microscopic analysis of the wind farm for simulations procedures.

#### 7.2.1.1 Assumptions, constraints, and limitations

We have considered for numerical simulation and validation process of  $LCOE_{wso}$  methodology, the following aspects:

#### 7.2.1.1.1 Assumptions

Table 7.2	Technical	parameters of	of wind	power	project
I doit /	reenneur	purumeters	JI WING	power	project

✿ Project name	FireStar Wind Farm
✿ Project type	Power (electricity)
✿ Grid type	Central grid
$\Leftrightarrow$ Life time (N)	25 yrs
☆ Sites	Araripe (Brazil); Corvo Island (Portugal) and Cape Saint James (Canada)
▷ Number of wind turbines ( $N_{WT}$ )	25
Solution Wind farm capacity ( $WF_{cap}$ )	50 MW <sub>e</sub>
✿ Wind turbine technology	See Table 7.3
$\Leftrightarrow$ Wind speed measured at ( $H_0$ )	10m
$\Leftrightarrow$ Hub height (H)	105m
$\Leftrightarrow$ Terrain rugosity factor (a)	0.14
<i>✿</i> Annual mean wind speed ( $v_{wc}$ )	7.4m/s; 9.1m/s and 12.5m/s
Source: Own elaboration	

- a) <u>Sites with suitable mean annual wind speed</u> (e.g. greater than 4 m/s) at the hub-height of the WEC system analyzed;
- b) We have considered <u>sites are further away from residential settlements</u> than other areas. Therefore any possible impacts that the wind farm might have on such settlements are expected to be small;
- c) <u>Annual constant mean wind speed and direction</u>: the annual mean wind speed is constant throughout the simulations and the wind speed direction is fixed with respect to the farm layout∴If another wind direction is wanted, a new simulation model must be produced with a rotated layout;
- d) The wind distribution and frequency are variable during the whole lifetime of the power plant;
- e) Climate data used for simulations, such as, <u>wind speed, atmospheric pressure and air</u> <u>temperature are constant during the lifetime of the wind farm for the three different sites chosen;</u>
- f) The wind turbines are considered to be <u>spaced in a way to minimize turbine-to-turbine</u> <u>interference</u> in the wind flow (wake and array effects);

- g) We have considered the <u>same wind turbine technology</u> during 25 years of lifetime of the wind farm operation and for each site chosen the availability of the same product (wind power plant equipment);
- h) <u>Proximity of the site to the electric grid</u> should preferably not exceed 3km; and accessibility of the site, in order to avoid expensive road construction etc., must be guaranteed;
- i) For each year of operation, <u>different *capacity factors* are expected</u>, due to the dynamic nature of WECS, and in particular, a wind farm analyzed in three different sites, during the simulations procedures;
- j) The <u>wind farm production are defined in *Wind Farm Life-Cycle Production Model* (*LCPM*<sub>WF</sub>) and information/data are based on Table 6.11;</u>
- k) The <u>Power Delivered  $(P_D)$ </u> is exported (sold) to the grid, so  $AEP_{avail}$  (Annual Energy Production available) is the <u>total power output from the hypothetical wind farm simulated;</u>
- 1) <u>Wind farm losses (for production phase) changes linearly</u> with power level output (*AEP*<sub>avail</sub>);
- m) We considered the <u>environmental impacts as minimal as possible for the wind farm</u> projected, specially related to the local *fauna* and *flora*.

### 7.2.1.1.2 Constraints

- a) We have considered constant the annual mean wind speed for all simulations at each chosen site during this Ph.D. research work;
- b) As we have considered only the production and transmission phases of the power plant (see Chapter 6, section 6.4.4.1; Figure 6.14), the <u>distribution costs and investment infrastructure are</u> <u>not included in the *LCOE*<sub>wso</sub> methodology;
  </u>
- c) The wind farm production is analyzed annually, but <u>monthly production variation is considered</u> <u>for wind farm production management;</u>
- d) The <u>effect of technology innovation for this power plant is not considered for cost of energy</u> <u>reduction</u>, because the model consider the same wind turbine technology for entire lifetime of the wind project;
- e) We have considered <u>only linear wind turbines layouts</u>, in order to simplify the  $LCOE_{wso}$ , <u>other</u> possible wind turbines layouts are not considered which in such way, limits this proposed <u>methodology for other cases of layouts</u>;
- f) For WECS, we have taken into consideration an <u>autonomous system</u>, which exclude any kind of energy production planning, so the variability can easily possible be more intense than done in the simulations studies.

# 7.2.1.1.3 Limitations

- a) The suitable mean annual wind speed and direction are considered fixed during 25 years of lifetime of the wind farm operation, so the <u>effect of variation due to climate change are not</u> <u>considered;</u>
- b) Due to the lack of availability of data, in particular sites with wind data at Canada, Brazil and Portugal for high elevations above the ground (at least 50m above ground level), it is presently <u>difficult to establish an accurate estimate for the wind energy production</u> as supposed to be this hypothetical wind farm (105m);
- c) When we have considered the same technology (wind turbine) for the power plant, we have discard the possibility the effect of updating the machineries and lower much more the cost of production;
- d) As we have consider the availability of wind turbines 'suppliers (Vestas V90-2MW) for the sites analyzed, it <u>was not considered the cost of transportation in these three different sites used for simulations;</u>
- e) The cost of transmission reflects the cost for a maximum distance of 3km (from wind farm to the distribution point), so the  $LCOE_{wso}$  calculated is applicable for this distance only, when this indicator is used for comparison among different wind farms.

# 7.2.1.2 WIND TURBINE TECHNOLOGY

Table 7.3 Technical da	ta of wind turbines
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✡	Model/type					Vestas V90-2MW
✡	Rated power					2 000 kW
众	Cut-in speed					4.0 m/s
众	Rated wind speed					12.0 m/s
众	Cut-out speed					25.0 m/s
✡	Type class					IEC IIIA
✡	Diameter					90.0 m
众	Rotor swept area					6 361.7 m <sup>2</sup>
✡	Rated rotor speed					14.9 rpm
众	Rotor speed range					9.0 - 14.9 rpm
✡	Generator type					Double-fed asynchronous generator
✡	Controls					Pitch regulated with variable speed
众	Tower type					Tubular steel tower
Sou	rce: Vestas Wind	Systems	A/S	(2013)	and	RETScreen <sup>®</sup> International Clean Energy

Source: Vestas Wind Systems A/S (2013) and RETScreen® International Clean Energy Decision Support Centre (2009)

According to Vestas Wind Systems A/S (2013) this wind turbine is designed for operating at certain conditions:

- 1. Ambient temperatures ranging from  $-20^{\circ}$ C to  $+30^{\circ}$ C. Special precautions must be taken outside these temperatures;
- 2. The placement of wind turbines have to operate at a distance of at least 5 rotor diameters (5D=450m) between the wind turbines themselves. If the wind turbines are placed in one row, perpendicular of the predominant wind direction, the distance between the wind turbines must be at least 4 rotor diameters (4D=360m).

Vestas V90-2MW model uses gearboxes with one planetary and two parallel stages from which the torque is transmitted to the generator through a composite coupling. This model also contains a 4-pole Doubly-Fed Asynchronous Generator (DFIG) with wound rotor (see Chapter 4, Figure 4.8 and Table 4.3). A partially rated converter controls the current in the rotor circuit of the generator, which allows control of the *reactive power*<sup>132</sup> and serves for smooth connection to the electric power grid.

#### 7.2.1.3 WIND FARM LAYOUT

In the present Ph.D. research work, a flat area was considered for the development of hypothetical wind farm in sites in *Brazil, Canada* and *Portugal*. A total of  $15 \text{km}^2$  area is considered for the development of wind farm of  $50 \text{MW}_e$  capacity. The wind farm is designed using 2000kW size wind machines by Vestas at a maximum hub-height of 105m high (see Table 7.3).

Different wind farm layout conditions are defined and considered for simulations:

- 1. The <u>5D/4D layout (see Figure 7.1)</u>: the default wind farm layout with 5 rotor diameters (5D) distance (450m) between the turbines and 4D between the rows (360m);
- The <u>5D/7D layout (see Figure 7.2)</u>: an alternative wind farm layout with 5 rotor diameters (5D) distance (450m) between the turbines and 7D between the rows (630m);
- 3. The <u>5D/10D layout (see Figure 7.3)</u>: another alternative wind farm layout with 5 rotor diameters (5D) distance (450m) between the turbines and 10D between the rows (900m);
- 4. The <u>6D/12D layout (see Figure 7.4)</u>: the final alternative wind farm layout with 6 rotor diameters (6D) distance (540m) between the turbines and 12D between the rows (1080m).

The wind turbines will be spaced in a way to minimize turbine-to-turbine interference in the wind flow. The exact spacing required depends on the size of the turbine selected, with increased spacing used for the larger turbines.

<sup>&</sup>lt;sup>132</sup> For Ackermann (2005) is a concept used by engineers to describe the electrical energy that circulates continuously among the various electrical and magnetic fields of alternating-current (AC) system, without producing work. These fields store energy which changes through each AC cycle.

In an onshore wind farm, interspacing between individual turbines is around 6 to 10 times the rotor diameter in the prevailing wind direction. The interspacing distance in the cross prevailing wind direction is around 2 to 5 diameters. The exact spacing will be determined after a detailed micrositing flow analysis. The micro-sitting analysis leads to an acceptable balance between yield maximization and making efficient use of the limited space available (Rehman, Ahmad, & Al-Hadhrami, 2011). The schema (5D/4D) is used as base-case for wind farm layout simulations.



Figure 7.1 Representation of 5D/4D layout used for simulations. Source: Own elaboration

The scheme of 5D/4D requires 4.374km<sup>2</sup> and represents 29.2% of the total area available for the wind farm (see Figure 7.1).



Figure 7.2 Representation of 5D/7D layout used for simulations. Source: Own elaboration

This alternative scheme of 5D/7D requires 6.998km<sup>2</sup> and represents 46.7% of the total area available for the wind farm (see Figure 7.2).



Figure 7.3 Representation of 5D/10D layout used for simulations. Source: Own elaboration

This alternative scheme of 5D/10D requires 9.623km<sup>2</sup> and represents 64.2% of the total area available for the wind farm (see Figure 7.3).



Figure 7.4 Representation of 6D/12D layout used for simulations. Source: Own elaboration

This alternative scheme of 6D/12D requires 13.057km<sup>2</sup> and represents 87.0% of the total area available for the wind farm (see Figure 7.4).

According to Li and Chen (2008) the penetration of wind power into the existing power system continues to increase, which implies the situation of the large wind farms is changing from being simple energy sources to having power plant status with grid support characteristics. They declare that one major challenge in the present and coming years is the connection and optimized integration of large wind farms into electrical grids.

In  $LCOE_{wso}$  methodology the *local wind turbines grid* is considered a capital expenses during the initial lifetime of a wind power project. As it has been connected to the wind turbines sites, the *Local Wind Turbines Grid (LWTG)* of any wind farm depends on the scheme of wind turbines sitting used, for simplification of electrical grid's types we have considered a linear configuration for *LWTG*, according to Figure 7.5.



Figure 7.5 Representation of Local Wind Turbines Grid used for simulations. Source: Own elaboration

The different type of wind farm layout also impacts on land area required for implementation of the power plant, as shown in Table 7.4.

6,5	1	
Layout type	Area (km <sup>2</sup> )	Total area occupation (%)
5D/4D	4 374	29.2
5D/7D	6 998	46.7
5D/10D	9 623	64.2
6D/12D	13 057	87.0

 Table 7.4
 Relation among layout, area and occupation

Source: Own elaboration

# 7.2.2 CLIMATE DATA USED FOR $V_W(M/S)$ , P(KPA) and $T(^{\circ}C)$

#### 7.2.2.1 WIND SPEED ( $V_W$ AND $V_{WC}$ )

Period	Aracati (Brazil)		Corvo Island (Portugal)		Cape Saint James (Canada)	
	$v_w(m/s)$	$v_{wc}^{(*)}(m/s)$	$v_w(m/s)$	$v_{wc}^{(*)}(m/s)$	$v_w(m/s)$	$v_{wc}^{(*)}(m/s)$
January	4.2	5.8	8.4	11.7	11.1	15.4
February	3.5	4.9	<i>8.3</i>	11.5	10.6	14.7
March	2.9	4.0	7.6	10.5	9.2	12.7
April	3.4	4.7	6.8	9.5	8.9	12.4
May	4.3	6.0	5.9	8.2	8.1	11.2
June	5.7	7.9	5.1	7.1	7.5	10.4
July	6.2	8.6	4.4	6.1	7.2	10.0
August	6.9	9.6	4.6	6.4	7.0	9.7
September	7.3	10.1	5.4	7.6	7.5	10.4
October	7.0	9.7	6.4	8.9	9.5	13.1
November	6.6	9.2	7.7	10.6	10.3	14.3
December	5.5	7.6	<i>8.3</i>	11.5	10.8	15.1
Annual Average	5.3	7.4	6.6	9.1	9.0	12.5

 Table 7.5
 Wind speed series at 10m data and calculated<sup>133</sup> at 105m for Aracati, Corvo Island and Cape Saint James

Source: RETScreen® International Clean Energy Decision Support Centre (2009)

<sup>(\*)</sup> Wind speed series for 105m calculated ( $v_{wc}$ ) by Petersen, Mortensen, Landberg, Højstrup, and Frank (1998).

Some findings about wind speed are:

- 1. In Aracati (Brazil) the windiest period is clearly June, July, August, September, October, November and December. During this period we can notice wind speed higher than annual average wind speed (7.4 m/s). When we calculate for hub height (H=105m), it was found the same situation, but also an increase of 39.0% in initial wind speed (H=10m).
- 2. In Corvo Island (Portugal) the windiest period is clearly *January*, *February*, *March*, *April*; *November* and *December*. During this period we can notice wind speed higher than annual average wind speed (9.1 m/s). When we calculate for hub height (H=105m), it was found the same situation, but also an increase of 39.0% in initial wind speed (H=10m).
- 3. In *Cape Saint James* (Canada) the windiest period is clearly *January*, *February*, *March*; *October*, *November* and *December*. During this period we can notice wind speed higher than annual average wind speed (12.5 m/s). When we calculate for hub height (*H*=105*m*), it was found the same situation, but also an increase of 39.0% in initial wind speed (*H*=10*m*).

<sup>&</sup>lt;sup>133</sup>  $I/7^{th}$  power law scaling to calculate the hub height wind speed ( $v_{wc}$ ): for each site (see Table 6.4) was calculated the wind speed at hub-height of 105 m used for electricity production from the hypothetical wind farm.

# 7.2.2.2 Atmospheric pressure (P)

Period	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)	
	P(kPa)	P(kPa)	P(kPa)	
January	100.4	102.0	100.1	
February	100.4	102.1	100.0	
March	100.4	101.9	100.0	
April	100.4	102.0	100.4	
Мау	100.5	102.1	100.5	
June	100.6	102.3	100.7	
July	100.7	102.5	100.8	
August	100.7	102.2	100.7	
September	100.6	102.0	100.5	
October	100.5	101.9	100.2	
November	100.4	101.9	99.9	
December	100.4	101.7	100.1	
Annual Average	100.5	102.1	100.3	

 Table 7.6
 Atmospheric pressure data for Aracati, Corvo Island and Cape Saint James

Source: RETScreen® International Clean Energy Decision Support Centre (2009)

Some findings about atmospheric pressure are:

- In Aracati (Brazil) the highest atmospheric pressure period is clearly *June*, *July*, *August* and *September*. During this period we can notice that atmospheric pressure is higher than annual average atmospheric pressure (100.5 kPa).<sup>.</sup>. The atmospheric pressure data series has presented a SD<sup>134</sup>=0.1 kPa, 100.4 kPa and 100.7 kPa as minimum and maximum values, respectively, for the same period.
- 2. In Corvo Island (Portugal) the highest atmospheric pressure period is clearly *June, July* and *August*. During this period we can notice that atmospheric pressure is higher than annual average atmospheric pressure (102.1 kPa)... The atmospheric pressure data series has presented a SD=0.2 kPa, 101.7 kPa and 102.5 kPa as minimum and maximum values, respectively, for the same period.
- 3. In Cape Saint James (Canada) the highest atmospheric pressure period is clearly *April, May, June, July, August* and *September*. During this period we can notice that atmospheric pressure is higher than annual average atmospheric pressure (100.3 kPa). The atmospheric pressure data series has presented a SD=0.3 kPa, 99.9 kPa and 100.8 kPa as minimum and maximum values, respectively, for the same period.

<sup>&</sup>lt;sup>134</sup> SD = Standard Deviation.

# 7.2.2.3 AIR TEMPERATURE (T)

Period	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
	$T(^{\circ}C)$	$T(^{\circ}C)$	$T(^{\circ}C)$
January	26.8	15.6	4.6
February	26.8	15.0	5.2
March	26.6	15.0	5.7
April	26.7	15.4	6.8
Мау	26.9	16.5	8.8
June	26.9	18.4	10.8
July	26.8	20.7	13.0
August	27.3	21.9	14.1
September	27.5	21.4	13.2
October	27.5	19.7	10.1
November	27.4	18.0	6.9
December	27.1	16.6	5.2
Annual Average	27.0	17.8	8.7

 Table 7.7
 Air temperature data for Aracati, Corvo Island and Cape Saint James

Source: RETScreen® International Clean Energy Decision Support Centre (2009)

Some findings about air temperature are:

- 1. In Aracati (Brazil) the hottest period is clearly *August, September, October, November* and *December*. During this period we can notice that air temperature is higher than annual average air temperature (27.0°C). The air temperature data series has presented a SD=0.3°C, 26.6°C and 27.5°C as minimum and maximum values, respectively, for the same period.
- 2. In Corvo Island (Portugal) the hottest period is clearly *June, July, August, September, October,* and *November*. During this period we can notice that air temperature is higher than annual average air temperature (17.8°C). The air temperature data series has presented a SD=2.5°C, 15.0°C and 21.9°C as minimum and maximum values, respectively, for the same period.
- 3. In Cape Saint James (Canada) the hottest period is clearly May, June, July, August, September and October. During this period we can notice that air temperature is higher than annual average air temperature (8.7°C). The air temperature data series has presented a SD=3.3°C, 4.6°C and 14.1°C as minimum and maximum values, respectively, for the same period.

•			•
	Aracati	Corvo Island	Cape Saint James
Period	(Brazil)	(Portugal)	(Canada)
	$\rho(kg/m^3)$	$\rho(kg/m^3)$	$ ho(kg/m^3)$
January	1.1665	1.2313	1.2561
February	1.1666	1.2345	1.2522
March	1.1671	1.2329	1.2495
April	1.1667	1.2317	1.2490
May	1.1670	1.2282	1.2425
June	1.1686	1.2224	1.2351
July	1.1698	1.2154	1.2275
August	1.1677	1.2075	1.2216
September	1.1657	1.2064	1.2234
October	1.1645	1.2126	1.2327
November	1.1638	1.2194	1.2429
December	1.1651	1.2237	1.2528
Annual Average	1.1666	1.2222	1.2404

 Table 7.8
 Air density calculated for Aracati, Corvo Island and Cape Saint James

Source: Own elaboration

Some findings about air density are:

- In Aracati (Brazil) the highest air density period is clearly *March, April, May, June, July* and *August*. During this period we can notice that air density is higher than annual average air density (1.1666 kg/m<sup>3</sup>). The air density calculated has presented a SD=0.0016 kg/m<sup>3</sup>, 1.1638 kg/m<sup>3</sup> and 1.1698 kg/m<sup>3</sup> as minimum and maximum values, respectively, for the same period.
- 2. In Corvo Island (Portugal) the highest air density period is clearly *January*, *February*, *March*, *April*, *May*, *June* and *December*. During this period we can notice that air density is higher than annual average air density (1.2222 kg/m<sup>3</sup>). The air density calculated has presented a SD=0.0095 kg/m<sup>3</sup>, 1.2064 kg/m<sup>3</sup> and 1.2345 kg/m<sup>3</sup> as minimum and maximum values, respectively, for the same period.
- 3. In Cape Saint James (Canada) the highest air density period is clearly *January*, *February*, *March*, *April*, *May*; *November* and *December*. During this period we can notice that air density is higher than annual average air density (1.2404 kg/m<sup>3</sup>). The air density calculated has presented a SD=0.0116 kg/m<sup>3</sup>, 1.2216 kg/m<sup>3</sup> and 1.2561 kg/m<sup>3</sup> as minimum and maximum values, respectively, for the same period.

# 7.3 ECONOMIC AND FINANCIAL ASPECTS OF THE WIND PROJECT

#### 7.3.1 Assumptions, constraints, and limitations

For simplicity, the economic and financial issues of the wind project to be simulated the assumptions, constraints and limitations are related to *O&M costs* and *project/turbine availability* and *other losses*; *financing structure and costs*; *project lifetime, income taxes, decommissioning rates and asset depreciation*.

#### 7.3.1.1 Assumptions

Table 7.9	Economic	and fi	nancial	assumptions	considered	for wind	project
							I ./

—	
$\Leftrightarrow$ Life time (N)	25 yrs
☆ Debt interest rate	5%/yr
✤ Debt ratio	50% <sup>135</sup>
✿ Debt term	14 yrs
✤ Depreciation method	Straight-line <sup>136</sup>
☆ Depreciation rate	4%/yr
	9%/yr
$\Leftrightarrow$ Revenue taxes ( $R_{taxes}$ )	30%
$\Rightarrow$ Inflation rate ( <i>ifr</i> )	2.5%/yr
☆ Period of O&M warranty	From 1 to 5 yr
Source: Own alaboration	

Source: Own elaboration

- a) The <u>Power Purchase Agreement Rate (PPAR)<sup>137</sup> is considered different for each site</u>, according to the energy policy by the country (Brazil, Portugal and Canada)∴ PPAR is defined in \$/kWh;
- b) We have considered the <u>25-year assumed project/economic life in all scenarios</u> used in simulations;
- c) The <u>interest</u>, <u>inflation</u>, <u>debt</u> and <u>discount</u> rates within <u>debt</u> ratio are constant during the economic lifetime of the wind project;
- d) The <u>financing structure of the wind project is constant</u> during the economic lifetime of the wind project too;
- e) <u>O&M costs and wind farm availability are also conditioned to *Operations and Maintenance* <u>management (O&M<sub>manag</sub>)</u> proposed as described in section 7.4.2;</u>

<sup>&</sup>lt;sup>135</sup> As suggested by Wiser (1997) the LCOE is minimized at a capital structure of approximately 50% debt and 50% equity.

<sup>&</sup>lt;sup>136</sup> For more explanation about depreciation methods, please, see Albadi, El-Saadany, and Albadi (2009).

<sup>&</sup>lt;sup>137</sup> A Power Purchase Agreement ("PPA") is a long-term agreement between the seller of wind energy and the purchaser.

- O&M costs<sup>138</sup> are accounted in in Wind Farm O&M Cost Model (O&M<sub>WFCM</sub>) and f) information/data are also based on Table 6.8:
- The cash flow model adopted for economic analysis by simulations is based on Welch and **g**) Venkateswaran (2009). We have also considered the items described in  $LCOE_{wso}$  proposed in Chapter 6;
- All monetary values used to calculate LCOE<sub>wso</sub> are converted<sup>139</sup> to 2010 US \$ and updated h) with the inflation rate defined, in order to uniform the input-output values presented in this Ph.D. research work;
- Initial capital costs of the wind project (yr=0) are accounted in Wind Farm Life-Cycle Capital i) <u>*Cost Model*</u> (*LCCCM*<sub>*WF*</sub>) and information/data are based on Table 6.7;
- Capital costs related to major review of the wind power system are accounted in Levelized j) Replacement Cost Model (LRCM) and information/data are based on Table 6.8;
- k) Decommissioning costs are included in Wind Farm Removal Cost Model ( $RCM_{WF}$ ) and information/data are also based on Table 6.8 and Table 6.9;
- The policy instruments that impacts on COE are defined in Renewable Energy Public 1) Incentive Model (REPIM) and information/data are also based on Table 6.10.

#### 7.3.1.2 Constraints

- a) We have considered *PPAR* constant during the lifetime of the wind project for all simulations, that avoid any change in energy policy during the period of instrument analyzed;
- b) As we have considered only one lifetime for the wind project, we cannot analyzed the effect of lifetime flexibility in the cost of energy produced by the power plant;
- c) As stated in section 7.3.1.1, item c), we cannot measure the effect of variation on macroeconomic indicators (e.g.: interest rate and inflation) for the different sites chosen for simulations;
- d) The wind project is capital-intensive and the financing structure<sup>140</sup> can be adequate to each project; in our case we have considered a constant financing structure for the wind project simulated;
- e) The energy market has changed and the competition through the economic agents raised up during the last decade, but we have considered the market and consumer able enough to buy

<sup>&</sup>lt;sup>138</sup> Shipping and warehousing costs for parts are not included. Given the variability and uncertainty of parts costs, and the number of options for warehousing spares, we may reasonably assume that shipping costs are included in the parts costs.

Exchange rates of 1.3252 (EUR/USD); 0.9998 (CAN/USD); 0.5986 (BRL/USD); based on rates on December 31, 2010. Available at http://www.oanda.com/currency/converter/. 140 For a better understanding about wind project financing structures, please see at Harper, Karcher, and Bolinger (2007).
(clean) green energy for the next 25 years  $\therefore$  The renewable energy market can change and we have considered it is favorable;

f) The <u>distribution grid of these selected sites</u> to install a new power plant, in other words, a new wind power plant, <u>is ready enough to receive one more producer with variable electricity</u> <u>generation</u>, which cannot be so true like that!;

## 7.3.1.3 Limitations

- a) The <u>wind project has an only price of electricity sold</u>, although, this price (*PPA*) has to be updated by the inflation rate adopted ∴ It can be analyzed as weakness due to the variation of the wind power plant;
- b) The <u>annualized economic variables can change during the year, but we have considered</u> <u>constant during the entire year</u>, and the possible change can occurs inter-years (from one year to another), what <u>can not reflect the real volatile nature of these variables;</u>
- c) The wind profile (distribution) at a site determines the *COE* and the revenue to a wind farm operator by determining the number of kWh sold∴Since WECS scales with the cube of wind velocity, the velocity of the wind is likely to be the most important single factor in determining the placement of wind farms and their profitability; we have considered these three sites in function of the highest annual mean wind speed available in RETScreen Climate Database;
- d) <u>COE can be also affect by availability of the wind farm</u>, in our analysis we have considered only  $O\&M_{manag(STD)}$ ;  $O\&M_{manag(A)}$ ;  $O\&M_{manag(B)}$  described in section 7.4.2, in literature is possible to find another factor (e.g.: load demanded; earthquakes or other natural disasters). In order to simplify the  $LCOE_{wso}$  we have not considered catastrophic events such as hurricanes, tornados, and lightning;
- e) The <u>three different wind farms are analyzed and compare each other in order to notice the</u> <u>influence of technical and economic variables simulated</u>; This analyzes can be more than comparison, but as we have stated in the objectives of this Ph.D. research work <u>only make</u> <u>economic evaluation of a candidate wind project through the *LCOE* optimization;</u>
- f) According to Ngala, Alkali, and Aji (2007) researches concerning about economic evaluation of WECS have shown a lack of common economic analysis technique, and elemental cost data for validation, the  $LCOE_{wso}$  calculated and named as the "optimized cost" cannot reflect the real minimum (optimized) cost of electricity produced by a wind farm;
- g) The <u>investment analysis done are not for exclusion reason</u>, due to <u>we have not considered</u> <u>limited funds for investment alternative</u>, even less we know it is an important aspect to be checked in this kind of analysis.

#### 7.3.2 REVENUE, CAPITAL, O&M, AND OTHER COSTS

Considering the variability of the wind resources, estimating the average annual revenue  $(AAR_{yr_n})$  of a wind farm may be challenging when the amount of information available is limited or when the idea is still in project phase. In this Ph.D. research work, we have considered revenues from the wind farm designed to be originated by product from  $AEP_{avail}$  and *electricity price sold (PPAR)* and the *expected market price (EMP) (year n)*<sup>141</sup>. Eqn 7.1 shows the algorithm developed to calculate  $AAR_{yr}$ .

$$AAR_{yr_n} = \left[ \left( PPAR_{yr_n} \times AEP_{avail} \right) + \left( EMP_{yr_n} \times AEP_{avail} \right) \right] \qquad [M\$/yr] \qquad Eqn (7.1)$$

So the Table 7.10 is shown the parameters used for calculating the average annual revenue of the hypothetical wind farm in simulations procedures.

<b>Table 7.10</b>	Revenue	parameters	considered	for	simulations
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✿	Type of agreement	PPA	
✡	Price of energy sold (PPAR)	$0.08581 USD/kWh^{\mbox{\tiny (a)}}, 0.16291 USD/kWh^{\mbox{\tiny (b)}}$ and $0.13835 USD/kWh^{\mbox{\tiny (c)}}$	
✡	Length of the agreement	1 to 20 yr	
✡	Expected market price (EMP <sub>yr</sub> )	21 to 25 yr	
✿	Economic indexation of PPAR a	and $EMP_{yr}$ Annual inflation rate (see Table 7.9)	

Source: Own elaboration. Note: <sup>(a)</sup>*PPAR* for Brazil (Chade, Juliana, & Sauer, 2013); <sup>(b)</sup>*PPAR* for Portugal (ERSE, 2013) and <sup>(c)</sup>*PPAR* for Canada (CanWEA, 2012).

Regarding to *capital costs* (investment costs)<sup>142</sup> of the hypothetical wind farm, we have considered the same classification presents in Chapter 5, Table 5.1. The referenced inputs for determining the capital costs for the simulations are based on Tables 6.7 and 6.8.

O&M costs are considered into two parts. One is the fixed O&M (see Eqn 6.2.3.1)... This named  $O\&M_{fixed_{CM}}$ , based on percentage ( $\varpi$ ) of capital cost (*LCCCM<sub>WF</sub>*) and land lease cost (*LLC*) per kWh (for cover costs such as interconnect fees and royalties including land costs)... We have also considered the relation between *wind farm layout* and *land area* (see Table 7.4). The other part of O&M costs are considered variable ( $O\&M_{variable_{CM}}$ ). This variable part of O&M cost are based on

<sup>&</sup>lt;sup>141</sup> *EMP*<sub>yr</sub> is applicable only after finish the period of *PPA*, we have not considered both, and one does not exclude another. We have considered as a parameter for *EMP*<sub>yr</sub> a ratio between *PPAR* and *EMP*<sub>yr</sub> of 0.7 (70%).

<sup>&</sup>lt;sup>142</sup> Capital costs are considered equal for the three different sites simulated.

warranty conditions, labor costs, revenue taxes, inflation and lifetime of the wind farm (see Eqn 6.2.3.2).

Wind farm reliability is a critical factor in the success of a wind energy project. Poor reliability directly affects both the project's revenue stream through increased O&M costs and reduced availability to power due to turbine downtime. Many researches has confirmed that condition, although we must consider the effect of the O&M warranty contracts, such as period, frequency, items supported and other aspect which can contribute to reduce or maintain constant (compatible with the level of production).



Figure 7.5 Estimated O&M cost per unit of energy production. Source: Christopher (2003)

As we can notice in Figure 7.5 higher O&M costs are accompanied by more frequent downtime of the wind turbines during the years of operation. This will imply a lower number of production hours and a substantial negative impact on the cost per kWh. For Blanco (2009) O&M costs make up around 10% of the expenditure, although there is substantial uncertainty around this category due to the fact that few wind turbines have reached the end of their lifetime.

The "other costs" of the wind power plant are difficult to be accounted analytically in a 100% included manner, and it could be an unnecessary effort due to the relative participation of "other costs" in the COE. The institutional setting, particularly spatial planning and public permitting practices, can make a significant impact on costs of energy produced by a wind farm.

The electricity market and industry influence directly on the *COE*, when we considered the price and costs of fossil-fuel technologies, price of steel, crude, labor, and others which can increase or decrease in function of the international economic scenario. For these variables, we consider the "*Market Cost Adjustment*" ( $MC_A$ ) in some items of the capital cost for a wind power plant.

## 7.4 O&M ASSUMPTIONS FOR WIND PROJECT SIMULATIONS

## $7.4.1 \quad \text{VARIABLES AND DATA}$

The Wind Farm  $O\&M Cost Model (O\&M_{WFCM})$  considers the typical costs associated with ongoing operations, including scheduled maintenance, unscheduled repairs, site management, and support personnel, of a facility that comprises any number of conventional wind turbines. We have summarized in Table 7.11 the variables and data for  $O\&M_{WFCM}$  calculations.

Variables	Data
$O\&M_{fixed}$	calculated
$LCCCM_{WF}$	calculated
LLC	based on Table 6.8
$\overline{\omega}$	based on Table 6.8
<i>if</i> r	based on Table 7.9
N	based on Table 7.2
$O\&M_{\text{variable}_{CM}}$	calculated
$N_{WT}$	calculated
$\left(\frac{AAR}{AEP_{avail}}\right)$	calculated
$n_{mlh}$ and $n_{tlh}$	based on Tables 6.11 and 7.12
MLC	based on Table 6.8
TLC	based on Table 6.8
R <sub>taxes</sub>	based on Table 7.9

Table 7.11 Variables and data for running O&M<sub>WFCM</sub>

Source: Own elaboration

For Poore and Walford (2008) most importantly, there are no complete and consistent data for any project over the entire useful lifetime of the wind turbines. Without exception, the older turbines (those reaching the end of their lifetime) are smaller and simpler versions of the machines installed in the last five years.

Data for simulations have come from a variety of sources, including manufacturer publications, published case studies and scientific journals. The quality (consistency) and quantity of the available data can best be described as *demonstrative*. In some cases general estimates of overall maintenance costs for specific projects for periods of one or two years were available; in other cases detailed information on actual expenditures for a variety of turbines (but only for a limited period of its entire lifetime) was provided. As expected, the data are not in an only one consistent format (\$/kW, \$/wind turbine, \$/hour, etc.) and are broken down into a surprising variety of categories for parts, labor, and downtime.

#### 7.4.2 O&M PROGRAMS PROPOSED

The *Operations and Maintenance management* ( $O\&M_{manag}$ ) proposed to the simulations are defined in  $O\&M_{manag(STD)}$ ;  $O\&M_{manag(A)}$ ;  $O\&M_{manag(B)}$  (see Table 6.5). Data used for each O&M program are based on the information available in Table 6.11.

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Variables	$O\&M_{manag(STD)}$	$O\&M_{manag(A)}$	$O\&M_{manag(B)}$		
$SC_{O\&M}$					
Number of days	5	2	3		
Period <sup>143</sup>	Feb/Jun/Nov	Feb/Jun/Nov	Feb/Jun/Nov		
$USC_{O\&M}$					
Frequency	1.5/yr	1.0/yr	1.8/yr		
Repair time	3h/repair	4h/repair	2h/repair		
0 0 11 /					

Table 7.12 O&M programs analyzed in simulations

Source: Own elaboration

Some assumptions are considered for O&M programs:

- a) The  $O\&M_{manag(STD)}$  is defined as the *base-case*. So the two more options ( $O\&M_{manag(A)}$  and  $O\&M_{manag(B)}$ ) are O&M programs 'variations;
- b) A work day considered is 8 work hours, so the hours required in each program must be calculated as for  $SC_{O\&M}$ : number of work days x period x 8 work hours/day;
- c) The *hours required* for  $USC_{O\&M}$  is related to product from the *number of wind turbines*, *frequency failure rate* and *repair time* for each turbine.
- d) The total hours of O&M required is the correspondent relation  $(SC_{O\&M} + USC_{O\&M})$  per year. Each alternative is simulated for each site to be installed the hypothetical wind farm. The objective is finding the best option (we must remember the less hours required better is the program proposed. It is an inverse relation);
- e) For labor costs of O&M, we have considered *MLC* for  $SC_{O\&M}$  and *TLC* for  $USC_{O\&M}$  and the data are based on Table 6.8;
- f) The availability of the wind farm is the relation of hours of production  $(H_{prod})$  and full load hour  $(FLH_{wf})$ .

<sup>&</sup>lt;sup>143</sup> We have considered the period with less hours available for production (see Figure 6.18).

## 7.5 ENERGY POLICY ASSUMPTIONS FOR WIND PROJECT SIMULATIONS

## 7.5.1 VARIABLES AND DATA

The *Renewable Energy Public Incentive Model (REPIM)* was developed in order to measure the effect of the public incentive on *COE* produced by RETs, in our case, WECS technology. We have focused on *investment* and *production* phase of the wind power project. As we already said, we handle with capital-intensive and variable production energy project that is why the cost of energy produced is strongly influenced by capital costs and production. Many studies indicate this relation (Barradale, 2010; Bolinger, 2009; Butler & Neuhoff, 2008; Ertürk, 2012; Lantz, Wiser, & Hand, 2012; Wiser & Pickle, 1998).

We have summarized in Table 7.13 the variables and data for *REPIM* calculations.

Variables	Data
<i>REI<sub>CM</sub></i>	calculated
$\psi_{total}$	based on Table 6.10
$n_{arphi}$	based on Table 6.10
$REP_{CM}$	calculated
$\mathcal{E}_0$	based on Table 6.10
n <sub>e</sub>	based on Table 6.10
$OREP_{CM}$	calculated
$CR_{f}$	based on Table 6.10
$GHG.R_{CM}$	calculated
$GHG_{_{EF_{ff}}}$	based on Table 6.10
$GHG_{_{EF_{wecs}co_2}}$	based on Table 6.10
$\mathcal{E}_0$	based on Table 6.10
$\xi_n$	based on Table 6.10

 Table 7.13
 Variables and data for REPIM calculations

Source: Own elaboration

The *REPIM* variable of  $LCOE_{wso}$  methodology is designed to represent a reduction of COE that is why we consider a negative sign in Eqn 6.2, in Chapter 6. Although, we have not considered the effect on  $LCOE_{wso}$  as a "*credit*" for the wind project.

We also can notice in the entire model proposed an excessive data requirement, because for each variable of the  $LCOE_{wso}$  ( $LCCCM_{WF}$ , LRCM,  $O\&M_{WFCM}$ ,  $RCM_{WF}$ , REPIM and  $LCPM_{WF}$ ) needs several parameters for several subcomponents of the WECS and wind project, at a technical and economical point of view.

#### 7.5.2 Energy policy instruments proposed

All the energy policy instruments are used for simulations as we have defined in Table 6.5. Data used for each *REPIM* instrument are based on the information available in Table 6.10. Each alternative is simulated for each site to be installed the hypothetical wind farm.

Instrument	Base-case	Case 1	Case <sub>2</sub>	Case <sub>3</sub>
REI <sub>CM</sub>				
$\psi_{total}$	30%	25%	20%	15%
$n_{arphi}$	6 yrs	5 yrs	4 yrs	3 yrs
$REP_{CM}$				
$\mathcal{E}_0$	88.20 €/MWh <sup>(a)</sup> ; \$75.00/MWh <sup>(b)</sup> ;	decreased 10%	decreased 15%	decreased 20%
$n_{\varepsilon}$	10 yrs <sup>(a)</sup> ; 15 yrs <sup>(b)</sup> ; 10 yrs <sup>(c)</sup>	12 yrs <sup>(a)</sup> ; 17 yrs <sup>(b)</sup> ; 12 yrs <sup>(c)</sup>	14 yrs <sup>(a)</sup> ; 18 yrs <sup>(b)</sup> ; 14 yrs <sup>(c)</sup>	15 yrs <sup>(a)</sup> ; 15 yrs <sup>(b)</sup> ; 20 yrs <sup>(c)</sup>
$OREP_{CM}$				
$CR_{f}$	80%	60%	40%	25%
$GHG.R_{CM}$				
$GHG_{EF_{ff}}{}_{co_2}$	410 g/kWh	690 g/kWh	890 g/kWh	1234 g/kWh
$GHG_{EF_{wecs} co_2}$	30 g/kWh	48 g/kWh	75 g/kWh	83 g/kWh
$\mathcal{E}_{c}$	$35 \notin tCO_2^{(a)};$ $13.00/tCO_2^{(b)};$ $30.00/tCO_2^{(c)}$	decreased 10%	decreased 15%	decreased 20%
$\xi_n$	25%;25%;25%;25%	50%;25%;25%;0%	10%;50%;20%;20%	0%;0%;50%;50%

**Table 7.14** *REPIM* instruments analyzed in simulations

Source: Own elaboration. Note: <sup>(a)</sup> Brazil; <sup>(b)</sup> Portugal and <sup>(c)</sup> Canada.

Some assumptions are considered for REPIM cases:

- a) We have considered a moderate decreasing interest of governments<sup>144</sup> in supporting RETs, reason why we consider decreasing trends for  $\varepsilon_0$  in cases 1, 2 and 3;
- b) The carbon credits ( $\mathcal{E}_c$ ) also follows the same trends of governments supporting for RETs, because the carbon credit market shows in the last 5 years;
- c) The *time of policy energy instrument*  $(n_{\varepsilon})$  is defined due to the current legislation of each country selected for simulations.

<sup>&</sup>lt;sup>144</sup> It can be probably due to the global economy recession. For more information, please see at Newell, Pizer, and Raimi (2013).

## 7.6 GENERAL SIMULATIONS PROCEDURES

## 7.6.1 Steps used for simulations

As we have discussed in Chapter 6, section 6.4.4.3 the simulation process should follow some standard steps  $\therefore$  During the simulations procedures we have followed the steps as shown in Figure 7.6:

1. Problem Definition	<i>Explained in section 1.2 (Interest and scope of the research) and section 6.4.3.1 (Research objectives)</i>
2. Overall Project Plan	Explained in section 6.4.2 (Methodological procedures)
3. System Definition	<i>Explained in section 6.4.4.1 (Variables relationship and research boundary)</i>
4. Conceptual Model	Explained in section 6.4.4.2 (Mathematical model structuring; Shown in Figure 6.16
5. Experimental Design	Explained in section 6.4.4(Research design)
6. Model Translation	The equations of $LCOE_{wso}$ model are written in MS Excel spreadsheet and imported to Matlab for simulations
7. Verification & Validation	<i>Explained in section 6.4.4.3 (Numerical simulation and validation process)</i>
8. Input Data Preparation	Explained in section 6.4.4.3 (Numerical simulation and validation process); See Tables 6.5, 6.6, 6.7, 6.8, 6.9.6,10 and 6.11
9. Operationalization	Explained in section 7.6 (General simulations procedures)
10.Analysis & Interpretation	Explained in Chapter 8 (Results and Discussion)
11.Implementation & Documentation	Explained in Chapter 9 (Conclusions and Implications)

**Figure 7.6** Steps of simulation of  $LCOE_{wso}$  algorithm. Source: adapted from Shannon (1992) and Banks (1999)

## 7.6.2 OPTIMIZATION CRITERIA

We have considered some hypotheses for developing  $LCOE_{wso}$  methodology as shown in Table 6.3. The optimization criteria are defined considering the relations among variables ( $v_{wc}$ ,  $L_{wb}$ ,  $O\&M_{manag}$ 

and  $E_{pi}$ ) and hypotheses ( $RH_1$ ,  $RH_2$ ,  $RH_4$ ,  $RH_5$ ,  $RH_6$  and  $RH_7$ ) of this Ph.D. research work. We have summarized in Table 7.15 the variables and hypotheses considered for optimization criteria definition.

 Table 7.15
 Variables and hypotheses considered for optimization criteria definition

Variables	Relation with	Impact expected on $LCOE_{wso}$	
1. Wind speed $(v_{wc})$	hypotheses $RH_{1,}RH_{2}$ and $RH_{5}$	down (-) and or up (+)	
2. Wind turbines layout $(L_{wt})$	hypotheses $RH_4$ and $RH_5$	down (-) and or up (+)	
3. O&M management ( $O\&M_{manag}$ )	hypotheses $RH_5$ and $RH_6$	down (-) and or up (+)	
4. Energy policy instruments $(E_{pi})$	hypotheses $RH_5$ and $RH_7$	down (-) and or up (+)	

Source: Own elaboration

We also try to answer two fundamentals questions through the optimization criteria:

- 1. Which variables are expected to have the largest effect on  $LCOE_{wso}$ ?
- 2. Which of these variables affect more than one component of the  $LCOE_{wso}$  decomposition?

As we have stated at section 6.4.3.4 (Research hypotheses and limitations), there is *no standard LCOE to be reference for this kind of research, it is not possible to harmonize all input/data assumptions* and the *site of the power plant becomes each wind project as unique*. Consequently, for simulation and validating the proposed algorithm ( $LCOE_{wso}$ ) we have considered as the main optimization criteria, when conditions can be confirmed simultaneously:

- 1. As *minimum as possible LCOE\_{wso}* calculated in the simulations for each site selected for the hypothetical wind farm;
- 2. For the same wind farm, the *lowest*  $LCOE_{wso}$  calculated in the simulations, considering the whole lifetime of the hypothetical wind farm and;
- 3. As *maximum as possible*  $AEP_{avail}$  calculated in the simulations for each site selected for the hypothetical wind farm.

As Ozerdem, Ozer, and Tosun (2006) have discussed about cost-effective solution means the most suitable alternative, technically and economically. The  $LCOE_{wso}$  methodology may lead to safe conclusions with respect to the best performance of a wind project, in a technical and economical point of view. Power projects in the electricity supply market live for long a period that is the case of wind farms last for about 20-30 years.

#### 7.6.3 SENSITIVITY ANALYSIS

The sensitivity analysis is a technique for finding out how the result from the reliability analysis varies, when changing the values of the input parameters. Thus, a sensitivity analysis is appropriate to use when input data suffer from a high degree of uncertainty, just as the case for the reliability data in this Ph.D. research work.

It is important to define the central point of the proposed sensitivity analysis. The sensitivity analysis done in the simulations is in order to *understand the influence of the governing parameters* on the  $LCOE_{wso}$  and the economic efficiency of the wind power plant analyzed. These values should be representative for the techno-economic situation of the wind farm. After extensive research data review, the following values are selected for the main parameters (data) for the wind project conditions and details (see Tables 6.5 to 6.11).

We have also considered the minimum value for each parameter (datum) used, in function of the orientation to find the *minimum*  $LCOE_{wso}^{145}$  calculated as possible in the simulations done  $\therefore$  Variables, parameters/data, variations and interactions for the sensitivity analysis are presented in Table 7.16.

Table 7.16 Variables, parameters, variations and interactions of the sensitivity analysis

Variables	Variations	Interactions ( <i>int</i> =900) with N=25yrs
1. Wind speed <sup>146</sup> ( $v_{wc}$ )	according to Table 7.5	1 $v_w x$ 3 different sites $x N = 75$ int
2. Wind turbines layout $(L_{wt})$	according to Table 7.4	4 $L_{wt} x$ 3 different sites $x N = 300$ int
3. O&M management ( $O\&M_{manag}$ )	according to Table 7.12	$3 O \& M_{manag} x 3$ different sites $x N = 225$ int
4. Energy policy instruments $(E_{pi})$	according to Table 7.14	4 $E_{pi}x$ 3 different sites $x N = 300$ int
0 0 11		

Source: Own elaboration

The sensitivity analysis is organized in two parts. The first part the variables are analyzed individually (see section 8.4.1). In this part is analyzes the impact of wind speed  $(v_{wc})$ , O&M management  $(O\&M_{manag})$ , wind turbines layout  $(L_{wt})$  and energy policy instruments  $(E_{pi})$  on  $LCOE_{wso}$ . The second part of the sensitivity analysis a multiple variable analysis is made (see section 8.4.2). We have analyzed the impact of wind speed  $(v_{wc})$  and wind turbines layout  $(L_{wt})$  and O&M management  $(O\&M_{manag})$  and energy policy instruments  $(E_{pi})$  on  $LCOE_{wso}$ .

The sensitivity analysis was conducted for gaining an *insight about the impact of the variables* selected to the cost of energy produced from the wind farm. The results are discussed and shown in graphs and tables in Chapter 8.

<sup>&</sup>lt;sup>145</sup> The reference values of *LCOE/NREL* are USD 50/MWh to USD 150/MWh (see Table 6.7), considering the same conditions as explained in Lantz et al. (2012); and IEA (2005, 2010).

<sup>&</sup>lt;sup>146</sup> Wind speed calculated  $(v_{wc})$  for hub height (H=105m).

## 7.7 SUMMARY AND CONCLUSIONS

The objective of this chapter is to implement numerical simulation and validation of the  $LCOE_{wso}$  methodology proposed in Chapter 6 of this Ph.D. research work. Model verification and validation are critical in the development of a simulation model. Unfortunately, there is no set of specific tests that can easily be applied to determine the "correctness" of a new model. Furthermore, no algorithm exists to determine what techniques or procedures to use to validate it. Every simulation study represents a new and unique challenge to the author(s) of the model.

We have designed the  $LCOE_{wso}$  to be applied in WECS technology which has driven us to develop a power system definition as we do in section 7.2. Furthermore, as the goal is to find the *minimum COE* using the  $LCOE_{wso}$  methodology, it is necessary to discriminate analytically the algorithm into sub-models as shown in Chapter 6, section 6.4.4.2. To performance the numerical simulation and validation of this model so many input/data were needed, as summarized in Tables 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13 and 7.14.

The calculations are done and the final results are compared with referenced values. We have considered a range for the  $LCOE_{wso}$  calculated in order to be numerically validated the methodology proposed and the technical and economic aspects of the power plant (wind farm) and institutional conditions (current energy policy) and climate conditions give us a large range  $\therefore$  The NREL<sup>147</sup> has estimated the *LCOE* for onshore wind energy for US and Europe, excluding incentives, an average *LCOE*<sub>2010</sub> of USD 71/MWh, as we can see in Figure 7.7.



**Figure 7.7** Estimated *LCOE* for wind energy between 1980 and 2009 for the United States and Europe (excluding incentives). Source: Lantz et al. (2012)

<sup>&</sup>lt;sup>147</sup> The National Renewable Energy Laboratory (NREL) is the U.S. Department of Energy's primary national laboratory for renewable energy and energy efficiency research and development. For more information, please see at <u>http://www.nrel.gov/</u>.

An analysis of the fundamentals of  $LCOE_{wso}$  methodology has resulted in a well-considered approach of cost modeling within the LCOE/NREL methodology that is worldwide used for cost-analysis of RETs.  $LCOE_{wso}$  as a cost method analysis has been developed that can simulate the major technical and economic aspects of an *onshore wind farm* to a degree sufficient to be of use in pilot and other preliminary studies and possible other RETS (e.g. solar power, hydropower, etc.).

Costs and performance of an onshore wind farm closely relate to the  $LCOE_{wso}$  variables simulated as defined in Tables 7.15 and 7.16. Particularly the  $LCOE_{wso}$  that is used to assess differences between various concepts must acknowledge this fundamental connection with the data to feed the model and its impacts on the *COE* of the wind farm analyzed. In this Ph.D. research work is considered the operational research approach, being an engineering and economical model simultaneously. A breakdown of costs into a summation of sub-models can lead to a straightforward accumulation of inaccuracies and every level of precision can be obtained with precise input data.

 $LCOE_{wso}$  has been applied for the economic analysis of the wind farm in three different sites (Brazil, Portugal and Canada). Although the simulation and validation of a model just represents a "single concept", the results of this cost model are unique for each site simulated.  $LCOE_{wso}$  proved a good basis to compare the effect of data (parameters) considered and to assess the effect of variations that affect both  $AEP_{avail}$  and LCOE." We should consider as "critical" when interpreting the trend of levelized production costs in a parameter variation analysis for making a decision about the power plant (project) analyzed.

As we said in the last paragraph, the effect of the parameters/data variations impact on  $LCOE_{wso}$  that is why we need to run (900 interactions) within a sensitivity analysis for numerical simulation and validation process, as detailed in section 7.6... The sensitivity analysis was defined and undertaken as explained in sections 7.6.1, 7.6.2 and 7.6.3. Two groups of analysis are done; one for individual variable ( $v_{wc}$ ,  $O\&M_{manag}$ ,  $L_{wt}$  and  $E_{pi}$ ) and other for multiple variables ( $v_{wc}$  and  $L_{wt}$ ;  $O\&M_{manag}$  and  $E_{pi}$ ) in order to analyzed the size of impact on  $LCOE_{wso}$ .

This Ph.D. research work has demonstrated the importance of cost of energy produced optimization from WECS. The results of the numerical simulations, validation and sensitivity analysis carried out in the present Ph.D. research work are presented and discussed deeply. Also the results of the individual and multiple variable sensitivity analysis indicate that among the parameters/data tested effectively have impacts on the estimated  $LCOE_{wso}$ , as demonstrated in Chapter 8.

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## **CHAPTER 8**

# **RESULTS AND DISCUSSION**

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This chapter demonstrates and discusses the results of the simulations carried out in the present Ph.D. research work. It is discussed the numerical treatment of wind resources (calculation procedures and distribution of wind speed series), simulations analysis results (reference case for comparison analysis, estimation of wind power production and economic evaluation results), sensitivity analysis results (individual and multiple variable sensitivities and conclusions and future analysis on cost of wind energy) and summary and conclusions are presented at the end, with the respective references.

## 8.1 INTRODUCTION

This chapter presents the results of the implementation of the of  $LCOE_{wso}$  methodology already detailed in Chapters 6 and 7 for wind power technology (WECS) in a computer program, which allowed analyzing relational data, such as the impact of the variations in some groups of variables on the cost of energy produced and the estimate of annual production. Sensitivity analyses were made to the variables selected ( $v_{wc}$ ,  $O\&M_{manag}$ ,  $L_{wt}$  and  $E_{pi}$ ). In addition, a comparison was made between the estimates of the annual energy production at three different sites, using the  $LCPM_{WF}$  methodology described in section 6.4.4.2.

The results and discussions about the  $LCOE_{wso}$  methodology go from the most general to the most detailed issues, taking into consideration the key assumptions and data. It started with *numerical treatment of wind resources* (section 8.2) where is explained the *calculation procedures* (section 8.2.1) and *distribution wind speed series* (section 8.2.2) for *Aracati* (section 8.2.2.1), *Corvo Island* (section 8.2.2.2) and *Cape Saint James* (section 8.2.2.3).

The simulations analysis results (section 8.3) are organized in reference case for comparison analysis (section 8.3.1) based on initial results summary of  $LCOE_{wso}$  as referenced values (section 8.3.1.1) and the breakdown structure of  $LCOE_{wso}$  (section 8.3.1.2). In the section 8.3.2 is presented the estimation of wind power production for each site chosen (see sections 8.3.2.1, 8.3.2.2 and 8.3.2.3). Section 8.3.3 is related about economic evaluation results also for each site (see sections 8.3.3.1, 8.3.3.2 and 8.3.3.3).

The sensitivity analysis results (section 8.4) was carried out based on Table 7.16 and the results were separated into two groups. The individual variable sensitivities (section 8.4.1), where we made some variations considering the impact on  $LCOE_{wso}$  of wind speed ( $v_{wc}$ ) (section 8.4.1.1), operations and maintenance management (section 8.4.1.2), wind turbines layout (section 8.4.1.3) and energy policy instruments (section 8.4.1.4). The multiple variable sensitivities (section 8.4.2) was also made, but we tested the impact on  $LCOE_{wso}$  of wind speed and wind turbine layout (section 8.4.2.1) and O&M management and energy policy instruments (section 8.4.2.2). Some conclusions and future analysis on cost of wind energy are presented in section 8.4.3. Finally, the summary and conclusions of this chapter are summarized in section 8.5 and all references (section 8.6) used are shown at the end of this chapter.

## 8.2 NUMERICAL TREATMENT OF WIND SPEED SERIES

#### 8.2.1 CALCULATION PROCEDURES

The wind measurements are usually made at a height different than the hub height of the wind turbine. The wind speed is extrapolated to the hub height by using the well-known " $1/7^{th}$  wind power law". The wind speeds for simulations procedures at hub-height of 105 m was also done considering the  $1/7^{th}$  wind power law, as described by Petersen, Mortensen, Landberg, Højstrup, and Frank (1998). We have considered some procedures for calculation of the numerical treatment of wind speed series, as follows:

- 1. Determine the calculated wind speed  $(v_{wc})$  per month based on wind speed  $(v_w)$  at 10 m high for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada);
- 2. We consider the Eqn. 8.1 as  $U(z) = U_r \left(\frac{z}{z_r}\right)^a$ , where, where  $(U_r)$  is the wind speed at a reference height (typically 10 m), and (U(z)) is the wind speed at height (z) above ground, is commonly used in the wind energy community to estimate the wind speed and (a) is the *terrain rugosity factor*;
- 3. Calculate the *annual wind speed* at hub-high (105 m) for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) (see Table 7.5 and Figures 8.1, 8.2 and 8.3).

Some assumptions were considered for wind speed series calculations:

- 1. Wind speeds for all calculations are considered in m/s in order we have the same metric for comparison purpose;
- 2. The *wind speed calculated* (*v<sub>wc</sub>*) is based on Table 7.5 for all simulations done for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada);
- 3. The *terrain rugosity factor* (*a*) for the three sites simulated is considered *constant* within the same value ( $a = \frac{1}{7}$ ; a=0.14); In order to simplify the simulations with  $AEP_{avail}$  and  $LCOE_{wso}$  model calculations we simulated the hypothetical wind farm at a macro site point of view for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) as well;
- 4. We have considered for wind speed calculated the same scale for the three sites chosen. The values range from 2 *m/s* (*minimum*) to 25 *m/s* (*maximum*). In order to differentiate the wind trends profile, for each site we use a type of line (see Figure 8.4);
- 5. Temperature, humidity, and atmospheric pressure data were are also based on Tables 7.6, 7.7 and 7.8 All these data were used in the calculations of *air density* ( $\rho$ ) in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada).

### 8.2.2 DISTRIBUTION OF WIND SPEED SERIES

## 8.2.2.1 IN ARACATI (BRAZIL)



**Figure 8.1** Calculated wind speed distribution for Aracati (Brazil). Source: based on RETScreen® International Clean Energy Decision Support Centre (2009)

Figure 8.1 shows the wind speed behavior in Aracati (Brazil) for one year and some considerations we can take from it:

- 1. In the beginning of the year the monthly *wind speed calculated for 105 m hub-high* is possible lower than in the rest of this same year. This initial wind profile is changed in fourth month in the year (*April*) and keep it up until the end of the year;
- As we already said in section 7.2.2.1 the <u>windiest period</u> is clearly *June*, *July*, *August*, *September*, *October*, *November* and *December*. The highest wind speed is in *September* (10.1 m/s) and in the same period (*from June to December*) the monthly wind speed is higher than annual average wind speed (7.4 m/s);
- 3. Statistically, during one year the wind speed series in Aracati (Brazil) has presented a SD=2.1 m/s, 4.0 m/s and 10.1 m/s as minimum and maximum wind speeds, respectively, for the same period.

#### 8.2.2.2 IN CORVO ISLAND (PORTUGAL)



**Figure 8.2** Calculated wind speed distribution for Corvo Island (Portugal). Source: based on RETScreen® International Clean Energy Decision Support Centre (2009)

Figure 8.2 shows the wind speed behavior in Corvo Island (Portugal) for one year and some considerations we can take from it:

- Differently from Aracati (Brazil), as shown in Figure 8.2, in the beginning of the year the monthly *wind speed calculated for 105 m hub-high* is possible highest than in the rest of this same year (*11.7 m/s in January*) at Corvo Island (Portugal)...This initial wind profile is changed in third month in the year (*March*) and there is an increasing trend since from *July* until the end of the year with a *monthly wind speed calculated* in *December* of 11.5 m/s;
- 2. As we already said in section 7.2.2.1 the <u>windiest period</u> are clearly *January*, *February*, *March*, *April*; *November* and *December*. The lowest wind speed is in *July* (6.1 m/s), where this initial wind profile changes to an increasing trend until the rest of the year;
- 3. Statistically, during one year the wind speed series in Corvo Island (Portugal) has presented a SD=2.0 m/s, 6.1 m/s and 11.7 m/s as minimum and maximum wind speeds, respectively, for the same period.

#### 8.2.2.3 IN CAPE SAINT JAMES (CANADA)



**Figure 8.3** Calculated wind speed distribution for Cape Saint James (Canada). Source: based on RETScreen® International Clean Energy Decision Support Centre (2009)

Figure 8.3 shows the wind speed behavior in Cape Saint James (Canada) for one year and some considerations we can take from it:

- Likely Corvo Island (Portugal), as shown in Figure 8.3, in the beginning of the year the monthly *wind speed calculated for 105 m hub-high* is possible highest than in the rest of this same year (15.4 m/s in January). This initial wind profile is changed in eighth month in the year (August) and there is an increasing trend since September until the end of the year with a monthly wind speed calculated in December of 15.1 m/s;
- 2. As we already said in section 7.2.2.1 the <u>windiest period</u> is clearly *January*, *February*, *March*; *October*, *November* and *December*. The highest wind speed is in *January* (15.4 m/s) and in the same period (*January*, *February*, *March*; *October*, *November* and *December*) the monthly wind speed is higher than annual average wind speed (12,7 m/s);
- 3. Statistically, during one year the wind speed series in Cape Saint James (Canada) has presented a SD=2.0 m/s, 9.7 m/s and 15.4 m/s as minimum and maximum wind speeds, respectively, for the same period.



**Figure 8.4** Comparison among the calculated wind speed behavior of the three sites selected. Source: Own elaboration

When we made the comparison of the wind profile during one year, according to the data shown in Figure 6.11, 6.12, 6.13 and Table 7.5, some evidences must be taken in relation the wind speed behavior in an a yearly basis. Figure 8.3 shows the annual wind speed behavior in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) and we highlight the following aspects:

- 1. Both Corvo Island (Portugal) and Cape Saint James (Canada) present a similar wind speed behavior during the year analyzed;
- Wind speed series of Aracati (Brazil) and Cape Saint James (Canada) make interception in *August* and *September*. The wind speeds are 9.6 m/s and 9.7 m/s in *August* for Aracati (Brazil) and Cape Saint James (Canada), respectively. The same situation happens in *September* the wind speed of 10.1 m/s and 10.4 m/s for Aracati (Brazil) and Cape Saint James (Canada), respectively;
- 3. The behavior of wind speed in Aracati (Brazil) and Corvo Island (Portugal) present similarities ∴ In *June* and *October* we can notice a monthly wind speed of 7.9 m/s and 7.1 m/s and 9.7 m/s and 8.9 m/s, respectively.

## 8.3 SIMULATION ANALYSIS RESULTS

## 8.3.1 REFERENCE CASES FOR COMPARISON ANALYSIS

Wind Project Information	Notes	
Project Name	Firestar Wind Farm	
Project Location	Aracati (Brazil)	
Turbine Model	Vestas V90-2MW	
Number of Wind Turbines $(N_{WT})$	25	[-]
Turbine Size	2 000	[kW]
Wind Farm Capacity (WF cap)	50 000	[kW]
Rotor Diamenter (D)	90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]
Hub height (H)	105.0	[m]
Wind speed measured at $(H_0)$	10.0	[m]
Terrain rugosity factor (a)	0.14	[-]
Betz Limit's coefficient $(C_{PBetz})$	0.5926	[-]
Lifetime of Wind Farm $(N)$	25	[yr]
Production Efficiency ( $WF_{PE}$ )	11.2%	[%]
Availability	97.9%	[%]
	357	[d/yr]

Wind Project Information	Notes	
Project Name	Firestar Wind Farm	
Project Location	Corvo Island (Portugal)	
Turbine Model	Vestas V90-2MW	
Number of Wind Turbines $(N_{WT})$	25	[-]
Turbine Size	2 000	[kW]
Wind Farm Capacity (WF cap)	50 000	[kW]
Rotor Diamenter (D)	90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]
Hub height (H)	105.0	[m]
Wind speed measured at $(H_0)$	10.0	[m]
Terrain rugosity factor (a)	0.14	[-]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]
Lifetime of Wind Farm $(N)$	25	[yr]
Production Efficiency (WF PE)	20.5%	[%]
Availability	97.9%	[%]
	357	[d/yr]

Wind Project Information	Notes	
Project Name	Firestar Wind Farm	
Project Location	Cape Saint James (Canada)	
Turbine Model	Vestas V90-2MW	
Number of Wind Turbines $(N_{WT})$	25	[-]
Turbine Size	2 000	[kW]
Wind Farm Capacity (WF cap)	50 000	[kW]
Rotor Diamenter (D)	90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]
Hub height (H)	105.0	[m]
Wind speed measured at $(H_0)$	10.0	[m]
Terrain rugosity factor (a)	0.14	[-]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]
Lifetime of Wind Farm $(N)$	25	[yr]
Production Efficiency ( $WF_{PE}$ )	48.5%	[%]
Availability	97.9%	[%]
	357	[d/yr]

**Figure 8.5** Wind project information for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration. Note: numbers in gray represent results from  $LCOE_{wso}$  methodology calculations

## 8.3.1.1 INITIAL RESULTS SUMMARY OF LCOE<sub>WSO</sub>

Initial Results	Summary	of LCOE wso	Notes		Initial Results	Summary	of LCOE wso	Notes
67.6603	yr <sub>1</sub>	70.7762	yr 15		73.0793	yr <sub>1</sub>	78.4116	yr 15
67.8118	yr <sub>2</sub>	69.8077	yr 15		73.4776	yr <sub>2</sub>	77.5903	<i>yr</i> 15
68.0210	yr 3	69.9988	yr 16		73.7436	<i>yr</i> <sub>3</sub>	78.1098	yr 16
68.1822	yr <sub>4</sub>	70.1987	yr 17		74.0885	yr <sub>4</sub>	78.5637	yr 17
68.4349	yr 5	70.3955	yr <sub>18</sub>		74.4286	<i>yr</i> 5	79.0704	yr <sub>18</sub>
68.6241	yr <sub>6</sub>	70.7564	yr 19		74.8887	yr <sub>6</sub>	79.5598	yr 19
68.8710	yr 7	70.3686	yr 20		75.1794	yr 7	77.6767	<i>yr</i> <sub>20</sub>
69.0863	yr <sub>8</sub>	70.5514	yr <sub>21</sub>		75.4693	yr <sub>8</sub>	78.1898	yr 21
69.2587	yr <sub>9</sub>	70.8222	<i>yr</i> <sub>22</sub>		75.9694	yr <sub>9</sub>	78.6500	yr 22
69.4873	yr 10	71.1051	yr <sub>23</sub>		76.3656	yr 10	78.9953	yr 23
69.7236	yr 11	71.3664	yr 25		76.6792	yr <sub>11</sub>	79.3896	yr 25
70.0026	<i>yr</i> <sub>12</sub>	69.6792	Mean		77.1795	<i>yr</i> <sub>12</sub>	76.8138	Mean
70.2282	<i>yr</i> <sub>13</sub>	1.0823	SD		77.5814	<i>yr</i> <sub>13</sub>	2.0085	SD
70.4423	yr <sub>14</sub>	-0.4514	$\Upsilon$ (skewness)		78.0080	<i>yr</i> <sub>14</sub>	-0.4651	$\Upsilon$ (skewness)
ICOF	69.6792	US \$/MWh	valid !		LCOF	76.8138	US\$/MWh	valid !
	0.069679	US \$/kWh			LCOL wso	0.076814	US\$/kWh	

Initial Results	Summary	of LCOE wso	Notes
84.2996	yr <sub>1</sub>	94.3718	yr 15
84.9743	yr <sub>2</sub>	94.0482	yr 15
85.6626	yr <sub>3</sub>	94.8532	yr 16
86.1247	yr <sub>4</sub>	95.7496	yr 17
86.8183	<i>yr</i> 5	96.6483	yr <sub>18</sub>
87.5429	yr <sub>6</sub>	97.4272	yr 19
88.1156	yr 7	93.9167	<i>yr</i> <sub>20</sub>
88.8127	yr <sub>8</sub>	94.6168	yr 21
89.7238	yr <sub>9</sub>	95.6632	<i>yr</i> <sub>22</sub>
90.3120	<i>yr</i> <sub>10</sub>	96.4289	yr <sub>23</sub>
91.1318	yr 11	97.4427	yr 25
91.8409	<i>yr</i> <sub>12</sub>	91.7081	Mean
92.5685	<i>yr</i> <sub>13</sub>	4.1890	SD
93.6087	<i>yr</i> <sub>14</sub>	-0.3343	$\Upsilon$ (skewness)
LCOF	91.7081	US \$/MWh	valid !
	0.091708	US \$/kWh	

**Figure 8.6** Initial results of  $LCOE_{wso}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration. Note: numbers in gray represent results from  $LCOE_{wso}$  methodology calculations

## 8.3.1.2 BREAKDOWN STRUCTURE OF LCOE<sub>WSO</sub>

$LCOE_{wso}^{148} = 67,6603 US / MWh (yr_1); 69,6792 US / MWh$					
(Mean); SD=1.0823 US\$/MWh; Y=-0,4514 (skewness)					
$LCCCM_{WF} = 1.20$	04.5180 \$/kW	7			
WT <sub>CM</sub> 553.7256 \$/kW	T 484.38	см 259 \$/kW	<i>LWTG<sub>CM</sub></i> 39.1957 \$/m/kW		
CP <sub>CM</sub> 30.9069 \$/kW	TX 11.456	S <sub>CM</sub> 56 \$/kW <sub>e</sub>	$SI_{CM}$ 42.7345 \$/m <sup>2</sup> /kW		
РО <sub>см</sub> 35.9374 \$/kW	F 3.771	<sup>Г</sup> см 2 \$/kW	ССС <sub>см</sub> 2.4042 \$/kW		
<b>LCPM</b> <sub>WF</sub> 48 856 319 kW <sub>e</sub> h/	yr		<b>O&amp;M</b> <sub>WFCM</sub> 0.124133 \$/kWh/yr		
WF <sub>CM</sub> 50.000 kW <sub>e</sub> /yr	WT <sub>LM</sub> 5D4D		0&M <sub>fixed cm</sub> 0.098275 \$/kWh		
PC <sub>PM</sub> 97.9% (availability)	P&D <sub>LM fice</sub> 0.83932	,, 5	0&M <sub>variable<sub>cm</sub> 0.025858 \$/kWh</sub>		
<b>LRCM</b> = 16.8443 \$/kW					
$\begin{tabular}{ c c c c c c c c c c c c c c c c c c c$					
$RCM_{WF} = 1.278.8970 \$ /kW					
DCM <sub>WF</sub> 1 339.9154 \$/k	εW	RVM <sub>WF</sub> 61.0184 \$/kW			
<b>REPIM</b> <sup>149</sup> = 420.0830 \$/proj					
REI <sub>CM</sub> 70.8203 \$/kW	7 e	REP <sub>CM</sub> 0.00002627 \$/kW <sub>e</sub> h			
OREP <sub>CM</sub> 13.0797 \$/kW	7 <sub>e</sub>	GHG.R <sub>CM</sub> 1 596.4321 \$/tCO <sub>2</sub>			

Figure 8.7 Breakdown structure of *LCOE*<sub>wso</sub> for Aracati (Brazil). Source: Own elaboration

<sup>&</sup>lt;sup>148</sup> All the values calculated of  $LCOE_{wso}$  for Aracati (Brazil) is based on the situation of year one (yr=1) <sup>149</sup> REPIM's values are calculated by the proportional to 25% for each energy policy instrument, according to Table 7.14.

$LCOE_{wso}^{150} = 73.0793 \ US\%/MWh \ (yr_1); \ 76.8138 \ US\%/MWh$					
(Mean); SD= 2.0085 US\$/MWh; Y=-0,4651 (skewness)					
$LCCCM_{WF} = 1.20$	04.5180 \$//	kW			
WT <sub>CM</sub> 553.7256 \$/kW	484	T <sub>CM</sub> 484.3859 \$/kW		<i>LWTG<sub>CM</sub></i> 39.1957 \$/m/kW	
CP <sub>CM</sub> 30.9069 \$/kW	11.4	TS <sub>CM</sub> 566 \$/A	kW <sub>e</sub>	<i>SI<sub>CM</sub></i> 42.7345 \$/m <sup>2</sup> /kW	
РО <sub>СМ</sub> 35.9374 \$/kW	3.7	F <sub>CM</sub> 712 \$/k	:W	ССС <sub>см</sub> 2.4042 \$/kW	
<b>LCPM</b> <sub>WF</sub> 89 657 257 kW <sub>e</sub> h/y	<b>LCPM</b> <sub>WF</sub> 89 657 257 kW <sub>e</sub> h/yr			<b>O&amp;M</b> <sub>WFCM</sub> 0.147210 \$/kWh/yr	
WF <sub>CM</sub> 50.000 kW <sub>e</sub> /yr	WT <sub>L</sub> 5D4	$WT_{LM}$ 5D4D		O&M <sub>fixed CM</sub> 0.098275 \$/kWh	
PC <sub>PM</sub> 97.9% (availability)	P&D <sub>LM</sub> 0.8393	P&D <sub>LM factor</sub> 0.839325		O&M <sub>variable<sub>cm</sub></sub> 0.048935\$/kWh	
<b>LRCM</b> = 16.8443 \$/kW					
AR <sub>CM</sub> 16.8442 \$/kW			ТО <sub>см</sub> 0.000033 \$/kW		
$RCM_{WF} = 1\ 278.8970\ \text{\$/kW}$					
DCM <sub>WF</sub> 1 339.9154 \$/kW			<i>RVM<sub>WF</sub></i> 61.0184 \$/kW		
<b>REPIM</b> <sup>151</sup> = 228.2900 \$/proj					
REI <sub>CM</sub> 70.8203 \$/kW <sub>e</sub>			REP <sub>CM</sub> 0.00001039 \$/kW <sub>e</sub> h		
OREP <sub>CM</sub> 21.2151 \$/kW	GHG.R <sub>CM</sub> 821.1245 \$/tCO <sub>2</sub>				

Figure 8.8 Breakdown structure of *LCOE*<sub>wso</sub> for Corvo Island (Portugal). Source: Own elaboration

<sup>&</sup>lt;sup>150</sup> All the values calculated of  $LCOE_{usso}$  for Corvo Island (Portugal) is based on the situation of year one (yr=1) <sup>151</sup> REPIM's values are calculated by the proportional to 25% for each energy policy instrument, according to Table 7.14.

$LCOE_{wso}^{152} = 84.2996 \ US\%/MWh \ (yr_1); \ 91.7091 \ US\%/MWh$ (Mean); SD=4.1890 US\%/MWh; Y=-0,3343 (skewness)							
$LCCCM_{WF} = 1.2$	$LCCCM_{WF} = 1\ 204.5180\ \text{\$/kW}$						
WT <sub>CM</sub> 553.7256 \$/kW	484.	T <sub>CM</sub> 3859 \$/kV	W	LWTG <sub>CM</sub> 39.1957\$/m/kW			
<i>CP<sub>CM</sub></i> 30.9069 \$/kW	11.4	TS <sub>CM</sub> 566 \$/kW	r e	SI <sub>CM</sub> 42.7345 \$/m <sup>2</sup> /kW			
РО <sub>СМ</sub> 35.9374 \$/kW	3.7	F <sub>CM</sub> 712 \$/kW	,	ССС <sub>см</sub> 2.4042 \$/kW			
<b>LCPM</b> <sub>WF</sub> 212 467 325 kW <sub>e</sub> h	LCPM <sub>WF</sub> 212 467 325 kW <sub>e</sub> h/yr			<b>&amp;M<sub>WFCM</sub></b> 139806 \$/kWh/yr			
WF <sub>CM</sub> 50.000 kW <sub>e</sub> /yr	WT <sub>L</sub> 5D4	м D		0&M <sub>fixed cm</sub> 0.098275 \$/kWh			
PC <sub>PM</sub> 97.9% (availability)	P&D <sub>LM</sub> 0.814	t <sub>jactor</sub> 145		0&M <sub>variable<sub>cm</sub> 0.041531 \$/kWh</sub>			
$LRCM = 16.8443 \ \text{/kW}$							
AR <sub>CM</sub> 16.8442 \$/kW			TO <sub>CM</sub> 0.000033 \$/kW				
$RCM_{WF} = 1\ 278.8970\ \text{\$/kW}$							
DCM <sub>WF</sub> 1 339.9154 \$/kW			<i>RVM<sub>WF</sub></i> 61.0184 \$/kW				
<b>REPIM</b> <sup>153</sup> = 1 154.5477 \$/proj							
<i>REI<sub>CM</sub></i> 70.8203 \$/kW <sub>e</sub>			REP <sub>CM</sub> 0.00000052 \$/kW <sub>e</sub> h				
OREP <sub>CM</sub> 56.8814 \$/kW		GHG.R <sub>CM</sub> 4 490.4890 \$/tCO <sub>2</sub>					

Figure 8.9 Breakdown structure of LCOE<sub>wso</sub> for Cape Saint James (Canada). Source: Own elaboration

<sup>&</sup>lt;sup>152</sup> All the values calculated of  $LCOE_{usso}$  for Cape Saint James (Canada) is based on the situation of year one (yr=1) <sup>153</sup> REPIM's values are calculated by the proportional to 25% for each energy policy instrument, according to Table 7.14.

#### 8.3.2 ESTIMATION OF WIND POWER PRODUCTION

#### 8.3.2.1 FOR ARACATI (BRAZIL)



**Figure 8.10**  $AEP_{avail}$  for 25 years of the wind farm for Aracati (Brazil) in standard operation. Source: Own elaboration

As we can see in Figure 8.10, the  $AEP_{avail}$  of the wind farm in Aracati (Brazil) varies from 48 055 *MWh/yr* to 49 213 *MWh/yr* with *SD*=288 *MWh*, 48 594 *MWh* (*Mean*) and 48 444 *MWh* (*Mode*). The  $AEP_{avail}$  has shown a *positive moderate asymmetric*<sup>154</sup> distribution (Y=0.2056) during the wind farm lifetime (N=25yrs).

In the years 16  $(yr_{16})$  and 19  $(yr_{19})$ , we can notice the highest and lowest level of production, respectively. This wind power plant expects to produce as  $AEP_{avail}$  about 1 214 852 MWh (1 215 GWh) during the operational phase (see Figure 8.13).

<sup>&</sup>lt;sup>154</sup> The *skewness* can be classified into *symmetric (if*  $\Upsilon \le 0.15$ ), moderate asymmetry (if  $0.15 \le |\Upsilon| \le 1.0$ ), strong asymmetry (if  $\Upsilon \ge 1.0$ ). For more explanations, please, see at Groeneveld and Meeden (1984).

8.3.2.2 FOR CORVO ISLAND (PORTUGAL)



**Figure 8.11**  $AEP_{avail}$  for 25 years of the wind farm in Corvo Island (Portugal) in standard operation. Source: Own elaboration

As we can see in Figure 8.11, the  $AEP_{avail}$  of the wind farm in Corvo Island (Portugal) also varies from 89 154 MWh/yr to 90 682 MWh/yr with SD=390 MWh, 90 035 MWh (Mean) and 90 318 MWh (Mode): The  $AEP_{avail}$  has shown a *negative moderate asymmetric* distribution (Y=-0.2882) during the wind farm lifetime (N=25yrs).

In the years 6 ( $yr_6$ ) and 25 ( $yr_{25}$ ), we can notice the highest and lowest level of production, respectively. This wind power plant expects to produce as  $AEP_{avail}$  about 2 250 871 MWh (2 251 GWh) during the operational phase (see Figure 8.13).

8.3.2.3 FOR CAPE SAINT JAMES (CANADA)



**Figure 8.12**  $AEP_{avail}$  for 25 years of the wind farm in Cape Saint James (Canada) in standard operation. Source: Own elaboration

As we can see in Figure 8.12, the  $AEP_{avail}$  of the wind farm in Cape Saint James (Canada) also varies from 212 224 MWh/yr to 213 959 MWh/yr with SD=626 MWh, 213 114 MWh (Mean) and 212 224 MWh (Mode): The  $AEP_{avail}$  has shown a *negative symmetric* distribution (Y=-0.1060) during the wind farm lifetime (N=25yrs).

In the years 7 ( $yr_7$ ) and 16 ( $yr_{16}$ ), we can notice the highest and lowest level of production, respectively. This wind power plant expects to produce as  $AEP_{avail}$  about 5 327 844 MWh (5 328 GWh) during the operational phase (see Figure 8.13).



**Figure 8.13** Total  $AEP_{avail}$  during the lifetime of 50MW<sub>e</sub> wind farm in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration

The  $AEP_{avail}$  and wind speed  $(v_{wc})$  have a direct as specific relation – the power output is the cube of wind speed – and in those three different wind speeds (wind resources) impacts on wind farm production as well as the wind speed increases. We can see this strong relation when we have done the correlation analysis between  $AEP_{avail}$  and wind speed  $(v_{wc})$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada), as shown in Table 8.1:

**Table 8.1** Correlation analysis between  $AEP_{avail}$  and wind speed  $(v_{wc})$ 

Items	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
$AEP_{avail}(GWh)$	1 215	2 251	5 328
$v_{wc}(m/s)$	7.4	9.1	12.5
Correlation Coeff. 0.994	4		

Source: Own elaboration

#### 8.3.3 ECONOMIC EVALUATION RESULTS

The economic evaluation results organized considering the same structure of the projected cash flow analysis (Appendix G). For Aracati (Brazil) (section 8.3.3.1), Corvo Island (Portugal) (section 8.3.3.2) and Cape Saint James (Canada) (section 8.3.3.3) the results have started with  $LCCCM_{WF}$ , AAR,  $O\&M_{WFCM}$ , LRCM, RCM<sub>WF</sub> and REPIM.

### 8.3.3.1 FOR ARACATI (BRAZIL)

The  $LCOE_{wso}$  methodology organizes the investment costs without any kind of public incentive effect (*REPIM*) in  $LCCCM_{WF}$ . For the standard (base-case) situation the  $LCCCM_{WF}$  has shown the following structure, as represented by Table 8.2:

Investment cost	US\$	%
$WT_{CM}$	27 686 278	46.0%
$T_{CM}$	24 219 295	40.2%
$LWTG_{CM}$	1 959 783	3.3%
$CP_{CM}$	1 545 346	2.6%
$TS_{CM}$	572 832	1.0%
$SI_{CM}$	2 136 726	3.5%
$PO_{CM}$	1 796 870	3.0%
$F_{CM}$	188 559	0.3%
$CCC_{CM}$	120 211	0.1%
LCCCM <sub>WF</sub>	60 225 901	100.0%

 Table 8.2 LCCCM<sub>WF</sub> breakdown structure for Aracati (Brazil)

Source: Own elaboration

The capital cost per kW installed is about 1 204.52 US\$/kW and the most part is centralized in wind turbines (46.0% for  $WT_{CM}$ ) and towers (40.2% for  $T_{CM}$ ). It is also important to highlight the local wind turbines grid (LWTG<sub>CM</sub>), collecting point (CP<sub>CM</sub>) and transmission system (TS<sub>CM</sub>) that represents about 7.0% of the total capital costs (6.9%).

When we consider the effect of public incentive (*REPIM*) on initial investments in multimegawatts wind farm (50 MW<sub>e</sub>) we notice a *reduction around*  $0.64\%^{155}$  and the *LCCCM<sub>WF</sub>* can reach the cost per kW about 1 196.82 US\$/kW.

<sup>&</sup>lt;sup>155</sup> In *LCOE*<sub>wso</sub> methodology, the *REPIM* instruments applied to Aracati (Brazil) are calculated considering the base-case defined in Tables 7.13 and 7.14.





**Figure 8.14** *AAR* (*US*M/yr) during the lifetime of the 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

According to Figure 8.14, the AAR of the wind farm in Aracati (Brazil) varies from 4 297 170 US\$M/yr to 6 873 465 US\$M/yr with SD=713 406 US\$M and 5 398 391 US\$M/yr (Mean). The

AAR has shown a *positive moderate asymmetry* distribution (Y=0.4437) during the wind farm lifetime (N=25yrs).

In the years 1  $(yr_1)$  and 20  $(yr_{20})$ , we can notice the lowest and highest level of revenue, respectively. This wind power plant expects to receive as total *AAR* about 134 959 772 *US*\$M during the operational phase. The relation between the total *AAR* and *LCPM<sub>WF</sub>* is 0.111092 *US*\$ per kWh produced. We have to remember the effect of the inflation rate (2.5% per year) on revenues.

For Gross, Blyth, and Heptonstall (2010) the returns of a wind power project depends on revenues as well as cost, so the price of electricity becomes an important risk factor in the investment decision.

The  $O\&M_{WFCM}$  of the hypothetical wind farm is shown in Figure 8.15 within its particularities and behavior. We have calculated the  $O\&M_{WFCM}$  per year according to Eqns 6.2.3, 6.2.3.1 and 6.2.3.2 with the conditions defined in Tables 7.11 and 7.12.



**Figure 8.15**  $O\&M_{WFCM}$  splited into *fixed* ( $O\&M_{fixed}_{CM}$ ) and *variable* ( $O\&M_{variable}_{CM}$ ) during the lifetime of the 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

As we can see in Figure 8.15, the  $O\&M_{WFCM}$  of the wind farm in Aracati (Brazil) varies from 0.0808 US\$ kWh/yr to 0.1323 US\$ kWh/yr with SD=0.0161 US\$ kWh and 0.1081 US\$ kWh/yr (Mean): The  $O\&M_{WFCM}$  has shown a negative moderate asymmetry distribution (Y=-0.1745) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 25 ( $yr_{25}$ ), we can notice the lowest and highest level of  $O\&M_{WFCM}$ , respectively. This wind power plant expects to spend as total  $O\&M_{WFCM}$  about 131 300 872 US\$M during the operational phase. The relation between the total  $O\&M_{WFCM}$  and  $LCPM_{WF}$  is 0.108080 US\$ per kWh produced. We also have to remember the effect of the inflation rate (2.5% per year) on O&M costs.

As have discussed Poore and Walford (2008) the facility costs are linked to the size of the facility and are assumed to remain constant over the life of the project. This implies that the infrastructure is maintained in good condition for the project's life and that no improvements or expansions are made. For this reason we have also considered in  $LCOE_{wso}$  methodology the *LRCM* and *RCM<sub>WF</sub>* for capital costs during the lifetime of the wind project (applied to specific cost for revisions or substitution of parts of WECS, such as, nacelles, wind turbines, rotor, blades, generators and other) that usually can occur during the lifetime of the power project) and when at the end of lifetime of the wind project (removing or repowering situation).

The *LRCM* of the hypothetical wind farm is shown in Figure 8.16 within its particularities and behavior. We have calculated the *LRCM per year* according to Eqns 6.2.2, 6.2.2.1, 6.2.2.1, 6.2.2.1, 6.2.2.2, and 6.2.2.2.1 with the conditions defined in Table 6.8.



**Figure 8.16** *LRCM* during the 15 years of the 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

As shown in Figure 8.16, the *LRCM* of the wind farm in Aracati (Brazil) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (Mean). The *LRCM* has shown a *positive symmetric* distribution (Y=0.1407) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 15 ( $yr_{15}$ ), we can notice the lowest and highest level of *LRCM savings*, respectively. This wind power plant expects to save as total *LRCM* about 15 480 065 US\$ during 15 years of the operational phase. The relation between the total *LRCM* and *kW produced* in 15 years is 182.0645 US\$ per kW produced. We also have to remember the effect of the inflation rate (2.5% per year) on *LRCM*.

As have stated Oliveira and Fernandes (2012) the aim of *LRCM* (equivalent to *LRC*) is to make funds available when needed to repair or total replacement of occurrence. The exercise involves calculating the net present value or even to allocate costs for review and replacement on an annualized basis consistent with other cost elements. That is why we have also considered the *costs for removing the wind farm at the end of its lifetime*, if the investor desires to stop operations

or repower it for a new phase. This mechanism works as a *saving account*, an *"economic reserve"*. It has been calculated year by year and named  $RCM_{WF}$ .

The  $RCM_{WF}$  of the hypothetical wind farm is shown in Figure 8.17 within its particularities and behavior. We have calculated the  $RCM_{WF}$  per year according to Eqns 6.2.4, 6.2.4.1, 6.2.4.1.1, 6.2.4.1.2, 6.2.4.1.3, 6.2.4.2, 6.2.4.2.1, 6.2.4.2.2 and 6.2.4.3 with the conditions defined in Tables 6.8 and 6.9.



**Figure 8.17**  $RCM_{WF}$  during the lifetime of the 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

According to Figure 8.17, the  $RCM_{WF}$  of the wind farm in Aracati (Brazil) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean).

The  $RCM_{WF}$  has shown a *positive moderate asymmetry* distribution (Y=0.2259) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 25 ( $yr_{25}$ ), we can notice the lowest and highest level of  $RCM_{WF}$  savings, respectively. This wind power plant expects to save as total  $RCM_{WF}$  about 89 552 736 US\$ during the operational phase. The relation between the total  $RCM_{WF}$  and kW produced in 25 years is 1 053 US\$ per kW produced. We also have to remember the effect of the inflation rate (2.5% per year) on  $RCM_{WF}$ .

The  $RCM_{WF}$  was developed in order to cover the costs of removing the wind farm and "*rebuild*" the local environment conditions, so when we get a *value equal or equivalent* amount of funds for cover the costs of decommissioning the wind farm, which is the purpose of this indicator! In the case of the hypothetical wind farm in Aracati (Brazil) if we have consider the total  $LCCCM_{WF}$
(60 225 901 US\$) added to LRCM (15 480 065 US\$), the  $RCM_{WF}$  about 89 552 736 US\$ really covers it (75 705 966 US\$ < 89 552 736 US\$).

The *REPIM* or *Renewable Energy Public Incentive Model* is a part of our proposed  $LCOE_{wso}$  methodology that measures the impact of some and *most common kinds of energy policy instruments applied to RETs*. We have proposed four different types of instruments: two of them are related to investment incentive (*REI*<sub>CM</sub> and *OREP*<sub>CM</sub>) and the others are related to energy production (*REP*<sub>CM</sub> and *GHG.R*<sub>CM</sub>).

The  $REI_{CM}$  of the hypothetical wind farm is shown in Figure 8.18 within its particularities and behavior. We have calculated the  $REI_{CM}$  for initial year of the wind project (yr=0) according to Eqns 6.2.5.1 with the conditions defined in Tables 6.10 and 7.14.

REI <sub>CM</sub>	70.8203	[\$/kW <sub>e</sub> ]
$LCCCM_{WF}$	1 204.5180	[\$/kW]
LRCM	16.8443	[\$/kW]
ifr	2.50%	[%/yr]
$\Psi_{total}$	30.00%	[%]
$n_{\Psi}$	6	[yr]

Figure 8.18 *REI*<sub>CM</sub> for 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

The total *REI<sub>CM</sub>* received by the hypothetical wind farm was calculated with the following Eqn 8.2:

$$Total_{REI_{CM}} = REI_{CM} WF_{cap} \xi_{REI_{CM}} \qquad [\$/kW_e] \qquad Eqn (8.2)$$

When we made the calculations according to data shown in Figure 8.18 and Tables 6.10 and 7.14, the expected value received from the government is  $221 \ 313 \ US\$$ . An analogous situation occurs to  $OREP_{CM}$  although according to Eqn 6.2.5.3.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

OREP $_{CM}$ 13.0797       [\$/kW_e] $LCCCM_{WF_{OREG_{CM}}}$ 2.7664       [\$/kW] $LCCCM_{WF}$ 1204.5180       [\$/kW] $WACC_{proj}$ 4.9000%       [\$/yr] $\psi_{total}$ 30.0%       [\$/yr] $ifr$ 2.5%       [\$/yr] $n_{\psi}$ 10       [yr] $CR_f$ 80.0%       [\$/]			
LCCCM $_{WF_{OREG_{CM}}}$ 2.7664       [\$/kW]         LCCCM $_{WF}$ 1 204.5180       [\$/kW]         WACC $_{proj}$ 4.9000%       [\$/yr] $\psi_{total}$ 30.0%       [%]         ifr       2.5%       [%/yr] $n_{\psi}$ 10       [yr]         CR f       80.0%       [%]	OREP <sub>CM</sub>	13.0797	[\$/kW <sub>e</sub> ]
LCCCM $_{WF}$ 1 204.5180       [\$/kW]         WACC $_{proj}$ 4.9000%       [%/yr] $\psi_{total}$ 30.0%       [%]         ifr       2.5%       [%/yr] $n_{\psi}$ 10       [yr]         CR f       80.0%       [%]	$LCCCM_{WF_{OREG_{CM}}}$	2.7664	[\$/kW]
WACC $_{proj}$ 4.9000%       [%/yr] $\psi_{total}$ 30.0%       [%] $ifr$ 2.5%       [%/yr] $n_{\psi}$ 10       [yr] $CR_f$ 80.0%       [%]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]
$\Psi_{total}$ 30.0%       [%] $ifr$ 2.5%       [%/yr] $n_{\Psi}$ 10       [yr] $CR_f$ 80.0%       [%]	WACC proj	4.9000%	[%/yr]
ifr $2.5\%$ $[\%/yr]$ $n_{\Psi}$ 10 $[yr]$ $CR_f$ $80.0\%$ $[\%]$	$\Psi_{total}$	30.0%	[%]
$\begin{array}{c} n_{\psi} & 10 & [yr] \\ CR_{f} & 80.0\% & [\%] \end{array}$	ifr	2.5%	[%/yr]
<i>CR</i> <sub>f</sub> 80.0% [%]	$n_{\psi}$	10	[yr]
	$CR_{f}$	80.0%	[%]

**Figure 8.19**  $OREP_{CM}$  for 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

The total  $OREP_{CM}$  received by the hypothetical wind farm was calculated with the Eqn 8.3:

$$Total_{OREP_{CM}} = OREP_{CM} WF_{cap} \xi_{OREP_{CM}}$$
 [\$/kWe] Eqn (8.3)

When we made the calculations according to data shown in Figure 8.19, the expected value received from the government is *163 497 US\$*.

We have also considered the side of production, in other words, the  $AEP_{avail}$  from the wind project analyzed. The  $REP_{CM}$  was developed according to Eqns 6.2.5.3 and 6.2.5.3.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

REP <sub>CM</sub>	0.00002627	$[/kW_eh]$
$AEP_{avail}/H_{prod}$	5 695	[kW/yr]
ifr	2.50%	[%/yr]
ε	0.1496	$[/kW_eh]$
$\mathcal{E}_0$	0.116883	$[/kW_eh]$
n <sub>e</sub>	10	[yr]

Figure 8.20 REP<sub>CM</sub> for 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

According to Table G.8, the  $REP_{CM}$  of the wind farm in Aracati (Brazil) varies from 1 447 US\$  $kW_eh/yr$  to 1 825 US\$  $kW_eh/yr$  with SD=117 US\$  $kW_eh$  and 1 629 US\$  $kW_eh/yr$  (Mean). The  $REP_{CM}$  has shown a *positive symmetry* distribution ( $\Upsilon=0.0838$ ) during the period of energy policy instrument.

In the years  $10 (yr_{10})$  and  $1 (yr_1)$ , we can notice the lowest and highest level of  $REP_{CM}$ , respectively. When we made the calculations according to data shown in Figure 8.20, the expected value received from the government during the period of the energy policy instrument is 16 285 US\$. We also have to remember the effect of the inflation rate (2.5% per year) on  $REP_{CM}$ .

The total  $REP_{CM}$  received by the hypothetical wind farm was calculated with the Eqn 8.4:

$$Total_{REP_{CM}} = \sum REP_{CM/yr} \xi_{REP_{CM}} \qquad [\$/kW_eh] \qquad Eqn (8.4)$$

Finally we development among the energy policy instruments analyzed, one regard to  $CO_2$  nonemissions, defined as  $GHG.R_{CM}$ . According to Eqns 6.2.5.4 and 6.2.5.4.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

GHG.R <sub>CM</sub>	1 596.4321	[\$/tCO <sub>2</sub> ]
$LCER_{CO_2}$	18.6	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$\sum AEP \int_{avail} \int_{yr_1+\ldots+yr_n}$	48 856	[MW <sub>e</sub> h]
$n_{\Psi}$	25	[yr]
$GHG_{EM_{ff}co_2}$	0.00041	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$GHG_{EM_{wecs co_2}}$	0.00003	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$\mathcal{E}_{c}$	46.3820	[\$/tCO <sub>2</sub> ]

Figure 8.21 GHG.R<sub>CM</sub> for 50MW<sub>e</sub> wind farm in Aracati (Brazil). Source: Own elaboration

According to Table G.8, the  $GHG.R_{CM}$  of the wind farm in Aracati (Brazil) varies from 221 US/ $tCO_2$  to 395 US/ $tCO_2$  with SD=53 US/ $tCO_2$  and 300 US/ $tCO_2$  (Mean). The  $GHG.R_{CM}$  has shown a *positive moderate asymmetry* distribution (Y=0.1961) during the period of energy policy instrument.

In the years 1 ( $yr_1$ ) and 25 ( $yr_{25}$ ), we can notice the lowest and highest level of  $GHG.R_{CM}$ , respectively. When we made the calculations according to data shown in Figure 8.21, the expected value received from the government during the period of the energy policy instrument is 7 495 US\$. We also have to remember the effect of the inflation rate (2.5% per year) on  $GHG.R_{CM}$ .

The total  $GHG.R_{CM}$  received by the hypothetical wind farm was calculated the following Eqn 8.5:

$$Total_{GHG,R_{CM}} = \sum GHG.R_{CM/yr} \xi_{GHG,R_{CM}} \qquad [US\$/tCO_2] \qquad Eqn (8.5)$$

### 8.3.3.2 FOR CORVO ISLAND (PORTUGAL)

The  $LCOE_{wso}$  methodology organizes the investment costs without any kind of public incentive effect (*REPIM*) in  $LCCCM_{WF}$ . For the standard (base-case) situation the  $LCCCM_{WF}$  has shown the following structure, as represented by Table 8.3:

686 278 219 295	46.0% 40.2%
219 295	40.2%
959 783	3.3%
545 346	2.6%
572 832	1.0%
136 726	3.5%
796 870	3.0%
188 559	0.3%
120 211	0.1%
225 901	100.0%
	959 783 545 346 572 832 136 726 796 870 188 559 120 211 225 901

 Table 8.3 LCCCM<sub>WF</sub> breakdown structure for Corvo Island (Portugal)

Source: Own elaboration

The capital cost per kW installed is about 1 204.52 US\$/kW and the most part is centralized in wind turbines (46.0% for  $WT_{CM}$ ) and towers (40.2% for  $T_{CM}$ ). It is also important to highlight the local wind turbines grid (LWTG<sub>CM</sub>), collecting point (CP<sub>CM</sub>) and transmission system (TS<sub>CM</sub>) that represents about 7.0% of the total capital costs (6.9%).

When we consider the effect of public incentive (*REPIM*) on initial investments in multimegawatts wind farm (50 MW<sub>e</sub>) we notice a *reduction around*  $0.81\%^{156}$  and the *LCCCM<sub>WF</sub>* can reach the cost per kW about 1 194.79 US\$/kW.

When we make the comparison between Corvo Island (Portugal) and Aracati (Brazil) considering the different periods of  $OREP_{CM}$  (Brazil=10 yrs and Portugal=15 yrs) the impact on  $LCCCM_{WF}$  (initial investment) reduce in a few more. An increasing of 26.4% is noticed on initial investment (from 0.64% to 0.81%). The reduction on  $LCCCM_{WF}$  changes from 7.6962 US\$/kW to 9.7300 US\$/kW. We can probably confirm that the period on the energy policy instrument makes a sensible difference on the results of competitiveness of RETs.

<sup>&</sup>lt;sup>156</sup> In *LCOE*<sub>wso</sub> methodology, the *REPIM* instruments applied to Corvo Island (Portugal) are calculated considering the base-case defined in Tables 7.13 and 7.14.



The *AAR* of the hypothetical wind farm is shown in Figure 8.22 within its particularities and behavior. We have calculated the *AAR per year* according to Eqn. 7.1 with the conditions defined in Table 7.10.



**Figure 8.22** AAR (US\$M/yr) during the lifetime of the 50MW<sub>e</sub> wind farm in Corvo Island (Portugal). Source: Own elaboration

5 000 USS

According to Figure 8.22, the AAR of the wind farm in Corvo Island (Portugal) varies from 14 970 925 US\$M/yr to 24 203 932 US\$M/yr with SD=2 524 373 US\$M and 18 990 481 US\$M/yr (Mean): The AAR has shown a positive moderate asymmetry distribution (Y=0.4655) during the wind farm lifetime (N=25yrs).

In the years 1  $(yr_1)$  and 20  $(yr_{20})$ , we can notice the lowest and highest level of revenue, respectively. This wind power plant expects to receive as total AAR about 474 762 014 US\$M during the operational phase. The relation between the total AAR and LCPM<sub>WF</sub> is 0.210924 US\$ per kWh produced. We have to remember the effect of the inflation rate (2.5% per year) on revenues.

When we compare AAR of Corvo Island (Portugal) and Aracati (Brazil) considering the different annual wind speed (Brazil=7.4 m/s and Portugal=9.1 m/s) (see Table 8.1) and PPARs (Brazil=0.08581 US\$/kWh and Portugal=0.16291 US\$/kWh) (see Table 7.10) the impact on AAR is tremendous: An increasing is noticed on total AAR (from 134 959 772 US\$M to 474 762 014 US\$M): The increasing of 23% and 89.8% in wind speed and PPAR, respectively, reflects in an increasing of 251.8% on total AAR.

The  $O\&M_{WFCM}$  of the hypothetical wind farm is shown in Figure 8.23 within its particularities and behavior. We have calculated the  $O\&M_{WFCM}$  per year according to Eqns 6.2.3, 6.2.3.1 and 6.2.3.2 with the conditions defined in Tables 7.11 and 7.12.



**Figure 8.23**  $O\&M_{WFCM}$  splited into *fixed* ( $O\&M_{fixed}_{CM}$ ) and *variable* ( $O\&M_{variable}_{CM}$ ) during the lifetime of the 50MW<sub>e</sub> wind farm in Corvo Island (Portugal). Source: Own elaboration

As we can see in Figure 8.23, the  $O\&M_{WFCM}$  of the wind farm in Corvo Island (Portugal) varies from 0.0969 US\$ kWh/yr to 0.1549 US\$ kWh/yr with SD=0.0180 US\$ kWh and 0.1280 US\$ kWh/yr (Mean): The  $O\&M_{WFCM}$  has shown a negative moderate asymmetry distribution (Y=-0.2251) during the wind farm lifetime (N=25yrs).

In the years  $1 (yr_1)$  and  $20 (yr_{20})$ , we can notice the lowest and highest level of  $O\&M_{WFCM}$ , respectively. This wind power plant expects to spend as total  $O\&M_{WFCM}$  about 309 664 717 US\$M during the operational phase. The relation between the total  $O\&M_{WFCM}$  and  $LCPM_{WF}$  is 0.137576 US\$ per kWh produced. We also have to remember the effect of the inflation rate (2.5% per year) on O&M costs.

The  $O\&M_{WFCM}$  in Corvo Island (Portugal) and Aracati (Brazil) shows some particularities. The cost per kWh produced as not high as the increasing of  $LCPM_{WF}$  (see Figure 8.13 and Table 8.1). Within the level of total energy production (1 215 GWh for Aracati and 2 251 for Portugal) and the average of  $O\&M_{WFCM}$  (0.108080 US\$/kWh for Aracati and 0.137576 US\$/kWh), which represents an increasing of 27.3% on  $O\&M_{WFCM}$ .

The *LRCM* of the hypothetical wind farm is shown in Figure 8.24 within its particularities and behavior. We have calculated the *LRCM per year* according to Eqns 6.2.2, 6.2.2.1, 6.2.2.1, 6.2.2.1, 6.2.2.2, and 6.2.2.2.1 with the conditions defined in Table 6.8.



**Figure 8.24** *LRCM* during the 15 years of the 50MW<sub>e</sub> wind farm in Corvo Island (Portugal). Source: Own elaboration

As shown in Figure 8.24, the *LRCM* of the wind farm in Corvo Island (Portugal) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (*Mean*)... The *LRCM* has shown a *positive symmetric* distribution (Y=0.1407) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 15 ( $yr_{15}$ ), we can notice the lowest and highest level of *LRCM savings*, respectively. This wind power plant expects to save as total *LRCM* about 15 480 065 US\$ during 15 years of the operational phase. The relation between the total *LRCM* and *kW produced* in 15 years is 182.0645 US\$ per kW produced. We also have to remember the effect of the inflation rate (2.5% per year) on *LRCM*.

We have notice the same figure for *LRCM* both to Aracati (Brazil) and Corvo Island (Portugal) which seems to be the way this sub model was developed. We can find the *same value per kW installed* (16.8443 US\$/kW) and some initial aspects of this part of  $LCOE_{wso}$  methodology:

- 1. The LRCM can work as an economic reserve, independent of AAR and  $LCPM_{WF}$ ;
- 2. The *LRCM* is not driven by the *price of electricity sold (PPAR)* the wind farm developer or manager can create the "*best cost strategy*" independent of the *price and the level of production of the wind farm*.

The  $RCM_{WF}$  of the hypothetical wind farm is shown in Figure 8.25 within its particularities and behavior. We have calculated the  $RCM_{WF}$  per year according to Eqns 6.2.4, 6.2.4.1, 6.2.4.1.1, 6.2.4.1.2, 6.2.4.1.3, 6.2.4.2, 6.2.4.2.1, 6.2.4.2.2 and 6.2.4.3 with the conditions defined in Tables 6.8 and 6.9.



**Figure 8.25**  $RCM_{WF}$  during the lifetime of the 50MW<sub>e</sub> wind farm in Corvo Island (Portugal). Source: Own elaboration

According to Figure 8.25, the  $RCM_{WF}$  of the wind farm in Corvo Island (Portugal) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean). The  $RCM_{WF}$  has shown a positive moderate asymmetry distribution (Y=0.2259) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 25 ( $yr_{25}$ ), we can notice the lowest and highest level of  $RCM_{WF}$  savings, respectively. his wind power plant expects to save as total  $RCM_{WF}$  about 89 552 736 US\$ during the operational phase. he relation between the total  $RCM_{WF}$  and kW produced in 25 years is 1 053 US\$ per kW produced. We also have to remember the effect of the inflation rate (2.5% per year) on  $RCM_{WF}$ .

The  $RCM_{WF}$  was developed in order to cover the costs of removing the wind farm and "*rebuild*" the local environment conditions, so when we get a *value equal or equivalent* amount of funds for cover the costs of decommissioning the wind farm, which is the purpose of this indicator! In the case of the hypothetical wind farm in Corvo Island (Portugal) if we have consider the total  $LCCCM_{WF}$  (60 225 901 US\$) added to LRCM (15 480 065 US\$), the  $RCM_{WF}$  about 89 552 736 US\$ really covers it (75 705 966 US\$ < 89 552 736 US\$).

For  $RCM_{WF}$  we have noticed the same conditions and conclusions of *LRCM* that is why we do not comment again (see page 329 of this Chapter).

As we have already said the *REPIM or Renewable Energy Public Incentive Model* is a part of the proposed  $LCOE_{wso}$  methodology that measures the impact of some and *most common kinds of energy policy instruments applied to RETs*. We have proposed four different types of instruments: two of them are related to investment incentive (*REI*<sub>CM</sub> and *OREP*<sub>CM</sub>) and the others are related to energy production (*REP*<sub>CM</sub> and *GHG.R*<sub>CM</sub>).

The  $REI_{CM}$  of the hypothetical wind farm is shown in Figure 8.26 within its particularities and behavior. We have calculated the  $REI_{CM}$  for initial year of the wind project (yr=0) according to Eqns 6.2.5.1 with the conditions defined in Tables 6.10 and 7.14.

REI <sub>CM</sub>	70.8203	[\$/kW <sub>e</sub> ]
$LCCCM_{WF}$	1 204.5180	[\$/kW]
LRCM	16.8443	[\$/kW]
ifr	2.50%	[%/yr]
$\Psi_{total}$	30.00%	[%]
$n_{\Psi}$	6	[yr]

Figure 8.26 REI<sub>CM</sub> for 50MW<sub>e</sub> wind farm in Corvo Island (Portugal). Source: Own elaboration

The total  $REI_{CM}$  received by the hypothetical wind farm was also calculated with the Eqn 8.2. When we made the calculations according to data shown in Figure 8.26 and Tables 6.10 and 7.14, the expected value received from the government is 221 313 US\$. An analogous situation occurs to  $OREP_{CM}$  although according to Eqn 6.2.5.3.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

21.2151	[\$/kW <sub>e</sub> ]
2.4451	[\$/kW]
1 204.5180	[\$/kW]
4.9000%	[%/yr]
30.0%	[%]
2.5%	[%/yr]
15	[yr]
80.0%	[%]
	21.2151 2.4451 1 204.5180 4.9000% 30.0% 2.5% 15 80.0%

Figure 8.27 OREP<sub>CM</sub> for 50MW<sub>e</sub> wind farm in Corvo Island (Portugal). Source: Own elaboration

The total  $OREP_{CM}$  received by the hypothetical wind farm was also calculated with the Eqn 8.3. When we made the calculations according to data shown in Figure 8.27, the expected value received from the government is 265 188 US\$.

As we already said the side of production is considered, in other words, the  $AEP_{avail}$  from the wind project analyzed. The  $REP_{CM}$  was developed according to Eqns 6.2.5.3 and 6.2.5.3.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

REP <sub>CM</sub>	0.00002627	$[/kW_eh]$
$AEP_{avail}/H_{prod}$	5 695	[kW/yr]
ifr	2.50%	[%/yr]
ε	0.1496	$[/kW_eh]$
${\mathcal E}_0$	0.116883	[\$/kW <sub>e</sub> h]
$n_{\varepsilon}$	10	[yr]

Figure 8.28 REP<sub>CM</sub> for 50MW<sub>e</sub> wind farm in Corvo Island (Portugal). Source: Own elaboration

According to Table G.9, the  $REP_{CM}$  of the wind farm in Corvo Island (Portugal) varies from 939  $US$ kW_eh/yr$  to 1 325  $US$ kW_eh/yr$  with  $SD=119 US$ kW_eh$  and 1 125  $US$ kW_eh/yr$  (Mean). The

 $REP_{CM}$  has shown a *positive symmetry* distribution (Y = 0.1260) during the period of energy policy instrument.

In the years 15  $(yr_{15})$  and 1  $(yr_1)$ , we can notice the lowest and highest level of  $REP_{CM}$ , respectively. When we made the calculations according to data shown in Figure 8.28, the total expected value received from the government during the period of the energy policy instrument is 16 879 US\$ (calculated with Eqn 8.4). We also have to remember the effect of the inflation rate (2.5% per year) on  $REP_{CM}$ .

Finally we also development among the energy policy instruments analyzed, one regard to  $CO_2$  *non-emissions*, defined as *GHG.R<sub>CM</sub>*. According to Eqns 6.2.5.4 and 6.2.5.4.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

GHG.R <sub>CM</sub>	821.1245	[\$/tCO <sub>2</sub> ]
$LCER_{CO_2}$	34.1	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$\sum AEP_{avail} y_{r_1+\dots+yr_n}$	89 657	[MW <sub>e</sub> h]
$n_{\psi}$	25	[yr]
$GHG_{EM_{ff}co_2}$	0.00041	$[tCO_2/MW_eh]$
GHG <sub>EMwecs CO2</sub>	0.00003	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$\mathcal{E}_{c}$	13.0000	[\$/tCO <sub>2</sub> ]



According to Table G.9, the  $GHG.R_{CM}$  of the wind farm in Corvo Island (Portugal) varies from 113 US/ $tCO_2$  to 204 US/ $tCO_2$  with SD=28 US/ $tCO_2$  and 156 US/ $tCO_2$  (Mean). The  $GHG.R_{CM}$  has shown a *positive moderate asymmetry* distribution (Y=0.1985) during the period of energy policy instrument.

In the years 1  $(yr_1)$  and 25  $(yr_{25})$ , we can notice the lowest and highest level of  $GHG.R_{CM}$ , respectively. When we made the calculations according to data shown in Figure 8.29, the total expected value received from the government during the period of the energy policy instrument is 3 893 US\$ (calculated with Eqn 8.5). We also have to remember the effect of the inflation rate (2.5% per year) on  $GHG.R_{CM}$ .

In order to compare the *REPIM* results between Aracati (Brazil) and Corvo Island (Portugal) we have resumed in Table 8.4.

Table 8.4 Comparison of REPIM in relation to Aracati (Brazil) and Corvo Island (Portugal)

Instrument	Unit	Aracati (Brazil)	Corvo Island (Portugal)
$REI_{CM}$	$US\$/kW_e$	221 313	221 313
$REP_{CM}$	$US\$/kW_eh$	16 285	16 879
$OREP_{CM}$	$US\$/kW_e$	163 497	265 188
$GHG.R_{CM}$	$US$ \$/ $tCO_2$	7 495	3 893

Source: Own elaboration

A brief analysis can be taken from the results shown in Table 8.4:

- Some of most interesting is the *GHG.R<sub>CM</sub>* that is *strongly* influenced by the *price of tCO*<sub>2</sub> paid by government per kWh produced in the wind farm.: For example the *price in US\$* for Aracati (Brazil) considered was 46.3820 US\$/tCO<sub>2</sub> and Corvo Island (Portugal) was 13 US\$/tCO<sub>2</sub>.: The difference of 33.3820 US\$/tCO<sub>2</sub> was big enough to overcome the higher level of energy production and better local wind resources (see Table 8.1);
- 2. In the case of *OREP<sub>CM</sub>* another important aspect must be explained, the period considering for the energy policy instrument applied to the energy project (*Aracati-Brazil=10 yrs and Corvo Island-Portugal=15 yrs*);
- 3. Energy policy maker have to take into consideration the *price of CO*<sub>2</sub>, *the periodicity of the instrument analyzed* and *the wind resources*, geographically defined in the legislation proposed to the renewable energy producers.

### 8.3.3.3 FOR CAPE SAINT JAMES (CANADA)

As we have said yet the  $LCOE_{wso}$  methodology organizes the investment costs without any kind of public incentive effect (*REPIM*) in  $LCCCM_{WF}$ . For the standard (base-case) situation the  $LCCCM_{WF}$  has shown the following structure, as represented by Table 8.5:

Investment cost	US\$	%
$WT_{CM}$	27 686 278	46.0%
$T_{CM}$	24 219 295	40.2%
$LWTG_{CM}$	1 959 783	3.3%
$CP_{CM}$	1 545 346	2.6%
$TS_{CM}$	572 832	1.0%
$SI_{CM}$	2 136 726	3.5%
$PO_{CM}$	1 796 870	3.0%
$F_{CM}$	188 559	0.3%
$CCC_{CM}$	120 211	0.1%
LCCCM <sub>WF</sub>	60 225 901	100.0%

**Table 8.5** LCCCM<sub>WF</sub> breakdown structure for Cape Saint James (Canada)

Source: Own elaboration

In the same conditions of investment as Aracati (Brazil), Corvo Island (Portugal) the capital cost per kW installed for Cape Saint James (Canada) is about 1 204.52 US\$/kW and the most part is centralized in wind turbines (46.0% for  $WT_{CM}$ ) and towers (40.2% for  $T_{CM}$ ). It is also important to highlight the local wind turbines grid (LWTG<sub>CM</sub>), collecting point (CP<sub>CM</sub>) and transmission system (TS<sub>CM</sub>) that represents about 7.0% of the total capital costs (6.9%).

Analogous to the two other sites when we consider the effect of public incentive (*REPIM*) on initial investments in multi-megawatts wind farm (50 MW<sub>e</sub>) we notice a *reduction around*  $1.55\%^{157}$  and the *LCCCM<sub>WF</sub>* can reach the cost per kW about 1 185.87 US\$/kW.

In comparison to Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) and the different periods of  $OREP_{CM}$  (Brazil and Canada=10 yrs; Portugal=15 yrs) the impact on  $LCCCM_{WF}$  (initial investment) for the wind farm in Cape Saint James (Canada) reduce more than the other two cited. In relation to Corvo Island (Portugal) there is an increasing of 91.6% and 142.3% to Aracati (Brazil), respectfully. The reduction on  $LCCCM_{WF}$  changes from 7.6962 US\$/kW to 18.6466 US\$/kW.

<sup>&</sup>lt;sup>157</sup> In  $LCOE_{wso}$  methodology, the *REPIM* instruments applied to Cape Saint James (Canada) are calculated considering the base-case defined in Tables 7.13 and 7.14.





**Figure 8.30** AAR (US\$M/yr) during the lifetime of the 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

According to Figure 8.30, the AAR of the wind farm in Cape Saint James (Canada) varies from 30 129 143 US\$M/yr to 48 311 614 US\$M/yr with SD=5 069 795 US\$M and 38 174 169 US\$M/yr

(Mean). The AAR has shown a positive moderate asymmetry distribution (Y=0.4408) during the wind farm lifetime (N=25yrs).

In the years 1  $(yr_1)$  and 20  $(yr_{20})$ , we can notice the lowest and highest level of revenue, respectively. This wind power plant expects to receive as total AAR about 954 354 217 US\$M during the operational phase. The relation between the total AAR and LCPM<sub>WF</sub> is 0.179126 US\$ per kWh produced. We have to remember the effect of the inflation rate (2.5% per year) on revenues.

When we compare AAR of Cape Saint James (Canada) with Corvo Island (Portugal) and Aracati (Brazil) considering the different annual wind speed (Brazil=7.4 m/s, Portugal=9.1 m/s and Canada=12.5 m/s) (see Table 8.1) and PPARs (Brazil=0.08581 US\$/kWh, Portugal=0.16291 US\$/kWh and Canada=0.13835 US\$/kWh) (see Table 7.10) the impact on AAR is tremendous. An increasing is noticed on total AAR (from 134 959 772 US\$M to 954 354 217 US\$M). The increasing of 69.3% and 61.2% in wind speed and PPAR, respectively, reflects in an increasing of 607.1% on total AAR.

The  $O\&M_{WFCM}$  of the hypothetical wind farm is shown in Figure 8.31 within its particularities and behavior. We have calculated the  $O\&M_{WFCM}$  per year according to Eqns 6.2.3, 6.2.3.1 and 6.2.3.2 with the conditions defined in Tables 7.11 and 7.12.



**Figure 8.31**  $O\&M_{WFCM}$  splited into *fixed* ( $O\&M_{fixed}_{CM}$ ) and *variable* ( $O\&M_{variable}_{CM}$ ) during the lifetime of the 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

As we can see in Figure 8.31, the  $O\&M_{WFCM}$  of the wind farm in Cape Saint James (Canada) varies from 0.0969 US\$ kWh/yr to 0.1549 US\$ kWh/yr with SD=0.0180 US\$ kWh and 0.1280 US\$ kWh/yr (Mean): The  $O\&M_{WFCM}$  has shown a *negative symmetric* distribution (Y=0.1280) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 20 ( $yr_{20}$ ), we can notice the lowest and highest level of  $O\&M_{WFCM}$ , respectively. This wind power plant expects to spend as total  $O\&M_{WFCM}$  about 682 022 915 US\$M during the operational phase. The relation between the total  $O\&M_{WFCM}$  and  $LCPM_{WF}$  is 0.128011 US\$ per kWh produced. We also have to remember the effect of the inflation rate (2.5% per year) on O&M costs.

The  $O\&M_{WFCM}$  in Cape Saint James (Canada), Corvo Island (Portugal) and Aracati (Brazil) shows some particularities  $\therefore$  The cost per kWh produced as not high as the increasing of  $LCPM_{WF}$  (see Figure 8.13 and Table 8.1). Within the level of total energy production (1 215 GWh for Aracati, 2 251 for Portugal and 5 328 GWh for Canada) and the average of  $O\&M_{WFCM}$  (0.108080 US\$/kWh for Aracati, 0.137576 US\$/kWh for Portugal and 0.128011 US\$/kWh for Canada), which represents an increasing of 18.4% on  $O\&M_{WFCM}$  (in relation to Aracati-Brazil). The *LRCM* of the hypothetical wind farm is shown in Figure 8.32 within its particularities and behavior. We have calculated the *LRCM per year* according to Eqns 6.2.2, 6.2.2.1, 6.2.2.1, 6.2.2.1, 6.2.2.2, and 6.2.2.2.1 with the conditions defined in Table 6.8.



**Figure 8.32** *LRCM* during the 15 years of the 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

As shown in Figure 8.32, the *LRCM* of the wind farm in Cape Saint James (Canada) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (*Mean*)... The *LRCM* has shown a *positive symmetric* distribution (Y=0.1407) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 15 ( $yr_{15}$ ), we can notice the lowest and highest level of *LRCM savings*, respectively. This wind power plant expects to save as total *LRCM* about 15 480 065 US\$ during 15 years of the operational phase. The relation between the total *LRCM* and *kW produced* in 15 years is 182.0645 US\$ per kW produced. We also have to remember the effect of the inflation rate (2.5% per year) on *LRCM*.

We have notice the same figure for *LRCM* in Cape Saint James (Canada), Aracati (Brazil) and Corvo Island (Portugal) which seems to be the way this sub model was developed. We can find the *same value per kW installed* (16.8443 US\$/kW) which can be understood as an *economic reserve*, independent of AAR and LCPM<sub>WF</sub> and it is not driven by the *price of electricity sold* (PPAR), so wind farm developer or manager can create the "best cost strategy" independent of the *price and the level of production of the wind farm*, as we have already said before.

The  $RCM_{WF}$  of the hypothetical wind farm is shown in Figure 8.33 within its particularities and behavior. We have calculated the  $RCM_{WF}$  per year according to Eqns 6.2.4, 6.2.4.1, 6.2.4.1.1, 6.2.4.1.2, 6.2.4.1.3, 6.2.4.2, 6.2.4.2.1, 6.2.4.2.2 and 6.2.4.3 with the conditions defined in Tables 6.8 and 6.9.



**Figure 8.33**  $RCM_{WF}$  during the lifetime of the 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

According to Figure 8.33, the  $RCM_{WF}$  of the wind farm in Cape Saint James (Canada) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean):. The  $RCM_{WF}$  has shown a positive moderate asymmetry distribution (Y=0.2259) during the wind farm lifetime (N=25yrs).

In the years 1 ( $yr_1$ ) and 25 ( $yr_{25}$ ), we can notice the lowest and highest level of  $RCM_{WF}$  savings, respectively. This wind power plant expects to save as total  $RCM_{WF}$  about 89 552 736 US\$ during the operational phase. The relation between the total  $RCM_{WF}$  and kW produced in 25 years is 1 053 US\$ per kW produced. We also have to remember the effect of the inflation rate (2.5% per year) on  $RCM_{WF}$ .

As we have discussed yet the  $RCM_{WF}$  was developed in order to cover the costs of removing the wind farm and "*rebuild*" the local environment conditions, so when we get a *value equal or equivalent* amount of funds for cover the costs of decommissioning the wind farm, which is the purpose of this indicator! In the case of the hypothetical wind farm in Cape Saint James (Canada) if we have consider the total  $LCCCM_{WF}$  (60 225 901 US\$) added to LRCM (15 480 065 US\$), the  $RCM_{WF}$  about 89 552 736 US\$ really covers it (75 705 966 US\$ < 89 552 736 US\$).

For  $RCM_{WF}$  in Cape Saint James (Canada) we have noticed the same conditions and conclusions of *LRCM* that is why we do not comment again (see page 329 of this Chapter).

For *REPIM model* we have also applied four different types of instruments to the wind farm in Cape Saint James (Canada): two of them are related to investment incentive (*REI*<sub>CM</sub> and *OREP*<sub>CM</sub>) and the others are related to energy production (*REP*<sub>CM</sub> and *GHG*. $R_{CM}$ ).

The  $REI_{CM}$  of the hypothetical wind farm is shown in Figure 8.34 within its particularities and behavior. We have calculated the  $REI_{CM}$  for initial year of the wind project (yr=0) according to Eqns 6.2.5.1 with the conditions defined in Tables 6.10 and 7.14.

REI <sub>CM</sub>	70.8203	[\$/kW <sub>e</sub> ]
$LCCCM_{WF}$	1 204.5180	[\$/kW]
LRCM	16.8443	[\$/kW]
ifr	2.50%	[%/yr]
$\Psi_{total}$	30.00%	[%]
$n_{\Psi}$	6	[yr]

Figure 8.34 REI<sub>CM</sub> for 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

The total  $REI_{CM}$  received by the hypothetical wind farm was also calculated with the Eqn 8.2. When we made the calculations according to data shown in Figure 8.34 and Tables 6.10 and 7.14, the expected value received from the government is 221 313 US\$. An analogous situation occurs to  $OREP_{CM}$  although according to Eqn 6.2.5.3.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

OREP <sub>CM</sub>	56.8814	[\$/kW <sub>e</sub> ]
$LCCCM_{WF_{OREGCM}}$	2.7664	[\$/kW]
LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]
WACC <sub>proj</sub>	4.9000%	[%/yr]
$\Psi_{total}$	30.0%	[%]
ifr	2.5%	[%/yr]
$n_{\Psi}$	10	[yr]
$CR_f$	80.0%	[%]

**Figure 8.35**  $OREP_{CM}$  for 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

The total  $OREP_{CM}$  received by the hypothetical wind farm was also calculated with the Eqn 8.3. When we made the calculations according to data shown in Figure 8.35, the expected value received from the government is 711 018 US\$.

As we already said the side of production is considered, in other words, the  $AEP_{avail}$  from the wind project analyzed. The  $REP_{CM}$  was developed according to Eqns 6.2.5.3 and 6.2.5.3.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

REP <sub>CM</sub>	0.00000052	$[/kW_eh]$
AEP avail/H prod	24 766	[kW/yr]
ifr	2.50%	[%/yr]
ε	0.0128	[\$/kW <sub>e</sub> h]
${\mathcal E}_0$	0.009998	[\$/kW <sub>e</sub> h]
n <sub>e</sub>	10	[yr]

**Figure 8.36**  $REP_{CM}$  for 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

According to Table G.10, the  $REP_{CM}$  of the wind farm in Cape Saint James (Canada) varies from 125 US\$  $kW_eh/yr$  to 156 US\$  $kW_eh/yr$  with SD=10 US\$  $kW_eh$  and 140 US\$  $kW_eh/yr$  (Mean). The

 $REP_{CM}$  has shown a *positive symmetry* distribution ( $\gamma = 0.1048$ ) during the period of energy policy instrument.

In the years 10  $(yr_{10})$  and 1  $(yr_1)$ , we can notice the lowest and highest level of  $REP_{CM}$ , respectively. When we made the calculations according to data shown in Figure 8.36, the total expected value received from the government during the period of the energy policy instrument is 1 403 US\$ (calculated with Eqn 8.4). We also have to remember the effect of the inflation rate (2.5% per year) on  $REP_{CM}$ .

Finally we also development among the energy policy instruments analyzed, one regard to  $CO_2$  *non-emissions*, defined as  $GHG.R_{CM}$ . According to Eqns 6.2.5.4 and 6.2.5.4.1 with the conditions defined in Tables 6.10, 7.13 and 7.14.

GHG.R <sub>CM</sub>	4 490.4890	[\$/tCO <sub>2</sub> ]
$LCER_{CO_2}$	80.7	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$\sum AEP avail yr_{1+\dots+yr_n}$	212 467	[MW <sub>e</sub> h]
$n_{\psi}$	25	[yr]
$GHG_{EM_{ff}co_2}$	0.00041	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$GHG_{EM_{wecs CO2}}$	0.00003	[tCO <sub>2</sub> /MW <sub>e</sub> h]
$\mathcal{E}_{c}$	30.0000	[\$/tCO <sub>2</sub> ]

**Figure 8.37** *GHG.R<sub>CM</sub>* for 50MW<sub>e</sub> wind farm in Cape Saint James (Canada). Source: Own elaboration

According to Table G.10, the *GHG*. $R_{CM}$  of the wind farm in Cape Saint James (Canada) varies from 621 US\$/ $tCO_2$  to 1 128 US\$/ $tCO_2$  with SD=152 US\$/ $tCO_2$  and 851 US\$/ $tCO_2$  (Mean). The *GHG*. $R_{CM}$  has shown a *positive moderate asymmetry* distribution (Y=0.2159) during the period of energy policy instrument.

In the years 1  $(yr_1)$  and 25  $(yr_{25})$ , we can notice the lowest and highest level of  $GHG.R_{CM}$ , respectively. When we made the calculations according to data shown in Figure 8.37, the total expected value received from the government during the period of the energy policy instrument is 21 268 US\$ (calculated with Eqn 8.5). We also have to remember the effect of the inflation rate (2.5% per year) on  $GHG.R_{CM}$ .

In order to better comprehension about *REPIM* mode through the results among Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) we have resumed the main values in the Table 8.6.

Table	8.6	Comparison	of	REPIM	in	Aracati	(Brazil),	Corvo	Island	(Portugal)	and	Cape	Saint
James	(Can	ada)											

Instrument	Unit	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
$REI_{CM}$	US\$/kW <sub>e</sub>	221 313	221 313	221 313
$REP_{CM}$	US\$/kW <sub>e</sub> h	16 285	16 879	1 403
$OREP_{CM}$	$US\$/kW_e$	163 497	265 188	711 018
$GHG.R_{CM}$	$US$ \$/ $tCO_2$	7 495	3 893	21 268
<u>a</u> <u>o</u> 11				

Source: Own elaboration

A conclusive analysis can be taken from the results shown in Table 8.6:

- 1. The  $REI_{CM}$  is not dependent of the level of production ( $LCPM_{WF}$ ), local wind speed at a constant percentage ( $\psi_{total}$ ) and period of the energy policy instrument ( $n_{\psi}$ );
- 2. On  $REP_{CM}$  the impact is *more effective* in function of the *value paid by government* ( $\varepsilon_0$ ) *than the time of policy energy instrument* ( $n_{\varepsilon}$ ). Although the wind farm in Cape Saint James (Canada) presents much more potential production ( $LCPM_{WF}$ ) (see Figure 8.13 and Table 8.1) but the value paid is the lowest (see Table 7.14);
- 3. The  $OREP_{CM}$  is driven by the *period of the energy policy instrument*  $(n_{\psi})$  and  $AEP_{avail}$  what can be justified the highest *value paid* to the wind far in Cape Saint James (Canada), even this government adopts the lowest *value paid*;
- 4. For *GHG*.*R*<sub>CM</sub> we can see analogous situation, but the *lowest value* paid is in Corvo Island (Portugal).

## 8.4 SENSITIVITY ANALYSIS RESULTS

#### 8.4.1 INDIVIDUAL VARIABLE SENSITIVITIES

#### 8.4.1.1 IMPACT ON $LCOE_{WSO}$ OF WIND SPEED ( $V_{WC}$ )



Figure 8.38 Impact on  $LCOE_{wso}$  of wind speed ( $v_{wc}$ ). Source: Own elaboration

The relation between  $LCOE_{wso}$  and wind speed  $(v_{wc})$  as we can understand from the Figure 8.38 seems to present a partial inverse relation: We can state that it works like the same principle of economy of scale. As has said Rosa (2009) the AEP from WECS is the cube of wind speed, that is why the local wind resources where the wind farm will be installed is a fundamental question for this type of RETs.

For these three different sites, we have noticed that when *wind speed*  $(v_{wc})$  *increases in 23.0%*, we get 10.2% of increasing on  $LCOE_{wso}$  (from Aracati-Brazil to Corvo Island-Portugal). The same situation occurs in relation to Corvo Island (Portugal) and Cape Saint James (Canada) when the *wind speed increases 37.4%* reflects and *increases 19.4% on LCOE<sub>wso</sub>* (see Table 8.7).

Items	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
$LCOE_{wso}$	69.6792	76.8138	91.7081
$v_{wc}$ (m/s)	7.4	9.1	12.5

**Table 8.7** Sensitivity analysis between  $LCOE_{wso}$  and  $v_{wc}$ 

Source: Own elaboration. Note: according to Tables 6.5 and 7.5.

8.4.1.2 IMPACT ON  $LCOE_{WSO}$  OF OPERATIONS AND MAINTENANCE MANAGEMENT ( $O\&M_{MANAG}$ )

According to Obdam, Braam, Rademakers, and Eecen (2007) O&M costs of wind farms contribute significantly to the energy production costs. Reliable estimates of these costs are required during planning and operation of the wind farm at several stages. Such estimates however have a large spread and are uncertain.

These O&M costs and strategies can oscillate during the lifetime of the wind farm and the impact on LCOE assumes a similar behavior. In our methodology the  $O\&M_{MANAG}$  has also impact on  $LCOE_{wso}$  and wind farm availability. Figure 8.39 shows the results of  $LCOE_{wso}$  due to the strategy simulated in the sensibility analysis done according to Table 7.12.



**Figure 8.39** Resume of sensitivity analysis of  $LCOE_{wso}$  and  $O\&M_{manag}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration

We focused our Ph.D. research work on  $LCOE_{wso}$  impact when is considered different strategies for O&M management in the wind farms analyzed. As we have defined in Chapter 7, section 7.6.2 (*optimization criteria*), the optimization moment is related finding (calculating) the *lowest*  $LCOE_{wso}$  as possible.

Table 8.8 shows the results and effects on  $LCOE_{wso}$  due to the  $O\&M_{manag}$  programs (strategies) tested by the sensitivity analysis done. We also highlight the "best option" to choose about O&M strategy to follow.

The wind farm availability increases in 0.44% for  $O\&M_{manag(A)}$  and 0.24% for  $O\&M_{manag(B)}$  in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Figure 8.40 shows the availability for each site and strategy considered.

	Strategies	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
ws0	$O\&M_{manag(STD)}$	69.6873 US\$/MWh	76.8138 US\$/MWh	91.7081 US\$/MWh
LCOE	$O\&M_{manag(A)}$	69.6991 US\$/MWh	76.8666 US\$/MWh	91.8264 US\$/MWh
	$O\&M_{manag(B)}$	69.6873 US\$/MWh	76.8666 US\$/MWh	91.7691 US\$/MWh
	0 11			

**Table 8.8** Sensitivity analysis between  $LCOE_{wso}$  and  $O\&M_{manag}$ 

Source: Own elaboration

When we analyze the effect of  $O\&M_{manag}$  on  $LCOE_{wso}$  for each site, we get some interesting aspects to be understood. First of all, we have considered as base for comparison the  $O\&M_{manag(STD)}$ . We possible conclude about  $O\&M_{manag}$  such considerations:

- 1. In the case of Aracati (Brazil) the option  $O\&M_{manag(B)}$  can be adopted, because there is no effect on the  $LCOE_{wso}$ , but if we get the  $O\&M_{manag(A)}$  the cost of electricity produced increases in 0.02%;
- 2. For Corvo Island (Portugal) both  $O\&M_{manag(A)}$  and  $O\&M_{manag(B)}$  increase the  $LCOE_{wso}$  in 0.07%. The  $O\&M_{manag(STD)}$  is the optimized strategy for O&M costs;
- 3. In Cape Saint James (Canada) occurs the same situation of Corvo Island (Portugal), but we get an increasing of 0.13% for  $O\&M_{manag(A)}$  and 0.07% for  $O\&M_{manag(B)}$ . Also the  $O\&M_{manag(STD)}$  is the optimized strategy for O&M costs.



**Figure 8.40** Resume of sensitivity analysis of  $O\&M_{manag}$  and wind farm availability for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration

### 8.4.1.3 IMPACT ON $LCOE_{wso}$ of wind turbines layout $(L_{wt})$

As has discussed by Eriksson (2008) is important to look at different wind farm layouts and compare the reliability and the investment between the alternatives, since it is hard to interpret the result from a reliability calculation for a single layout without comparing it to alternatives.

In  $LCOE_{wso}$  methodology the  $L_{wt}$  has also impact on the costs of the wind farm as a whole. Figure 8.41 shows the results of  $LCOE_{wso}$  due to the alternative wind farm layouts (5D4D, 5D7D, 5D10D and 6D12D) simulated in the sensibility analysis done according to Table 6.5.



**Figure 8.41** Resume of sensitivity analysis of  $LCOE_{wso}$  and  $L_{wt}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration

We focused our Ph.D. research work on  $LCOE_{wso}$  impact when is considered alternative layouts for  $L_{wt}$  variable in the wind farms analyzed. As we have defined in Chapter 7, section 7.6.2 (optimization criteria), the optimization moment is related finding (calculating) the *lowest*  $LCOE_{wso}$  as possible. Table 8.9 shows the results and effects on  $LCOE_{wso}$  due to  $L_{wt}$  alternatives tested by the sensitivity analysis done. We also highlight the "best option" to choose of  $L_{wt}$  to be implemented.

As we can see at Figure 8.42 the wind turbines layout impacts on  $LCCCM_{WF}$  because the *distances* between the wind turbines, dimension of local wind turbines grid (LWTG) and correlated capital costs influenced by  $L_{wt}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). The 5D7D, 5D10D and 6D12D layouts can increase the  $LCCCM_{WF}$  in 0.25%, 0.51% and 1.10%, respectively.

	Layouts	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
	5D4D	69.6792 US\$/MWh	76.8138 US\$/MWh	91.7081 US\$/MWh
$E_{wsc}$	5D7D	69.8318 US\$/MWh	76.9663 US\$/MWh	91.8606 US\$/MWh
ГСС	5D10D	69.9843 US\$/MWh	77.1188 US\$/MWh	92.0131 US\$/MWh
	6D12D	70.3401 US\$/MWh	77.4747 US\$/MWh	92.3690 US\$/MWh

**Table 8.9** Sensitivity analysis between  $LCOE_{wso}$  and  $L_{wt}$ 

Source: Own elaboration

When we analyze the effect of  $L_{wt}$  on  $LCOE_{wso}$  for each site, we get some interesting aspects to be understood. First of all, we have considered as base for comparison the layout 5D4D. We possible conclude about  $L_{wt}$  such considerations:

- 1. In the case of Aracati (Brazil) the option 5D4D can be adopted, because it is cheapest alternative (*effect on LCOE*<sub>wso</sub>), but if we get the 5D7D, 5D10D or 6D12D the cost of electricity produced increases in 0.22%, 0.44% and 0.95%, respectively;
- 2. For Corvo Island (Portugal) both we can see a similar situation with Aracati (Brazil) with the cost of electricity produced increases in 0.20%, 0.40% and 0.86%, respectively;
- 3. In Cape Saint James (Canada) occurs the same situation of Corvo Island (Portugal) and Aracati (Brazil) with the cost of electricity produced increases in 0.17%,0.33% and 0.72%, respectively;
- 4. We can confirm, *mutatis mutandis*, among the layouts alternatives analyzed that 5D4D is the *optimized solution* for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). This layout is pointed by many researchers (Dicorato, Forte, Pisani, & Trovato, 2011; Lundberg, 2003, 2006a, 2006b) as one possible optimized onshore wind turbines.





8.4.1.4 IMPACT ON  $LCOE_{WSO}$  OF ENERGY POLICY INSTRUMENTS  $(E_{PI})$ 

Globally, governments tend to appreciate the advantages of renewable energy production more than conventional energy production. Therefore, to support the expansion of production capacity of renewable energy in many ways that basically aims to reduce the disadvantages of most technologies for renewable energy production: *the cost and the lack of controllability*.

The cost (investment and/or production) can reduce with the RETs project receive some support from government for construction or investment incentives such as accelerated depreciation, tax advantages or subsidies may lead to the construction of a significant number of new renewable power plants (Enzensberger, Wietschel, & Rentz, 2002). The *energy policy instruments* are represented in  $LCOE_{wso}$  methodology by *REPIM* model within its sub-models  $REI_{CM}$ ,  $REP_{CM}$ ,  $OREP_{CM}$  and  $GHG.R_{CM}$  (see Chapter 6, pp. 238-241).

The sensitivity analysis in *REPIM* was done according to Table 7.14 and optimization criteria defined in section 7.6.2.



**Figure 8.43** Resume of sensitivity analysis of  $LCOE_{wso}$  and  $E_{pi}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration

We focused our Ph.D. research work on  $LCOE_{wso}$  impact of alternative public incentives for  $E_{pi}$  variable in the wind farms analyzed. As we have defined in Chapter 7, section 7.6.2 (*optimization criteria*), the optimization moment is related finding (calculating) the *lowest*  $LCOE_{wso}$  as possible. Table 8.10 shows the results and effects on  $LCOE_{wso}$  due to  $E_{pi}$  alternatives tested by the sensitivity analysis done. We also highlight the "best option" to choose of case for  $E_{pi}$  to be implemented.

In  $LCOE_{wso}$  methodology the  $E_{pi}$  has also impact on  $LCCCM_{WF}$ . Figure 8.44 shows the results of  $LCCCM_{WF}$  due to the alternative  $E_{pi}$  (*Base-case*, *Case* <sub>1</sub>, *Case* <sub>2</sub> and *Case* <sub>3</sub>) simulated in the sensibility analysis done according to Table 6.5.

,	Situations	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
	Base-case	69.6792 US\$/MWh	76.8138 US\$/MWh	91.7081 US\$/MWh
$E_{wsc}$	Case $_1$	69.6792 US\$/MWh	76.8138 US\$/MWh	91.7081 US\$/MWh
ГСC	Case $_2$	76.8138 US\$/MWh	76.8138 US\$/MWh	91.7081 US\$/MWh
	Case 3	69.6792 US\$/MWh	76.8138 US\$/MWh	91.7081 US\$/MWh

**Table 8.10** Sensitivity analysis between  $LCOE_{wso}$  and  $E_{pi}$ 

Source: Own elaboration

According to Table 8.10 it is possible to take some conclusions about the effect of  $E_{pi}$  on  $LCOE_{wso}$ :

- 1. In the case of Aracati (Brazil) only the Case <sub>2</sub> makes the cost of electricity produced increases in 10.24%;
- 2. For Corvo Island (Portugal) and Cape Saint James (Canada) the *cost of electricity produced remains* in the same level as the base-case;
- 3. We also can say that *base-case situation* is the *optimized solution* for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada).

Figure 8.44 shows the impacts of  $E_{pi}$  on  $LCCCM_{WF}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Both *Case* 1 and *Case* 3 decrease the  $LCCCM_{WF}$  in 1.23%, 1.34% and 1.79%, respectively. In Case 3 there is an increasing of 0.19% and 0.10% for Aracati (Brazil), and Corvo Island (Portugal) and decreases 0.22% for Cape Saint James (Canada) (see Table V.5).



**Figure 8.44** Impact on  $LCCCM_{WF}$  due to alternative energy policy  $(E_{pi})$ . Source: Own elaboration

### 8.4.2 MULTIPLE VARIABLE SENSITIVITIES



#### 8.4.2.1 IMPACT ON $LCOE_{WSO}$ OF WIND SPEED ( $V_{WC}$ ) AND WIND TURBINE LAYOUT ( $L_{WT}$ )

**Figure 8.45** Resume of sensitivity analysis of the impact on  $LCOE_{wso}$  of wind speed  $(v_{wc})$  and wind *turbine layout*  $(L_{wt})$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration

When we analyzed the sensibility studies considering multiple variables, case of this section, when it is crossed  $LCOE_{wso}$ ,  $v_{wc}$  and  $L_{wt}$  a wider conclusion can be made. First of all, we also confirm the same ideas from individual analysis of these variables, such as, (a) the lowest  $LCOE_{wso}$  is 5D7D layout for  $L_{wt}$ , (b)  $LCOE_{wso}$  as higher as the  $v_{wc}$  is, but not in the same proportion and (c) the  $v_{wc}$  has stronger impact on  $LCOE_{wso}$  than  $L_{wt}$  (see Figure 8.45).

As we considered the 5D4D as the reference layout and optimized one, due to find the lowest  $LCOE_{wso}$  among Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). The mean calculated of them is 79.4004 US\$/MWh. For the other layouts simulated in sensitivity analysis we found 79.5529 US\$/MWh, 79.7054 US\$/MWh and 80.0613 US\$/MWh for 5D7D, 5D10D and 6D12D, respectively.

According to Table V.4 the  $LCOE_{wso}$  increases 0.19%, 0.38% and 0.83% considering the 5D4D layout as reference, as we already said before, for 5D7D, 5D10D and 6D12D, respectively.

8.4.2.2 IMPACT ON  $LCOE_{WSO}$  OF O&M MANAGEMENT ( $O\&M_{MANAG}$ ) and energy policy instruments ( $E_{Pl}$ )

The  $O\&M_{manag}$  and  $E_{pi}$  as supposed to have different impacts on  $LCOE_{wso}$ . In the case of the possible combinations of  $O\&M_{manag(A)}$ ,  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* 1, *Case* 2 and *Case* 3) we found some interesting situations (see Tables 8.11, 8.12 and 8.13).

**Table 8.11** Resume of sensitivity analysis of the impact on  $LCOE_{wso}$  of  $O\&M_{manag(A)}$  and  $E_{pi}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada)

		Aracati	Corvo Island	Cape Saint James
	Item	(Brazil)	(Portugal)	(Canada)
			$O\&M_{manag(A)}$	
6	Reference	69.6792	76.8138	91.7081
$E_{wse}$	Case $_1$	69.6991	76.8666	91.8264
CO	Case $_2$	69.6991	76.8666	91.8264
Π	Case 3	69.6991	76.8666	91.8264

Source: Own elaboration

 $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case 1, 2 and 3*) for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) we found an increasing of 0.03%, 0.07% and 0.13%, respectively, in relation to reference situation.

**Table 8.12** Resume of sensitivity analysis of the impact on  $LCOE_{wso}$  of  $O\&M_{manag(B)}$  and  $E_{pi}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada)

Item		Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
			$O\&M_{manag(B)}$	
0	Reference	69.6792	76.8138	91.7081
$E_{ws}$	Case $_1$	69.6873	76.8666	91.7691
,CO	Case $_2$	69.6873	76.8666	91.7691
Γ	Case <sub>3</sub>	<i>69.6873</i>	76.8666	91.7691

Source: Own elaboration

 $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case 1, 2* and *3*) for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) we found an increasing of 0.01%, 0.07% and 0.07%, respectively, in relation to reference situation.

In Table 8.13 shows the difference of O&M programs and  $E_{pi}$  simulated in the sensitivity analysis done for understanding the optimized option for O&M proposed programs.

Item		Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
			$O\&M_{manag(A)}$ - $O\&M_{manag(B)}$	
0	Reference	69.6792	76.8138	91.7081
$E_{ws_n}$	Case $_1$	0.0117	nihill	0.0574
,CO	Case $_2$	0.0117	nihill	0.0574
Γ	Case 3	0.0117	nihill	0.0574

**Table 8.13** Resume of sensitivity analysis of the impact on  $LCOE_{wso}$  of  $O\&M_{manag(A-B)}$  and  $E_{pi}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada)

Source: Own elaboration

Some conclusions can be taken by the results obtained for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada):

- 1. The optimized situation is the *reference* one. As we have already discussed the mean of *LCOE*<sub>wso</sub> is 79.4004 US\$/MWh;
- 2. The relation between the  $LCOE_{wso}$  for each site and the mean of  $LCOE_{wso}$  is -14.0%, 10.2% and 31.6% for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada), respectively;
- 3. For *O&M programs (O&M<sub>manag(A)</sub> and O&M<sub>manag(B)</sub>)* and *E<sub>pi</sub> (Cases 1, 2</sub> and 3)*, in Aracati (Brazil) and Cape Saint James (Canada) increase *0.0117 US\$/MWh* and *0.0574 US\$/MWh*, respectively;
- 4. In Corvo Island (Portugal) shows no variation between  $O\&M_{manag(A)}$  and  $O\&M_{manag(B)}$ , but as we already said, increases 0.0528 US\$/MWh in relation to reference situation;
- 5. We can possible conclude that O&M management  $(O\&M_{manag})$  and energy policy instruments  $(E_{pi})$  combined have a positive impact on  $LCOE_{wso}$ . We have to remember that the optimized solution for these variables analyzes is the reference situation.

As have stated Barradale (2010) about energy policy when discuss that alongside cost-effectiveness and other dimensions that are usually considered in the choice of policy incentives, therefore, stability should be added to the list of criteria to be explicitly considered. This *stability* refers to the macroeconomic situation of the government that subsidizes the renewable energy technologies from the supporting programs practice.

### 8.4.3 Conclusions and future analysis on cost of wind energy

The cost of the electricity produced depends on, apart from the *initial capital investment costs*, on the general wind conditions at the site  $(v_{wc})$ , O&M expenses and on the financing mechanism adopted for the wind power project.

The results of simulations done according to Table 7.15 within the variables selected ( $v_{wc}$ ,  $L_{wt}$ ,  $O\&M_{manag}$  and  $E_{pi}$ ) for validation the  $LCOE_{wso}$  methodology confirm the impact expected on the *cost of energy produced* by the hypothetical wind farms at Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). As expected, changes in *wind speed* ( $v_{wc}$ ) have such a significant impact on the  $LCOE_{wso}$  in function of the  $AEP_{avail}$ . Table 8.14 shows the main results from the simulations, but the *strong correlation* confirm the *expected impact* of this variable.

**Table 8.14** Relation among  $LCOE_{wso}$ ,  $AEP_{avail}$  and  $v_{wc}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada)

Item	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
LCOE <sub>wso</sub> (US\$/MWh)	69.6792	76.8138	91.7081
$AEP_{avail} (GWh)$	1 215	2 251	5 328
$v_{wc}$ (m/s)	7.4	9.1	12.5
Correlation Coeff. 0.9969	)		

Source: Own elaboration

In relation to the *energy production cost*, there is a *strong evidence of direct dependence* of the *average wind speed* ( $v_{wc}$ ). As an example, the *energy production cost* at an average wind speed of 7.4*m/s* was increased in 10.2% as the cost for an average wind speed of 9.1*m/s*. It was also found that the *energy production cost decreases* when the power of the wind farm increases.

The *layout effect* ( $L_{wt}$ ) was analyzed and some aspects can be highlighted. In the hand of *investment* costs ( $LCCCM_{WF}$ ) there is a direct relation as we can see at Figure 8.42. As more as spaced as the wind turbines layout, more is the investment needed to be done. Afterword, this increasing of  $LCCCM_{WF}$  impacts on  $LCOE_{wso}$ . We also remember that Table 7.4 shows the relation of *layout*, area ( $km^2$ ) and occupation rate (%). It could be an interesting analysis takes into consideration two options for land costs: one the land area is rented and the other is part of *initial investment* ( $LCCCM_{WF}$ ). In our  $LCOE_{wso}$  methodology we considered only the rent option, so it was included into  $O\&M_{variable_{AV}}$  (see Eqn. 6.2.3.1).

Another aspect analyzed was the  $O\&M_{MANAG}$ . The  $O\&M_{MANAG}$  impacts on  $AEP_{avail}$  ( $LCPM_{WF}$ ) because is connected directly to *period of electricity production* ( $H_{prod}$ ) by the wind farm. This effect sensible reflects on others aspects of the  $LCOE_{wso}$  methodology, such as O&M costs, total AAR, wind farm availability. For illustration, Figure 8.46 shows the impact on  $H_{prod}$  and availability of the wind farm in Aracati (Brazil).



**Figure 8.46** Impact of  $O\&M_{MANAG}$  on hours of production  $(H_{prod})$  and wind farm availability for Aracati (Brazil). Source: Own elaboration

The *total AAR* of wind farms for 25 years is affected by  $v_{wc}$ ,  $O\&M_{manag}$ , and  $O\&M_{manag}$  combined with  $E_{pi}$ . The  $L_{wt}$  has not impacted on *total AAR* due to the objective of the alternatives layouts simulated (*constant WF<sub>cap</sub> and cost impacts driven to LCCCM<sub>WF</sub>*), otherwise the different layouts impacts direct on *total AAR*. Table 8.15 summarize the variables simulated and the impact on *total AAR* (*US\$M*) for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada).

In the simple variable analysis the  $O\&M_{manag}$  impacted on *total AAR* differently for each wind farm and program analyzed. In the case of  $O\&M_{manag(A)}$  increases the *total AAR* in 0.45%, 0.43% and 0.44%, respectively for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada).  $O\&M_{manag(B)}$  also increases the *total AAR* in 0.24%, 0.43% and 0.23%, respectively for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada).

In the multiples variables analyzes when we consider the combination of  $O\&M_{manag(A)}$ ,  $O\&M_{manag(B)}$ ,  $E_{pi}$  (*Cases* 1, 2 and 3). For the first group of variables ( $O\&M_{manag(A)}$ + *Case* 1,2,3) we can notice an increasing on *total AAR* of 0.45%, 0.43% and 0.44%, respectively for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Although in second group of variables ( $O\&M_{manag(B)}$ + *Case* 1,2,3) we also have an increasing on *total AAR* of 0.24%, 0.43% and 0.23%, respectively, for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) (see Table 8.15).

Variables	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
Simple variable	7.4 m/s	9.1m/s	12.5m/s
$\mathcal{V}_{wc}$	134 959 772	474 762 014	954 354 217
$L_{wt}$			
5D7D	134 959 772	474 762 014	954 354 217
5D10D	134 959 772	474 762 014	954 354 217
6D12D	134 959 772	474 762 014	954 354 217
$O\&M_{manag}$			
$O\&M_{manag(STD)}$	134 959 772	474 762 014	954 354 217
$O\&M_{manag(A)}$	135 567 821	476 812 536	958 516 231
$O\&M_{manag(B)}$	135 279 734	476 812 536	956 513 783
Epi			
Case $_{1}$	134 959 772	474 762 014	954 354 217
Case $_2$	134 959 772	474 762 014	954 354 217
Case $_3$	134 959 772	474 762 014	954 354 217
Multiples variables			
$O\&M_{manag(A)}+Case_{1}$	135 567 821	476 812 536	958 516 231
$O\&M_{manag(A)}+Case_2$	135 567 821	476 812 536	958 516.231
$O\&M_{manag(A)}+Case_3$	135 567 821	476 812 536	958 516 231
$O\&M_{manag(B)}+Case$ 1	135 279 734	476 812 536	956 513 783
$O\&M_{manag(B)}+Case_2$	135 279 734	476 812 536	956 513 783
$O\&M_{manag(B)}+Case_3$	135 279 734	476 812 536	956 513 783

**Table 8.15** Variables simulated and the impact on *total AAR (US\$M)* for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada)

Source: Own elaboration

For future analyzes we recommend explaining some more relations and behavior for  $LCOE_{wso}$  methodology proposed, such as:

- $LCOE_{wso}/AAR$ : develop correlations with cost of energy produced and the revenues of the wind farm in order to measure the elasticity between them. It is important to define the level of *AAR* for certain  $LCOE_{wso}$  desired or constrained by the energy policy instrument, for example.
- $LCOE_{wso}/DPB$ : define the influence of the cost of electricity produced and the payback period of the wind project. As we have not the objective to analyze it, but we know it is important the payback for the investor/financer of the project.
- ★  $LCOE_{wso}/ifr$ : what size of the influence of inflation on  $LCOE_{wso}$  because this kind of analysis is applied for long term (N=25 yrs). The inflation effect on the values must be carefully analyzed, if can change the type of decision made (during the Ph.D. research work, all analyzes done the inflation rate was constant).

- $\Rightarrow LCOE_{wso}/LCPM_{WF}: \text{ in } LCOE_{wso} \text{ methodology the production of the wind farm is determined by the } LCPM_{WF}. It could be a great indicator some variable that make the correlation and influence of production on <math>LCOE_{wso}$ . The wind farm output (production) can be analyzed by the  $P\&D_{LM factor}$ , but we do not make any analysis with this variable and  $LCOE_{wso}$ .
- $\Rightarrow LCOE_{wso}/O&M warranty conditions: as we have defined the O&M contracts influence on the O&M costs, so, try to develop some algorithm for calculating these variations would be important for O&M effect on <math>LCOE_{wso}$  at all.
- ☆ LCOE<sub>wso</sub>/PPAR-EMP: define the correlation and sensibility between the cost of energy produced and the price of electricity sold. For this Ph.D. research work we have considered the PPAR/EMP constant for all simulations done. Meanwhile we recognize price is a key-parameter for the success of a wind project (Blanco, 2009; Chapman, 1974; Gross et al., 2010; Ibenholt, 2002; Lee, Chen, & Kang, 2009; Levitt, Kempton, Smith, Musial, & Firestone, 2011; Milborrow, 1995; Robert S, 1993; Strbac, Jenkins, & Allan, 1997).

So we suggest many "*roads*" to follow in future analysis on *cost of wind energy* both *onshore* and *offshore*, the challenge of wind energy Ph.D. research lies in developing alternative methodologies that make the optimization with respect to both cost and production. One of the prerequisite to overcome this challenge for the cost-effective analysis is the availability of a systematic group of equations that generates accurate and reliable results according the official data published in the scientific renewable energy community.



**Figure 8.47** Relation of *total*  $AEP_{avail}$  and  $LCOE_{wso}$  during the lifetime of 50MW<sub>e</sub> wind farm in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration. Source: Own elaboration

As we can notice in Figure 8.47 the simulations and sensitivity analysis show that increasing  $AEP_{avail}$  leads to increasing  $LCOE_{wso}$ .  $AEP_{avail}$  and related variables must be considered together, and they have a *strong influence* on  $LCOE_{wso}$ .

# 8.5 SUMMARY AND CONCLUSIONS

This chapter shows the results from the simulations and sensitivity analysis in  $v_{wc}$ ,  $L_{wt}$ ,  $O\&M_{manag}$  and  $E_{pi}$  to a 50 MW<sub>e</sub> onshore wind farm located at Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada), operating for 25 years. We start by simulation a *standard situation* (*reference simulation*) and developed 900 interactions for  $LCOE_{wso}$  calculations according to Table 7.16.

We show the results expected to  $LCCCM_{WF}$ , AAR,  $O\&M_{WFCM}$ , LRCM, RCM<sub>WF</sub> and REPIM (see section 8.3.3) for each site analyzed. The *investment costs* (measured by  $LCCCM_{WF}$ ) calculated about 1 205 USD/kW for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada), but in the sensitivity analysis the  $LCCCM_{WF}$  oscillates as shown in Figure 8.42 in function of the *alternatives wind farm layouts* ( $L_{wt}$ ).

The *total AAR* for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) varies from *134 959 772 US\$M* to *958 516 231 US\$M*. We can resume the main results of *AAR* for each site analyzed, as:

- 1. In Aracati (Brazil) varies from 4 297 170 US\$M/yr to 6 873 465 US\$M/yr with SD=713 406 US\$M and 5 398 391 US\$M/yr (Mean);
- 2. In Corvo Island (Portugal) varies from *14 970 925 US\$M/yr* to *24 203 932 US\$M/yr* with *SD*=*2 524 373 US\$M* and *18 990 481 US\$M/yr* (*Mean*);
- 3. In Cape Saint James (Canada) varies from *30 129 143 US\$M/yr* to *48 311 614 US\$M/yr* with *SD*=*5 069 795 US\$M* and *38 174 169 US\$M/yr* (*Mean*).

The operation costs of the wind farm also have shown a peculiar behavior.  $O\&M_{WFCM}$  in the  $LCOE_{wso}$  methodology analyzed the operational costs and we get the final results:

- 1. In Aracati (Brazil) varies from 0.0808 US\$ kWh/yr to 0.1323 US\$ kWh/yr with SD=0.0161 US\$ kWh and 0.1081 US\$ kWh/yr (Mean);
- 2. In Corvo Island (Portugal) varies from 0.0969 US\$ kWh/yr to 0.1549 US\$ kWh/yr with SD=0.0180 US\$ kWh and 0.1280 US\$ kWh/yr (Mean);
- 3. In Cape Saint James (Canada) varies from 0.0969 US\$ kWh/yr to 0.1549 US\$ kWh/yr with SD=0.0180 US\$ kWh and 0.1280 US\$ kWh/yr (Mean).

In the case of the *techno-economic reserves*, case of *LRCM* and *RCM*<sub>WF</sub>. These models shown different results. For *LRCM* we obtain some interesting values, as detailed:

- 1. In Aracati (Brazil) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (Mean);
- 2. In Corvo Island (Portugal) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (Mean);
- 3. In Cape Saint James (Canada) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (Mean).

For  $RCM_{WF}$ , the main results are:

- 1. In Aracati (Brazil) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean);
- 2. In Corvo Island (Portugal) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean);
- 3. In Cape Saint James (Canada) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean).

The government support to RETs in the  $LCOE_{wso}$  methodology is represented by *REPIM* model. According to Table 8.6 the sub-models of *REPIM* have the main results:

- 1. For Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) the *REI*<sub>CM</sub> is about 221 313 US\$/kW<sub>e</sub>;
- *REP<sub>CM</sub>* is about *16 285 US\$/kW<sub>e</sub>h* (for Aracati (Brazil)), *16 879 US\$/kW<sub>e</sub>h* (for Corvo Island (Portugal)) and *1 403 US\$/kW<sub>e</sub>h* (Cape Saint James (Canada));
- OREP<sub>CM</sub> is about 163 497 US\$/kW<sub>e</sub> (for Aracati (Brazil)), 265 188 US\$/kW<sub>e</sub> (for Corvo Island (Portugal)) and 711 018 US\$/kW<sub>e</sub> (Cape Saint James (Canada));
- 4. *GHG.R<sub>CM</sub>* is about 7 495 *US\$/tCO*<sub>2</sub> (for Aracati (Brazil)), 3 893 *US\$/tCO*<sub>2</sub> (for Corvo Island (Portugal)) and 21 268 *US\$/tCO*<sub>2</sub> (Cape Saint James (Canada)).

Figure 8.48 shows the final  $LCOE_{wso}$  results for the sites selected for the hypothetical 50 MW<sub>e</sub> onshore wind farm.



**Figure 8.48** Final values of  $LCOE_{wso}$  for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration. Source: Own elaboration

In general, the results from the  $LCOE_{wso}$  model show that the necessity and importance of methodologies for cost-effective analysis in the Renewable Energy Technologies (RETs), case of wind power and we can confirm, mutatis mutandis, that  $LCOE_{wso}$  is equivalent to LCOE/NREL and the results are similar according to Figure 7.7.

An analysis of the fundamental variables of the  $LCOE_{wso}$  cost model has resulted in a wellconsidered approach of cost modeling within the wind power project, both onshore and offshore. A breakdown of costs into a summation of components can lead to a straightforward accumulation of inaccuracies and every level of precision can be obtained with precise input data (*so the data considered must be from a secure source*). A breakdown of energy production in a multiplication of efficiencies has an inherent error, associated with the correlation between contributions to energy loss (*in this numerical simulation and validation was considered constant*).

The core of the  $LCOE_{wso}$  model can be simplified and does not need to specify the cost breakdown. However, this simplification must be done considering the historical data applied to that submodel. Furthermore, each data-component must be specified clearly to ensure a comprehensive and consistent breakdown of costs and performance of the power system analyzed.

For this Ph.D. research work a *generic fixed* breakdown has been defined and the cost models have been implemented while some corrections were done in equations developed. The final definition of the sub-model and the results that are generated for each component has not been applied without comparing within the official data, in order not increases risk of inconsistency. Future implementations or corrections should reduce the possibility to incorporate inconsistent data due to the several inputs needed. Costs of energy levelized are calculated according to the suggested algorithm (Eqn. 6.2) and with the input parameter.

According to Botterud (2003) the models can be applied by individual power plants in the power system to evaluate investment projects for new power generation capacity. The models can also serve as a *decision support tool* on a *regulatory level*, providing analyses of the long-term performance of the power system under different regulations and market designs into the different energy policy instruments.
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"By three methods we may learn wisdom: First, by reflection, which is noblest; second, by imitation, which is easiest; and third by experience, which is the bitterest."

Confucius

# **CHAPTER 9**

# **CONCLUSIONS AND IMPLICATIONS**

9.1 Introduction

- 9.2 Main findings and contributions
  - 9.2.1 Chapter 2
  - 9.2.2 Chapter 3
  - 9.2.3 Chapter 4
  - 9.2.4 Chapter 5
  - 9.2.5 Chapter 6
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- 9.3 Recommendations for future researches
  - 9.3.1 For  $v_{wc}$
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  - 9.3.3 For  $O\&M_{manag}$
  - 9.3.4 For  $E_{pi}$
  - 9.3.5 For others
- 9.4 General summary and conclusions
- 9.5 References

This final chapter presents a brief introduction about the research work design. Main findings and contributions of this Ph.D. research work are discussed within some recommendations for future researches and a general summary and conclusions of the whole thesis is summarized. The references used in this chapter are also presented in the end.

### 9.1 INTRODUCTION

The increased use of wind power requires modifications in methodologies of cost analysis for planning and management purposes, because it includes more a component of uncertainty that need to be properly studied in RETs. However, many studies that evaluate the COE of WECS in reliability still represent it as conventional power plants. As discussed in this Ph.D. work, due to *wind speed variations, intermittent nature,* and its *specificities* should be considered. This research had as objective the *development of an algorithm for Economic Optimization of Wind Farms in Function of the Cost of Energy* for representation in reliability and feasibility studies of implementation of wind power plants.

Currently there is a *high investment* in the production of energy through renewable resources. Thus, high investment in wind power plants, either in Europe or in the United States of America, as shown in Chapter 3. Essentially, the production of *electrical energy-electricity* through wind resources due to the maturity of their technology and resources available.

The wind energy conversion systems (WECS) were studied extensively in Chapter 4, due the necessity of understanding the multiple conversion chain performance by this technology. As we have to detail the WECS and how this mechanism can transform kinetic energy into electrical energy form, so, how we can get the *final energy production* ( $AEP_{avail}$ ) of a power plant.

During the extensive literature review, we have defined the *thematic areas of this research work* (see Figure 6.4), and go forward in the *economic measures and optimization models* discussed in Chapter 5. After that we could be able to understand what kind of *economic metric* could fit to the objective of this research work, the *LCOE methodology*, developed by NREL (1995). As deeper we analyze the *LCOE/NREL* we notice that we possible could modify it or adapt it to the objective of this research work.

In Chapter 6, we discussed about the *theoretical framework and hypotheses development* (section 6.4.3) and *research design* (section 6.4.4) within the *mathematical model structuring* (section 6.4.2). The  $LCOE_{wso}$  was developed in order to *maximize the wind farm production* ( $AEP_{avail}$ ) and *minimize the cost of energy produced* (COE), in the context of the *lifetime of the power plant*. We have to explain that is not a question of exchanging methodologies, even, it is an equivalence question! That is why it was necessary to make a numerical simulation and validation of the  $LCOE_{wso}$  methodology.

The *numerical simulation and validation* process designed in Chapter 7 considering the details and conditions in order to be more objective and realist and try to *"imitate a real wind power plant and its costs reliability and operation"*. The results of  $LCOE_{wso}$  simulations shown in Chapter 8 were used to validate de alternative methodology, in other words, we took this *"road"* because we could not test this methodology in a real wind farm. This final chapter is organized in five sections  $\therefore$  It starts with the *introduction* (section 9.1), main findings and contributions are shown in section 9.2, some recommendations for future researches are also shown in section 9.3 and we finalize this Ph.D. research work with *general summary and conclusions* (section 9.4) and the *references* used in this chapter (section 9.5).

### 9.2 MAIN FINDINGS AND CONTRIBUTIONS

According to Figure 1.1, the Ph.D. research work is organized in 9 chapters, so we decided to declare the *main findings and contributions* in the same way. The *introduction* part of this research work is set to Chapter 1, so we started from Chapter 2.

### 9.2.1 CHAPTER 2

- 1. *Humankind evolution is closely linked to energy* the primitive history of Egypt is an excellent example of the role that energy, measured in surplus food/energy, played in the structure and activities of a primitive society∴Although the structures of the societies of today are much more complex, the energy continues to be an important factor in the development of mankind;
- 2. Energy production and consumption is strongly associated with the environmental pressure on the planet For example, emissions of  $SO_2$  (sulfur dioxide), greenhouse gases and other  $CO_2$  and  $NO_x$  (nitrogen oxides) for a certain period, depends on the amount of electricity produced and the technological mix of plants operating in each electrical system for some period;
- Renewable energies have generally lower emissions than conventional power stations

   properly assess the potential effects of wind on the system cost of electricity compared to other existing production systems should take into account the fuel savings and emissions avoided ∴ Both the amount of CO<sub>2</sub> reduction and additional costs attributed to the system depends on the characteristics of the electricity system under analysis.

In general, renewable energy technologies, named the wind power can provide an important contribution to reducing fossil fuel consumption and meet international environmental commitments. However, interconnection capacity, the combination of the existing capacity of production and characteristics of the wind power system to have a significant effect on how the variable production is assimilated by the system and on the extent of their contribution to meet the needs of modern society.

#### 9.2.2 CHAPTER 3

1. Organizational model in wind energy industry — WECS are type of CoPS (Complex Product System), high-cost, engineering-intensive systems∴Today, wind power is often subsidized, but it is approaching a cost level that makes it economically attractive compared to established energy production methods, assuming good wind conditions ∴ The technology development stages of wind energy industry are R&D, Demonstration, Deployment and Diffusion/Commercialization;

- 2. *Wind resources worldwide* North America and Antarctica are the best locations for electricity production by wind energy technology. But they are also very favorable to electricity production by wind energy technology in the northern Europe, especially along the North Sea, the southern tip of South America (*Tierra del Fuego or Fireland*) and Tasmania, in Oceania;
- 3. *Trends in wind power technology* the main markets driving growth are Europe and Asia, which installed 96.6 GW and 82 GW respectively in the end of 2011 ∴ Vestas and GE Energy have the largest market shares of wind energy converters (wind turbines). According to WWEA (2011) by the end of the year 2010, about 670 000 people were employed worldwide directly and indirectly in the many areas in the wind industry. During the last five years, the number of jobs almost tripled, from 235 000 in 2005.

In comparison to other RETs, wind energy is certainly the one that is closest to making the transition from niche to mass market. It is strongly linked with long-term prosperity. For Pablo (2008) *investment* explains the productive capacity of an economy. Investments made in the renewable energy industry have in addition a strong influence on the degree of dependence among economies, their competitiveness, sustainability, and on all kinds of environmental issues including climate change.

### 9.2.3 CHAPTER 4

- 1. Wind energy technology the power of the wind has been utilized for at least 3 000 years and this energy captured by wind turbines is highly dependent on the local average wind speed. The concept of the windmill-device was described by Heron of Alexandria. The working principle of WECS involves two main conversion processes, which are carried out by its main components: the rotor, which extracts kinetic energy from the wind and converts it into a mechanical torque, and the producing system (generator), which converts this torque into electricity;
- 2. *Wind farm planning* the wind farm planning is a long and complex process which each phase is remarkable for the whole wind power plant lifetime. A major issue in the planning of a wind farm is to identify the optimal rating and design of the installation. Several phenomena limits the maximum possible capacity of wind farms;
- 3. Wind energy production the calculation of the annual theoretical production of electrical power from a wind farm is resulting from the product of electrical power installed, total hours of production for one year and capacity factor of the wind farm. The capacity factor is due to production losses, stops for maintenance and periods where the wind speed is not suitable for the production of electricity by wind turbines.

The success of wind power as a renewable energy sources is obviously a direct function of the economics of production of WECS  $\therefore$  In this regard, the role of improved power output through the

development of better aerodynamic performance offers some potential return; however, the focus is on the cost of the entire system. However, WECS is not free of negative impacts, although the public attitude in relation to *wind energy* is generally positive, local people may react negatively to specific projects. In the particular case of wind energy impacts on the ecosystem, noise pollution (noise) and negative impacts on the landscape have been reported.

#### 9.2.4 CHAPTER 5

- 1. Wind energy cost identification for economic evaluations for wind energy projects, the costs are classified and structured *investment costs, operating costs, maintenance costs* and *financial costs*. All these classes and cost structure have their own characteristics depending on the location, size, types of financing and regulations;
- 2. Investment analysis of wind energy projects wind energy projects NPV is a function of AAR and the ICC. As a result, to maximize NPV also maximizes the absolute wealth created by investment. Because of this, NPV is biased toward larger investments. While on return is greater than the discount rate. The analysis of the NPV will push the decision to bigger projects, even if the relative profitability is smaller. The SPB, DPB and IRR are functions of ICC/AAR;
- 3. *Cost analysis of wind energy projects* the cost analysis of a wind power plant must be done by *cost centers*, classified into *wind turbines cost center*, *electrical system cost center* and *grid interface cost center*. These cost centers change its costs and subdivisions depending on the kind of application of wind power plant (Dicorato, Forte, Pisani, & Trovato, 2011). Characterization of the boundaries of wind projects under study has impact and different values for LCOE.
- 4. *Optimization models for energy systems* the optimization process of an energy system can be considered at three levels (*Design optimization, Synthesis optimization* and *Operation optimization*) (Frangopoulos, 2003). The cost per kWh from a power plant, a wind farm, must be understood as a result from a systemic components interlinked.

In order to improve the reliability of projected and REPs already in operation the key players of renewable energy industry, case of wind energy sector, more and more adopt simulation and optimization methods. The simulation and optimization methods since the end of nineties decade, as shown in Figure 5.9 have increased exponentially. Techniques for simulation and optimization of RETs vary greatly depending on the exact problem setting. The case of RE projects the local conditions such as orography, (micro) climate, local population and government must be taken into consideration. Many systems simulation and optimization in areas such as *manufacturing, distribution, financial evaluations*, are too complex to be analyzed discretely.

#### 9.2.5 CHAPTER 6

- 1. *Nature of the research for wind power systems* this Ph.D. research work fits to this kind of research. Operations research helps the manager/investor to achieve its goals using scientific methods and can be used in particular for wind farm design decisions. It is often concerned with optimizing of some objectives (maximum of profit, performance, etc. or minimum of loss, risk, cost, etc.) at limited resources;
- LCOE driven-variables influence based on LCOE/NREL methodology the variables were grouped into four categories: (1) Wind speed (v<sub>wc</sub>); (2) Wind turbines layouts (L<sub>wt</sub>); (3) Operations and Maintenance management (O&M<sub>manag</sub>) and (4) Energy policy instruments (E<sub>pi</sub>). The reason for grouping these variables into these categories was based on research hypotheses presented at Table 6.3. The variables relationship and research boundary (see Figure 6.14) were explained in section 6.4.4.1 which driven the simulation procedures done and shown in Chapter 7;
- LCOE<sub>wso</sub> development and constitution the LCOE<sub>wso</sub> methodology was developed with six main modules: Wind Farm Life-Cycle Capital Cost Model (LCCCM<sub>WF</sub>); Wind Farm O&M Cost Model (O&M<sub>WFCM</sub>); Levelized Replacement Cost Model (LRCM); Wind Farm Removal Cost Model (RCM<sub>WF</sub>); Renewable Energy Public Incentive Model (REPIM) and Wind Farm Life-Cycle Production Model (LCPM<sub>WF</sub>). Each of them was integrated into sub-models, as shown in Figure 6.16;
- 4. Main difference between  $LCOE_{wso}$  and  $LCOE/NREL LCOE_{wso}$  takes into consideration the *LRCM* or *Levelized Replacement Cost Model*, related to a cost item treated as "saving account" for the wind power project as the *LCOE/NREL*, but not obsolescence cost effect.  $LCOE_{wso}$  designed with two sub-models: the Annual Replacement Cost Model ( $AR_{CM}$ ) (see Eqn 6.2.2.1) and Technological Obsolescence cost Model ( $TO_{CM}$ ) (see Eqn 6.2.2.2). This model was developed in order to guarantee at a certain period (5, 10 and 15 years) funds enough to make the necessary review in the producing power system.

During the elaboration of  $LCOE_{wso}$  methodology we notice the necessity to verify if the model and sub-models would be a real *response* to the *research question* and *objectives* designed for this research work, so we have to make the *parameterization* of the data for the *inputs* to feed the  $LCOE_{wso}$  calculations.

#### 9.2.6 CHAPTER 7

Power system parameters used for simulations — a 50 MW<sub>e</sub> onshore wind farm with 25 wind turbines (Vestas V90-2MW). The electrical generators of wind turbines contain 4-pole Doubly-Fed Asynchronous Generator (DFIG) with wound rotor (see Chapter 4, Figure 4.8 and Table 4.3). The numerical simulation and validation of *LCOE<sub>wso</sub>* performanced according to Tables 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.7, 7.8, 7.9, 7.10, 7.11,

7.12, 7.13 and 7.14. We have also considered the total of  $15 \text{km}^2$  for wind farm installations. The types of layouts simulated were 5D4D, 5D7D, 5D10D and 6D12D;

- 2. Economic and financial aspects of the wind project even the economic and financial assumptions considered *constant* in the simulations done, the variables chosen ( $v_{wc}$ ,  $L_{wt}$ ,  $O\&M_{manag}$  and  $E_{pi}$ ) promote *an oscillation* on the final value of  $LCOE_{wso}$  in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Many researchers (Cory & Schwabe, 2009; George & Schweizer, 2008; Lantz & Tegen, 2008; Lantz, Wiser, & Hand, 2012; Milligan & Graham, 1997; Tegen et al., 2012; Tidball, Bluestein, Rodriguez, & Knoke, 2010) agree that economic classical variables impacts directly the cost of electricity produced from a wind farm (e.g. inflation rate, discount rate, debt rate, debt ratio, price of electricity sold, capital structure, and others);
- 3. O&M assumptions for wind project simulations the O&M costs were associated to  $O\&M_{WFCM}$  with two alternatives of O&M programs (see Table 7.12). In the proposed  $O\&M_{WFCM}$  was done a separation of O&M costs because we believe that the costs for O&M could have two types of behavior, one related to the power plant itself (size, land area, and other administrative expenses) and other related to the production of the wind farm. Christopher (2003) has highlighted the effort to minimize wind turbine O&M costs must start with a better understanding of the current costs and other factors that drive these costs;
- 4. Energy policy assumptions for wind project simulations in  $LCOE_{wso}$  methodology the energy policy instruments are computed in *REPIM* model. This model includes the following sub-models: (1) Renewable Energy Investment Credit Mode ( $REI_{CM}$ ); (2) Renewable Energy Production Credit Mode ( $REP_{CM}$ ); (3) Other REPs Credit Mode ( $OREP_{CM}$ ) and (4) GHG Reduction Credit Model (GHG. $R_{CM}$ ). Strong focus on capacity installations might result in the construction of projects with little productive efficiency. Production incentives, in contrast, help to specially stimulate the development of efficient projects, resulting in a higher output of renewable energy per supporting capital involved (Enzensberger, Wietschel, & Rentz, 2002);
- 5. General simulations procedures the simulations were done for 25 years of wind farm operation. The sensitivity analysis was organized in two parts. The first part the variables are analyzed individually (see section 8.4.1). In this part is analyzes the impact of  $v_{wc}$ ,  $O\&M_{manag}$ ,  $L_{wt}$  and  $E_{pi}$  on  $LCOE_{wso}$ . The second part of the sensitivity analysis a multiple variable analysis is made (see section 8.4.2). We have analyzed the impact of  $v_{wc}$  and  $L_{wt}$ ;  $O\&M_{manag}$  and  $E_{pi}$ ) on  $LCOE_{wso}$ .

The effect of the parameters/data variations impact on  $LCOE_{wso}$  that is why we need to run (900 interactions) within a sensitivity analysis for numerical simulation and validation process, as detailed in section 7.6. The sensitivity analysis was defined and undertaken as explained in sections 7.6.1, 7.6.2 and 7.6.3.

#### 9.2.7 CHAPTER 8

- 1. Distribution of wind speed series the wind profile during one year, according to the data shown in Figure 6.11, 6.12, 6.13 and Table 7.5 shows some evidences in relation the wind speed behavior ∴ Figure 8.3 shows the annual wind speed behavior in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Corvo Island (Portugal) and Cape Saint James (Canada) present a similar wind speed behavior during the year analyzed. Wind speed series of Aracati (Brazil) and Cape Saint James (Canada) make interception in August and September ∴ The wind speeds are 9.6 m/s and 9.7 m/s in August for Aracati (Brazil) and Cape Saint James (Canada). In September occurs the same as in August and September, the wind speed of 10.1 m/s and 10.4 m/s for Aracati (Brazil) and Cape Saint James (Canada), respectively. The behavior of wind speed in Aracati (Brazil) and Corvo Island (Portugal) present similarities ∴ In June and October the monthly wind speed is 7.9 m/s and 7.1 m/s and 9.7 m/s and 8.9 m/s, respectively;
- 2. Simulations analysis results the total AAR for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) varies from 134 959 772 US\$M to 958 516 231 US\$M. We can resume the main results of AAR for each site analyzed, as: (1) in Aracati (Brazil) varies from 4 297 170 US\$M/yr to 6 873 465 US\$M/yr with SD=713 406 US\$M and 5 398 391 US\$M/yr (Mean); (2) in Corvo Island (Portugal) varies from 14 970 925 US\$M/yr to 24 203 932 US\$M/yr with SD=2 524 373 US\$M and 18 990 481 US\$M/yr (Mean); (3) in Cape Saint James (Canada) varies from 30 129 143 US\$M/yr to 48 311 614 US\$M/yr with SD=5 069 795 US\$M and 38 174 169 US\$M/yr (Mean); for O&M<sub>WFCM</sub>: (1) in Aracati (Brazil) varies from 0.0808 US\$ kWh/yr to 0.1323 US\$ kWh/yr with SD=0.0161 US\$ kWh and 0.1081 US\$ kWh/yr (Mean); (2) in Corvo Island (Portugal) varies from 0.0969 US\$ kWh/yr to 0.1549 US\$ kWh/yr with SD=0.0180 US\$ kWh and 0.1280 US\$ kWh/yr (Mean);(3) in Cape Saint James (Canada) varies from 0.0969 US\$ kWh/yr to 0.1549 US\$ kWh/yr with SD=0.0180 US\$ kWh and 0.1280 US\$ kWh/yr (Mean); for LRCM: (1) in Aracati (Brazil) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (Mean);(2) in Corvo Island (Portugal) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (Mean); (3) in Cape Saint James (Canada) varies from 863 268 US\$ kW/yr to 1 219 776 US\$ kW/yr with SD=109 970 US\$ kW and 1 032 004 US\$ kW/yr (Mean); for RCM<sub>WF</sub>: (1) in Aracati (Brazil) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean); (2) in Corvo Island (Portugal) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean); (3) in Cape Saint James (Canada) varies from 2 621 739 US\$ kW/yr to 4 742 007 US\$ kW/yr with SD=635 804 US\$ kW and 3 582 109 US\$ kW/yr (Mean); for REPIM: Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) the  $REI_{CM}$  is about 221 313 US\$/kW<sub>e</sub>;  $REP_{CM}$  is about 16 285 US\$/kW<sub>e</sub>h (for Aracati (Brazil)), 16 879 US\$/kWeh (for Corvo Island (Portugal)) and 1 403 US\$/kWeh (Cape Saint James (Canada)); OREP<sub>CM</sub> is about 163 497 US\$/kW<sub>e</sub> (for Aracati (Brazil)), 265 188 US\$/kWe (for Corvo Island (Portugal)) and 711 018 US\$/kWe (Cape Saint James

(Canada)); GHG.R<sub>CM</sub> is about 7 495 US\$/tCO<sub>2</sub> (for Aracati (Brazil)), 3 893 US\$/tCO<sub>2</sub> (for Corvo Island (Portugal)) and 21 268 US\$/tCO<sub>2</sub> (Cape Saint James (Canada));

Sensitivity analysis results — For these three different sites, we have noticed that when 3. wind speed  $(v_{wc})$  increases in 23.0%, we get 10.2% of increasing on  $LCOE_{wso}$  (from Aracati-Brazil to Corvo Island-Portugal). The same situation occurs in relation to Corvo Island (Portugal) and Cape Saint James (Canada) when the wind speed increases 37.4% reflects and increases 19.4% on LCOE<sub>wso</sub>; The wind farm availability increases in 0.44% for O&M<sub>manag(A)</sub> and 0.24% for O&M<sub>manag(B)</sub> in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada); For  $O\&M_{manag}$ : In the case of Aracati (Brazil) the option  $O\&M_{manag(B)}$  can be adopted, because there is no effect on the  $LCOE_{wso}$ , but if we get the  $O\&M_{manag(A)}$  the cost of electricity produced increases in 0.02%; For Corvo Island (Portugal) both  $O\&M_{manag(A)}$  and  $O\&M_{manag(B)}$  increase the  $LCOE_{wso}$  in 0.07%. The  $O\&M_{manag(STD)}$  is the optimized strategy for O&M costs; In Cape Saint James (Canada) occurs the same situation of Corvo Island (Portugal), but we get an increasing of 0.13% for  $O\&M_{manag(A)}$  and 0.07% for  $O\&M_{manag(B)}$ . Also the  $O\&M_{manag(STD)}$  is the optimized strategy for O&M costs; For  $L_{wt}$ : in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). The 5D7D, 5D10D and 6D12D layouts can increase the LCCCM<sub>WF</sub> in 0.25%, 0.51% and 1.10%, respectively; In the case of Aracati (Brazil) the option 5D4D can be adopted, because it is cheapest alternative (effect on LCOE<sub>wso</sub>), but if we get the 5D7D, 5D10D or 6D12D the cost of electricity produced increases in 0.22%, 0.44% and 0.95%, respectively; For Corvo Island (Portugal) both we can see a similar situation with Aracati (Brazil) with the cost of electricity produced increases in 0.20%, 0.40% and 0.86%, respectively; In Cape Saint James (Canada) occurs the same situation of Corvo Island (Portugal) and Aracati (Brazil) with the cost of electricity produced increases in 0.17%, 0.33% and 0.72%, respectively; We can confirm, *mutatis mutandis*, among the layouts alternatives analyzed that 5D4D is the optimized solution for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) and the other alternative layouts; For  $E_{pi}$ : in the case of Aracati (Brazil) only the Case 2 makes the cost of electricity produced increases in 10.24%; For Corvo Island (Portugal) and Cape Saint James (Canada) the cost of electricity produced remains in the same level as the base-case; The base-case situation is the optimized solution for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada); for  $v_{wc}$  and  $L_{wt}$ : the  $LCOE_{wso}$  mean is 79.5529 US\$/MWh, 79.7054 US\$/MWh and 80.0613 US\$/MWh for 5D7D, 5D10D and 6D12D, respectively; LCOE<sub>wso</sub> increases 0.19%, 0.38% and 0.83% considering the 5D4D layout as reference, as we already said before, for 5D7D, 5D10D and 6D12D, respectively; O&M<sub>manag</sub> and E<sub>pi</sub>: O&M<sub>manag(A)</sub> and E<sub>pi</sub> (Case 1, 2 and 3) for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) we found an increasing of 0.03%, 0.07% and 0.13%, respectively, in relation to reference situation;  $O\&M_{manag(B)}$  and  $E_{pi}$  (Case 1, 2 and 3) for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada) we found an increasing of 0.01%, 0.07% and 0.07%, respectively, in relation to reference situation;  $O\&M_{manag(A-B)}$ : the relation between the  $LCOE_{wso}$  for each site and the mean of  $LCOE_{wso}$ is -14.0%, 10.2% and 31.6% for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada), respectively; For O&M programs ( $O\&M_{manag(A)}$  and  $O\&M_{manag(B)}$ ) and  $E_{pi}$  (*Cases* 1, 2 and 3), in Aracati (Brazil) and Cape Saint James (Canada) increase 0.0117 US\$/MWh and 0.0574 US\$/MWh, respectively; in Corvo Island (Portugal) shows no variation between  $O\&M_{manag(A)}$  and  $O\&M_{manag(B)}$ , but as we already said, increases 0.0528 US\$/MWh in relation to reference situation; O&M management ( $O\&M_{manag}$ ) and energy policy instruments ( $E_{pi}$ ) combined have a positive impact on  $LCOE_{wso}$ . We have to remember that the optimized solution for these variables analyzes is the reference situation;

4. Conclusions and future analysis on cost of wind energy — in relation to the energy production cost, there is a strong evidence of direct dependence of the average wind speed  $(v_{wc})$ . As an example, the energy production cost at an average wind speed of 7.4m/s was increased in 10.2% as the cost for an average wind speed of 9.1m/s. It was also found that the *energy production cost decreases* when the power of the wind farm increases;  $O\&M_{MANAG}$  impacts on  $AEP_{avail}$  (LCPM<sub>WF</sub>) because is connected directly to period of electricity production  $(H_{prod})$  by the wind farm; in the simple variable analysis the O&M<sub>manag</sub> impacted on total AAR differently for each wind farm and program analyzed. In the case of  $O\&M_{manag(A)}$  increases the total AAR in 0.45%, 0.43% and 0.44%, respectively for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada).  $O\&M_{manag(B)}$  also increases the total AAR in 0.24%, 0.43% and 0.23%, respectively for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada); In the multiples variables analyzes when we consider the combination of  $O\&M_{manag(A)}$ ,  $O\&M_{manag(B)}$ ,  $E_{pi}$  (Cases 1, 2 and 3). For the first group of variables  $(O\&M_{manag(A)} + Case_{1,2,3})$  there is an increasing on total AAR of 0.45%, 0.43% and 0.44%, respectively for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Although in second group of variables ( $O\&M_{manag(B)} + Case_{1,2,3}$ ) we also have an increasing on total AAR of 0.24%, 0.43% and 0.23%, respectively, for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada).

An analysis of the fundamental variables of the  $LCOE_{wso}$  cost model has resulted in a wellconsidered approach of cost modeling within the wind power project, both onshore and offshore. A breakdown of costs into a summation of components can lead to a straightforward accumulation of inaccuracies and every level of precision can be obtained with precise input data (so the data considered must be from a secure source). A breakdown of energy production in a multiplication of efficiencies has an inherent error, associated with the correlation between contributions to energy loss (in this numerical simulation and validation was considered constant).

### 9.3 **Recommendations for future researches**

#### 9.3.1 For $V_{WC}$

The wind speed behavior analyzed at any particular time and site is one measure of the elements of the current weather conditions. If we keep analyzing the same wind behavior during years, now get its climatology. We have considered the same and generally accepted definitions of *weather* and *climate* according to Petersen, Mortensen, Landberg, Højstrup, and Frank (1998):

- ★ Weather is the totality of instantaneous atmospheric conditions at any particular site and time. The elements of the weather are such as *temperature, atmospheric pressure, wind, humidity, cloudiness, rain; sunshine and visibility* make the difference from a place to another, and
- Climate is the sum of the weather experienced at a site in the course of the year and over the years. Because the average conditions of the weather elements change from year to year, climate can only be defined in terms of some period of time. Some chosen run of years, a particular decade or some decades.

After defined the concept of *weather* and *climate*, we suggest as *wind speed* research focus:

- 1. Develop more efficient methods for determining wind resources and identifying regions rich in poorly-exploited wind resources, in order to enable increased and more cost-effective wind farm assets by energy policy instruments;
- 2. Add in the  $LCOE_{wso}$  methodology the wind speed variability as the "elasticity wind speed-cost" in function of the production variation ( $\$/m.s^{-1}$ );
- 3. Determine the impact on  $LCOE_{wso}$  of wind speeds higher than the rated wind speed of the wind turbine and high production hours.
- 9.3.2 For  $L_{WT}$ 
  - 4. Studying of the impact on  $LCOE_{wso}$  from different wind turbines sizes and hub heights in a same wind farm;
  - 5. A potential field of further studies, though not one examined in detail in this Ph.D. research work may be the *building of more sustainable wind power plants* in function of the alternative wind turbines layouts;
  - 6. Developing and linking a decision making model for a wind power plant to the  $LCOE_{wso}$  predictions and verifying it with the real k wh produced;
  - 7. Developing *layout efficiency indicator* based on *LCOE*<sub>wso</sub> results for different wind farms according to the installed capacity;
  - 8. Designed and optimized *wind turbines layouts* can be analyzed with  $LCOE_{wso}$  as analysis tool for better predictions of *initial investment reduction*;

#### 9.3.3 FOR $O\&M_{MANAG}$

- 9. Developing a wind farm index from  $O\&M_{MANAG}$  and  $LCOE_{WSO}$  data for sites with good wind resources that are also predictable;
- 10. Developing an *economic safety index* for wind farms of O&M programs and  $LCOE_{wso}$  during the operational phase;
- 11. Developing a *component reliability model* for predict the unscheduled maintenance and efforts the scheduled maintenance for *reducing the downtime of onshore and offshore wind turbines*, so, reduce the LCOE;
- 12. Quantifying the impact of different  $O\&M_{MANAG}$  on  $O\&M_{WFCM}$  over the time by a standard reporting scheme among organizations, and many of the historical records may be viewed from the wind power industry associations;
- 9.3.4 For  $E_{PI}$ 
  - 13. Developing a *social tax incentive* in  $LCOE_{wso}$  methodology in function of the number of direct employs created where the wind farm operates;
  - 14. Analysis of the impact of *inflation rate* on  $E_{pi}$ , and how the *macroeconomic environment* can change the quantitative variables of the energy policy instrument analyzed (*REI*<sub>CM</sub>, *REP*<sub>CM</sub>, *OREP*<sub>CM</sub> and *GHG*.*R*<sub>CM</sub>);
  - 15. Measurement of transmission, tax, environmental, and other policies that also affect the economics of wind power in the  $LCOE_{wso}$  methodology context;
- 9.3.5 FOR OTHERS
  - 16. Applying the  $LCOE_{wso}$  in a real case, in other words, in a wind farm for consolidation of the methodology and corrections, if needed, and compare with other types of economic controls currently used in the wind market sector;
  - 17. Analysis of *elasticity* of  $LCOE_{wso}$  in function of the *cost of financing* variations in the financing period for the same wind farm;
  - 18. Studying the size effect of wind farms on *LCOEwso*, as many studies suggest that a large wind farm is more economical than a small one;
  - 19. In  $LCOE_{wso}$  only internal costs were considered, as externalities (*environmental* & *social impacts*) are analytically different from internal costs, would be interesting modify the proposed methodology and compare the final values of LCOE (Simas & Pacca, 2013);
  - 20. Studying the *lifetime effect* on  $LCOE_{wso}$  for determining the optimized lifetime of a certain wind farm as have been studied by Ohunakin, Oyewola, and Adaramola (2013).

#### 9.4 GENERAL SUMMARY AND CONCLUSIONS

In summary, the proposed methodology for LCOE, *life-cycle cost of energy* for wind power system planning and management, provides a *new methodology* and effective way to evaluate the *cost of a project*, a wind project, in the private point of view. However, it is worth noting that the accuracy of  $LCOE_{wso}$  model is totaly dependent on the data/inputs for calculation and the uncertainties, which might be discussed in the future research about cost-effectiveness analysis.

The success of developing a wind project will be unique to the macroeconomic environment and renewable energy policies it is subject to. We noticed that the *price of electricity sold* is a fundamental question (*PPAR and EMP*), due to this approach is also depending on *AAR* of the wind project. These will include government subsidies (*REPIM*) that help the installation and running of the wind farm as well as the site location and terrain that influence the *investment costs* (*LCCCM<sub>WF</sub>*). However different each project might be (*understood when we compare Aracati-Brazil, Corvo Island-Portugal and Cape Saint James-Canada*), it is important to have a general method for evaluating them.

Before the installation of a wind farm begins, agreements need to be formulated to remove or reduce some uncertainties. These agreements include a connection and power purchasing agreement (*PPA*) with a utility company, a loan agreement from a financial institution, an operation and maintenance agreement ( $O\&M_{ccm}$  and  $n_w$ ), site and construction agreements, as well as insurance agreements. Investors will hire *financial analysts* to value the wind projects feasibility and worth, and to help set the *benchmarks* when contracting agreements. Apart from the *total revenues (total AAR)* and cost projections, the financial analyst will want to perform standard risk measures (*DPB, IRR, NPV and others*). This will be subject to the investors risk tolerance, and should be thought about carefully when making the decision to invest or not.



**Figure 9.1** Comparison of paybacks for Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada). Source: Own elaboration

Figure 9.1 shows the payback period for the same wind project but installed in Aracati (Brazil), Corvo Island (Portugal) and Cape Saint James (Canada), within the respectively *PPARs*. The DPB found is *12*, *9* and *9* years, respectively for the same sites. What wind project should we invest, if we have to exclude some of the alternatives? Curiously the wind farms in Corvo Island (Portugal) and Cape Saint James (Canada) expected to have a production totally different (see Figure 8.13).

Simulating the electricity production costs by the  $LCOE_{wso}$  was the most challenging when forecasting the wind farm revenues. It is possible to leave out the simulation effort and assume a set price of electricity over the horizon of the wind project and consider the renewable market trends. However, this is a highly simplified methodology and does not take into consideration the volatility of energy markets prices and costs.

In this Ph.D. thesis we consider as *limitations* for this methodology proposed some aspects after the simulations and general conclusions:

- 1. The  $LCOE_{wso}$  methodology does not adequately reflect the market realities characterized by uncertainties and dynamic pricing;
- 2. The  $LCOE_{wso}$  methodology provides production costs at the power plant level and does not include the distribution costs of the production (AEP);
- 3. The  $LCOE_{wso}$  methodology reveals little information on the contribution of a given technology to addressing energy security and environmental sustainability;
- 4. The  $LCOE_{wso}$  methodology does not indicate the relative likely stability of production costs over a plant's lifetime, and therefore the potential contribution to cost and possibly price stability.

During this Ph.D. research work, in other words, it was a long trip, we arrived at a number of crossings which forced us to choose how to move on, without knowing very well where each of the possibilities would lead us. The *light* always arrived in the right moment and were discovered different ways to continue the walking in order to help evaluation their merits for selecting the most promising option to follow. Furthermore, the hard and extensive review of the literature until the end of this research work, in fact, this behavior and felling, "*constant search for the best way to go*" gave me more power to help me healing the psychical and psychological pains obtained during my *journey for getting the knowledge* as one day I had dreamt about it. So now it is finished the research work, but never the search for the true light, *the wisdom*!

### 9.5 **References**

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From Appendix A to V

### **APPENDIX** A

Item	Nomenclature
1.1.1	$cost_{tot} = cost$ total; $cost_{gy} = cost$ per generator per year; $N = total$ number of turbines; e = 2.718282 (Euler number); s = estimated selling price for a kWh; $E_{tot} = total$ expected energy output [kWh] of the wind farm per year.
1.1.2	$E_{cost}$ = energy production cost [EUR/kWh]; Invest = investment [EUR]; $P_{out,AVG^{T}}$ =
	average output power [kW]; $r =$ interest rate [-]; $N =$ lifetime of the wind farm [years]; $PR =$ profit in %; $K =$ constant
1.1.3	$C_{w,i}(w_i) = cost \text{ of wind-generated power; } d_i = direct \text{ cost coefficient for the } w_i \text{ wind generator}$
1.1.4	cost = total cost/year for the entire wind farm; N= total number of turbines; e = 2.718282 (Euler number)
1.1.5	$C_t$ = total annual cost per kilowatt installed; $n$ = the lifetime of a wind turbine; $C_{in}$ =
	annual installation cost; $C_{O\&M} = annual O\&M cost$
1.1.6	$C = total cost; C_i = contributions from the different wind turbine main componentes;$
	$R_i$ = percentage cost for the ith component; $b_i$ = cost fixed part contribution;
	$\mathbf{m}_{i} = design \ loads \ factor$
1.1.7	$C_{cp}$ = installation cost; $C_{op}$ = operational cost; $N$ = number of turbines; $\ell$ = cost
	constant calculation
1.1.8	$LPC = levelized production cost; CC = Capital Cost; C_{O&M,a} = annual operation and$
	maintenance; $a = annuity factor; E_a = annual energy production$
1.1.9	$g = objective function; cost_m = per unit value of cost/year of the whole wind farm; P_{total}$
	= total energy produced in one year (MWatt); $W_1$ and $W_2$ = arbitrarily chosen weights
1.1.10	$C_{i,t}$ = total cost of the hybrid system; $C_{i,PV}$ = capital costs of PV solar array; $C_{i,W}$ =
	capital cost of wind machines; $C_{i,Q}$ = capital cost of battery storage system; A= area
	$(m^2)$ ; $C = number of cloudy days; A_{PV} = area of the PV array (m^2); X_i = solar/wind$
	power ratio; $WC = capital cost of the wind machine; BC = cost of energy storage capacity; Q = total energy storage requirement$
1.1.11	$profit_{max} = maximaze profite; k = estimated selling price for a kilowatt-hour of$
	electricity in a given market; $cost_{tot} = total cost$ ; $P_{tot} = total power output$
1.1.12	$LCE = levelized cost of energy; CO_{PV} = sum of capital cost and maintenance cost in the$
	lifespan of the whole PV system; $CO_W = sum$ of capital cost and replacement or
	maintenance cost in the lifespan of the whole wind power generation system; $CO_{Bat}$ =
	sum of capital cost and the lifespan maintenance cost of baterry bank; $Y_{PV}$ = lifetime
	year of PV system; $Y_W$ = lifetime year of wind system; $Y_{Bat}$ = the lifetime year of battery
	bank; $E_{an}(\gamma,\beta,h) = annual energy supplied from the hybrid solar-wind system; \beta =$
	slope angle of the plane (radians); $\gamma = azimuth$ angle of the plane (radians) and $h =$
	hour of production

**Table A.1**Summary of basic notation of Table 5.8

Source: Own elaboration

Item	Nomenclature
1.1.13	$ACS = annualized \ cost \ of \ system; \ C_{acap} = annualized \ capital \ cost; \ C_{arep} = annualized$
	replacement cost; $C_{amain}$ = annualized maintenance cost; $P_V = PV$ array; $W_{ind}$ = wind
	turbine; $B_{at}$ = battery; $T_{ower}$ = wind turbine tower
1.1.14	$OBJ = Objective optimization function; LPC = levelized production cost; \beta = weight$
	factor for reliability; $R_s$ = system reliability of the wind farm
1.1.15	$c_s = PV \cos t \ per \ unit \ area \ (\$/m^2); \ \alpha_s = PV \ size \ (m^2); \ c_w = WG \ cost \ per \ unit \ area \ (\$/m^2);$
	$\alpha_w = WG \ size \ (m^2)$
1.1.16	$TC = total \ cost; \ F_i = fixed \ cost \ (\$); \ C_i = nameplate \ capacity \ of \ generator \ i; \ pf_i = price$
	of fuel (\$/GJ) used by generator i; $E_{t,i}$ = fuel consumption (GJ) of generator i at time t;
	$c_i = non-fuel$ variable (or operating and maintenance, $O\&M$ ) costs of generator i
	(\$/MWh); $Q_{t,i} =$ electricity output (MW) delivered by generator (power plant) i at time t
1.1.17	$C$ = total generation cost; $F_j$ = cost function of generator j; $P_j$ = electrical output of
	generator j; $a_j$ , $b_j$ e $c_j$ = cost coefficients of generator j; $J$ = set for all generators
0	

Table A.2Summary of basic notation of Table 5.8 (Continuation)

Source: Own elaboration

## **APPENDIX B**

Item	Nomenclature
2.1.1	$f(x_1) = fitness function 1; P_{total} = total energy from the wind farm; P_{max} = energy sum of$
	the isolated wind turbine for the same wind conditions at the flat terrain; $f(x_2) = fitness$ function 2; costs = annual total costs of the wind farm
2.1.2	$Obj = objective function; cost = total cost; P_{tot} = total power production; N = number of$
	wind turbines; $u = initial$ wind speed; $u_0 = mean$ wind speed; $u_i = final$ wind speed;
2.1.3	$E_{WF}$ = electric energy generated by a wind farm; $T$ = number of hours in a year (T=8760 h); $N_t$ = number of turbines; $V_{ci}$ = cut-in wind speed; $V_{co}$ = cut-out wind speed; $P_{gen} j(v)$ = wind generator type considered in the wind farm
2.1.4	$P = wind park power production per year; h_y = number of the hours over the year; \eta =$
	nominal power utilization coefficient; N= number of wind park turbines; $P_{wt}$ = wind
	turbine power rating; $N_{row}$ = rows turbines numbers; $N_{col}$ = columns turbines numbers;
	$L_x = area with length (for row); SD_x = ; k_{row} and k_{col} = coefficients for wind turbines$
	placement in rows and columns, respectively; $D =$ wind turbine rotor diameter; $L_y =$
	area with length (for column)
2.1.5	$P_{tot}(t) = total power of the system; P_{PV}(t) = power generated by the PV generator;$
	$P_{WD}(t) = power generated by the wind turbine; t = hour t$
2.1.6	$P_{tot}(t) = total power of the system; N_h, N_w and N_s = total no. of micro-hydro, wind, solar PV, respectively; P_h, P_w and P_s = electrical power generated by the micro-hydro, wind and solar PV unit, respectively;$
2.1.7	$e_{CO2}$ ; $e_{CH4}$ and $e_{N_2O}$ = emissions factors for the fuele/source considered for CO <sub>2</sub> , CH <sub>4</sub>
	and $N_2O$ , respectively; $\text{GWP}_{CO2}$ , $\text{GWP}_{CH4}$ and $\text{GWP}_{N_2O}$ = global warming potentials
	for $CO_2$ , $CH_4$ and $N_2O$ , respectively; $\eta = is$ the fuel conversion efficiency; $\lambda = fraction$ of electricity lost in transmission and distribution
2.1.8	$P_{tot}$ = total power generation for all the turbines in the wind farm; N = total number of
	turbines placed in the wind farm; $P_i$ = turbine i power rating
2.1.9	$E_{windfarm} = Amount of electricity produced by the windfarm; IC = installed capacity; CF$
	= capacity factor; $h_{year}$ = number of hours in a year
2.1.10	$E_{AP}$ = annual electrical energy output (kWh); $S_R$ = swept area of the rotor (m <sup>2</sup> ); $f(V)$ = Weibull probability density function of wind speed; $C_P(V)$ = coefficient of performance;
	$\eta_{GB} = gearbox \ efficiency; \ \eta_G = generator \ efficiency; \ \rho_{air} = air \ density \ (kg/m^3)$
2.1.11	$P_{opt}$ = target (optimum) power; $k$ = mechanical and electrical restrictions; $\omega_r$ = rotation speed
2.1.12	$MAWPC = Maximal Available Wind Park Capacity; FOR_t = Forced Outage Rate, interpreted as a probability of unavailability; IWPC = Installed Wind Park Capacity$
Carries	· Orum alabamatian

**Table B.1**Summary of basic notation of Table 5.9

Source: Own elaboration

Item	Nomenclature
2.1.13	$N = total$ number of wind turbines; $n = unit$ cell solution; $R = wind$ farm radius; $X_p = receptor$ density for the wind farm
2.1.14	$V =$ wind speed at the hub; $V_{ref} =$ reference wind speed at the reference hub height; $H_{ub_{Ht}} =$ hub height; $H_{ref} =$ reference hub height (70 m)
2.1.15	$E_y = annual energy production of the wind farm; E_i = gross energy production; W_{ake} = wake effect of wind farm; coll_{ection} = production collection; a_{vail} = availability of the wind farm; trans_{mission} = production transmission$
2.1.16	$P_{i,j}$ = monthly solar/wind hybrid power production; $P_{sj}$ = hourly-calculated solar power in the month J; $X_i$ = monthly basis solar energy percentage; $P_{wj}$ = wind power in the month J
2.1.17	$C_p$ = power curve of wind turbines; $C_{pr}$ = nominal power coefficient; $u$ = wind speed (m/s); $u_r$ = nominal wind speed (m/s); $s$ = operating range of wind speed (m/s)

 Table B.2
 Summary of basic notation of Table 5.9 (Continuation)

Source: Own elaboration

# **APPENDIX C**

Table C.1	Glossary of terms
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Capacity factor $(C_f)$	The term "capacity factor" refers to the capability of a wind turbine to produce energy in a year. It is defined as the ratio of the actual energy output to the energy that would be produced if it is operated at rated power throughout the year. $C_f = \frac{\text{Annual energy output}}{\text{rated power \times time in a years}} \qquad Eqn (AC_1)$
Gearbox	To convert the kinetic energy of the rotor into electrical energy, for conventional converters equipped with common four or six-pole synchronous or asynchronous generators, generally revolutions of 1,000 or 1,500 r/min are required when adhering as much as possible to grid specifications (50 Hz). Current rotor revolutions of 10 to 50 r/min with wind energy converters of installed capacities ranging from several 100 kW up to the multi-megawatt range thus require a transmission gear if no specific generators are applied (Ragheb & Ragheb, 2010).
Generator	The generator converts the mechanical rotation energy of the power train into electrical energy. For this purpose slightly adapted commercially available generators are used for conventional converters while especially designed three-phase alternators are applied for gearless converters. The main commonly applied generator types are synchronous and asynchronous generators (Bang, Polinder, Shrestha, & Ferreira, 2008).
Rotor	The system component of a modern wind energy converter that transforms the energy contained in the wind into mechanical rotations is referred to as rotor. It consists of one or several rotor blades and the rotor hub. The rotor blades extract part of the kinetic energy from the moving air masses according to the lift principle. The current maximum efficiency of the kinetic energy of the free flow in relation to the rotor surface amounts to 50%; usually, the so-called aerodynamic efficiency of state-of-the-art rotors amounts to between 42 and 48 % at the turbine design point (Barlas & van Kuik, 2010; Fuglsang & Madsen, 1999; Tangler, 2000).
1/7 <sup>th</sup> wind power law	The wind speed and power available in the wind increases with increasing elevation. The relationship is commonly referred to as the one seventh power law (Rehman & Al-Abbadi, 2005).

Source: Own elaboration

# **APPENDIX D**

Region/Country	tCO2/MWh	Region/Country	tCO2/MWh	Region/Country	tCO2/MWh	Region/Country	tCO2/MWh
OECD Americas	0.485	Armenia	0.145	Singapore	0.523	Marocco	0.690
USA (average)	0.531	Azerbaijan	0.462	Sri Lanka	0.425	Mozambique	0.000
Canada	0.184	Belarus	0.300	Thailand	0.530	Namibiae	0.253
Mexico	0.455	Bosnia-Herzegovina	0.908	Vietnam	0.409	Nigeria	0.396
Chile	0.398	Bulgaria	0.492	Other Asia	0.274	Senegal	0.594
OECD Europe	0.341	Croatie	0.337	Middle East	0.687	South Africa	0.900
Austria	0.183	Estonia	0.735	Bahrain	0.718	Sudan	0.470
Belgium	0.239	FYR of Macedonia	0.753	Cyprus	0.755	Togo	0.271
Czech Republic	0.534	Georgia	0.127	Iraq	0.731	Tunisia	0.547
Denmark	0.311	Gibraltar	0.756	Islamic Rep. Of Iran	0.609	United Rep. Of Tanzania	0.257
Finland	0.207	Kazakhstan	0.485	Israel	0.721	Zambia	0.003
France	0.089	Kyrgyzstan	0.087	Jordan	0.586	Zimbabwe	0.619
Germany	0.447	Latvia	0.160	Kuwait	0.810	Other Africa	0.489
Greece	0.739	Lithuania	0.116	Lebanon	0.698	America	0.178
Hungary	0.326	Malta	0.904	Oman	0.859	Argentina	0.358
Iceland	0.001	Republic of Moldova	0.513	Qatar	0.496	Bolivia	0.368
Ireland	0.482	Romania	0.436	Saudi Arabia	0.740	Brazil	0.075
Italy	0.416	Russia	0.322	Syria	0.649	Colombia	0.136
Luxembourg	0.382	Serbia	0.662	United Arab Emirates	0.694	Costa Rica	0.058
Netherlands	0.389	Slovenia	0.337	Yemen	0.649	Cuba	0.735
Norway	0.010	Tajikistan	0.031	Africa	0.641	Dominican Republic	0.633
Poland	0.652	Turkmenistan	0.810	Algeria	0.590	Ecuador	0.301
Portugal	0.379	Ukraine	0.373	Angola	0.220	El Salvador	0.304
Slovak Republic	0.223	Uzbekistan	0.462	Benine	0.695	Guatemala	0.354
Spain	0.337	Bangladesh	0.575	Botswanae	1.916	Haiti	0.513
Sweden	0.041	Brunei Darussalam	0.738	Cameroon	0.228	Honduras	0.391
Switzerland	0.040	China (incl. Hong Kong)	0.765	Congoe	0.139	Jamaica	0.478
Turkey	0.484	Chinese Taipei	0.647	Côte d'Ivoire	0.428	Netherlands Antilles	0.707
United Kingdom	0.480	DPR of Korea	0.483	DR of Congo	0.003	Nicaragua	0.506
OECD Asia	0.503	India	0.950	Egypt	0.459	Panama	0.297
Australia	0.862	Indonesia	0.757	Eritrea	0.665	Paraguay	0.000
Japan	0.435	Malaysia	0.638	Ethiopia	0.094	Peru	0.225
Korea	0.471	Myanmar	0.249	Gabon	0.366	Trinidad and Tobago	0.725
New Zealand	0.191	Nepal	0.004	Ghana	0.254	Uruguay	0.221
Non-OECD	0.503	Pakistan	0.447	Kenya	0.321	Venezuela	0.203
Albania	0.023	Philippines	0.471	Libya	0.868	Other Latin America	0.242

**Table D.1** Electricity emission factors  $(EF_{el})$  for different countries for 2007-2009

Source: IEA (2011)

# **APPENDIX E**



Figure E.1 Value creation stages for Gamesa. Source: Gamesa (2012)

Table	<b>E.1</b>	KW	to MW	conversion table	•
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Power (kilowatts)	Power (megawatts)
0 kW	0 MW
1 kW	0.001 MW
10 kW	0.01 MW
100 kW	0.1 MW
1000 kW	1 MW
10000 kW	10 MW
100000 kW	100 MW
1000000 kW	1000 MW
Source: SI	

# **APPENDIX F**



**Figure F.1** Photos of current MW-onshore wind farms at Aracati (Brazil)<sup>(a)</sup>, Corvo Island (Portugal)<sup>(b)</sup> and Cape Saint James (Canada)<sup>(c)</sup>. Sources: Grupo Servtec (2013); DGGE (2009) and CanWEA (2012)

## APPENDIX G

LCOE wso Mode	l Inputs											Financial Ind	exes	Γ	Notes
Legend				-			_		Revenues		Notes	Inflation	rate (ifr)	2,50%	[%/yr]
Green cells indicate information and are updated automatically based on user input into yellow cells. O&M warranty con		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0,08581	[\$/kWh]		$MC_A$	50	[\$/kW]	
Yellow cells are for use input information about the project.		Costs covered by manufacturer (O&M_m)	80,00%	[%]	Depreciation rate per year	4,00%	[%/yr]	Expected Market Price	0,06007	[\$/kWh]		WACC proj	4,9000%	[%/yr]	
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70,00%	[%]		UCRF	0,070243	[-]
WE IN SALE OF		N		I	N (	WELE B 10		N		885.254	N	W2-1 P	Color Bard		N
Wind Project Information	Exector Wind Form	Notes	Levelized Replacement Cost Model Notes		Wind Farm Removal Co	1 220 0154	Notes (\$ ANU)	Renewable Energy Public Inc	centive Model	Notes (SAW)	Wind Farm Life-Cycle Pro		so ooo	Notes	
Project Location	Aracati (Brazil)		Depr	76,9840	[\$/kW]	RMWT	22,3284	[\$/kW]	LCCCM <sub>WF</sub>	1.204,5180	[\$/kW]	WF our		50.000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553,7256	[\$/kW]	WF cap	50.000	[kW]	LRCM	16,8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484,3859	[\$/kW]	N <sub>WT</sub>	25	[-]	ifr	2,50%	[%/yr]	WT rated		2.000	[kW]
Turbine Size	2.000	[kW]	N	25	[yr]	Mhrman	100	[m-h]	$\psi_{total}$	30,00%	[%]	Nrow		5	[-]
Wind Farm Capacity (WF cap)	50.000	[kW]	ifr	2,50%	[%/yr]	C Mbranger	85,00	[\$/m-h]	n <sub>w</sub>	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90,0	[m]	Depry	60,1398	[S/kW]	D N <sub>mmur</sub>	3	[-]	REP CM	0,00002627	[\$/kWeh]	D		90,0	[m]
Swept Area per Turbine (A)	6.361,7	[m*]	Y <sub>RC</sub>	0.000022	[yr]		2,0	[d] (\$/4)	AEP avail/H prod	5.695	[KW/yr]	I L <sub>x nu</sub>		1.800	[m]
Wind speed measured at (H <sub>o</sub> )	10.0	[m]	TI IO CM	1 798 743	[3/kW]	PM cr	20.1954	[3/4] [\$/kW]	ijr 6	0.1495	[%/y1] [\$/kW h]	SD		450	[m]
Terrain rugosity factor (a)	0.14	[-]		237.699.000	(kW)	WF	50.000	[kW]	ε <sub>0</sub>	0.116883	[\$/kW_h]	SD <sub>real</sub>		540	[m]
Betz Limit's coefficient (C PBetz)	0,5926	[-]	$V_0$	6.100.000	[kW]	NWT	25	[-]	nz	10	[yr]	FLH <sub>wf</sub>		8.760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	c <sub>0</sub>	1.457,72	[\$/kW]	Murma	3,0	[m-h]	OREP CM	13,0797	$[S/kW_e]$	PC PM			
Production Efficiency (WF PE)	11,2%	[%]	PR	0,70	[-]	C <sub>Mbracr</sub>	85,00	[\$/m-h]	LCCCM WFOREG	2,7664	[\$/kW]	AEP anail		48.856.319	[kW <sub>e</sub> h/yr]
Availability	97,9%	[%]	b	-1,94	[-]	Nmmer	3	[-]	$LCCCM_{WF}$	1.204,5180	[\$/kW]	$\eta_{vecs}$		20,98%	[%]
	357	[d/yr]	LRCM	16,8443	[\$/kW]	D <sub>m</sub> <sub>BMCT</sub>	2,0	[d]	WACC proj	4,9000%	[%/yr]	$\eta_{_{unct_{(m0)}}}$		25,00%	[%]
				r		$C_{md_{RNCT}}$	3.500,00	[\$/d]	$\psi_{total}$	30,0%	[%]	$P\&D_{Lb}$	factor	0,839325	[-]
Wind Farm Life-Cycle Capite	al Cost Model	Notes	Wind Farm O&M Cost 1	Model	Notes	S&RV	1.297,3916	[\$/kW]	ifr	2,5%	[%/yr]	NwT		25	[-]
WT CM	553,7256	[\$/kW]	O&M <sub>ful cr</sub>	0,098275	[\$/kWh]	WF cap	50.000	[kW]	n <sub>w</sub>	10	[yr]	A		6.361,7	[m <sup>2</sup> ]
CM <sub>WT</sub> PC	265,32	[\$/KW]	TCCCM <sub>WF</sub>	1.204,5180	[\$/KW]	N <sub>WT</sub>	42.00	[-]	CHCR	80,0%	[%]	AEP rated		438.000.000	[kW <sub>e</sub> h/yr]
Curr	400.00	(\$/JW)	uc	0.0530	[20] [\$/kWh]	M <sub>WT</sub>	43,00	[m/wt]	LCER	1.390,4321	CO-MW-N	PaD <sub>IM</sub>	- 1	7.00%	[96]
IPT	10.00%	[%]	N	25	[(rkr) II]	Cue	85.00	[\$/m-h]	$\sum AEP_{aval}$	48.856	[MW.h]	2.41		0.00%	[%]
T <sub>CM</sub>	484,3859	[\$/kW]	ifr	2,50%	[%/yr]	N <sub>m</sub>	3	[-]	n <sub>w</sub>	25	[yr]	Âd		5,00%	[%]
Tmass	138.000	[kg]	O&M variable cu	0,025858	[\$/kWh]	D <sub>m san</sub>	3,0	[d]	GHG <sub>IM f m</sub>	0,00041	[tCO2/MWah]	λm		5,00%	[%]
RC <sub>T</sub>	26,30%	[%/\$/kW]	MLC	71,5608	[\$/h]	C <sub>md saw</sub>	3.500,00	[\$/d]	GHG <sub>EM</sub>	0,00003	[tCO2/MWah]	LCPM WF		48.856.319	[kWeh/yr]
Csted	0,1900	[\$/kg]	TLC	124,5688	[\$/h]	RVM WF	61,0184	[\$/kW]	ε, ε	46,3820	[\$/tCO2]	-			
LWTG CM	39,1957	[\$/m/kW]	R tases	30,00%	[%]	NWT	25	[-]	REPIM distribution	100,0%	[%]	Project Finan	cing		Notes
WF cap	50.000	[kW]	ifr	2,50%	[%/yr]	WTS VM	1,4442	[\$/kW]	$\xi_1 REI_{CM}$	25,0%	[%]	Debt ratio		50,0%	[%]
$L_g$	13.950	[m]	N	25	[yr]	WF cap	50.000	[kW]	$\xi_2 REP_{CM}$	25,0%	[%]	Debt term		14	[yr]
CAB cost	2.000,00	[\$/m]	n <sub>mih</sub>	72	[h]	ifr	2,50%	[%/yr]	$\zeta_3 \text{ OREP }_{CM}$	25,0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30,9069	[\$/kW]	n <sub>tih</sub>	113	[h]	N	25	[yr]	$\zeta_4 GHG.R_{CM}$	25,0%	[%]	Debt in	terest rate	5,00%	[%/yr]
EF c	400,00	[\$/kW]	AAR	4.192.361	[SM]	WIweight	200.000	[kg]	REPIM	420,0830	[\$/proj]	Debt value		29.920.545	[5]
75	11.4566	[%] (\$.4397.1	ALF avail	48.830.319	[KWIFy1]	C steel	0,1900	[5/Kg] (\$74327)	Exchange rates	ſ	Noter	E avita sati	syments	50.00	[5/yr]
TI TI	0.0400	[5/KW c]	OCCM WFCM	0,124133	[\$/KWII/yr]	1 S VM	0,9963	[5/KW] (1/W)	EURAISD	1 2252	roles	Equity ran	o valua	20.020.545	[%]
TL <sub>c</sub>	1 200	(1/1/AV2)	0.8.11	Г	Notar	Wr cap	2 50%	[05 (un)]	CAN/USD	0,0008		Dircow	t rate	0.00%	[J]
12, L	3.000	[1/k/r]	SC or M	0.000105	(\$/kWh]	iji N	2,50%	[/u/ j1]	BRI/USD 1 2010	0,5986	[-]			7,00%	[/0/ ]1]
SR -	113.00	(\$/kWh]	Work days	30	[d]		138.000	[ke]	are2010	40,000		Initial Results	Summary	of LCOE	Notes
SLOW	42 7345	(\$/m <sup>2</sup> /FW)	Feh/Jun/Nov	9	[4]	RCMwr	1.278.8970	[\$/kW]	Conditions for LCOE	Ī	Notes	67 6603	NT.	70 7762	NT 15
WF cm	50.000	[JAM / KW]	Hours required	72.0	(m) (h)	110-11 W/		14.0.17	O&M WECH			67.8118	VF 2	69.8077	VE 15
WT inst	42,5238	[\$/kW]	USC ORM	0,000287	[\$/kWh]	Hours Distribution	$FLH_{uc}(h)$	$H_{max}(h)$	O&M	1	[1/0]	68,0210	yr a	69,9988	yr 16
Bld	500,00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80,0%	[%]	68,1822	yr <sub>4</sub>	70,1987	yr 17
Bld area	300,0	[m <sup>2</sup> ]	Frequency	1,5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			68,4349	yr <sub>5</sub>	70,3955	yr 18
PO <sub>CM</sub>	35,9374	[\$/kW]	Repair time	3,0	[h]	March	744	735	REPIM distribution			68,6241	yr <sub>6</sub>	70,7564	yr 19
FS	19,88	[\$/kW]	Hours required	112,5	[h]	April	720	711	$\xi_1 REI_{CM}$	1	[1/0]	68,8710	$yr_7$	70,3686	yr 20
DT	87,22	[\$/kW]	SC O&M+USC O&M	184,5	[h/yr]	May	744	735	$\xi_2 REP_{CM}$	1	[1/0]	69,0863	$yr_8$	70,5514	yr21
EG	404,52	[\$/kW]		0,000392	[\$/kWh/yr]	June <sup>(*)</sup>	720	687	$\xi_3 \text{ OREP }_{CM}$	1	[1/0]	69,2587	$yr_{g}$	70,8222	yr 22
F <sub>CM</sub>	3,7712	[\$/kW]		,		July	744	735	Ĝ₄ GHG.R <sub>CM</sub>	1	[1/0]	69,4873	yr 10	71,1051	yr <sub>23</sub>
WACC proj	4,900%	[%/yr]				August	744	735	P&D <sub>IM</sub>		(a. (a)	69,7236	yr 11	71,3664	yr 25
n fin	1,0	[yr]				September	720	711	λ	1	[1/0]	70,0026	yr 12	69,6792	Mean SD
WFCM CCC CM	0,30%	[%] (\$/7W]				Neurophan <sup>(+)</sup>	744	687	A 141 2 1	1	[1/0]	70,2282	yr 13 Yr 14	-0.4514	SU Y (demonstr)
K	0,20%	[%]				December	744	735	λ	1	[1/0]	70,4423	69,6792	US\$/MWb	valid !
LCCCM <sub>WF</sub>	1.204,5180	[\$/kW]				Total [h/vr]	8.760	8.579	·· /#	p.s.: 1 = yes an	d 0=no	LCOE was	0.069679	US\$/kWh	
	,					"Pariod of less hours for produ	ation					-	,		

**Figure G.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with reference situation. Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes	Γ	Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2,50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	e updated vellow cells		O& M warranty conditio	ns Not	es	Depreciation		Notes	Power Purchase Agreement Rate	0,16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information about the project.		Costs covered by manufacturer (OAM)	80,00% [%	a l	Depreciation rate per year	4,00%	[%/yr]	Expected Market Price	0,11403	[S/kWh]		WACC proj	4,9000%	[%/yr]	
Gray cells are not used.			Period of warranty (nw)	5 (y	r]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70,00%	[%]		UCRF	0,070243	[-]
Wind Desired Information	Г	Natas	I line d Benderson en de	Cont Model Net		Wind Frame Brannel C	and Market	Natas	Bananahla Farana Bublia Inc	antina Madal	Notes	Wind Farm Life	Cuala Baad	untion Model	Natas
Project Name	Firestor Wind Form	ivoles	AR an	168442 ISA	w	DCM we	1 339 9154	(S/kW)	RELau	70.8203	Is/kW 1	WF ou	-Cycle 170a	50.000	fkW /yr]
Project Location	Corvo Island (Portugal)		Deprwr	76,9840 [\$/k	w	RM <sub>WT</sub>	22,3284	[\$/kW]	LCCCM <sub>WF</sub>	1.204,5180	[\$/kW]	WF om		50.000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553,7256 [\$/k	w]	WF car	50.000	[kW]	LRCM	16,8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N <sub>WT</sub> )	25	[-]	T <sub>CM</sub>	484,3859 [S/k	w]	NWT	25	[-]	ifr	2,50%	[%/yr]	WT rated		2.000	[kW]
Turbine Size	2.000	[kW]	N	25 [y	r]	Mirmur	100	[m-h]	$\psi'_{total}$	30,00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50.000	[kW]	ifr	2,50% [%/	yr]	CMURANNET	85,00	[\$/m-h]	Π.Ψ	6	[yr]	N col		5	[-]
Rotor Diamenter (D)	90,0	[m]	$Depr_{T_{ac}}$	60,1398 [\$/k	W]	N <sub>mener</sub>	3	[-]	REP CM	0,0001039	[\$/kWeh]	D		90,0	[m]
Swept Area per Turbine (A)	6.361,7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15 [y	r]	D <sub>m mer</sub>	2,0	[d]	AEP anait/Hprod	10.451	[kW/yr]	L <sub>x</sub> ,		1.800	[m]
Hub height (H)	105,0	[m]	TO CM	0,000033 [S/k	W]	C <sub>ad mar</sub>	2.500,00	[\$/d]	ifr	2,50%	[%/yr]			2.430	[m]
Wind speed measured at $(H_0)$	10,0	[m]	TI	1.798.743 [S/k	wj	RM CT	20,1954	[\$/kW]	3	0,1086	[\$/kW_eh]	5D <sub>1</sub>		450	[m]
Terrain rugosity factor (a)	0,14		V	237.699.000 [kV	V]	WF cap	50.000	[kW]	ε <sub>0</sub>	0,075000	[\$/kW_eh]	SD <sub>scal</sub>		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0,5926		Vo	6.100.000 [kv	vj m	N <sub>WT</sub>	25	[-] (1)	n <sub>x</sub>	15	[yr]	FLH <sub>wf</sub>		8.760	[h/yr]
Deschation Efficiency (WE	20.5%	[yr] (96.)	<i>c</i> <sub>0</sub>	0.70	wj	т <sub>ыг шст</sub>	3,0	[m-n]	LCCCM	21,2151	[\$/KW_c] (\$/AW)	PC PM		90.657.257	fIAV h/mel
A wélobiliw	20,3%	[70]	FR L	1.01	1	N N	2,00	[3/11/1]	LCCCM WFORDCM	1 204 5190	(\$7.5W)	nuar anait		20.08%	[KW ett y1]
Availability	31,3%	[70] [d/sel	IRCM	16 8442 18/	1	D	20	[-] [4]	WACC .	4 9000%	[3/KW] [96/97]	n		25,00%	[96]
	337	[u: j1]	LICM	10,0445 [\$/k	"]	C.	3 500.00	[0] [\$/d]	Mile proj	30.0%	[96]	Philosophia		0.839325	[/v] [_]
Wind Farm Life-Cycle Canite	al Cost Model	Notes	Wind Farm O&M Cost	Model Not	ar	S.& PV	1 207 3016	[(#W)	7 10411	2.5%	[%]	Num	factor	25	6
WT ou	553 7256	(S/VW)	O&M	0.098275 (\$4)	es Nhl	WF	50,000	[J/W]		15	[10794]	4		63617	[] [m <sup>2</sup> ]
CMmr	265.32	(\$/VW)	ICCCM we	1 204 5180 (\$72	wi	N cap	25	[_]	CR	80.0%	[96]	AFP		438 000 000	f/W h/orl
RC wr	73 70%	[%/\$/kW]	σ	0.000001% [%	a .	Awr	43.00	[m <sup>2</sup> /wt]	GHG R cu	821 1245	[S/(CO)]	P&D.u.		4.51.000.000	[km 210 91]
CkW	400,00	[\$/kW]	LLC	0,0530 [\$/k\	wh]	M <sub>M</sub>	3,0	[m-h]	LCER <sub>co</sub>	34,1	[ICO2/MW,h]	λ		7,00%	[%]
IPT	10,00%	[%]	N	25 (y	d í	C	85,00	[\$/m-h]	$\sum AEP_{avail}$	89.657	[MW,h]	2.41		0,00%	[%]
T <sub>CM</sub>	484,3859	[\$/kW]	ifr	2,50% [%/	yr]	Nm	3	[-]	n	25	[yr]	$\lambda_d$		5,00%	[%]
Tmass	138.000	[kg]	O&M <sub>variable cu</sub>	0,048935 [\$/k]	Wh]	$D_{m_{XAW}}$	3,0	[d]	GHG <sub>IM COR</sub>	0,00041	[tCO2/MW,h]	λ		5,00%	[%]
RC T	26,30%	[%/\$/kW]	MLC	71,5608 [\$/	h]	C <sub>md sary</sub>	3.500,00	[\$/d]	GHG <sub>FM</sub>	0,00003	[tCO2/MW,h]	LCPM WF		89.657.257	[kWeh/yr]
C steel	0,1900	[S/kg]	TLC	124,5688 [\$/	h]	RVM WF	61,0184	[\$/kW]	E.	13,0000	[\$/tCO <sub>2</sub> ]				
LWTG CM	39,1957	[\$/m/kW]	R	30,00% [%	a -	NWT	25	[-]	REPIM distribution	100,0%	[%]	Project Finan	ring	Г	Notes
WF cap	50.000	[kW]	ifr	2,50% [%/	yr]	WTS VM	1,4442	[\$/kW]	$\xi_1 REI_{CM}$	25,0%	[%]	Debt ratio		50,0%	[%]
L <sub>g</sub>	13.950	[m]	N	25 [y	r]	WF cap	50.000	[kW]	$\xi_2 REP_{CM}$	25,0%	[%]	Debt term		14	[yr]
CAB cost	2.000,00	[\$/m]	n mib	72 [h	]	ifr	2,50%	[%/yr]	$\tilde{\zeta}_3 \text{ OREP }_{CM}$	25,0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30,9069	[\$/kW]	n <sub>tih</sub>	113 [h	]	N	25	[yr]	$\xi_4 GHG.R_{CM}$	25,0%	[%]	Debt in	erest rate	5,00%	[%/yr]
EF c	400,00	[\$/kW]	AAR	14.605.780 [SN	4]	WTweight	200.000	[kg]	REPIM	228,2900	[\$/proj]	Debt value		29.869.699	[\$]
ς	0,08%	[%]	AEP anail	89.657.257 [kW1	ı/yr]	C steel	0,1900	[\$/kg]				Debt pa	yments	3.017.556	[\$/yr]
TS CM	11,4566	$[S/kW_c]$	O&M WFCM	0,147210 [\$&W	h/yr]	$TS_{VM}$	0,9965	[\$/kW]	Exchange rates		Notes	Equity rati	2	50,0%	[%]
TLc	0,0400	[\$/m]				WF cap	50.000	[kW]	EUR/USD dec2010	1,3252	[-]	Equity	alue	29.869.699	[\$]
TL,	1.200	[1/kW]	O&M <sub>manag(STD)</sub>	Not	es	ifr	2,50%	[%/yr]	CAN/USD dec2010	0,9998	[-]	Discour	t rate	9,00%	[%/yr]
L	3.000	[m]	SC ORM	0,000057 [\$/k]	Wh]	Ν	25	[yr]	BRL/USD dec2010	0,5986	[-]				
SB <sub>c</sub>	113,00	[\$/kWh]	Work days	3,0 [d	]	Tmass	138.000	[kg]				Initial Results	Summary	of LCOE wso	Notes
SI CM	42,7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9 [d	]	RCM WF	1.278,8970	[\$/kW]	Conditions for LCOE win		Notes	73,0793	$yr_1$	78,4116	yr 15
WF cap	50.000	[kW]	Hours required	72,0 [h	]				O&M WFCM			73,4776	$yr_2$	77,5903	yr 15
WT inst	42,5238	[\$/kW]	USC ORM	0,000156 [\$/k]	Wh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M ccm	1	[1/0]	73,7436	$yr_3$	78,1098	yr 16
Bld cost	500,00	[\$/m <sup>2</sup> ]	NWT	25 [-	1	January	744	738	(%) ccm	80,0%	[%]	74,0885	$yr_4$	78,5637	yr 17
Bld area	300,0	[m <sup>2</sup> ]	Frequency	1,5 [per	yr]	February (*)	672	639	REPIM			74,4286	$yr_S$	79,0704	yr 18
PO <sub>CM</sub>	35,9374	[\$/kW]	Repair time	3,0 [h	]	March	744	735	REPIM distribution			74,8887	yr 6	79,5598	yr 19
FS	19,88	[\$/kW]	Hours required	112,5 [h	]	April	720	711	$\xi_1 REI_{CM}$	1	[1/0]	75,1794	$yr_{7}$	77,6767	yr 20
DT	87,22	[\$/kW]	SC O&M+USC O&M	184,5 [h/y	r]	May	744	735	$\xi_2 REP_{CM}$	1	[1/0]	75,4693	$yr_8$	78,1898	yr 21
EG	404,52	[\$/kW]		0,000214 [\$&W	h/yr]	June <sup>(*)</sup>	720	687	$\zeta_3 OREP_{CM}$	1	[1/0]	75,9694	yr 9	78,6500	yr 22
F <sub>CM</sub>	3,7712	[\$/kW]				July	744	735	$\xi_4 GHG.R_{CM}$	1	[1/0]	76,3656	yr 10	78,9953	yr 23
WACC proj	4,900%	[%/yr]				August	744	735	P&D <sub>LM</sub>			76,6792	yr 11	79,3896	yr 25
n <sub>fin</sub>	1,0	[yr]	1			September	720	711	λ., 1	1	[1/0]	77,1795	yr 12	76,8138	Mean SD
WFCM	0,30%	[%] (\$/1432)	1			October	744	135	A x&i	0	[1/0]	77,5814	yr 13	2,0085 3	SD Yeshaman -
K K	2,4042	[3/KW] [96]	1			November' '	720	735	2		[1/0]	78,0090	yr 14 76 81 29	-0,4051	valid (
LCCCM	1 204 5190	[70]	1			Total [h/]	8 760	8 570	A.m.		10-00	LCOE was	0.07(01)	TREAM.	vunu ?
LCCCM WF	1.204,3180	<i>[φ/κ</i> ₩ ]				ionan [n/yr]	0./00	0.3/9	L	p.s.: 1 = yes an	uu v=no	L	0,076814	CO \$/K WII	

**Figure G.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with reference situation. Source: Own elaboration
LCOE was Mode	l Inputs											Financial Ind	exes		Notes
Legend									Revenues	1	Notes	Inflation	rate (ifr)	2,50%	[%/yr]
Green cells indicate information and an automatically based on year input into	re updated vallow calle		0& M warranty conditio		Notes	Depreciation	Ĩ	Notes	Power Purchase Agreement Rate	0,13835	[\$/kWh]		MCA	50	[\$/kW]
Yellow cells are for use input informatio	on about the project.		Concovered by manufacturer (0.6M	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC	4,9000%	[%/vr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70,00%	[%]		UCRF	0,070243	[-]
						· · · ·									
Wind Project Information		Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR CM	16,8442	[\$/kW]	DCM WF	1.339,9154	[S/kW]	REICM	70,8203	[\$/kWe]	WF CM		50.000	[kW <sub>o</sub> /yr]
Turbine Model	Vestas V90-2MW		WT cu	553,7256	[5/kW]	WF	50.000	[JKW]	LECCM WF LRCM	16.8443	[5/kW]	Nwr		25	[-]
Number of Wind Turbines (N <sub>WT</sub> )	25	[-]	Тси	484,3859	[\$/kW]	NWT	25	[-]	ifr	2,50%	[%/yr]	WTrated		2.000	[kW]
Turbine Size	2.000	[kW]	N	25	[yr]	$M_{i\nu_{swar}}$	100	[m-h]	$\Psi_{total}$	30,00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50.000	[kW]	ifr	2,50%	[%/yr]	CMBrann	85,00	[S/m-h]	n w	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90,0	[m]	Depr <sub>rac</sub>	60,1398	[\$/kW]	N <sub>mmar</sub>	3	[-]	REP CM	0,00000052	[S/kWeh]	D		90,0	[m]
Swept Area per Turbine (A)	6.361,7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]		2,0	[d]	AEP avail/H prod	24.766	[kW/yr]			1.800	[m]
Mind anod measured at (H.)	103,0	[m]	10 <sub>CM</sub>	1,708,742	[\$/KW] [\$/LW]	PM	2.300,00	[5/d] (\$//W)	ıfr C	2,30%	[%/yr] (\$/kW/b)			2.430	[m]
Terrain rugosity factor (a)	0.14	[]	v	237.699.000	[3KW]	WF	50.000	[JKW]	ε ε,	0,0128	[S/kW <sub>c</sub> h]	SD <sub>x</sub>		430 540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0,5926	[-]	Vo	6.100.000	[kW]	N <sub>WT</sub>	25	[-]	- 0 n_	10	[yr]	FLH <sub>vf</sub>		8.760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	<i>c</i> <sub>0</sub>	1.457,72	[\$/kW]	M <sub>hr mcr</sub>	3,0	[m-h]	OREP CM	56,8814	[\$/kWe]	PC <sub>PM</sub>			
Production Efficiency (WF PE)	48,5%	[%]	PR	0,70	[-]	C <sub>MBrace</sub>	85,00	[S/m-h]	LCCCM <sub>WFORSIGCM</sub>	2,7664	[\$/kW]	AEP avail		212.467.325	$[kW_eh/yr]$
Aválability	97,9%	[%]	b	-1,94	[-]	N <sub>m sucr</sub>	3	[-]	LCCCM WF	1.204,5180	[\$/kW]	$\eta_{wes}$		20,35%	[%]
	357	[d/yr]	LRCM	16,8443	[\$/kW]	$D_{m_{BM_{CT}}}$	2,0	[d]	WACC proj	4,9000%	[%/yr]	$\eta_{wacs_{(n0)}}$		25,00%	[%]
when we are a			WE LE DAMO	I		C <sub>nd sucr</sub>	3.500,00	[\$/d]	$\Psi_{total}$	30,0%	[%]	P&D <sub>LM</sub>	factor	0,814145	[-]
Wind Farm Life-Cycle Capite	al Cost Model	Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1.297,3916	[\$/kW]	ifr	2,5%	[%/yr]	NWT		25	[-]
WI CM	265.32	[S/KW] [S/FW]	LCCCM	0,098275	[\$/kWh] [\$/bW]	WF cap	50.000	[KW]	n v CR	80.0%	[yr]	A AFP		6.361,7	[m <sup>*</sup> ]
RC wr	73,70%	[%/\$/kW]	TT	0.0000001%	[%]	Awr	43.00	[m <sup>2</sup> /wt]	GHG.R cu	4,490,4890	[\$/tCO <sub>2</sub> ]	P&Dist		400.000.000	[kright]
CkW	400,00	[S/kW]	LLC	0,0530	[\$/kWh]	M <sub>11</sub>	3,0	[m-h]	LCERCO	80,7	[tCO/MW_h]	λ.,		7,00%	[%]
IPT	10,00%	[%]	N	25	[yr]	CMbrsan	85,00	[S/m-h]	$\sum AEP_{mat}$	212.467	[MW <sub>c</sub> h]	λ <sub>x&amp;i</sub>		3,00%	[%]
T <sub>CM</sub>	484,3859	[\$/kW]	ifr	2,50%	[%/yr]	N <sub>m xan</sub> .	3	[-]	n <sub>w</sub>	25	[yr]	λa		5,00%	[%]
Tmass	138.000	[kg]	O&M <sub>variable cu</sub>	0,041531	[\$/kWh]	D <sub>m saav</sub>	3,0	[d]	$GHG_{EM_{F_{CO_1}}}$	0,00041	[tCO <sub>2</sub> /MW <sub>4</sub> h]	Âm		5,00%	[%]
RC T	26,30%	[%/\$/kW]	MLC	71,5608	[\$/h]	C <sub>md saw</sub>	3.500,00	[\$/d]	$GHG_{EM_{um}}$	0,00003	[tCO2/MWah]	LCPM <sub>WF</sub>		212.467.325	[kWeh/yr]
C steel	0,1900	[\$/kg]	TLC	124,5688	[S/h]	RVM WF	61,0184	[S/kW]	$\mathcal{E}_{c}$	30,000	[\$/tCO <sub>2</sub> ]	<b>n n</b>		г	N .
LWIG <sub>CM</sub>	59,1957	[S/III/KW]	R taxes	2 500	[%] [%/ur]	IN WT WTS	1 4442	[=]	KEFIM distribution	25.0%	[%] (0()	Project Finant	cing	50.0%	r (%)
I.	13 950	[m]	n N	2,00%	[vr]	WF	50.000	[3KW]	EREP ou	25,0%	r [%]	Debt term		14	[70]
CAB cost	2.000,00	[\$/m]	n mlh	72	[h]	ifr	2,50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM	25,0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30,9069	[\$/kW]	R alb	113	[h]	Ň	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	25,0%	[%]	Debt int	erest rate	5,00%	[%/yr]
EF c	400,00	[\$/kW]	AAR	29.394.286	[\$M]	WT <sub>weight</sub>	200.000	[kg]	REPIM	1.154,5477	[\$/proj]	Debt value		29.646.785	[\$]
ç	0,08%	[%]	AEP avail	212.467.325	[kWh/yr]	C steel	0,1900	[S/kg]				Debt pa	yments	2.995.036	[\$/yr]
TS CM	11,4566	[\$/kW <sub>e</sub> ]	O&M WFCM	0,139806	[\$/kWh/yr]	$TS_{VM}$	0,9965	[\$/kW]	Exchange rates		Notes	Equity ratio	p	50,0%	[%]
TL <sub>c</sub>	0,0400	[\$/m]		,		WF cap	50.000	[kW]	EUR/USD dec2010	1,3252	[-]	Equity v	alue	29.646.785	[\$]
TL,	1.200	[1/kW]	O&M <sub>manag(STD)</sub>		Notes	ifr	2,50%	[%/yr]	CAN/USD dec2010	0,9998	[-]	Discour	t rate	9,00%	[%/yr]
L	3.000	[m]	SC ORM	0,000024	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0,5986	[-]				
SB c	113,00	[S/kWh]	Work days	3,0	[d]	T <sub>mass</sub>	138.000	[kg]	0 Fr. 6 100F	1	N. 4	Initial Results	Summary	of LCOE win	Notes
SI CM	42,7345	[\$/m*/kW]	Feb/Jun/Nov	9		RCM WF	1.2/8,89/0	[\$/KW]	Conditions for LCOE wso		ivotes	84,2996	yr i	94,3/18	yr 15
WF cap	50.000	[KW]	Hours requirea	0 000066	(CAWL)	II Distribution		n a)	Occar WFCM		(1/0)	84,9745	yr <sub>2</sub>	94,0482	yr 15
WI inst	42,5238	[5/KW]	N	25	[]	lanuary	744	738	(%) com	80.0%	[1/0]	85,0020	yr3	94,8532	yr 16
Bld	300.0	[\$/m] [m <sup>2</sup> ]	Frequency	1.5	[per vr]	February <sup>(*)</sup>	F 672	639	REPIM	00,070	[70]	86,8183	yr 4 yr 5	96,6483	37 17 VT 19
PO CM	35,9374	[S/kW]	Repair time	3,0	(h)	March	744	735	REPIM distribution			87,5429	VF 6	97,4272	YT 19
FS	19,88	[\$/kW]	Hours required	112,5	[h]	April	r 720	711	REI CM	1	[1/0]	88,1156	yr 7	93,9167	yr 20
DT	87,22	[\$/kW]	SC O&M+USC O&M	184,5	[h/yr]	May	744	735	REP CM	1	[1/0]	88,8127	$yr_8$	94,6168	yr 21
EG	404,52	[\$/kW]		0,000090	[\$/kWh/yr]	June <sup>(*)</sup>	720	687	OREP CM	1	[1/0]	89,7238	$yr_g$	95,6632	yr 22
F <sub>CM</sub>	3,7712	[\$/kW]				July	744	735	GHG.R CM	1	[1/0]	90,3120	yr 10	96,4289	yr 23
WACC proj	4,900%	[%/yr]				August	744	735	P&D <sub>IM</sub>		(1 m)	91,1318	yr 11	97,4427	yr 25
n <sub>fin</sub>	1,0	[yr] [96]				September October	720	711	λ	1	[1/0]	91,8409	yr 12	91,7081	Mean SD
WFCH CCC CM	2,4042	[%]				November <sup>(*)</sup>	720	687	~ x&i 2 d	1	[1/0]	93,6087	yr 13 yr 14	-0.3343	Y (skewness)
ĸ	0,20%	[%]				December	744	735	λm	1	[1/0]	LOOT	91,7081	US\$/MWh	valid !
LCCCM WF	1.204,5180	[\$/kW]				Total [h/yr]	8.760	8.579	1	p.s.: 1 = yes ar	nd 0=no	LCOE was	0,091708	US\$/kWh	
						"Period of less hours for produ	ection								

**Figure G.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with reference situation. Source: Own elaboration

Table G1 Energ	y production	n (AEP avail)	) map of th	e wind farn.	for Aracati	(Brazil)																				ĺ
Months	V nc	H pro	po											$AEP_a$	vail(kWh)											1
	(m/s) (kg/	(u) (u)	yr.	ı yr.	2 yr3	<i>yr</i> 4	yr5	$yr_6$	yr 7	yr 8	yr 9	yr 10	yr II	yr 12	0T 13 YT	14 yr	15 yr 16	yr 17	yr 18	yr 19	<i>yr</i> 20	yr21	yr 22	yr 23	VT 24	yr 25
, January	5,8 1,1	1665 7	738 1.693.	132 8.890.	198 3.802.1	165 7.507.41	10 557.36	361.068.8	8 557.36.	1 557.361	4.232.212	8.890.198	8.890.198	557.361 3.8	02.165 7.507	7.410 4.232	212 8.890.15	18 8.890.1	8 557.361	3.802.165	7.507.410	557.361	3.802.165 7.	507.410 42	32.212 4.2	32.212
February	4,9 1,1	1666 6.	39 847.5	940 6.783.	520 3.662.5	67 6.783.52	20 777.31	6 6.783.520	9 777.31k	5 777.316	4.713.419	6.783.520	6.783.520	777.316 3.6	62.567 6.783	8.520 482.	342 48234	2 3.290.4	3 4.713.415	7.693.599	1.572.412	1.572.412	7.693.599 6.	783.520 4.7	13.419 4.7	13.419
March	4,0 I,i	1671 7.	735 555.6	190 7.476.	817 5.424.3	10 8.853.97	70 975.82	9 7.476.817	7 975.829	975.829	6.543.367	7.476.817	7.476.817	975.829 5.4	24.310 8.853	3.970 894.	553 894.55.	3 1.809.5	8 4.214.960	1.809.568	1.686.232	1.686.232	7.806.630 8.	853.970 3.7	86.671 6.5	43.367
April	4,7 1,1	1667 7.	11 865.0	198 6.327.	908 6.327.9	08 4.076.17	76 1.630.70	18 6.327.908	\$ 1.630.70	8 1.630.708	7.230.621	6.327.908	6.327.908 1	.749.983 6.3.	27.908 4.076	176 943.	697 943.69	7 1.630.7	8 6.327.908	1.630.708	3.661.984	943.697	7.230.621 6.	327.908 1.7	49.983 7.2	30.621
May	6,0 1,1	670 7.	35 1.809	500 5.424.	109 7.476.5	39 5.424.10	19 1.809.50	10 5.424.109	7 1.809.500	9 1.809.500	7.806.340	5.424.109	5.424.109 1	.686.169 7.4.	76.539 6.543	1.124 1.686	.169 1.686.16	9 975.75	2 8.853.641	975.792	555.069	894.520	6.543.124 4.	214.809 1.6	86.169 7.8	06.340
, June	1.1 6.2	686 6	87 3.944.5	904 3.944.	904 7.306.4	.44 6.124.12	0 3.544.05	1 3.944.904	1 3.544.05.	1 3.544.051	8.286.679	3.944.904	3.944.904 3	544.051 7.3	J6.444 5.076	(764 1.693)	625 1.693.62	5 837.25	7 7.306.444	837.237	837.237	3.544.051	5.076.764 5.	076.764 91	3.305 8.2	86.679
July	8,6 1,1	1698 7.	35 5.437.0	972 3.795	580 8.874.8	51.069.1 10	19 4.224.88	12 3.795.580	1 4.224.88.	3 4.224.882	556.396	556.396	3.795.580 5	:437.072 8.8.	74.801 1.813.	1.825 3.795	580 3.795.58	0 556.35	6 7.494.407	556.396	978.125	4.224.882	4.224.882 L	690.199 85	6.658 55	56.396
Auoust	06 11	1677 7	35 74801	0181 705	506 1.810.5	<u>95 018 1 - 90</u>	V6 8.85856	1 810506	CI 202 2	\$ 5427123	805 017	805017	1 810 506 4	81 151 2165	10 506 1 687	207 5 901.	781067	90182 8.	210 208 8	151 210 7	7 810 678	5 427 123	1 810 506 1.	810 506 55	5 378 80	5 017
Cantamhar	11 101		11 8 55 4	284 1670	10091 921	76 2.65854	SF CF3 2 2.	9210C91 C	× 201 0K	2 6 271 062	012 610	012 810	y y21 00 y 1	371.062.16	2017K 2.658	102 9 293	0.62 7 7 7 2 8 2	\$ 7372.8	8 013 CVD	122 086 5	8 554 284	K 271 0K2	5 9LI0C91	K58 543 K3	0 29010	018 01
or premier	11 20	L 373.	-1000 II	101 073 4	12 620 023	20 62 02	71037 1	VJ76701 70	101 077 E (	0021700 C	LJF 007 1	L20 107 1	0 037620	01 COLITCY	50000 01167	17C'0 CLCC	320037 301	0.0137.0	0 1005500	11/04710	100.700	301037 2	0 037620	00 037 620	71 00676	01017L
Uctober	1'' I''	/	.68/./ CC	VC/6 107	0.6/6 000	20.000 VC	717067/ 14	100.076 02	/.400.12	C71.00#/ C	1.062.40/	1.082.40/	> 000.016	19 202-4-202	.000 UC0.0	1047/ 1027	:/\27C'0 C71	7.820.0 60	70.001 6	66/.820.0	4.200	C71.004.1	e 000.076	8.8 UC0.C/	34.205 1.0	07.40/
November	9,2 1,1	1638 6	87 6.098.	939 <i>8</i> 33	795 833.7	95 833.79	5 6.09895	39 833.795	5 7.276.40	I 7.276.401	1.686.661	1.686.661	833.795	7.276.401 85	3.795 833.	.795 7.276	401 5.055.88	39 5.055.8	0 1.571.70.	6.968.989	6.098.939	7.276.401	833.795 8	33.795 72	76.401 1.6	86.661
December	7,6 1,1	1651 7.	735 3.780.	365 554	166 554.1	66 974.20	14 5.415.27	77 554.166	5 8.839.22	6 8.839.226	3.780.365	3.780.365	554.166	7.464.366 55	4.166 974.	.204 8.839	.226 4.207.94	(6 4.207.9	6 3.780.36	7.793.630	5.415.277	8.839.226	554.166 5	54.166 7.4	64.366 3.7	80.365
Annual	7,4 1,1	1666 8.5	79 48.856.	319 48.444	328 48.676.1	926 48.290.4	93 48.895.0.	32 48.444.325	8 48.844.48	5 48.844.485	48.356.354	48.391.173	48.444.328 4	(8.841.866 48.	676.026 48.36.	2.288 49.05.	3.015 49.213.2t	55 48.817.4	13 48:463.565	48.054.765	48.883.303	48.747.993	48.179.078 48	8.285.240 48	430.728 48.	356.354
Table G2 Energ	y production	n map of the	wind farm.	for Corvo I:	sland (Portug	gal)																				
	V <sub>wr</sub>	H	P											$AEP_{m}$	$_{ail}(k Wh)$											
Months	'm/s) (kg/i	n <sup>3</sup> ) (h)	, vr	Wr 2	. yr3	Yr 4	yr 5	W6	¥F7	$yr_8$	YF 9	$yr_{10}$	yr 11	Yr 12 1	T 13 VL	14 VI	15 VF 16	YF 17	yr 18	VF 19	yr 20	YF 21	VF22	VF 23	0F 24	VT 25
January	11,7 1,2	313 7:	38 14.451.	298 14.451	.298 14.451.	298 14.451.2	98 14.451.2	98 14.451.29	8 14.451.25	V8 10.842.026	10.842.026	14.451.298	10.842.026	10.842.026 10	842.026 14.45	1.298 10.84	2026 10.842.0	26 14.451.	98 10.842.02	5 10.842.026	10.842.026	10.842.026	10.842.026	0.842.026 10	.842.026 16	1842.026
February	11.5 1.2	.345 6:	39 11.923.	902 4.233.	203 11.923.9	902 11.923.9	92 11.923.9	a 3.369.392	2 11.923.96	12.538.268	1.770.714	3.369.392	12.538.268	1.770.714 9.1	15.121 11.92	13.902 6.580	1843 12.538.2	68 4.233.2	13 5.409.69	p 3.369.392	2.776.293	11.923.902	2.077.293 6.	580,843 11	.923.902 12	2538.268
March	105 12	320 7:	3.5 10.471.	380 3.180	384 13.6981	987 13.698.0	87 13.698.0	KYFICY A	9 13.698.05	7 13.698.087	2 386 378	7 180 384	13.608.087 3	386 378 13	60.8 DK7 13.60	N. 087 6214	0 869 81 0 0 93	97 3 870 7	11 7 560 02	1 4 863 071	13,608,087	14 403 865	1 681 150 6	0.471.380 14	403.865 3	180 384
4	4'r 20		3062 11.	201-2 200	1 07 101 L00	1 677 01 321	1 077 01 32	200 JUC L 30	21 07 01 L	202 002 1 2.	121 000 0	1 305 000 L	017 100 01	ci 121 000 0	007 1 017 200	170 1000	12 PEC CL 2020	1.000 01	20100/11 12	11000011 3	122 010 61	017 200 01	· 101.000 c	cr 121 000	- 017 Let	117 012
When	71 16	·/ //C	.cnc/ 11	.cnc./ /00	00/ 10.440.	1.044-01 011	rettar ci	.00"CNC"/ C/	1.04401 /	JAC.440.4 C	1/1720010	/00.000./	. 010'/C7'CI	CI 1/17200.0	160'+ oro'/c7	.40.4 04C.4	37/C7/CI 06C%	17001C 01	10.611.01 1/	1/1700.0 4	1/0/616/01	010.707.01	C 1/1700.C	cr 1/1700	"C 010'/C7"	40.014
May	2'1 7'2	./ 797:	50 4.844.	80/ 10.45	2.005 IU.452.	0.254-01 SCO	77161.0 20	SU 10:452:02	10.432.0.	50 IU.452.05	5200.04	0.191.280	. ccn.724.01	41 461.0029	549.708 10.45	102.5 500.25	0.194 10.452.6	57/57 SQ	10 13.040.04	0.191.280	2.5//.410	10.452.030	1 461.003:5	4.549./08 10	452.005 42	844.807
June	7,1 1,2	224 6v	87 2.955.	541 12.695	3.755 7.005.7	728 7.005.7.	28 7.005.7.	28 10.014.12.	1 4.506.51	5 12.693.755	4.506.515	10.014.121	7.005.728	4.506.515 7.1	05.728 2.21	1.411 2.95.	5.541 7.005.72	28 1.885.0	38 12.693.75	5 7.005.728	1.885.038	7.005.728	4.506.515 1	2.693.755 7.0	05.728 5.	758.970
July	6,1 1,2	154 7.	35 2.005.	275 13.505	1.424 4.793.5	962 6.126.3	95 10322.5	72 13.503.42.	4 7.452.58	7 3.144.060	6.126.305	2.005.275	6.126.305 t	5.126.305 6.1	26.305 2.000	5.275 2.35	2,466 6,126.3	95 6.126.5	05 14.199.17	2 10.322572	3.815.724	6.126.305	6.126.305 1	3.503.424 3.2	815.724 7.4	452.587
August	6,4 1,2	075 7.	35 2337.	182 10.585	1.661 3.790.5	235 3.790.9	35 3.790.9.	35 13.415.69	6 6.086.50	4 3.790.935	7.404.169	2.337.182	4.762.817	7.404.169 4.7	62.817 10.58	83.661 1.992	2.247 4.762.8	17 13.415.4	96 1.992.24.	7 13.415.696	4.762.817	4.762.817	7.404.169 4	762.817 3.1	123.634 16	1255.509
September	7,6 1,2	064 7.	71 3.663.	832 1.925.	451 5.882.4	(34 4.603.IL	29 4.603.I.	29 4.603.129	9 1.925.45	1 5.882.434	099711676	9.911.660	3.663.832 5	0.911.660 3.6	63.832 5.8%	2.434 9.91	1.660 3.663.8.	32 12.965.4	92 2.258.82.	I 12.965.892	5.882.434	3.663.832	9.911.660 3.	663.832 2.2	258.821 1.9	925.451
October	8,9 1,2	126 7:	35 6.112.	412 6.112.	412 3.136.9	130 2.000.7	27 3.136.9:	30 2.000.72;	7 2.347.13	1 7.435.686	13.472.801	13.472.801	3.136.930	13.472.801 3.1	36.930 7.435	5.686 13.47	2801 3.136.95	30 10.628.	11 3.136.930	9 2.000.727	7.435.686	3.136.930	13.472.801 2	347.131 20	00.727 2.	347.131
November	10.6 1.2	.194 68	87 9.990.	034 3.578.	305 2.206.0	192 2.206.00	72 2.206.09	72 2.206.092	2 2.948.43.	3 2.206.092	12 663.223	4.495.676	2.206.092	12.663.223 2.2	06.092 2.948	8.433 12.66	3223 2206.05	72 9.680.2	88 3.578.30.	5 2.206.092	9.680.288	2.206.092	12.663.223 1.	.880.504 5.3	745.118 12	2663.223
December	11.5 1.2	237 7:	35 13.595.	706 2.368.	542 2.0189	179 3.165.54	17 2.018.9	79 3.165.54;	7 3.841.80	1 2.018.979	14,296,210	13.595.706	2.018.979	14.296.210 2.0	18.626 3.841	1.801 14.25	6210 2.018.97	79 7.503.5	18 4.826.72.	4 14.296.210	13.595.706	2.018.979	14.296.210 6.	168.172 4.8	826.724 13	(595.706
Ammund	01 13	23 22	70 80.657	222 00 222	275 80 782	0 YFX 80 844 0	1 20 20 10	00 V81 08-	5 00.056.03	02018208 5.	292 818 00	00 330 663	80.668.733	20.218.867 00	163 201 00 11	28.08 3535	-2 899 08 8CF 2.	33 00.00	67 00 363 73	1 00 560 850	00.671.187	80 760 146	0 777 750 0	0 245 823 80	615 010 - 80	153.675
Annual	9,1 1,2	.2.2 8.2.2	/9 89.657	257 90.377	7.375 89.783	574 89.846.9	76 89.792.1	05 90.681.98	5 90.056.9.	35 89.381.971	90.318.367	90.339.663	89.668.733	90.318.367 96	163.301 90.11	13.636 89.8.	17.428 89.668.7	33 90.220.	67 90.263.72	1 90.560.856	90.671.187	89.760.146	90.272.750 9	0.345.823 89	.615.940 89	153.675
Table G3 Energ.	v production	map of the	wind farm.	for Cape Sa	int James (Ca	anada)																				
Months	V nc	H proc	P											$AEP_a$	ail(k Wh)											
	m/s) (kg/t.	( <i>h</i> ) ( <i>h</i> )	)T'I	yr2	yr3	yr.4	yr 5	yr 6	yr 7	yr 8	yr 9	yr 10	yr II	yr 12 )	#13 yr	H JT	15 JT 16	yr 17	yr 18	yr 19	yr20	yr 21	yr 22	yr23	VT 24 2	yr 25
Jamuary	2,1 4,01	·/ 100	30 32.134.	727 27.724	101 6010 5	-/-86/-76 - 60/	77.427.47	90 32./34./9	1. 32./30 EV	0 26.736.79	22.134.190	24.192.194	22.134.190	XU15.494 32.	2/76 26/76/	27.20 32.72	7.46 32/34.1	96 32./34	90 32.134.19	5 52/54/70	400.4C/.04	34.739.796 76.779.570	2 047.967.26	(3.019.994 5.0	113.494 /.1	100.955
rebraary	127 12	10 275	25 18 276	104-41 440	C 716'0 4740	C.022.02 COC	20 19-376-50	CE 106-16 47	4C-077-07 +	0 20.220.220	COC.216.0	12 276 504	18.236.522 (	07 C76'6#/'/	16.0 070.077 880W	101112 29C3	VC716-0 707-1	2716-0 00	.0C.216.0 CC	COC.216.0 C	#/C-70#-77	07077707	2 07C'077'07 2 07C'077'07	0.0 058.000 010	51 VV0120	007-1001
Anril	12.4 1.2.	490 71	11 16.057.	711 19.287.	404 9.641.8	90 24.828.9	13 9.641.89	40 19.287.40 <del>4</del>	1 24.828.91	3 24.828.913	0641.890	0.641.890	19.287.404 9	1641.890 24.	828.913 9.641	1.890 26.91	3.496 9.641.89	20. 29.111.6	00 0.641.800	068189.6 (	22.185.639	60672670	24.828.913 2	4.919.931 9.4	1 800 18	139.032
Mav	11.2 1.2	425 75	3.5 12.306.	614 25.533	644 9.915.5	60 19.834.84	48 9.915.56	0 25.533.644	1 19.834.84	8 19.834,848	9.915.560	9.915.560	25.533.644	12.306.614 19.	834.848 9.915	5.560 25.53	3.644 9.915.56	50 27.677.5	95 9.915 560	9.915.560	20.989.216	19.834.848	19.834.848	9.089.277 12	306.614 16	k 168.320
June	10,4 1,2	351 68	87 9.212.4	474 25.714	865 11.433.5	285 16.838.31	88 8.218.71	8 25.714.865	5 16.838.38	8 16.838.388	11.433.985	8.218.718	25.714.865	15.342.558 16.	838.388 11.43	B.985 16.83	8.388 11.433.9	85 23.723.1	22 11.433.98:	5 11.433.985	16,955.390	16.838.388	16.838.388 1	6.760.685 15	342.558 14	(949.503
July	10,0 1,2	275 73	35 8.739.:	531 29.577.	37718791 669.	303 16.314.80	13 7.795.26	6 29.577.695	9 16.314.80	3 16.314.803	16.314.803	7.795.266	29.577.699	17.905.422 16.	314.803 16.31	4.803 7.795	.266 16314.80	93 19.596.2	05 16.314.80.	3 16314.803	15.530.715	16.046.466	16.314.803 1	6.760.185 17	.905.422 8.0	525.161
August	9,7 1,2	216 73	35 7.757.3	712 12.099.	17.819.1	161 12:099.9;	72 17.819.10	51 12.099.972	2 12.099.97	2 12.099.972	17.819.161	17.819.161	12.099.972	19.501.798 12.	999.972 17.81	9.161 8.697	1.428 17.819.16	17.819.1	61 17.819.16.	1 17.819.161	12.908.119	15.377.861	12 099.972	2.588.985 19	501.798 7.	806.111
September	10,4 1,2.	234 71	11 9.444.	238 7.515.	148 18.892.0	928 9.444.25	18 26.361.75	91 7.515.148	8 9.444.23.	8 9.444.238	18.892.028	26.361.791	7.515.148	24.319.940 9.4	44.238 18.89	2.028 9.444	1.238 18.892.0.	28 15.728.2	41 18.892.02.	3 18.892.028	12.321.085	13.275.521	9.444.238 8.	.842.059 24	319.940 15	1029.793
October	13,1 1,2	327 75	35 19.679.	010 8.776.	461 29.702.t	582 9.837.65	56 25.333.02	32 8.776.461	9.837.65	6 9.837.656	29.702.682	25.333.032	8.776.461	27.459.940 9.8	37.656 25.33	B.032 9.837	.656 25.333.0.	32 12.209.5	24 29.702.68.	25.333.032	12.242.414	8.858.686	9.837.656 8.	122.639 27	459.940 21	596.003
November	14,3 1,2	429 68	87 23.874.	256 9.271.	165 25.878.4	588 8.271.07	78 27.99228	85 9.271.165	5 8.271.07.	8 8.271.078	25.878.688	27.992.285	9.271.165	27.992.285 8.2	71.078 25.87	8.688 11.56	6.828 25.878.6	88 9.271.1	55 25.878.68.	\$ 25.878.688	7.423.013	8.271.078	8.271.078 8.	.870.902 27	.992.285 21	.951.058
December	15,1 1,2.	528 7.	35 30.186.	350 9.997.	848 25.745.:	545 7.955.65	77 19.999.4:	56 9.997.848	8 7.955.67	7 7.955.677	25.745.545	19.999.456	9.997.848	32.498.621 7.5	55.677 30.15	\$6.350 16.65	0.529 30.186.3.	50 9.997.8	48 25.745.54	5 30.186.350	6.350.393	7.955.677	7.955.677 9.	.163.644 32	498.621 42	2475.115
Annual	12,5 1,2	404 8.5.	79 212.467.	325 213.202	961 213.887.5	985 212.223.6.	70 212.655.9.	74 213.202.961	1 212.223.67	0 212.223.676	213.887.985	212.655.974	13.202.961 2.	12.704.429 212.	223.670 213.95	9.139 213.43	7.670 213.959.1.	39 213.678.0	13 213.887.98	5 213.959.139	213.109.827	213.228.530	212 223.670 21	3.512.714 212	704.429 213	(419.415

Table G4 Wind s	speed serie.	s simulation.	s for AEP	and in Arac	cati (Brazil)																					1
Months V	wc VS)	VF /	VF 3	VF 2	PL-7	VF 5	VF6	VF 7	$VF_S$	VF 0	WF 10	Wind spe vr	ed data sen	ies for simu	vr 14	UT IS	VFIG	VF 17	VF18	VF 10	VF 20	VF 21	VF 22	VF23	<i>FC JA</i>	VF25
Identification	5.8	5.8 16	10	76	9.6	01	101	40	10	7.0	1 01	101	40	76	9.6	70	101	101	40	76	9.6	40	7.6	90	7.0	70
February	4,9	4.9 5	9,7	0''	9.7	4.7	1'01 6'2	4.7	4.7	8,6	1,01 9,7	9.7	4.7	7,9	9.7	4.0	4,0	7.6	8.6	1.01	0's	6.0	1.01	9,7	8.6	8.6
March	4,0	4,0 5	9'6	8,6	10,1	4,9	9'6	4,9	4,9	9,2	9,6	9'6	4,9	8,6	10,1	4,7	4,7	6,0	7,9	6,0	5,8	5,8	9,7	10,1	7,6	9,2
April	4,7	4,7 5	9,2	9,2	7,9	5,8	9,2	5,8	5,8	9'6	9,2	9,2	6,0	9,2	7,9	4,9	4,9	5,8	9,2	5,8	7,6	4,9	9'6	9,2	6,0	9,6
May	6,0	6,0 8	8,6	9,6	8,6	6,0	8,6	6,0	6,0	9,7	8,6	8,6	5,8	9,6	9,2	5,8	5,8	4,9	10,1	4,9	4,0	4,7	9,2	7,9	5,8	9,7
June	7,9	7,9 ;	7,9	9,7	9,2	7,6	7,9	7,6	7,6	10,1	7,9	7,9	7,6	9,7	8,6	6,0	6,0	4,7	9,7	4,7	4,7	7,6	8,6	8,6	4,9	101
July	8,6	8,6 ;	7,6	10,1	5,8	7,9	7,6	7,9	7,9	4,0	4,0	7,6	8,6	10,1	6,0	7,6	7,6	4,0	9,6	4,0	4,9	7,9	7,9	5,8	4,7	4,0
August	9,6	9,6 6	6,0	6,0	6,0	10,1	6,0	8,6	8,6	4,7	4,7	6,0	7,9	6,0	5,8	8,6	9,7	9,7	4,7	7,9	9,7	8,6	6,0	6,0	4,0	4,7
September	10,1	10,1 5	5,8	5,8	7,6	9,7	5,8	9,2	9,2	4,9	4,9	5,8	9,2	5,8	7,6	9,2	9'6	9'6	4,9	8,6	10,1	9,2	5,8	7,6	9,2	4,9
October	9.7	9.7 4	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	0.0	9.2	7.9	9.6	4.9	4.9	10.1	5.8
November	0.2	4 20	47	4.7	47	0.2	4.7	9.7	07	60	60	47	0.7	4.7	4.7	0 7	86	86	5.8	9.6	0.2	07	4.7	47	0.7	60
December	7.6	7.6 4	4.0	4.0	4.0	8.6	4.0	10.1	10.1	2.6	2.6	4.0	9.6	4.0	4.9	10.1	2.9	7.9	2,6	9.7	8.6	10.1	4.0	4.0	9.6	0'0 7.6
Annual	7,4	7,4 7	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4
Table G5 Win	d sneed se	ries simulatio	ions for AF	т. 	orvo Island	Portneall																				
	Vwc					(manino a)						Wind sp	reed data se	ries for sim	ulations (m	(8)										
Months	( <i>m</i> / <i>s</i> )	VI 1	VT 2	VI 3	VLA	VF <	Vrk	VF 7	VF 8	Vra	VF 10	VLI	VL 12	VF 13	VLIA	VLis	VF 16	VF 1.7	VF 18	VF 10	VF 20	VF 21	Vr	VF 32	VF 24	Vras
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	9.01	11.7	9.01	10.6	11.7	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
February	11,5	11,5	8,2	11,5	11,5	11.5	7,6	11,5	11.7	6,1	7,6	11.7	6,1	10,5	11.5	9,5	11.7	8,2	8,9	7,6	1.7	11,5	6,4	9,5	11,5	11.7
March	10,5	10,5	1'1	11,5	11,5	11,5	8,9	11,5	11,5	6,4	1'1	11,5	6,4	11,5	11,5	8,9	11,5	7,6	9,5	8,2	11,5	11.7	6,1	10,5	11.7	7,1
April	9,5	9,5	9,5	10,6	10,6	10,6	9,5	10,6	8,2	1'1	9,5	11,5	1'1	11,5	8,2	8,2	11,5	7,1	10,5	7,1	11,7	11,5	7,1	1'1	11,5	7,6
May	8,2	8,2	10,5	10,5	10,5	8,9	10,5	10,5	10,5	7,6	8,9	10,5	7,6	11,7	10,5	7,6	10,5	6,4	11,5	8,9	6,4	10,5	7,6	11.7	10,5	8,2
June	7,1	7,1	11,5	9,5	9,5	9,5	10,6	8,2	11,5	8,2	10,6	9,5	8,2	9,5	6,4	7,1	9,5	6,I	11,5	9,5	6,1	9,5	8,2	11,5	9,5	8,9
July	6,I	6, I	11,5	8,2	8,9	10,5	11,5	9,5	1'1	8,9	6,1	8,9	8,9	8,9	6,1	6,4	8,9	8,9	11.7	10,5	7,6	8,9	8,9	11,5	7,6	9,5
August	6,4	6,4	10,6	7,6	7,6	7,6	11,5	8,9	7,6	9,5	6,4	8,2	9,5	8,2	10,6	6,1	8,2	11,5	6,I	11,5	8,2	8,2	9,5	8,2	7,1	10,5
September	7,6	7,6	6,I	8,9	8,2	8,2	8,2	6,I	8,9	10,5	10,5	7,6	10,5	7,6	8,9	10,5	7,6	11,5	6,4	11,5	8,9	7,6	10,5	7,6	6,4	6,1
October	8,9	8,9	8,9	1'1	6,I	7,1	6,1	6,4	9,5	11,5	11,5	7,1	11,5	7,1	9,5	11,5	1'1	10,6	7,1	6,1	9,5	7,1	11,5	6,4	6,1	6,4
November	10,6	10,6	7,6	6,4	6,4	6,4	6,4	7,1	6,4	11,5	8,2	6,4	11,5	6,4	1'1	11,5	6,4	10,5	7,6	6,4	10,5	6,4	11,5	6,1	8,9	11,5
December	11,5	11,5	6,4	6,I	7,1	6, I	1'1	7,6	6, I	11,7	11,5	6,I	11,7	6,I	7,6	11,7	6,I	9,5	8,2	11,7	11,5	6,I	11,7	8,9	8,2	11,5
Annual	1'6	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1	1'6	9,1	9,1	<i>I'6</i>	9,1	1'6	<i>1</i> '6	<i>1'6</i>	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1
Table G.6 Win	id speed se	ries simu lati	ions for A	<i>EP</i> avri in C	ape Saint Ja	umes (Can ac	la)																			
	Vwc											ts puiM	veed data se	sries for sim	ulations (m	(2)										
SHIHOW	(m/s)	$yr_1$	yr 2	yr3	yr 4	yr 5	yr 6	yr 7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
January	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	9,7	15,4	15,4	15,4	15,4	15,4	15,4	15,4	16, 6	15,4	15,4	14,7	9,7	9,3
Feb mary	14,7	14,7	12,4	9,7	15,1	12,4	12,4	15,1	15,1	9,7	12,4	12,4	10,0	15,1	9,7	13,1	9,7	9,7	9,7	9,7	14,3	15,1	15,1	15,6	10,0	13,1
March	12,7	12,7	12,7	10,0	14,7	11,2	12,7	14,7	14,7	10,0	11,2	12,7	10,4	14,7	10,0	15,1	10,0	10,0	10,0	10,0	13,8	14,7	14,7	15,3	10,4	12,9
April	12,4	12,4	13,1	10,4	14,3	10,4	13,1	14,3	14,3	10,4	10,4	13,1	10,4	14,3	10,4	14,7	10,4	15,1	10,4	10,4	13,8	13,3	14,3	14,3	10,4	12,9
May	11,2	11,2	14,3	10,4	13,1	10,4	14,3	13,1	13,1	10,4	10,4	14,3	11,2	13,1	10,4	14,3	10,4	14,7	10,4	10,4	13,4	13,1	13,1	13,0	11,2	12,3
June	10,4	10,4	14,7	11,2	12,7	10,0	14,7	12,7	12,7	11,2	10,0	14,7	12,4	12,7	11,2	12,7	11,2	14,3	11,2	11,2	12,8	12,7	12,7	12,7	12,4	12,2
July	10,0	10,0	15,1	12,4	12,4	9,7	15,1	12,4	12,4	12,4	9,7	15,1	12,7	12,4	12,4	9,7	12,4	13,1	12,4	12,4	12,2	12,3	12,4	12,5	12,7	10,0
August	9,7	9,7	11,2	12,7	11,2	12,7	11,2	11,2	11,2	12,7	12,7	11,2	13,1	11,2	12,7	10,0	12,7	12,7	12.7	12,7	11,4	12,1	11,2	11,4	13,1	9,4
September	10,4	10,4	9,7	13,1	10, 4	14,7	9,7	10,4	10,4	13,1	14,7	9,7	14,3	10,4	13,1	10,4	13,1	12,4	13,1	13,1	11,4	11.7	10,4	10,2	14,3	13,2
October	13,1	13,1	10,0	15,1	10,4	14,3	10,0	10,4	10,4	15,1	14,3	10,0	14,7	10,4	14,3	10,4	14,3	11,2	15,1	14,3	11,2	10,1	10,4	9,8	14,7	13,5
November	14,3	14,3	10,4	14.7	0'01	15,1	10,4	0'01	0'01	14,7	15,1	10,4	15,1	0,01	14,7	11,2	14,7	10,4	14,7	14.7	9,7	0'01	0,01	10,3	15,1	13,9
December	1,01	1,01	10,4	14,5	1,4	13,1	10,4	1,4	1.6	14,5	13,1	10,4	10,4	1,4	1,01	12,4	1,01	10,4	14,5	1,01	9,0	7,6	7,6	101	10,4	10,9
AIIII ILLI	C,21	C'7 I	C'7I	C,21	14,0	C'7I	14,0	C,41	C, 21	14,7	C,21	14,0	C'71	14,7	C'7I	C,21	C'71	C,21	C,21	C'71	14,7	C'71	C'71	C'71	C'71	14,0

Table G7 kWh per H <sub>prod</sub>																								
Citan												k W/yr												
yr yr	1 yr2	$yr_3$	$yr_4$	$yr_5$	$yr_{\delta}$	yr 7	yr8	× yr9	yr 10	yr 11	yr 12	yr13	yr14	yr15	yr 16	yr17	yr18	yr 19	yr 20	yr21	yr 22	yr 23	yr 24	yr25
Aracari (Brazil) 5.69.	5 5.647	5.674	5.629	5.699	5.647	5.694	5.694	5.637	5.641	5.647	5.693	5.674	5.637	5.718	5.737	5.690	5.649	5.602	5.698	5.682	5.616	5.628	5.645	5.637
Corvo Island 10.45. (Portugal)	I 10.535	10.466	10.473	10.467	10.570	10.498	10.419	10.528	10.530	10.452	10.528	10.510	10.504	10.472	10.452	10.517	10.522	10.556	10.569	10.463	10.523	10.531	10.446	10.392
Cape Saint James 24.761 (Canada) 24.761	6 24.852	24.932	24.738	24.788	24.852	24.738	24.738	24.932	24.788	24.852	24.794	24.738	24.940	24.879	24.940	24.908	24.932	24.940	24.841	24.855	24.738	24.888	24.794	24.877
					1																			
Table G8 Cashflow for 25 years of 1	the wind farm	project	50.000 kV	V An	tcati (Brazil)		refer	ence situation				Vag	2											
Item	0	-	2	3	4	5	6	7 8	6	10	Ξ	12	13	14	15	16	17 1	8 19	20	21	13	23	24	25
(-) LCCCM <sub>WF</sub>	60.225.901																							
WT CM	27.686.278	•									•	•	•								'	•	•	
$T_{CM}$	24.219.295	•			,	,		,			•	•	•	•		,	,	,			'	•	•	
LWTG CM	1.959.783					,											,				•			
CP ON	1.242.240																							
IS CM	2.136.726																							
POC	0/28/96/1							,																
$F_{CM}$	188.559																				,			
CCCCM	120.211	•									•	•	•								•		•	
LCPM WF (kWh/yr)	•	48.856.319	48.444.328 4	8.676.026 48.	290.403 48	.895.032 48.	444.328 48.8	344.485 48.844	1,485 48.356.	354 48.391.1	73 48.444.328	3 48.841.866	48.676.026	48.362.288	49.053.015 4	9.213.265 48.	817.403 48.40	3.568 48.054.	.765 48.883.2	03 48.747.99	48.179.078	48.285.240	48.430.728	8.356.354
(+) AAR $(SM/yr)$		4.297.170	4.367.456	4.498.053 4.	573.979 4	747.030 4	820.855 45	982.192 5.100	5747 5.182	105 5.315.4	83 5.454.354	4 5.636.591	5.757.889	5.863.796	6.096.233	6.269.053 6.	374.091 6.48	(6.088 6.592.	.161 6.873/	45 4.918.06	4.982.181	5.117.988	5.261.744	5.385.005
FLAK		0/11/67%	0C470C.4	4 CCU/0444	4 6/6/C/C	4 //0.00 4	3'F CC2'072'	NULC 241.284	791.0 /4/3	4°CIC.C OUL	.404.00.00	160,000,0 +	699./0/.0	06/.008.0	CC2.0KU.0	0 CON/60710	14.0 140.44	760'0 990'0	/0/2/0 101	- 018/04	- 4 087 181	5 117 088	- 2761744	
(-) O&M were		3.949.353	4.013.810	4.133.691 4.	203.326 4.	362.211 4,	455.205 4.6	03.526 4.717	.835 4.786	682 4.909.1	10 5.036.591	5.204.091	5.315.304	5.412.299	5.626.056	5.784.761 5.	380.906 5.98	3.464 6.080.	550 6.339.2	42 5.846.63	5.922.095	6.082.752	6252834	6.398.541
O& M fixed		2.654.579	2.697.997	2.778.672 2	825.574 2	.932.474 2.	978.078 3.0	177.743 3.154	1.685 3.201.	236 3.283.6	28 3.369.414	1 3.481.989	3.556.919	3.622.341	3.765.927	3.872.684 3.	337.570 4.00	6.754 4.072.	279 4.2460	52 4.340.15	4.396.739	4.516.586	4.643.449	4.752.224
$O\& M_{variable}$		1.294.774	1.315.813	1.355.018 1.	377.752 1	.429.737 1.	21 121.174	525.784 1.565	3.150 1.585.	447 1.625.4	82 1.667.177	7 1.722.102	1.758.385	1.789.958	1.860.129	1.912.077 1.	943.336 1.97	6.710 2.008.	.271 2.093.1	90 1.506.48	1.525.356	1.566.166	1.609.385	1.646.316
(+) LRCM	•	863.268	884.850	906.971	929.646	952.887	976.709 1.( 775.002 2.6	001.127 1.026	5155 1.051.	809 1.078.1	04 1.105.057	7 1.132.683	1.161.000	1.190.025	1.219.776							-		- 102 107 1
(=) Profit before tax	,	3.664.570	3.753.318	3.849.027 3.	942.434 4.	.045.894 4.	118.251 4.2	25.083 4.331	489 4436	565 4.548.5	00 J.140.000 13 4.663.487	4.784.368	4.903.249	5.023.678	5.156.663	1037.669 4.	0*2.212 3.1. 135.397 4.25	5.892 4.338.	210 4.4564	187 3.091.74	3.180.914	3.259.085	3.338.355	3.424.146
(-) Revenue tax		1.289.151	1.310.237	1.349.416 1.	372.194 1	424.109 1.	446.256 1.4	194.658 1.532	024 1.554	632 1.594.6	45 1.636.306	5 1.690.977	1.727.367	1.759.139	1.828.870	1.880.716 1.	912.227 1.94	5.827 1.977.	648 2.062.0	40 1.475.41	1.494.654	1.535.396	1.578.523	1.615.502
(+) REPIM	384.810	2.045	1.989	1.961	1.910	1.898	1.847 1	.829 1.75	97 1.74	8 1.720	280	289	296	301	313	322	327	<b>133</b> 33.	5SE 6.	361	365	375	386	395
$REI_{CM}$	221.313																							
$REP_{CM}$		1.825	1.765	1.730	1.675	1.654	1.599 1	.573 1.5.	35 1.48.	2 1.447		•		,							,	,		
$OREP_{CM}$	163.497										•	•												
$GHG.R_{CM}$	•	21	224	231	235	244	248	256 24	8 8	6 273	280	289	296	301	313	322	327	33 33	35:	361	365	375	386	395
(=) Profit after tax w/out interest		2.377.464	2.445.071	2.501.572 2	572.150 2	.623.683 2	673.841 2.	732.254 2.80	262 2.883.	681 2.955.6	18 3.027.46	3.093.680	3.176.178	3.264.840	3.328.106	2.157.275 2.	223.497 2.29	0.398 2.360.	.900 2.394.	00 1.616.68	1.686.625	1.724.064	1.760.218	1.809.039
(-) Debt payments		- 7 671 720	2 0012015	2754464 2	072 276 7	419.899 3.2 902.000 7	055 757 300	2031 3.682.5 MO 412 2.116	57 3.774.9. . 424 2.104	224 2.774 H	3.966.034	4.065.185	2 575 047	4.2.70.985 2.614.006	4.377.160 2.704.449	2 707 060 2	- 200	- 200 1 000 1	- 101 0 10	- 420600	- 4 402 475	- 4 512 511	- 1676.240	- 742 007
(+) ACM WF		2 453 485	2 514 877	7 +0+/+C//7	2 020.020	2 404.040	AC 102,00%	ALC: CI4:040	1421 C 4247	333 30640	140/00000 06	3210185	146107010	3 382 156	3.466710	3553 277 3.	160 006160 513 10 273	300.4 002.6	-171.4 010. 500 3.0777	20.02.4 0.03	C24-CU4-4 1	110.010.4	4 320 445	4.142.001
(=) Free net cashflow	-59.841.090	7.452.688	4.471.459	4.578.620 4.	.701.124 4	805.881 4.	910.595 5.0	124.926 5.151	251 5292	420 5.424.5	75 5.558.142	5.687.628	5.834.975	5.990.107	6.121.504	9.507.712 9.	757.695 10.01	2.951 10.276.	517 10.5082	07 9.933.03	10.210.879	10.461.423	10.716.012	0.988.728
$\Sigma$ free net annual cash flow		-52.388.403 -	47.916.944 -4	3.338.324 -38	637.200 -33	.831.319 -28	920.725 -23.8	895.799 -18.744	1.548 -13.452	128 -8.027.5	52 -2.469.41(	3.218.218	9.053.193	15.043.300	21.164.804 3	0.672.516 40.	430.211 50.4	3.162 60.719.	.678 71.2275	86 81.161.01	91.371.895	101.833.319	112.549.330	123.538.058
	LCOE uno	67,66	67,81	68,02	68,18	68,43	68,62 6	58,87 69,1	99 69,2	6 69,49	69,72	70,00	70,23	70,44	70,78	69,81	70,00 71	,20 70,4	0 70,76	70,37	70,55	70,82	11'12	71,37

Table G9 Cashflow for 25 years of the	s wind farm pr	oject	50.000 kW	Corv	/o Island (P.	(ortugal)	refe	rence situatio	ę																
Item	0	-	2	3	4	5	9	7	8 9	10	П	12	Years 13	14	15	16	17	18	19	20	21	7	23	24	25
(-) LCCCM <sub>WF</sub>	60.225.901																•						,	,	,
WT <sub>CM</sub>	27.686.278																								
LWTG cM	1.959.783																								
$CP_{CM}$	1.545.346		,	,	,	,		,	,								,		,	,		,	,	,	,
TS CM	572.832															•	•	•							
SI Gr	2.136.726																								
F CM	188.559																								
CCC GI	120.211								,								,	1	,				,	,	
LCPM WF (k Wh/yr)	-	9.657.257	90.377.375 89	783.574 89.8	346.976 89.	792.106 90	681.985 90.	056.935 89.3	81.970 90.31	3.367 90.339	663 89.668	733 90.318.	367 90.163.	901 90.113.6	36 89.837.42	8 89.668.733	90.220.267	90.263.721	90.560.856	90.671.187 1	89.760.146 9	0.272.750 90	345.823 89.6	15.940 89.	153.675
(+) AAR (\$M/yr)		14.970.925	15,468,449 15	5.750.988 16.1	156.163 16.	549.954 17	.131.821 17.	439.078 17.7	41.084 18.37	5.119 18.838	939 19.166	502 19.787.	994 20.247.	871 20.742.6	36 21.196.03	4 21.685.138	22.363.982	22.934,122	23.584.858	24.203.932	17.191.828 1	7.722.258 18	180.019 18.4	83.975 18.1	848.346
PPAR		14.970.925	15.468.449 15	5.750.988 16.1	156.163 16.	549.954 17	.131.821 17.	439.078 17.7	41.084 18.37	5.119 18.838	1939 19.166	502 19.787.	994 20.247.	871 20.742.6	36 21.196.03	4 21.685.138	22.363.982	22.934.122	23.584.858	24.203.932			-		-
EMP	,	- 200 001											-				-				17.191.828	7.722.258 18	180.019 18.4	83.975 18.1	848.346
(-) O&M WFCH		9.368.374	9.679.566 5	856.225 10.	109.621 10.	355,890 10	719.839 10.	011.955 11.1 2.1.200 2.1	00.782 11.49	7.361 11.78	429 11.992	241 12.380.	956 12.668.	548 12.977.9	55 13.261.49	7 13.567.366	13.991.943	14.348.504	14.755.487	15.142.655	13.154.746 1	3.560.473 13	910.592 14.	43.024 14.4	421.679
O&M fixed		4.871.474	5.033.363	5.125.297 5.1	257.137 5.	385.272 5	574.606 5.	674.583 5.7	72.851 5.97	0.160 6.13	0.081 6.236	.666 6.438.	893 6.588.	532 6.749.5	22 6.897.05	2 7.056.201	060/1727	7.462.607	7.674.349	7.875.789	7.991.568	8.238.134	450.920 8.	92.210 8.	761.584
UCCIT variable		062 269	4 00701010	0.05 071 0.06	4 4047C0	C 010'0/6'	1 002/02/02	71 201100	301 33130	201 008	2011 1011	244.0 010	000 0000	10 0.228.4	12 01 01 01 01 01 01 01 01 01 01 01 01 01	00111100 0	0.056.411.0	060.000.0	(cf.100.)	000'007''/	0/1.001.0	- 600770°C	2.6 2/0.664	re crenc	C/01/000
(+) LANCIN (+) Derrectation		2 440 315	2 510 548 2	9 6 618 825.	237.645 2	703 586 2	771176 2	840.455 2.6	11466 298	1.253 3.058	850 3135	331 3.013	101.1 3 204	NUCT 1 12000	18 3 4 60 81	5 3547330	3.636.022	3 776 973	3 820.066	3 015 508	4.013.488	4 113 826	216.671 45	72.088 4.7	430 140
(=) Profit helions tax		8 915 134	9 18/281 9	375 046 96	13.833 0.	850537 10	159.866 10	368 705 10	1001 20011	81 11 028	11 414	649 11 753	435 12 034	80 12 331 1	0.0000	1 11 665 110	12 008 061	12312540	12 649 468	12 976 875	025 050 8	8 275 610	486.008 84	63.040 8.1	856 807
(-) Revenue tax	,	4.491.277	4.640.535 4	725.296 4.8	346.849 4	964.986 5	139.546 5	231.723 5	22.325 5.51	536 5.65	682 5.749	951 5.936	398 6.074	61 6.222.7	91 6358.81	0 6.505.541	6.709.195	6.880.237	7.075.458	7.261.179	5.157.549	5.316.677	454.006 5.	45.193 5.4	654.504
(+) REPIM	486 502	1 438	1 420	1 382	. 355	1327	1314	280	245 1.2	35 1.2	110	0 116	114	1123	1 100	164	921	174	g.	183	186	192	197	200	204
BEI	201313	-	0.000			-		-	-	-	-	2			-	5	2			1	1				5
REPCU	-	1325	1:303	1 263	. 233	1 202	1.184	147	110	01 50	-01	101	60	996	050	,	,		,	,	,		,	,	
OREP	265.188	'	'				'	. '								,	,	,	,	,	,	,	,	,	,
GHGR		113	117	119	122	125	130	130	134	30	12 12	5 15	15	157	161	164	170	174	97. I	183	186	661	197	200	204
(=) Profit after tax w/out interest		205 205	4 545 166 4	.651 132 47	768.339 4.	886.878 5	001634 5	138.261 5.3	56843 540	10 553	1003 5665	878 5818	204 5 961	163 6 109 4	CT 12C9 LE	1 5159734	5 209 037	5 432 478	5 574 189	5 71 5 879	2 80C 508 C	501.050.0	032.280 31	18.047 3.3	205 200
(-) Deht navments	,		3.170.319 3.	249.577 3.33	10.817 3.4	14.087 3.4	99.439 3.5	86.925 3.67	5.598 3.768	513 3.862	26 3.959.2	94 4.058.27	7 4.159.73	4 4 263 727	4.370.320					-	-		-		-
$(\pm)$ BCM		2 621 739	C C8C 787 C	2 PALAGE 28	173 376 7	6 000 208	5 150990	040.413 3 1	015 15424	334 3.77	3356	047 3.430	3 575	M7 36140	3704.44	8 3797.060	3 801 086	3 080 286	4 089 018	4 101 243	4 206 024	4 403 425	513511 47	0.6348 4.	742 007
(+) Demension		2 440 215	C 502/00/2	223 312 24	2 27.645 2	2 202,020 2	C 921122	0 C 250 000	30.6 39410	353 3.050	2135 2135	331 3713	10710 3 204	0111010 11100	3.460.91	0 3547330	3.636.000	3 776 073	3 000005	2 015 509	4 013 499	113 926	10000	1 01000	430.140
(-) Essent cashgan	-60 730 300	010/6440/0	7 0HC101C7	2 710.012	2 08 403 7	2 00CCD/	750,677 7	12 PUC 21	11,400 2.20	2010 S 000 S 000 S	2018 8021	0.67 8.413	10/8 085	133 8 836.7	10.004/0 01	CCC/#C/C 0	220/00/07	13 148 686	13 483 203	102 003 01	1 162 606 11	- 070'CTT+-	0 CI 120 017		374.654
$(-)$ receives the custometer $\Sigma$	**************************************	20.243.050	921202120	30 105.627.6	1 CC 685 CPL	472.263 -15	712.636 -8	- 05-204 280.432 - 4	10/ +01/00	0000 CCCC	1610 0721	586 31760	175 40 381	200000 000	81.0222016 +1	102 70 117 301 0	83.601.366	96750.053	110.233.356	124.056.076	135.258.797	1 6/ 6/ 6/ 4/	8.497.644 170	564.127 182	2.938.782
4. freend annual caldflow		- 000'047'00	1C- 7/C'N/0'C+	100- 140/1460	77- 650750	CI- 007716	0- 00071/	- 701-07	HT1 16771	#1'01 0/7'1	040'07 470'0	00/10 000	100'0# 0/1	011776+ 000	01.012.00 22	17074/1/0/ 6	000100000	cc0/0c/ '06	0001007/011	0/0/000/1871	161.907.001	1 0/1/00/108	0.11 ##0.17.6#10	701 /71%00	707.076
	LCOE un	73,08	73,48	73,74	74,09	74,43	74,89	75,18 7	5,47 75,	97 76.	37 76,6	8 77.1	8 77.5	78.01	78,41	77,59	78,11	78,56	79,07	79,56	77,68	78,19	78,65 7	8.	79.39
Table G10 Cashflow for 25 years of the	te wind fam p	miect	50.000 kW	Cape	e Saint Jame	es (Canada)	of a	ren ce s ituati	-																
Item													Years												
	•	-	7	8	4	\$	0	1	8	Ĭ	=	12	13	14	15	16	11	18	19	20	21	51	53	74	52
(-) LCCCM <sub>WF</sub>	60.225.901							,							'		•	•							
$WT_{CM}$	27.686.278		,	,					,							•	•	•			,		,		
$T_{CM}$	24.219.295		,	,					,								•				,		,		
LWTGCH	1.959.783					,		,	,	,														,	
$CP_{CM}$	1.545.346								,														,		
TS CM	572.832								,																
21 CH	2.136.726																								
FU CM	1. /90.8/0		,		,	,	,	,	,		,							,					,	,	,
	120211																								
LCPM we (kWh/vr)	-	212.467.325	213.202.961 23	13.887.985 212	223.670 21	2.655.974 21	3.202.961 215	223.670 212	223.670 213.89	7.985 212.65	5.974 213.20	2.961 212.704	429 212.223	670 213.959.1	39 213.437.65	0 213.959.139	213.678.613	213.887.985	213.959.139	213.109.827	213.228.530 2	12.223.670 2	3.512.714 212	704.429 213	3.419.415
(+) AAR $(SM/yr)$	1	30.129.143	30.989.297 31	1.866.088 32.4	408.583 33.	.286.465 34	206.386 34.	900.500 35.7	73.012 36.95	4.893 37.66	1580 38.701	.386 39.576.	163 40.473	80 41.824.9	78 42.766.11	7 43.942.368	44.981.873	46.151.597	47.321.124	48.311.614	34.682.891 3	5.382.431 30	487.277 37.3	57.877 38.2	317.694
PPAR	1	30.129.143	30.989.297 31	1.866.088 32.4	408.583 33.	.286.465 34	206.386 34.	900.500 35.7	73.012 36.95	4.893 37.66	0.580 38.701	.386 39.576.	163 40.473.	880 41.824.9	78 42.766.11	7 43.942.368	44.981.873	46.151.597	47.321.124	48.311.614					
EMP			,														•				34.682.891 3	5.382.431 30	487.277 37.2	57.877 38.	317.694
(-) O&M wrcu		20.588.652	21.176.288 21	1.775.288 22.	145.848 22	.745.587 23	374.047 23.	848.205 24.4	44.263 25.25	1.713 25.73	8.770 26.444	.813 27.042.	405 27.655	568 28.578.7	21 29.221.64	7 30.025.220	30.735.351	31.534.456	32.333.422	33.010.054	29.394.775 2	9.987.509 30	923.746 31.5	76.700 32.4	474.765
$O\&M_{fixed}$		11.544.286	11.873.856 12	2.209.801 12.4	417.656 12	.754.019 13	.106.489 13.	372.438 13.7	06.743 14.15	9.584 14.42	0.968 14.828	.755 15.163.	927 15.507.	888 16.025.5	65 16.386.16	4 16.836.847	17.235.134	17.683.316	18.131.422	18.510.929	18.984.265	9.367.163 19	971.913 20.3	93.707 20.	973.809
$O\&M_{variable}$		9.044.366	9.302.432	9.565.487 9.	728.192 9	.991.568 10	267.558 10.	475.767 10.7	37.520 11.09	2.129 11.30	3.802 11.616	.058 11.878.	478 12.147.	781 12.553.1	56 12.835.48	4 13.188.373	13.500.217	13.851.140	14.202.000	14.499.125	10.410.511 1	0.620.346 10	951.834 11.1	82.993 11.	500.957
(+) LRCM		863.268	884.850	206.971	929.646	952.887	976.709 I.	011 721.100	26.155 1.05	1.809 1.071	\$104 1.105	.057 1.132.	683 1.16U	0.01.190.0	71.219.77					- 00.0					
(+) Depreciation		2.421.050	2181812	12 1021 1027	7 006710	2 608-080.	2 464-00/.	27 /07/619	067 067.68	100.0 286.1	111.6 160.0	201 1202	1607.5 06/	2.102.6 4/4	01 5:454.50 UI	208.025.5	1008.800.0	011/060.0	19070161101	1/0.008.0	000.086.0	4.085.122 2.479.046	74 CD7 C21		6/07/62
(=) rrojn bejore tax (-) Banama tax		0.038 7/13	0.006790101	0 200 200 00000	0 373 007	01 010 280	11 240.000	UI 0510210	31 001 1 001 1 00	100101 0/67	01201 01210	00001 1000	CV1 C1 0V8	10/11/00/14	02 12 22023	13 187 2010	13 404 562	13.845.470	14 106 3 37	107.101.01	1 230 107 0	0.614.720.11	0.46.192 11.1	77363 11	100.004
(+) NEPDM	037 331	LLL	701	806	812	100 LC8	843	853	848	0 00		18 18	S 141741	098	881	500	200100101	051	520	500	1001	1.041	1074	000	1128
RFI COL	221313	. '		-			È		, ,	` ~ '		5					1	· ·	2					- -	
REPORT	-	156	153	150	145	142	138	13.4	131		55					,	,	,	,	,	,	,	,	,	,
OREP	711.018		'	'	. '											,		,			,		,	,	,
GHGRCH	'	621	638	656	668	686	705	719	737 7	61 7	76	7 81	5 83	862	881	905	927	951	975	566	1.021	1.041	1.074	960	1.128
(=) Profit after tax w/out interest	,	3.796.830	3.893.674 3	3.992.859 4.0	088.578 4.	.192.062 4	298.470 4.	403.382 4.5	13.607 4.63	1.393 4.74	8.672 4.863	.942 4.984	138 5.107.	55 5.240.8	60 5.370.28	2 4256.209	4.361.773	4.471.722	4.583.926	4.695.448	-1.132.195 -	1.135.642 -1	196.376 -1.2	05.256 -1.	254,173
(-) Debt payments	,	1	3.146.660 3.1	225.326 3.30	3.5 3.5	388.608 3.4	13.323 3.5	60.156 3.64	9.160 3.740.	389 3.833.	3.929.7	47 4.027.95	0 4.128.65	0 4.231.907	4.337.705	,	,	,	,	,	,	,	,	,	,
$(+) RCM_{WF}$	•	2.621.739	2.687.282 2	2.754.464 2.8	823.326 2.	.893.909 2	966.257 3.	040.413 3.1	16.424 3.19	4.334 3.27/	1.193 3.356	.047 3.439.	949 3.525.	947 3.614.0	96 3.704.44	8 3.797.060	3.891.986	3.989.286	4.089.018	4.191.243	4.296.024	4.403.425 4	513.511 4.0	26.348 4.7	742.007
(+) Depreciation		2.431.036	2.491.812 2	2.554.108 2.4	617.960 2	.683.409 2	750.494 2.	819.257 2.8	89.738 2.96	1.982 3.03	5.031 3.111	.932 3.189.	730 3.269.	174 3.351.2	10 3.434.99	1 3.520.865	3.608.887	3,699.109	3.791.587	3.886.377	3.983.536	4.083.125 4	185.203 4.2	89.833 4.	397.079
(=) Free net cashflow	-59.293.569	8.849.605	5.926.109	5.076.105 6.	223.905 6	.380.773 6	541.898 6.	702.895 6.8	70.608 7.04	7.219 7.219	2097 7.402	.175 7.585.	826 7.7741	86 7.974.2	59 8.172.01	6 11.574.134	11.862.647	12.160.117	12.464.531	12.773.068	7.147.366	7.350.908	502.337 7.7	10.925 7.3	884.912
$\Sigma$ free net annual cashflow		50,443.964 -	44.517.855 -51	8.441.751 -32	217.845 -22	837.073 -19	295.175 -12	592.280 -5.	21.672 1.52	5.648 8.54:	5.644 15.94/	.820 23.535.	646 31.30/.	732 39.281.9	91 47.454.00	0 59.028.140	70.890.787	83.050.904	95.515.435	108.288.503	115.435.868 1	22.786.776 1	0.289.113 158	cel 145	5.884.950
	$LCOE_{wro}$	84,30	84,97	85,66 2	86,12	86,82	87,54	88,12 8	8,81 89,	72 90.	16 18	3 91,8	4 92,5	93,61	94,37	94,05	94,85	95,75	96,65	97,43	93,92	94,62	95,66 5	6,43 5	97,44

### **APPENDIX H**

LCOE wso Mode	l Inputs									_		Financial Ind	exes		Notes
Legend				_			-		Revenues		Notes	Inflation	rate (ifr)	2,50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns N	otes	Depreciation		Notes	Power Purchase Agreement Rate	0,08581	[S/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_ow)	80,00%	%]	Depreciation rate per year	4,00%	[%/yr]	Expected Market Price	0,06007	[\$/kWh]		WACC proj	4,9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70,00%	[%]		UCRF	0,070243	[-]
Wind Project Information		Notes	Levelized Replacement	Cost Model N	otes	Wind Farm Removal (	Cost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR <sub>CM</sub>	16,8442 [\$	kW]	DCM WF	1.339,9154	[\$/kW]	REI <sub>CM</sub>	70,8203	$[\text{KW}_e]$	WF CM		50.000	$[kW_o/yr]$
Project Location	Aracati (Brazil)		Depr <sub>WT<sub>int</sub></sub>	76,9840 [\$	kW]	RM WT	22,3284	[\$/kW]	LCCCM WF	1.204,5180	[\$/kW]	WF <sub>cap</sub>		50.000	[kW]
Turbine Model Number of Wind Turbines (N)	vestas v90-2MW	[-]	WI CM	553,7256 [S 484.3850 [S	kwj vwi	WF cap N	50.000	[KW]	LRCM if.	2 50%	[S/KW] [%/wr]	NWT .		25	[-] [/W]
Turbine Size	2.000	[kW]	N N	25	vr]	M <sub>WT</sub>	100	[m-h]	Up Wand	30,00%	[%]	N rated		5	[-]
Wind Farm Capacity (WF cap)	50.000	[kW]	ifr	2,50% [9	5/yr]	C <sub>Mbrmyr</sub>	85,00	[\$/m-h]	n <sub>w</sub>	6	[yr]	Ncol		5	[-]
Rotor Diamenter (D)	90,0	[m]	Depr	60,1398 [\$	kW]	N <sub>mmur</sub>	3	[-]	REP CM	0,00002628	[\$/kW <sub>e</sub> h]	D		90,0	[m]
Swept Area per Turbine (A)	6.361,7	[m <sup>2</sup> ]	$Y_{RC}$	15	yr]	$D_{m_{BW_{BT}}}$	2,0	[d]	AEP anail/H prod	5.693	[kW/yr]	L <sub>x 200</sub>		1.800	[m]
Hub height (H)	105,0	[m]	TO CM	0,000033 [\$	kW]	$C_{sud_{BM_{BT}}}$	2.500,00	[\$/d]	ifr	2,50%	[%/yr]	$L_{x_{col}}$		2.430	[m]
Wind speed measured at $(H_0)$	10,0	[m]	77	1.798.743 [\$	kW]	RM CT	20,1954	[\$/kW]	8	0,1496	[\$/kWeh]	SD <sub>s</sub>		450	[m]
Terrain rugosity factor (a)	0,14		V	237.699.000 [1	W]	WF cap	50.000	[kW]	£0	0,116883	[\$/kWeh]	SD <sub>xcol</sub>		540	[m]
Lifetime of Wind Farm (N)	0,3928	[-] [vr]	V <sub>0</sub>	1.457.72 [\$	kW1	M <sub>WT</sub>	30	[=] [m-h]	OREP or	13 0764	[yr] [\$/kW]]	PC au		8.700	[n/yr]
Production Efficiency (WF as )	11.2%	[96]	PR	0.70	[-]	C <sub>Mr</sub>	85.00	[\$/m-h]	LCCCM	2.7664	[\$/kW]	AEP		49.057.055	[kW_h/yr]
Availability	98,4%	[%]	b	-1,94	EI	N <sub>m</sub>	3	[-]	LCCCM WF	1.204,5180	[\$/kW]	$\eta_{max}$		20,98%	[%]
· · ·	359	[d/yr]	LRCM	16,8443 [\$/	kW]	D <sub>n</sub> w	2,0	[d]	WACC proj	4,9000%	[%/yr]	$\eta_{mex_{mex}}$		25,00%	[%]
						C <sub>nd max</sub>	3.500,00	[\$/d]	$\Psi_{total}$	30,0%	[%]	P&D <sub>LM</sub>	factor	0,839325	[-]
Wind Farm Life-Cycle Capita	al Cost Model	Notes	Wind Farm O&M Cost 1	Model N	otes	S&RV	1.297,3916	[\$/kW]	ifr	2,5%	[%/yr]	NWT		25	[-]
WT CM	553,7256	[\$/kW]	O&M <sub>fund</sub> cu	0,098275 [\$/	kWh]	WF cap	50.000	[kW]	n <sub>w</sub>	10	[yr]	Α		6.361,7	[m <sup>2</sup> ]
CM WT	265,32	[\$/kW]	LCCCM WF	1.204,5180 [\$	kW]	NWT	25	[-]	$CR_f$	80,0%	[%]	AEP rated		438.000.000	$[kW_eh/yr]$
RC WT	73,70%	[%/\$/kW]	Φ	0,000001%	%]	$A_{WT}$	43,00	[m <sup>2</sup> /wt]	GHG.R CM	1.602,9913	[\$/tCO2]	$P\&D_{LM}$			
C kW	400,00	[\$/kW]	ЦС	0,0530 [\$/	kWh]	M <sub>kr sur</sub>	3,0	[m-h]	$\sum_{AEP} \Delta EP$	18,6	[tCO2/MWah]	λ <sub>a</sub>		7,00%	[%]
IPI T	10,00%	[%] (6.430)	N	25	yr]	C <sub>Mhrsanv</sub>	85,00	[\$/m-h]	∠ run aval <sub>y11-1ys</sub>	49.057	[MW <sub>e</sub> h]	A 181		0,00%	[%]
T CM	484,3839	[5/KW] [kg]	9r 0&M	2,50% [7	www.hl	D Name	30	[-]	n	0.00041	[yr]	2		5,00%	[%]
RC z	26 30%	[%5]	MIC	71 5608	8/h]	C <sub>m</sub>	3 500.00	[\$/d]	GHG <sub>m</sub>	0.00003	hCO-MW-bl	LCPM <sub>wr</sub>		49.057.055	[/~]
Crited	0,1900	[\$/kg]	TLC	124,5688	5/h]	RVM wF	61.0184	[\$/kW]	E	46,3820	[\$/tCO <sub>2</sub> ]				[
LWTG CM	39,1957	[\$/m/kW]	R	30,00%	%]	Nwr	25	[-]	REPIM distribution	100,0%	[%]	Proiect Finan	cing		Notes
WF cap	50.000	[kW]	ifr	2,50% [%	/yr]	WTS VM	1,4442	[\$/kW]	$\xi_1 REI_{CM}$	25,0%	[%]	Debt ratio		50,0%	[%]
$L_g$	13.950	[m]	N	25	yr]	WF cap	50.000	[kW]	$\xi_2 REP_{CM}$	25,0%	[%]	Debt term		14	[yr]
CAB cost	2.000,00	[\$/m]	n <sub>mlb</sub>	48	[h]	ifr	2,50%	[%/yr]	$\xi_3 \text{ OREP}_{CM}$	25,0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30,9069	[\$/kW]	n <sub>tih</sub>	100	[h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	25,0%	[%]	Debt in	terest rate	5,00%	[%/yr]
EF c	400,00	[\$/kW]	AAR	4.209.586	5M]	WTweight	200.000	[kg]	REPIM	421,7220	[\$/proj]	Debt value		29.920.566	[\$]
ç	0,08%	[%]	AEP avail	49.057.055 [kV	/h/yr]	Csteel	0,1900	[\$/kg]		r		Debt pa	yments	3.022.694	[\$/yr]
TS CM	11,4566	[\$/kW_c]	O&M <sub>WFCM</sub>	0,124115 [\$Ak	Wh/yr]	TS VM	0,9965	[\$/kW]	Exchange rates		Notes	Equity rati	o	50,0%	[%]
IL <sub>c</sub>	0,0400	[5/m]	0.01			WF cap	50.000	[KW]	EUR/USD dec2010	1,3252	[-]	Equity	value	29.920.566	[5]
IL,	1.200	[1/KW]	O&M O&Mmanag(A)	0.000070 (S)	otes	ifr	2,50%	[%/yr]	CAN/USD dec2010	0,9998	[-]	Discour	ii rate	9,00%	[%/yr]
L <sub>1</sub> SP	112.00	(C/AWA)	SC OLM Work down	20	cwnj ca	T T	128.000	[yr] [ka]	BRL/USD dec2010	0,5986	[-]	Initial Paculte	Summary	<i>sticor</i>	Noter
SI cu	42 7245	(\$/m <sup>2</sup> /kW)	Feh/Jun/Nov	2,0	(d)	RCM	1.278.8970	[NE]	Conditions for LCOE	Г	Notes	67.6756	vr	70 7929	NULS NEW
WF	50.000	[\$/m /k W]	Hours required	48.0	h]	Real WF	11270,0770	[wkn]	O&M WECH		TORS	67,8295	NT 2	69.8226	NT 15
WT	42 5238	[\$/kW]	USCORM	0.000254 (\$/	Wh1	Hours Distribution	FLH .[h]	H .[h]	O&M	1	[1/0]	68.0385	NT.	70.0172	NT 12
Bld	500.00	[\$/m <sup>2</sup> ]	Nwr	25	[-]	January	744	740	(%) ccm	80.0%	[%]	68,2028	NT (	70.2229	NT 10
Bld area	300,0	[3: III ] [m <sup>2</sup> ]	Frequency	1,0 [p	er yr]	February <sup>(*)</sup>	672	648	REPIM		,	68,4513	Vr s	70,4241	NT 18
PO CM	35,9374	[\$/kW]	Repair time	4,0	[h]	March	744	736	REPIM distribution			68,6399	yr 6	70,7751	yr 19
FS	19,88	[\$/kW]	Hours required	100,0	[h]	April	720	712	$\xi_1 REI_{CM}$	1	[1/0]	68,8858	yr 7	70,3899	yr 20
DT	87,22	[\$/kW]	SC O&M+USC O&M	148,0 [h	/yr]	May	744	736	$\xi_2 \operatorname{REP}_{CM}$	1	[1/0]	69,1016	$yr_8$	70,5764	yr 21
EG	404,52	[\$/kW]		0,000324 [\$#	Wh/yr]	June <sup>(*)</sup>	720	696	$\xi_3 \text{ OREP }_{CM}$	1	[1/0]	69,2789	yr 9	70,8470	yr 22
F <sub>CM</sub>	3,7712	[\$/kW]				July	744	736	$\xi_4 GHG.R_{CM}$	1	[1/0]	69,5063	yr 10	71,1302	yr 23
WACC proj	4,900%	[%/yr]				August	744	736	P&D <sub>1M</sub>			69,7421	yr 11	71,3951	yr 25
n <sub>fin</sub>	1,0	[yr]	1			September	720	712	λ	1	[1/0]	70,0200	yr 12	69,6991	Mean
WFOU CCC.CV	2,4042	[%] [\$/VW]	1			November <sup>(*)</sup>	744	696	×	1	[1/0]	70,2471	yr 13 87 14	-0.4/79	SU Y (dame-)
ĸ	0,20%	[%]	1			December	744	736	Å	1	[1/0]	70,4039	69,6991	US\$/MWb	valid !
	1.204.5180	[\$/kW]	1			Total [h/vr]	8,760	8.616	~ <u>n</u>	p.s.: I = yes an	d 0=no	LCOE was	0.069699	US\$/kWh	
		T-1.1.1				I chan [h/yr]	0.700					L	0,009099		

**Figure H.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(A)}$ . Source: Own elaboration

LCOE wso Mode	l Inputs										Financial Ind	exes		Notes
Legend						-		Revenues		Notes	Inflation	rate (ifr)	2,50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated vellow cells.	O&M warranty conditio	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0,16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	on about the project.	Costs covered by manufacturer (O&M_m)	80,00%	[%]	Depreciation rate per year	4,00%	[%/yr]	Expected Market Price	0,11403	[S/kWh]		WACC proj	4,9000%	[%/yr]
Gray cells are not used.		Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70,00%	[%]		UCRF	0,070243	[-]
Wind Project Information	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	entive Model	Notes	Wind Farm Life	-Cycle Prod	luction Model	Notes
Project Name	Firestor Wind Form	AR au	16 8442	(\$/kW]	DCM	1 339 9154	[S/kW]	REL au	70.8203	(S/kW )	WF au	-cycle 1704	50.000	fkW /yr]
Project Location	Corvo Island (Portagal)	Deprov	76,9840	[\$/kW]	RM wr	22.3284	[\$/kW]	LCCCM ws	1,204,5180	[\$/kW]	WF		50.000	[kW]
Turbine Model	Vestas V90-2MW	WICH	553,7256	[\$/kW]	WF	50.000	[kW]	LRCM	16.8443	[\$/kW]	Nwr		25	[-]
Number of Wind Turbines (Nwr)	25 [-]	Tax	484,3859	[\$/kW]	Nwr	25	[-]	ifr	2.50%	[%/vr]	WTented		2.000	[kW]
Turbine Size	2.000 [kW]	N	25	[yr]	M	100	[m-h]	Ψ <sub>total</sub>	30,00%	[%]	N		5	[-]
Wind Farm Capacity (WF cap)	50.000 [kW]	ifr	2,50%	[%/yr]	C <sub>Mbratur</sub>	85,00	[\$/m-h]	n	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90,0 [m]	Depry	60,1398	[\$/kW]	N <sub>mma</sub>	3	[-]	REP CM	0,00001039	[\$/kW_h]	D		90,0	[m]
Swept Area per Turbine (A)	6.361,7 [m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	D	2,0	[d]	AEP avail/H prod	10.458	[kW/yr]	L		1.800	[m]
Hub height (H)	105,0 [m]	TO CM	0,000033	[\$/kW]	Cod	2.500,00	[\$/d]	ifr	2,50%	[%/yr]	L. ~~		2.430	[m]
Wind speed measured at $(H_0)$	10,0 [m]	TI	1.798.743	[\$/kW]	RM <sub>CT</sub>	20,1954	[\$/kW]	3	0,1086	[\$/kW <sub>e</sub> h]	$\hat{SD}_{x}$		450	[m]
Terrain rugosity factor (a)	0,14 [-]	V	237.699.000	[kW]	WF car	50.000	[kW]	£0	0,075000	[\$/kW <sub>e</sub> h]	SD <sub>scol</sub>		540	[m]
Betz Limit's coefficient (C PBetz)	0,5926 [-]	Va	6.100.000	[kW]	NWT	25	[-]	n <sub>e</sub>	15	[yr]	FLH <sub>wf</sub>		8.760	[h/yr]
Lifetime of Wind Farm (N)	25 [yr]	CO	1.457,72	[\$/kW]	Muran	3,0	[m-h]	OREP CM	21,2289	[\$/kWe]	PC PM			
Production Efficiency (WF PE)	20,6% [%]	PR	0,70	[-]	CMbrar	85,00	[\$/m-h]	LCCCM <sub>WFoworce</sub>	2,4451	[\$/kW]	AEP anail		90.107.610	[kW_eh/yr]
Aváilability	98,4% [%]	b	-1,94	[-]	N.,	3	[-]	LCCCM WF	1.204,5180	[\$/kW]	$\eta_{max}$		20,98%	[%]
-	359 [d/yr]	LRCM	16,8443	[\$/kW]	D,	2,0	[d]	WACC proj	4,9000%	[%/yr]	$\eta_{wecz_{n=0}}$		25,00%	[%]
					C <sub>ml m</sub>	3.500,00	[\$/d]	$\Psi_{total}$	30,0%	[%]	P&DLM	factor	0,839325	-
Wind Farm Life-Cycle Capita	al Cost Model Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1.297,3916	[\$/kW]	ifr	2,5%	[%/yr]	NWT		25	[-]
WTCM	553,7256 [\$/kW]	O&M fund	0.098275	[\$/kWh]	WF	50.000	[kW]	n <del>-</del>	15	[vr]	Α		6.361.7	(m <sup>2</sup> )
CM <sub>WT</sub>	265,32 [\$/kW]	LCCCMWF	1.204,5180	[\$/kW]	N <sub>WT</sub>	25	[-]	CR	80,0%	[%]	AEP rated		438.000.000	[kW_h/yr]
RC WT	73,70% [%/\$/kW]	σ	0,0000001%	[%]	Awr	43,00	[m <sup>2</sup> /wt]	GHG.R CM	825,2491	[\$/tCO <sub>2</sub> ]	P&Din			
CAW	400,00 [\$/kW]	LLC	0,0530	[\$/kWh]	M	3,0	[m-h]	LCERco	34,2	[tCO2/MWah]	$\lambda_a$		7,00%	[%]
IPT	10,00% [%]	N	25	[yr]	Culture	85,00	[\$/m-h]	$\sum AEP_{aval}$	90.108	[MWeh]	2,41		0,00%	[%]
Тсм	484,3859 [\$/kW]	ifr	2,50%	[%/yr]	N <sub>-</sub>	3	[-]	n w	25	[yr]	λd		5,00%	[%]
Tmass	138.000 [kg]	O&M variable or	0,048925	[\$/kWh]	D	3,0	[d]	GHG <sub>EM a</sub>	0,00041	[tCO2/MWah]	λ.,		5,00%	[%]
RCT	26.30% [%/\$/kW]	MLC	71.5608	[\$/h]	Cmd	3.500.00	[\$/d]	GHG	0.00003	[tCO:/MW.h]	LCPM wr		90,107,610	[kW.h/yr]
Cuted	0.1900 [\$/kg]	TLC	124,5688	[\$/h]	RVM we	61.0184	[\$/kW]	E	13.0000	[S/tCO <sub>2</sub> ]				
LWIGen	39 1957 [\$/m/kW]	R	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[96]	Project Finan	cinø	ſ	Notes
WF	50.000 [kW]	ifr	2.50%	[%/vr]	WTS und	1 4442	[S/kW]	Č. RELat	25.0%	[%]	Deht ratio		50.0%	[%]
L	13.950 [m]	N	25	[vr]	WF	50.000	[kW]	Č. REP cv	25.0%	[%]	Dehtter		14	[vr]
CAB	2.000.00 [S/m]	R!!		0-1	m cap			53 HLL CM			Deptient			6)
CP.cu	30.9069 [\$//W]	intro (	48	h	ifr	2.50%	[%/vr]	Č, OREP CH	25.0%	[%]	Debt gr	ace period		IVE
FF		17 alla	48	[h] [h]	ifr N	2,50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM $\tilde{\zeta}_4$ GHG R CM	25,0%	[%]	Debt tent Debt gri Debt in	ace period terest rate	5.00%	[95/yr]
	400.00 [\$/kW]	n elle AAR	48 100 14 679 146	[h] [h] [\$M]	ifr N WT	2,50% 25 200.000	[%/yr] [yr] [ke]	$\tilde{\zeta}_3$ OREP CM $\tilde{\zeta}_4$ GHG.R CM <b>REPIM</b>	25,0% 25,0% 229,3246	[%] [%]	Debt gri Debt ini Debt value	ace period terest rate	5,00%	[yr] [%/yr]
C	400,00 [\$/kW] 0.08% [%]	n the AAR AEP	48 100 14.679.146 90.107.610	[h] [h] [\$M] [kWb/yr]	ifr N WT <sub>weight</sub>	2,50% 25 200.000 0.1900	[%/yr] [yr] [kg] [S/ke]	$\tilde{\xi}_3 \text{ OREP }_{CM}$ $\tilde{\xi}_4 \text{ GHG.R }_{CM}$ <b>REPIM</b>	25,0% 25,0% <b>229,3246</b>	[%] [%] [\$/proj]	Debt term Debt gri Debt ini Debt value Debt pa	ace period terest rate	5,00% 29.869.613 3.017.547	[9r] [%/yr] [\$] [\$/yr]
S	400,00 [5/kW] 0,08% [%]	n th AAR AEP avail	48 100 14.679.146 90.107.610	[h] [h] [\$M] [kWh/yr]	ifr N WT <sub>weight</sub> C <sub>steel</sub>	2,50% 25 200.000 0,1900 0.9965	[%/yr] [yr] [kg] [\$/kg]	ζ <sub>3</sub> OREP <sub>CM</sub> ζ <sub>4</sub> GHG.R <sub>CM</sub> <b>REPIM</b>	25,0% 25,0% 229,3246	[%] [%] [\$/proj]	Debt term Debt in Debt value Debt pa Faulty mil	ace period terest rate syments	5,00% 29.869.613 3.017.547 50.0%	[9/yr] [%/yr] [\$/yr]
ς τs <sub>cm</sub> τ	400,00 [S/kW] 0,08% [%] 11,4566 [S/kW <sub>c</sub> ]	n eth AAR AEP avail O&M WFCM	48 100 14.679.146 90.107.610 0,147200	[h] [h] [\$M] [kWh/yr] [\$/kWh/yr]	ifr N WT <sub>weight</sub> C <sub>steel</sub> TS <sub>VM</sub> WF	2,50% 25 200.000 0,1900 0,9965 50.000	[%/yr] [yr] [kg] [\$/kg] [\$/kW] [\$/kW]	$\zeta_3^2 OREP_{CM}$ $\zeta_4 GHGR_{CM}$ <b>REPIM</b> <b>Exchange rates</b>	25,0% 25,0% 229,3246	[%] [%] [\$/proj] Notes	Debt term Debt gr Debt value Debt value Debt pa Equity ratio	ace period terest rate syments o	5,00% 29.869.613 3.017.547 50,0%	[yr] [%/yr] [\$] [\$/yr] [%]
ς TS <sub>CM</sub> πL <sub>c</sub>	400,00 [S'kW] 0,08% [%] 11,4566 [S'kW <sub>e</sub> ] 0,0400 [S'm]	n elle AAR AEP avail O&M WFCM	48 100 14.679.146 90.107.610 0,147200	[h] [h] [\$M] [kWh/yr] [\$/kWh/yr]	ifr N WT <sub>wright</sub> C <sub>steel</sub> TS <sub>VM</sub> WF <sub>cap</sub>	2,50% 25 200.000 0,1900 0,9965 50.000	[%/yr] [yr] [kg] [S/kg] [S/kW] [kW]	$\zeta_3^- OREP_{CM}$ $\zeta_4^- GHGR_{CM}$ <b>REPIM</b> <b>Exchange rates</b> EUR/USD dec2010 CUMUED	25,0% 25,0% 229,3246 1,3252	[%] [%] [\$/proj] Notes [-]	Debt rem Debt gr Debt int Debt value Debt value Equity rati Equity v	ace period terest rate syments o value	5,00% 29.869.613 3.017.547 50,0% 29.869.613	[yr] [%/yr] [\$] [\$/yr] [%] [\$]
с ТS <sub>см</sub> П.,	400,00 [5/kW] 0,08% [%] 11,4566 [5/kW <sub>4</sub> ] 0,0400 [5'm] 1.200 [1/kW]	n the AAR AEP avoil O&M <sub>WFCM</sub>	48 100 14.679.146 90.107.610 0,147200	[h] [h] [\$M] [kWh/yr] [\$#Wh/yr] Notes	ifr N WTweight C storel TS VM WF cop ifr	2,50% 25 200.000 0,1900 0,9965 50.000 2,50%	[%/yr] [yr] [kg] [S/kg] [S/kW] [kW] [%/yr]	$\xi_{3}^{c}$ OREP <sub>CM</sub> $\xi_{4}^{c}$ GHG.R <sub>CM</sub> <b>REPIM</b> <b>Exchange rates</b> EUR/USD dec2010 CAN/USD dec2010 DD (1000	25,0% 25,0% <b>229,3246</b> 1,3252 0,9998	[%] [%] [\$/proj] Notes [-] [-]	Debt term Debt gri Debt value Debt value Equity rati Equity v Discour	ace period terest rate syments o value ut rate	5,00% 29.869.613 3.017.547 50,0% 29.869.613 9,00%	[9r] [%/yr] [\$] [\$/yr] [%] [\$] [%/yr]
ς ΤS <sub>CM</sub> ΤL <sub>c</sub> ΤL <sub>r</sub> L <sub>i</sub>		n ith AAR AEP avoid O&M WFCM O&M O&Massag(A) SC 00M	48 100 14.679.146 90.107.610 0,147200 0,000038	[h] [h] [\$M] [kWh/yr] [\$/kWh/yr] Notes [\$/kWh/	ifr N WTwight C <sub>stat</sub> TS <sub>VM</sub> ifr N T	2,50% 25 200.000 0,1900 0,9965 50.000 2,50% 25 120.000	[%/yr] [yr] [kg] [S/kg] [S/kW] [kW] [%/yr] [yr] [yr]	$\zeta_{a}^{c}$ , OREP <sub>CM</sub> $\zeta_{a}^{c}$ GHC.R.CM <b>REPIM</b> <b>Exchange rates</b> EUR/USD <sub>dav2010</sub> CAN/USD <sub>dav2010</sub> BRL/USD <sub>dav2010</sub>	25,0% 25,0% <b>229,3246</b> 1,3252 0,9998 0,5986	[%] [%] [\$/proj] Notes [-] [-] [-]	Debt term Debt gri Debt value Debt value Equity rati Equity v Discour	ace period terest rate syments o value 11 rate	29.869.613 3.017.547 50.0% 29.869.613 9,00%	[yr] [%/yr] [\$] [\$/yr] [%] [\$] [%/yr]
ς TS <sub>CM</sub> TL <sub>c</sub> TL <sub>r</sub> L <sub>r</sub> SB <sub>c</sub>		n ith AAR AEP evoil O&M WFCM O&M O&Massag(A) SC 0&M Work days	48 100 14.679.146 90.107.610 0,147200 0,000038 2,0	[h] [h] [\$M] [kWh/yr] [\$/kWh/yr] Notes [\$/kWh] [d]	ifr N WTweight C start TS VM WF cop ifr N Tmax	2,50% 25 200.000 0,1900 0,9965 50.000 2,50% 25 138.000	[%/yr] [yr] [kg] [\$/kg] [\$/kW] [kW] [%/yr] [yr] [kg]	ζ <sub>3</sub> OREP <sub>Col</sub> ζ <sub>4</sub> GHCR <sub>Cu</sub> <b>REPIM</b> Exchange rates EUR/USD <sub>dec2010</sub> CAN/USD <sub>dec2010</sub> BO RUG Dec2010 BO RUG DEC2010	25,0% 25,0% <b>229,3246</b> 1,3252 0,9998 0,5986	[%] [%] [\$/proj] Notes [-] [-] [-]	Debt term Debt gr Debt ini Debt value Debt value Equity rati Equity value Discour	ace period terest rate syments o value ut rate Summary	29.869.613 3.017.547 50,0% 29.869.613 9,00% of LCOE was	(yr) (%/yr) (\$) (\$/yr) (%) (\$) (%/yr) Notes
ς ΤS <sub>CM</sub> Π., L, SB <sub>c</sub> SI <sub>CM</sub>	400.00 [\$kW] 0.08% [%] 11,4566 [\$kW,] 0.0400 [\$m] 1.200 [1/kW] 3.000 [m] 113,00 [\$kWh]	n ith AAR AEP avail O&M WFCM O&M ORAMINISTICA SC OAM Work days Feb:/Jun/Nov	48 100 14.679.146 90.107.610 0,147200 0,000038 2,0 6	[h] [h] [\$M] [kWh/yr] [\$/kWh/yr] Notes [\$/kWh] [d] [d]	ifr N WTweight C stat TS VM WF cap ifr N T mass RCM WF	2,50% 25 200.000 0,1900 0,9965 50.000 2,50% 25 138.000 1.278,8970	[%/yr] [yr] [kg] [S/kg] [\$/kW] [kW] [%/yr] [yr] [kg] <b>[\$/kW]</b>	$ \begin{aligned} & \vec{\xi}_1 \ OBEP_{Cut} \\ & \vec{\xi}_2 \ GHOR_{Cut} \\ \hline & \textbf{REPIM} \\ \hline & \textbf{Exchange rates} \\ & EUR(SD_{duc2010} \\ & CAN(USD_{duc2010} \\ & BRLUSD_{duc2010} \\ \hline & BRLUSD_{duc2010} \\ \hline & \textbf{Conditions for $LCOE_{uut}$} \end{aligned} $	25,0% 25,0% 229,3246 1,3252 0,9998 0,5986	[%] [%] [\$/proj] [\$/proj] [-] [-] [-] Notes	Debi term Debt yn Debt yn Debt value Debt yalue Debt ya Equity yr atli Equity yr Discour Initial Results 73,1255	ace period terest rate syments o value ut rate Summary yr 1	1 5,00% 29,869,613 3,017,547 50,0% 29,869,613 9,00% of LCOE wire 78,4712	(yr) (%/yr) (\$) (\$/yr) (%) (\$) (%/yr) <i>Notes</i> <i>yr</i> 15
$\zeta$ $TS_{CM}$ $TL_c$ $TL_r$ $SB_c$ $SI_{CM}$ $WF_{cop}$	400.00 [S/kW] 0.08% [%] 11.4566 [S/kW_] 0.0400 [S/m] 1.200 [1/kW] 3.000 [m] 113.00 [S/kWh] 42.7345 [S/m²/kW]	n ith AR AEP sould O&M WFCM O&M O&Mmenog(A) SC 08M Work days Feb Jun/Nov Hours required	48 100 14.679.146 90.107.610 0,147200 1 0,000038 2.0 6 48.0	[h] [k] [\$M] [kWh/yr] [\$/kWh/yr] Notes [\$/kWh] [d] [d] [h]	iff N WT <sub>weight</sub> C <sub>stad</sub> TS <sub>VM</sub> WF <sub>cop</sub> iff N T <sub>maxe</sub> RCM <sub>WF</sub>	2,50% 25 200.000 0,1900 0,9965 50.000 2,50% 25 138.000 1.278,8970	[%/yr] [yr] [kg] [S/kg] [S/kW] [%/yr] [yr] [kg] [\$/kW]	ζ <sub>1</sub> OREP cu ζ <sub>1</sub> GHG Rcu <b>REPIM</b> Exchange rates EUR/USD dou2010 CANUSD dou2010 RRL/USD dou2010 RRL/USD dou2010 Conditions for LCOE vu Odd wrcu	25,0% 25,0% <b>229,3246</b> 1,3252 0,9998 0,5986	[%] [%] [\$/proj] [\$/proj] [-] [-] [-] Notes	Debt telm Debt gri Debt m Debt value Debt value Equity rati Equity rati Equity rati Thitial Results 73,1255 73,5187	ace period terest rate syments o value at rate <u>Summary</u> yr 1 yr 2	5,00% 29,869,613 3,017,547 50,0% 29,869,613 9,00% of LCOE was 78,4712 77,6515	(yr) [%/yr] [%] [%/yr] [%] [%] [%/yr] Notes yr 1s yr 1s
$\zeta$ $TS_{CM}$ $TL_e$ $TL_r$ $SB_e$ $SI_{CM}$ $WF_{cop}$ $WT_{inst}$	400.00 [\$/kW] 0.08% [%] 11.4566 [\$/kW_4] 0.0400 [\$'m] 1.200 [1/kW] 3.000 [m] 113.00 [\$/kWh] 42.7345 [\$/m <sup>2</sup> /kW] 5.0000 [kW]	n sis AR <u>AF</u> <sub>sould</sub> <u>O&amp;M vrCM</u> <u>O&amp;M vrCM</u> <u>SC GMM vrCM</u> <u>SC GMM vrCM</u> Work days Feb/Jun/Nov Hours required <u>USC GMM</u>	48 100 90.107.610 0,147200 0,147200 2,0 6 48,0 0,000138	[h] [h] [SM] [kWh/yr] [s/kWh/yr] [s/kWh/yr] [d] [d] [h] [s/kWh]	if N WT <sub>wight</sub> C <sub>stat</sub> TS <sub>VM</sub> WF <sub>cop</sub> if N T <sub>mass</sub> RCM <sub>WT</sub> Hours Distribution	2,50% 25 200.000 0,9965 50.000 2,50% 25 138.000 1.278,8970 FLH <sub>vf</sub> (h)	[%/yr] [yr] [kg] [S/kW] [kW] [%/yr] [yr] [kg] [\$/kW] [\$/kW]	ζ <sub>1</sub> OREP cu           ζ <sub>1</sub> GHCR cu           REPIM           Exchange rates           EUR/USD dec2010           CAN/USD dec2010           BRL/USD dec2010           Conditions for LOCE www           O&M wrst           O&M wrst	25,0% 25,0% <b>229,3246</b> 1,3252 0,9998 0,5986	[%] [%] [%/proj] Notes [-] [-] [-] Notes [1/0]	Debt telm Debt gr Debt tim Debt value Debt pa Equity value Discour Initial Results 73,1255 73,5187	ace period terest rate yments o value tt rate Summary yr 1 yr 2 yr 3	5,00% 29,869,613 3,017,547 50,0% 29,869,613 9,00% of LCOE w10 78,4712 77,6515 78,1612	yr] [%/yr] [\$] [\$/yr] [%] [%] [%/yr] <i>Notes</i> <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 16
ς TS <sub>CM</sub> TL <sub>e</sub> TL <sub>r</sub> SB <sub>e</sub> SI <sub>CM</sub> WF <sub>inep</sub> WT <sub>inep</sub> Bid <sub>Just</sub>	40000 [25.W] 0.08% [%] 11,4566 [54.W] 0.0400 [5m] 1.200 [1/kW] 3.000 [m] 113.00 [5kW] 42,7345 [5m <sup>2</sup> /kW] 50.000 [kW] 50.000 [5m <sup>2</sup> ]	n its AAR AEP event O&M verces O&M of Museue(1) SC and Work days Fels/Jun/Nov Hour required USC acts N wr	48 100 14.679.146 90.107.610 0,147200 1 0,000038 2,0 6 6 48,0 0,000138 2,5	[h] [sM] [kWh/yr] [skwh/yr] Notes [s/kWh] [d] [d] [h] [s/kWh] [-]	iff N WTwight C stand TS VM WF cop iff N Tmass RCM wr Hours Distribution January	2,50% 25 200,000 0,9965 5,50% 25 138,000 <i>I.278,8970</i> <i>FLH</i> <sub>vf</sub> [h] 744	[%/yr] [yr] [kg] [S/kg] [S/kW] [kW] [%/yr] [yr] [kg] [\$/kW] 740	ζ <sub>1</sub> OREP cu ζ <sub>1</sub> GHGR cu REPIM Exchange rates EUR(ISD dec2010 CAN/ISD dec2010 RRU/ISD dec2010 RRU/ISD dec2010 Odd mccu Odd mccu (%) ccm	25,0% 25,0% 229,3246 1,3252 0,9998 0,5986 1 80,0%	[%] [%] [%/proj] Notes [-] [-] [-] [-] [-] [/0] [%]	Debt reim Debt gr Debt in Debt value Debt value Equity vit Equity vi Discour Initial Results 73,1255 73,5187 73,7873 74,1334	ace period terest rate yments o value tt rate <u>Summary</u> yr 1 yr 2 yr 3 yr 4	5,00% 29,869,613 3,017,547 50,0% 29,869,613 9,00% of LCOE wire 78,4712 77,6515 78,1612 78,6568	(yr] [%/yr] [\$] [\$/yr] [%] [%] [%/yr] Notes yr 15 yr 16 yr 17
5 75 cm 71 L <sub>e</sub> 1, 58 e 51 cm WF cmp WT cmu Bild cma Bild cma Bild cma	40005 [15kW] 0,08% [%] 11.4566 [53W] 1.200 [17kW] 3.000 [m] 13.00 [54W] 42.7345 [5m <sup>2</sup> AW] 50.000 [5m <sup>2</sup> ] 300.0 [m <sup>2</sup> ]	n ib AAR AEP soul O&M wrcu O&M wrcu SC ass Work days Felolyan/Nov Hourn required USC ass Nwr Frequency	48 100 14.679.146 90.107.610 0,147200 1 0,000038 2,0 6 48,0 0,000138 25 1,0	[h] [s] [s] [k] [k] [k] [k] [k] [k] [k] [k] [k] [k	if N WTwight C suit TS typ WF cop if N Tmax <b>RCM</b> wr <b>Interview Distribution</b> January February <sup>(+)</sup>	2,50% 25 200,000 0,1900 0,9965 50,000 2,50% 255 138,000 <i>I.278,8970</i> <i>FLH<sub>*f</sub>(h)</i> 744 672	[%/yr] [yr] [kg] [S'kg] [S'kW] [kW] [%/yr] [yr] [kg] [\$/kW] 740 648	ζ <sub>1</sub> OREP cu           ζ <sub>1</sub> GH5R cu           REPIM           Exchange rates           EUR/USD du2010           CAN/USD du2010           BRL/USD du2010           Conditions for LOCE www           OMM wscu           OAM wscu           (%) ccm           (%) ccm           REPIM	25,0% 25,0% 229,3246 1,3252 0,9998 0,5986 1 80,0%	[%] [%] [%/proj] Notes [-] [-] [-] Notes [1/0] [%]	Debt rein Debt gr Debt sin Debt value Debt yalue Debt yalue Discourt Tajjiya T	ace period terest rate yments o value tt rate <u>Summary</u> yr 1 yr 2 yr 3 yr 4 yr 5	5,00% 29,869,613 3,017,547 50,00% 29,869,613 9,00% of LCOE wite 78,4712 77,6515 78,1612 78,6268 79,1175	(yr] [%/yr] [\$] [\$/yr] [%] [%/yr] <b>Notes</b> yr <sub>15</sub> yr <sub>16</sub> yr <sub>17</sub> yr <sub>18</sub>
ς TS col TL., L., SB., SI col WT max Bild arm Bild arm PO col	40000 [15kW] 0.08% [%] 11.4566 [51W] 1.200 [16W] 1.200 [16W] 1.200 [16W] 4.27345 [Surl <sup>3</sup> AW] 50000 [kW] 4.27328 [51W] 50000 [kW] 50000 [surl <sup>3</sup> ] 50000 [surl <sup>3</sup> ] 500	n its AAR AEP out O&M vector O&M optimized SC and Work days Fels/Jun/Nov Hours required USC and Nwy Frequency Repair time	448 100 14.679.146 90.107.610 0,147200 1 0,000038 2.00 6 48,0 0,000138 25 1,0 1,0 4,0	[h] [s] [s] [k] [k] [k] [k] [k] [k] [k] [k	if N WT <sub>velpts</sub> C <sub>stat</sub> TS <sub>504</sub> WF <sub>cop</sub> if n T <sub>max</sub> <b>RCM</b> <sub>WF</sub> <b>Houry</b> Distribution January February <sup>(+)</sup> March	2,50% 25 200,000 0,1900 0,9965 50,000 2,50% 25 138,000 <b>1.278,8970</b> <b>FLH</b> <sub>*f</sub> [h] 744 672 744	[%/yr] [yr] [kg] [S/kg] [S/kW] [kW] [%/yr] [kg] <b>H</b> prod [h] 740 648 736	ζ <sub>1</sub> OREP cu ζ <sub>1</sub> CHGR cu <b>REPIM</b> Exchange rates EURISD au-2010 RAVISD au-2010 BRL/USD au-2010 BRL/USD au-2010 OAM wecu OAM wecu OAM wecu OAM on (%) cm REPIM distribution	25,0% 25,0% 229,3246 1,3252 0,5998 0,5986 1 80,0%	[%] [%] [\$/proj] Notes [-] [-] [-] [-] [-] [-]	Debt sm           Debt sm           Debt sm           Debt sm           Debt sm           Debt sm           Equity ratic           Equity ratic           Equity ratic           Faulty           Discourt <b>Initial Results</b> 73,1255           73,5157           73,5187           74,4345           74,4746           74,9273	ace period terest rate yments o value tt rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6	29.869.613 3.017.547 50.0% 29.869.613 9.00% of LCOEo 78.4712 77.6515 78.1612 78.6268 79.1175 79.6115	(yr] (%/yr] (%) (%) (%) (%) (%) (%) (%) (%)
5 TL <sub>c</sub> TL <sub>r</sub> L <sub>i</sub> SB <sub>c</sub> SI <sub>CU</sub> WF cop WT corr Bid area PO col FS	40005 [15kW] 0,08% [%] 0,08% [%] 11,4566 [54W] 1,200 [17W] 1,200 [17W] 1,200 [m <sup>2</sup> ] 1,300 [54W] 42,734 [5m <sup>2</sup> XW] 50,000 [kW] 42,5238 [54W] 50,000 [m <sup>2</sup> ] 3,000	n its AAR AEP sout O&M Nercs O&M Nercs SC ast Work days Hours required USC ast Ner Feels Juni Nev Hours required Ner Frequency Repair time Hours required	48 100 14.679.146 90.107.610 0,147200 1 0,000038 2,0 6 48,0 0,000138 25 1,0 4,0 0,00138 25	[h] [h] [SM] [kWh/yr] [skWh/yr] [skWh/yr] [d] [d] [h] [skWh/ [-] [per yr] [h] [h]	if N WTwight C stat TS tot WF cop if N Tmax RCM wr Hours Distribution January February <sup>(*)</sup> March March	2.50% 25 200.000 0.1900 0.9965 50.000 2.50% 25 138.000 <b>1.278,8970</b> <b>FLH</b> <sub>wf</sub> [h] 744 672 744 720	[%6/yr] [yr] [kg] [S'kg] [S'kW] [kW] [%/xW] [%/yr] [yr] [kg] [\$/kW] H prod [h] 700 648 736 712	ζ <sub>1</sub> OREP Cu ζ <sub>1</sub> GHGR Cu <b>REPIM</b> Exchange rates EUR(ISD des2010 CANUSD des2010 RRI-USD des2010 RRI-USD des2010 Conditions for LCOE vus OAM wrcu OAM wrcu OAM mm (%) ccm <b>REPIM</b> REPIM distribution ζ <sub>1</sub> REI <sub>CU</sub>	25,0% 25,0% 229,3246 1,3252 0,95986 0,5986 1 80,0%	[%] [%] [%]/proj] Notes [-] [-] [-] [/0] [%] [1/0]	Debr icim Debt gr Debt gin Debt an Equity rati Equity rati Equity rati Equity rati T3,1255 73,1255 73,5187 73,7873 74,1334 74,4746 74,9273 75,2253	ace period terest rate yments o value at rate <u>Summary</u> yr 1 yr 2 yr 3 yr 4 yr 5 yr 6 yr 7	5,00% 29,869,613 3,017,547 50,0% 29,869,613 9,00% of LCOE www 78,4712 77,6515 78,1612 78,6268 79,1175 79,6115 77,7347	(yr) (%/yr) (%) (%) (%) (%) (%) (%) (%) (%
$\varsigma$ $TS_{CM}$ $TL_{c}$ $L_{i}$ $SB_{c}$ $SI_{CM}$ $WT_{inst}$ $Bid_{cont}$ $Bid_{cont}$ $PO_{CM}$ FS DT	40000 [S1W] 0.08% [%] 0.08% [%] 1.1466 [S1W] 1.200 [Sm] 1.200 [NW] 1.200 [NW] 4.2734 [Sm <sup>2</sup> AV] 50000 [kW] 4.2734 [S1W] 50000 [kW] 50000 [sm <sup>2</sup> ] 50000 [s <sup>2</sup> ] 5000 [s <sup>2</sup> ] 5000 [s <sup>2</sup> ] 50	n th AAR AEP and O&M or CM O&M or CM SC OM Work days Felch Jun Nov Hours required USC OM N wr Frequency Repair time Hours required SC OM+USC OM	448 100 14.679.146 90.107.610 0,147200 1 0,000038 2.0 6 48,0 0,000138 2.2 1.0 4.90 100,0 148,0	[h] [SM] [SM] [kWh/yr] [SkWh/yr] [d] [d] [d] [h] [s/kWh] [-] [per yr] [h] [h] [h]	if N WTweffe C circl TS vot WF cop if A N Tauss RCM wy Hours Distribution January Fabruary <sup>(+)</sup> April May	2.50% 25 200.00 0,1900 0,9965 50.000 2.50% 25 138.000 <b>1.278,8970</b> <b>FLH</b> _r/[h] 744 672 744 720 744	[%6/yr] [yr] [kg] [S'kg] [S'kg] [kW] [%/yr] [yr] [kg] [\$/kW] 740 648 736 712 736	ζ <sub>1</sub> OREP Cu ζ <sub>1</sub> CHGR Ccc <b>REPIM</b> Exchange rates EURISD <sub>66,2200</sub> CANISD <sub>66,2200</sub> BRLUSD <sub>66,2200</sub> BRLUSD <sub>66,2200</sub> Conditions for LCOE <sub>ww</sub> OM wcca OM wcca OM wcca OM wcca Conditions for LCOE ww OM wcca Conditions for LCOE ww OM wcca Conditions for LCOE ww Conditions for	25,0% 25,0% 2229,32246 1,3252 0,5998 0,5986 1 80,0% 1 1	[%] [%] [\$\[stroig] Notes [-] [-] [-] [-] [-] [1/0] [%] [1/0] [1/0] [1/0]	Debt sen Debt sen Debt sen Equity ratit Equity ratit Equity ratit Equity valit Thitial Results 73,285 73,5187 73,7873 74,434 74,4746 74,9273 75,5275	ace period terest rate yments o value tt rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6 yr 7 yr 8	29.869.613 3.017.547 50.0% 29.869.613 9.00% of LCOE was 78.4712 77.6515 78.1612 78.6288 79.1175 79.6115 77.7347 78.2446	(yr] (%/yr] (%) (%) (%) (%) (%) (%) (%) (%)
ς TL <sub>c</sub> , L, L, SB <sub>c</sub> WF cop WT cost Bid down Bid down Bid down FS DT EG	40000         [\$1kW]           0.08%         [%]           0.0400         [\$siw]           0.0400         [\$siw]           1.056         [\$kW]           0.0400         [\$siw]           1.000         [m]           1.000         [m]           1.300         [\$kW]           4.7345         [\$kw]'           4.7355         [\$kw]'           5.0000         [\$kw]'           9.28         [\$kw]'           9.28         [\$kw]'           40.52         [\$kw]	n its AAR and O&M wrest O&M wrest SC ass Work days Felo JuniNov Hours required USC ass N wr Frequency Repair time Hours required SC cass	488 100 14.679.146 9.0.107.610 0,147200 6 48,0 0,000138 2.0 6 48,0 0,000138 2.5 1.0 4,0 1.0,0 0,000176 1.48,0 0,000176	[h] [s] [SM] [SWh/yr] [S/kWh/yr] [d] [d] [d] [h] [S/kWh/ [-] [per yr] [h] [h] [h]	(f N WTweight C stat TS yut WF cop (f N Tmass <b>RCMup</b> <b>Hourse Distribution</b> January February <sup>(*)</sup> March March March May June <sup>(*)</sup>	2,50%, 25 200,000 0,9965 5,0000 2,50%, 25 138,000 1.278,8970 FLH <sub>*</sub> /[h] 744 672 744 720	[%6/yr] [yr] [kg] [S/kg] [S/kW] [kW] [%/yr] [yr] [kg] [s/kW] Hprod [h] 740 648 736 648 736 648	ζ <sub>1</sub> OREP Cu ζ <sub>1</sub> GHG R Cu <b>REPIM</b> <b>Exchange rates</b> <b>EUR</b> (ISD <sub>26,2200</sub> CANUSD <sub>26,2200</sub> OKM (ISD <sub>26,2200</sub> OKM (ISD <sub>26,2200</sub> ) <b>Conditions for LCOE</b> www OKM wrcu (%) of Cm <b>REPIM</b> REPIM distribution ζ <sub>1</sub> REI Cu ζ <sub>2</sub> REP Cu ζ <sub>3</sub> REP Cu	25,0% 25,0% 229,3246 1,3252 0,9986 0,5986 1 1 80,0%	[%] [%] [ <i>\$</i> [ <i>p</i> roj] [-] [-] [-] [-] [-] [-] [1/0] [%] [1/0] [1/0] [1/0]	Debt sin           Debt ga           Debt min           Debt ga           Equity min           Equity min           Equity min           Discour           Initial Results           73,1255           73,5187           74,334           74,4746           74,0273           75,2253           76,0152	ace period terest rate yments o value tt rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 7 yr 5 yr 7 yr 7 yr 8 yr 9	5,00%, 29,869,613 3,017,547 50,0%, 29,809,613 9,00%, of LCOE was 78,4712 78,615 78,4162 78,635 79,1175 79,6115 79,6115 77,7347 78,2346 78,7103	(yr) [%/yr] [%/yr] [%] [%] [%/yr] <i>Notes</i> yr1s yr1s yr1s yr1s yr1s yr1s yr1s yr2s yr2s yr2s yr2s
5 75 cst 71 L, 1, 58 , 51 cst WF may WT max Bid dissus Bid dissus PO cst FS DT EG F cst	40005 [35.W] 0,08% [%] 11.4566 [53.W] 0,0400 [57m] 1.200 [1/kW] 3.000 [m] 113.00 [54.W] 42.7345 [54m <sup>2</sup> /kW] 50.000 [5m <sup>2</sup> ] 3.000 [m <sup>2</sup> ] 3.000 [m <sup>2</sup> ] 3.000 [m <sup>2</sup> ] 3.000 [stw] 19.88 [54.W] 8.722 [54.W] 3.7712 [54.W]	n its AAR AEP soud O&M or CM SC 004 Work days Felschan/Nov Hours required USC 004 Work days Felschan/Nov Hours required USC 004 N wr Frequency Repair time Hours required SC 004+USC 004	48 100 14.679.146 90.107.610 0.147200 147200 6 48.0 0.000138 25 1.0 1.00 1.48.0 0.000176 1.48.0 0.000176	[h] [SM] [SM] [kWh/yr] [SkWh/yr] [d] [d] [h] [S/kWh/ [-] [per yr] [h] [h] [h/yr] [SkWh/yr]	if N WTweffel C cital TS vg WF cop if N Tmass RCM vg RCM vg Hours Distribution Janary February <sup>(*)</sup> March April May June <sup>(*)</sup> July	2.50% 25 2000.00 0.1900 2.50% 25 3188000 1.278,8970 FLH <sub>-1</sub> (h) 744 672 744 720 744 720 744	[%6/yr] [yr] [kg] [S/kg] [S/kW] [%/kW] [%/yr] [yr] [kg] (\$/kW] [%/yr] [yr] [kg] (\$/kW] [%/yr] [yr] [kg] (\$/kW] [%/yr] [%/	ξ <sub>1</sub> OREP Cut         ξ <sub>2</sub> CHCR PCut           ξ <sub>2</sub> CHCR CC         REPIM           Exchange rates         EUCRISD describe           EUCRISD describe         BRL USD describe           ORM wrecut         ORM wrecut           ORM wrecut         ORM describe           OKM mem         (%) ccm           REPIM distribution         ξ <sub>1</sub> REPIM           ξ <sub>2</sub> REPICut         ξ <sub>2</sub> OREP Cut           ξ <sub>3</sub> OREP Cut         ξ <sub>4</sub> OREP Cut           ξ <sub>4</sub> GHCR Cut         ξ <sub>4</sub> GHCR Cut	25,0% 25,0% 229,3246 1,3352 0,5998 0,5998 0,5998 1,3552 1,3552 1,3552 1,3552 1,3552 1,3552 1,3555 1,5596 1,1596 1,	[%] [%] [\$/proj] Notes [-] [-] [-] [-] Notes [1/0] [%] [1/0] [1/0] [1/0] [1/0]	Leon term           Dob's m           Dob's value           Docoration           T31255           T35187           T41334           T44746           T42773           T452253           T65125           T64152	ace period terest rate yments o value tt rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6 yr 7 yr 8 yr 9 yr 9 yr 10	5,00%, 29,806,613 3,017,547 5,00%, 29,869,613 9,00%, of LCOE ess 78,4712 78,4712 78,4712 78,4712 78,4712 78,4712 78,4712 78,4712 78,4712 78,4712 78,4712 78,4712 77,7347 77,7347 78,2446 78,7103 79,0644	(yr) (%/yr) (%) (%) (%) (%) (%) (%) (%) (%
ς ΤΣ <sub>CM</sub> ΤL, L, SB, STcu WF mp WT mu Bid ann Bid ann Bid ann Bid ann EG FCu WACC <sub>proj</sub>	40000 [\$1W] 0.08% [%] 0.08% [%] 1.1456 [\$1W] 0.0400 [\$rm] 1.300 [10W] 3.000 [m] 1.3.00 [\$2W] 5.0000 [\$W] 5.0000 [	n its AAR AEP event O&M vgrcss O&M vgrcss O&M vgrcss Coss Work days Work days Work days Work days Work days Work days Hours required USC coss N vgr FeglumNov Hours required SC coss Hours required	48 100 14.679.146 99.10761 0,147200 6 48,0 0,000138 2,0 6 48,0 148,0 0,000176 148,0	[h] [SM] [SM] [kWh/yr] [s/kWh/yr] [d] [d] [d] [h] [s/kWh] [-] [per yr] [h] [h] [h] [h]/yr] [s/kWh/yr]	if N WTweight C stual TS yet WF cop if n Tmass RCM wp Houry Distribution January February <sup>(*)</sup> March March March May June <sup>(*)</sup> July August	2.50% 25 20.00.00 0.1900 0.9965 50.000 2.55% 25 1138.000 1.278,8970 744 672 744 672 744 720 744 720 744 720	[%6/yr] [yr] [kg] [Sikg] [Siky] [kW] [%/yr] [yr] [kg] <b>[SikW]</b> <b>H</b> prod (h) 740 648 736 736 736 736 736 736 736	ζ <sub>1</sub> OREP Cu ζ <sub>1</sub> GHGR Cu <b>REPIM</b> <b>Exchange rates</b> <b>EURUSD</b> <sub>06,2010</sub> CURUSD <sub>06,2010</sub> CURUSD <sub>06,2010</sub> <b>CONDITIONAL OF CONTENT</b> <b>CONDITION OF LECOE</b> un <b>OKM</b> unCU <b>OKM</b> unCU <b>OKM</b> unCU <b>OKM</b> unCU <b>OKM</b> unCU <b>OKM</b> unCU <b>OKM</b> unCU <b>OKM</b> unCU <b>CINCLED</b> un <b>CINCLED</b>	25,0% 229,3246 1,3252 0,9998 0,5986 1 80,0% 1 1 1 1 1 1 1	[%] [%] [\$/proj] Notes [-] [-] [-] [/0] [%] [1/0] [1/0] [1/0] [1/0] [1/0]	Leon term Dob'r gr Dob'r m Deb'r value Deb'r value Equity van Equity van Equi	ace period terest rate yments o value tt rate Summary yr 3 yr 4 yr 5 yr 6 yr 7 yr 8 yr 9 yr 9 yr 9 yr 9 yr 9 yr 10 yr 11	5,00% 22,860,613 3,017,547 5,00% 22,860,613 9,00% 9,00% 78,616 71,6515 70,615 70,6115 70,6115 70,6115 70,6115 70,7103 70,0644 78,7103 70,0644 79,0704	(yr] (%/yr] (%)yr] (%) (%) (%) (%) (%) (%) (%) (%)
ς TL <sub>e</sub> TL <sub>e</sub> L <sub>i</sub> SB <sub>e</sub> SI <sub>Cu</sub> WF <sub>cup</sub> WT <sub>mu</sub> Bid <sub>uron</sub> Bid <sub>uron</sub> Bid <sub>uron</sub> Bid <sub>uron</sub> FS DT EG F <sub>Cu</sub> WACCC <sub>prel</sub> n <sub>fm</sub>	40005 [35W] 0,08% [%] 0,08% [%] 11,4566 [54W] 1.200 [1/kW] 3.000 [m] 13.20 [35W%] 42,734 [5m <sup>2</sup> /kW] 42,734 [5m <sup>2</sup> /kW] 50,000 [kW] 42,528 [54W] 50,000 [m <sup>2</sup> ] 35,9274 [54W] 19,88 [54W] 87,22 [54W] 49,928 [54W] 49,929 [%y7] 1,0 [y7]	n its AAR AEP soul O&M operation SC 664 Work days Felolum/New Hours required USC 664 Work days Felolum/New Hours required USC 664 New Frequency Repair time Hours required SC 664 SC 664 USC 664	48 100 0,147571.46 0,147200 6,000138 2,0 6,000138 2,0 6,000138 1,0 1,0 1,0 1,0 0,000176	[h] [SM] [KWh/yr] [ <i>kWh/yr</i> ] [ <i>s/kWh/yr</i> ] [d] [d] [d] [h] [ <i>s/kWh</i> ] [-] [per yr] [h] [h] [ <i>h</i> ] [ <i>k</i> ]	if N WTweight C stat TS tota WF cop if N Tmax Tmax Tmax Total Mar Hour Distribution January Fobraop <sup>(*)</sup> March April May June <sup>(*)</sup> July September	2.50% 25 200.000 0.1900 0.9905 50.000 2.50% 25 138000 1.278,8970 744 672 744 672 744 720 744 720 744 720	[%6/yr] [yr] [ky] [S/kg] [S/kW] [kW] [%/yr] [yr] [kg] [S/kW] Hprod (h) 740 648 736 712 736 696 736 736 736 736	ζ <sub>1</sub> OREP Cu ζ <sub>1</sub> GHGR Cu <b>REPIM</b> EUR(SD do2010 CANUSD do2010 RRUSD do2010 RRUS	25,0% 25,0% 229,3246 1,3352 0,9598 0,5968 1 80,0% 1 1 1 1 1 1	[%] [%] [\$\u03c6 proj] Notes [-] [-] [-] [-] [\u03c6 proj [\u03c6 proj [\u03c6 proj [\u03c6 proj [\u03c6 proj [\u03c6 proj] [\u03c6 proj] [\u0	Leon term Dobi ng Dobi ng Dobi ng Dobi ng Dobi ng Equity ndi Equity ndi Equit	ace period terest rate yments o value tt rate <u>Summary</u> yr1 yr2 yr3 yr4 yr5 yr4 yr5 yr7 yr7 yr8 yr9 yr9 yr10 yr11 yr2 yr9 yr9 yr10 yr11 yr2 yr2 yr7 yr9 yr10 yr12 yr12 yr12 yr12 yr12 yr12 yr12 yr12	5,00%, 28,866,613 3,017,547 50,00%, 29,869,613 9,00%, of <i>LCOE</i> , well 78,4712 78,6515 78,4712 78,6515 78,4712 78,6515 78,1715 79,6115 77,1747 78,2746 78,7103 79,0644 78,7103 70,0644	(yr) [%/yr] [%/yr] [%] [%] [%/yr] <i>Notes</i> yr 15 yr 15 yr 15 yr 15 yr 17 yr 18 yr 19 yr 20 yr 21 yr 22 yr 22 yr 22 <i>Yr</i> 25 <i>Mean</i>
ς TS <sub>CM</sub> TL, L, SB, SICu WF <sub>any</sub> WT <sub>inut</sub> Bid <sub>sens</sub> Bid <sub>sens</sub> PO <sub>CM</sub> FS DT EG F <sub>CM</sub> WACC <sub>prej</sub> w <sub>K</sub> <sub>K</sub> <sub>K</sub> <sub>K</sub> WACC <sub>prej</sub>	40000 [\$1W] 0.08% [%] 0.08% [%] 1.1456 [\$1W] 0.0400 [\$1W] 1.200 [1kW] 3.000 [m] 113.00 [\$1W] 4.735 [\$1w <sup>2</sup> 1X9] 50.000 [kW] 50.000 [kW] 50.000 [\$1W <sup>2</sup> ] 3.000 [m <sup>2</sup> ] 3.000 [m <sup>2</sup> ] 3.000 [\$1W <sup>2</sup> ] 50.000 [\$1W	n its AAR AEP and O&M optimization O&M optimization SC and Work days Fels/Jun/Nov Hours required USC and Nwr Hours required USC and Nwr Repair time Hours required SC and Hours required	48 100 14,679,146 9,0107,610 0,147,200 6,047,200 48,0 0,000138 25 10,0 1,000 1000 1000 148,0 0,000176	[h] [SM] [SWh/yr] [kWh/yr] [s/kWh/yr] [d] [d] [h] [s/kWh/ [-] [per yr] [h] [h] [hyr] [S/kWh/yr]	if N WT <sub>velpts</sub> C <sub>stat</sub> TS <sub>504</sub> WF op if n T <sub>mass</sub> <b>RCM<sub>WF</sub></b> <b>Hours Distribution</b> January February <sup>(*)</sup> March March March May June <sup>(*)</sup> July September October	2.50%. 25 20.00.00 0.9985 50.000 2.50%. 25 138.000 <i>I.278,8970</i> <i>FLH<sub>-1</sub>(h)</i> 744 672 744 720 744 720 744 720 744 720 744	[%6/yr] [yr] [Skg] [Skg] [SkW] [kW] [%/yr] [yr] [kg] [S/kW] Hprod [h] 740 648 736 740 648 736 740 648 736 740 648 736 736 736 736	ζ, OREP Cu ζ, ORER Cu <b>REPIM</b> Exchange rates EUCUSD <sub>dualitit</sub> CANISD <u>dualitit</u> CANISD <u>dualitit</u> C	250% 250% 229,3246 1,3252 0,9998 0,5996 1 1 80,0%	[%] [%] [%] <i>[Notes</i> [-] [-] [-] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0]	Leon term           Dob's m           Dob's m           Dob's m           Dob's m           Equity suit           Failed           T3.125           T3.325           T4.746           74.0746           74.0746           74.0716           74.0716           74.0716           74.0716           74.0716           74.0716           74.0716           74.0716           74.0716           74.0716           74.0716           75.2717           76.0182           76.211	ace period terest rate yments o alue tt rate <b>Summary</b> yr 1 yr 2 yr 3 yr 4 yr 9 yr 1 yr 3 yr 4 yr 3 yr 9 yr 9 yr 1 yr 1 yr 3 yr 4 yr 9 yr 9 yr 9 yr 9 yr 9 yr 9 yr 9 yr 9	5,00% 28,806,613 3,017,547 5,00% 29,869,613 9,00% 9,00% 9,00% 78,6412 78,6412 78,6412 78,6412 78,6412 78,6412 78,6412 78,6412 78,6412 78,6412 78,6413 79,0444 78,7103 70,8646 78,7103 70,8646 79,7105 70,8646 70,8705 70,8646 70,8705 70,8646 70,8705 70,8646 70,8705 70,9705	(yr) [%/yr] [%] [%] [%] [%] [%/yr] Notes yr15 yr15 yr15 yr15 yr15 yr15 yr15 yr15 yr15 yr15 yr15 yr15 yr15 yr12 yr25 yr22 yr22 yr23 yr25 Mean SD
$\zeta$ $TL_{e}$ $TL_{r}$ $L_{i}$ $SB_{v}$ SCurrent $WF corpWT court Rd d_{urav}Rd d_{urav}Rd d_{urav}FO COU FSDTEGFCurrent FCurrent WF_{current}WF_{current}WF_{current}WF corp (MT) = 0MT = $	40005 [SkW] 0.08% [%] 0.08% [%] 0.0400 [Sm] 1.200 [IAW] 1.200 [IAW] 1.200 [IAW] 4.734 [Sm <sup>2</sup> XW] 50.000 [Sm <sup>2</sup> ] 30.00 [m <sup>2</sup> ] 3.000 [m	n is AAR AEP sout O&M operation SC ast Work days Felolum/Nov Hours required USC ast Ney Frequency Repair time Hours required SC cast	48 100 0,0107.016 0,0107.010 0,047200 0,000038 2,0 6 4,000 4,000138 4,000 148,0 0,000176	[h] [SM] [kWh/yr] [skWh/yr] [skWh/yr] [d] [d] [h] [skWh/ [-] [per yr] [h] [h] [h] [k] [k/yr]	if N WTweight C stat TS yul WF cap if N Tmax <b>RCM</b> wr <b>Hours Distribution</b> January February <sup>(*)</sup> March April May June <sup>(*)</sup> July August September October November <sup>(*)</sup>	2.50% 25 20.00.00 0.9985 50.000 2.50% 25 138.000 1.278,8970 1.378,8970 744 672 744 720 744 720 744 720 744 720 744 720 744 720	[%6/yr] [yr] [Skg] [Skg] [SkW] [kW] [kW] [yr] [yr] [kg] <b>(SkW)</b> <b>H</b> prod [h] 740 648 736 712 736 696 736 736 736 736 736 696	$ \begin{array}{c} \xi_{i} \ OREP_{Cd} \\ \xi_{i} \ OREP_{Cd} \\ \hline \\ $	250% 250% 229,3246 1,3352 0,599% 0,599% 0,599% 1 1 80,0%	[%] [%] [%] Notes [-] [-] [-] [-] [1/0] [%] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0]	Leon stan Dobi ng Dobi ng Dobi ng Dobi ng Equity nuti- Equity nuti- Equity nuti- Equity nuti- Equity nuti- Equity nuti- Ti.5187 73.5187 74.134 74.05 75.5275 76.0152 7	ace period terest rate yyments o value tt rate Summary yr1 yr2 yr3 yr4 yr7 yr6 yr7 yr7 yr8 yr7 yr7 yr8 yr10 yr11 yr11 yr11 yr13 yr13 yr14	5,00%, 22,889,613 3,017,547, 50,0%, 29,889,613 9,00%, 9,00%, 9,412,028,428, 78,4125 78,4515 78,4515 78,4515 78,4515 77,7347 78,24163 78,7415 78,745 78	(yr) [%/yr] [%] [%] [%] [%] [%] [%] [%] [%
ς TS <sub>CM</sub> TL, L, SB, SICu WF <sub>enp</sub> WF <sub>enp</sub> WF <sub>enp</sub> Bid <sub>sum</sub> Bid <sub>sum</sub> Bid <sub>sum</sub> Bid <sub>sum</sub> Bid <sub>sum</sub> FOCM FS DT EG FCu WACC <sub>pref</sub> N <sub>F</sub> CCC <sub>pref</sub> N <sub>F</sub> CCC <sub>pref</sub> N <sub>F</sub> CCC <sub>pref</sub> N <sub>F</sub> CCC <sub>pref</sub> N <sub>F</sub> CCC CCC <sub>pref</sub> N <sub>F</sub> CCC CCC <sub>pref</sub> N <sub>F</sub> CCC CCC <sub>pref</sub> N <sub>F</sub> CCC CCC <sub>pref</sub> CCC <sub>pref</sub> N <sub>F</sub> CCC CCC <sub>pref</sub> N <sub>F</sub> CCC CCC CCC CCC CCC CCC CCC C	40000 [\$1W] 0.08% [%] 0.08% [%] 1.1456 [\$1W] 1.200 [\$1W] 1.200 [\$1W] 1.300 [\$1W] 1.300 [\$1W] 1.300 [\$1W] 1.2538 [\$1W] 1.2538 [\$1W] 1.928	n its AAR AEP and O&M optimized SC and Work days Feld/an/Nov Hourn required USC and New New Feld/an/Nov Hourn required USC and New New Repair time Hourn required SC and SC and SC and SC and New New Repair time	48 100 0,107,146 0,007,146 0,007,147 0,007,147 0,007,147 100 0,000,147 100 0,000,148 0,000,176	[h] [b] [SM] [kWh/yr] [S&Wh/yr] [d] [d] [h] [s&Wh/ [d] [h] [b] [b] [h] [h] [h] [b] [kWh/yr]	if N WTweffer C stat TS vst WF cop if n N Taust RCM wy RCM wy Houry Distribution January February <sup>(*)</sup> March April May August September October November <sup>(*)</sup> December	2.50% 25 200.000 0.900 0.95% 2.50% 2.50% 2.50% 7.85% 7.85% 7.85% 7.85% 7.44 7.20 7.44 7.44 7.44 7.44 7.44 7.44 7.44 7.4	[%6/yr] [yr] [S/kg] [S/kg] [S/kW] [kW] [kW] [kw] [yr] [kg] (S/kW) 740 648 736 648 736 648 736 648 736 736 736 736 736 736 736 736 736 736	ζ, OREP Cu ζ, OREP Cu Z, OHGR Cox REPIM EUCUSD Δ <sub>2020</sub> CANISD Δ <sub>2020</sub> BRL/USD Δ <sub>2020</sub> CANISD Δ <sub>2020</sub>	250% 229,3246 1,3252 0,5986 0,5986 1 1 80,0% 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	[%] [%] [%]roj] Notes [-] [-] [-] [1/0] [%] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0] [1/0]	Leon term Dobi ng Dobi ng Dobi ng Dobi ng Leguity nit Equity nit Bacous Talasse Talass	ace period terest rate yments o summary yr1 yr2 yr3 yr3 yr4 yr5 yr6 yr6 yr9 yr6 yr9 yr9 yr9 yr9 yr9 yr9 yr9 yr9 yr9 yr9	5,00% 22,880,613 3,017,547 5,00% 29,880,613 9,90% 9,90% 9,90% 9,90% 9,90% 9,90% 9,90% 9,00% 17,547 78,618 70,117 78,628 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,5415 70,117 70,541 70,545 70,54	(yr) [%/yr] [%/yr] [%] [%] [%/yr] [%/yr] yr 15 yr 15 yr 16 yr 17 yr 19 yr 20 yr 21 yr 22 yr 22 yr 25 SD Y (skewness) valid !

**Figure H.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(A)}$ . Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2,50%	[%/yr]
Green cells indicate information and a automatically based on user input into	re updated vellow cells.		O&M warranty conditio	ns	Notes	Depreciation	ſ	Notes	Power Purchase Agreement Rate	0,13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	, on about the project.		Costs covered by manufacturer (O&M)	80,00%	[%]	Depreciation rate per year	4,00%	[%/yr]	Expected Market Price	0,09684	[\$/kWh]		WACC proj	4,9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70,00%	[%]		UCRF	0,070243	[-]
WE IN SALE OF		N	I	Cart Madal	N /	Wind From Brownel C	and Madel	N /	Bananakla France Bublis In	Madal	N .	Wind Farm Life	Cualo Baad	nation Model	N.
Wind Project Information	Einsten Wind Fame	notes	Levenzea Kepiacemeni	16 8442	inotes	DCM	1 220 0154	(SAW)	Renewable Energy Fublic Ind	70.9202	INOLES (SAMU)	WE	•Cycle 110a	50.000	INOLES
Project Location	Care Saint James (Canada)		Depr	76 9840	[3/kW]	RM wr	22 3284	[3/kW]	LCCCM we	1 204 5180	[3/kW]	WF		50.000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553,7256	[\$/kW]	WF con	50.000	[kW]	LRCM	16,8443	[\$/kW]	Nwr		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CH</sub>	484,3859	[\$/kW]	NWT	25	[-]	ifr	2,50%	[%/yr]	WT rated		2.000	[kW]
Turbine Size	2.000	[kW]	N	25	[yr]	$M_{\nu_{\mu\nu_{\mu\nu}}}$	100	[m-h]	$\Psi_{total}$	30,00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50.000	[kW]	ifr	2,50%	[%/yr]	$C_{Mbr_{EM_{WT}}}$	85,00	[S/m-h]	n <sub>v</sub> .	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90,0	[m]	Depry	60,1398	[\$/kW]	N <sub>mater</sub>	3	[-]	REP CM	0,0000052	[S/kWeh]	D		90,0	[m]
Swept Area per Turbine (A)	6.361,7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]		2,0	[d]	AEP avail/H prod	24.780	[kW/yr]			1.800	[m]
Hub height (H)	105,0	[m]	TO CM	0,000033	[\$/kW]	C adatas	2.500,00	[\$/d]	ifr	2,50%	[%/yr]			2.430	[m]
wind speed measured at $(H_0)$ Tompin magnitum factor $(\pi)$	10,0	[m]	п v	1.798.743	[5/KW] [1/W]	KM CT WE	20,1934	[5/KW] [1/W]	£ 6-	0,0128	[5/KW_en]	SD		430	[m]
Betz Limit's coefficient (C PR-re)	0.5926	[-]	V.	6 109 000	[kW]	WF cap N wr	25	[-]	n,	0,009998	[3'Kwell]	FIH.d		8760	(h/yr)
Lifetime of Wind Farm (N)	25	[vr]	, , , , , , , , , , , , , , , , , , ,	1.457.72	[\$/kW]	Mw	3.0	[m-h]	OREP CH	56,9120	[\$/kW_c]	PCPM			[11]
Production Efficiency (WF PE)	48,7%	[%]	PR	0,70	[-]	C <sub>MH<sub>k-7</sub></sub>	85,00	[S/m-h]	LCCCM <sub>WFeestern</sub>	2,7664	[\$/kW]	AEP avail		213.509.813	[kW_h/yr]
Aválability	98,4%	[%]	ь	-1,94	[-]	N	3	[-]	LCCCM WF	1.204,5180	[\$/kW]	$\eta_{max}$		20,35%	[%]
	359	[d/yr]	LRCM	16,8443	[\$/kW]	Dman	2,0	[d]	WACC proj	4,9000%	[%/yr]	$\eta_{wecz_{int}}$		25,00%	[%]
	-			_		C <sub>nd</sub> <sub>RKcr</sub>	3.500,00	[\$/d]	$\Psi_{total}$	30,0%	[%]	P&D <sub>LM</sub>	factor	0,814145	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1.297,3916	[\$/kW]	ifr	2,5%	[%/yr]	$N_{WT}$		25	[-]
WT CM	553,7256	[\$/kW]	O&M <sub>find</sub>	0,098275	[\$/kWh]	WF cap	50.000	[kW]	n <sub>v</sub> .	10	[yr]	Α		6.361,7	[m <sup>2</sup> ]
CM WT	265,32	[\$/kW]	LCCCM WF	1.204,5180	[\$/kW]	$N_{WT}$	25	[-]	$CR_f$	80,0%	[%]	AEP rated		438.000.000	[kW_eh/yr]
RC WT	73,70%	[%/\$/kW]	σ	0,000001%	[%]	A WT	43,00	[m <sup>2</sup> /wt]	GHG.R CM	4.512,5219	[\$/tCO2]	P&D <sub>LM</sub>			
C kW	400,00	[S/kW]		0,0530	[\$/kWh]	M Ir Jur	3,0	[m-h]	$\sum AEP$	81,1	[tCO2/MWah]	ž.,		7,00%	[%]
IP1 T	10,00%	[%]	N	25	[yr]	C <sub>Mhr<sub>san</sub></sub>	85,00	[S/m-h]	∠ <i>rus</i> and <sub>x1x-xx</sub>	213.510	[MW <sub>e</sub> h]	× 141		5,00%	[%]
T CM	484,3839	[5/KW] [ke]	O&M	2,30%	[%/yr] [\$//Wh]	D N M MANY	30	[-]	GHG	0.00041	[yr] hCO-MW hi	2		5,00%	[%]
PC -	26 30%	[%5]	MIC	71 5608	[\$/b]	C .	3 500.00	[5/4]	GHG	0,00003	ICO MW N	ICPM		213 509 813	[~] fkW b/sel
C	0.1900	[%/ke]	TIC	124 5688	[5/h]	RVM me	61 0184	[3/kW]	E	30,0000	[\$/tCO_1	Let in WF		215.569.615	[411,42,11]
LWTG cu	39,1957	[\$/m/kW]	R	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cine	1	Notes
WF can	50.000	[kW]	ifr	2,50%	[%/vr]	WTS VM	1,4442	[\$/kW]	Š. RELCH	25,0%	[%]	Debt ratio		50,0%	[%]
L	13.950	[m]	N	25	[yr]	WF car	50.000	[kW]	$\xi$ , REP <sub>CM</sub>	25,0%	[%]	Debt term		14	[yr]
CAB cost	2.000,00	[\$/m]	n mlh	48	[h]	ifr	2,50%	[%/yr]	$\tilde{\zeta}_3$ OREP <sub>CM</sub>	25,0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30,9069	[\$/kW]	n <sub>zlb</sub>	100	[h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	25,0%	[%]	Debt int	erest rate	5,00%	[%/yr]
EFc	400,00	[\$/kW]	AAR	29.538.512	[\$M]	WTweight	200.000	[kg]	REPIM	1.160,0636	[\$/proj]	Debt value		29.646.593	[\$]
ç	0,08%	[%]	AEP anail	213.509.813	[kWh/yr]	C steel	0,1900	[S/kg]				Debt pa	yments	2.995.017	[\$/yr]
TS CM	11,4566	[\$/kW <sub>e</sub> ]	O&M WFCM	0,139802	\$/kWh/yr]	$TS_{VM}$	0,9965	[\$/kW]	Exchange rates		Notes	Equity ratio	0	50,0%	[%]
TL <sub>c</sub>	0,0400	[\$/m]		-		WF cap	50.000	[kW]	EUR/USD dec2010	1,3252	[-]	Equity v	alue	29.646.593	[\$]
TL,	1.200	[1/kW]	O&M <sub>O&amp;Mmanag(A)</sub>		Notes	ifr	2,50%	[%/yr]	CAN/USD dec2010	0,9998	[-]	Discour	t rate	9,00%	[%/yr]
L <sub>t</sub>	3.000	[m]	SC ORM	0,000016	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0,5986	[-]			r	
SB <sub>c</sub>	113,00	[\$/kWh]	Work days	2,0	[d]	Tmass	138.000	[kg]		1		Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42,7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6	[d]	RCM WF	1.278,8970	[\$/kW]	Conditions for LCOE <sub>wso</sub>		Notes	84,3997	yr 1	94,4943	yr 15
WF cap	50.000	[kW]	Hours required	48,0	[h]				O&M WFCM			85,0669	yr <sub>2</sub>	94,1699	yr 15
WT inst	42,5238	[S/kW]	USC ORM	0,000058	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	85,7507	yr <sub>3</sub>	94,9708	yr 16
Bld cort	500,00	[\$/m <sup>2</sup> ]	N <sub>WT</sub>	25	[-]	January D. 1 (*)	744	740	(%) ccm	80,0%	[%]	86,2255	$yr_4$	95,8775	yr 17
Bld area	25 0274	[m]	Prequency President time	1,0	(per yr)	February'	744	726	REFIM PEPIM distribution			80,9190	yr 5	90,7795	yr 18
FS FS	19.88	[3/KW] [5/FW]	Hours required	100.0	[11] [15]	Anril	744	712	RELIM	1	[1/0]	88 2242	yr <sub>6</sub>	91,0102	yr 19
DT IS	19,88	[5/kW]	SC or u+USC or	148.0	[h/vr]	May	744	736	REP out	1	[1/0]	88,9241	yr 7	94,0505	37 20 X7 au
FG	404 52	[S/kW]	a c dem i c b c dem	0.000074	S/kWh/wr	June <sup>(*)</sup>	720	696	OREP CH	1	[1/0]	89.8260	yr s	95,8087	37 21 VI 33
FCM	3,7712	[\$/kW]		0,0000/4 [		July	744	736	GHG.R CM	1	[1/0]	90,4267	yr 10	96,5649	yr 23
WACC proj	4,900%	[%/yr]		Г		August	744	736	P&D <sub>IM</sub>		(,	91,2477	yr 11	97,5891	yr 25
n <sub>fin</sub>	1,0	[yr]				September	720	712	$\lambda_{a}$	1	[1/0]	91,9572	yr 12	91,8264	Mean
w <sub>FCH</sub>	0,30%	[%]				October	744	736	$\lambda_{xAi}$	1	[1/0]	92,6946	yr 13	4,2043	SD
CCC CM	2,4042	[\$/kW]				November <sup>(*)</sup>	720	696	$\lambda_d$	1	[1/0]	93,7245	yr 14	-0,3333	$\gamma_{(skewness)}$
ĸ	0,20%	[%]				December	744	736	λ	1	[1/0]	LCOE	91,8264	US\$/MWh	valid !
LCCCM WF	1.204,5180	[\$/kW]				Total [h/yr]	8.760	8.616		p.s.: 1 = yes as	nd 0=no		0,091826	US\$/kWh	

**Figure H.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(A)}$ . Source: Own elaboration

Table H.1 Ener	gy productio	on (AEP an	u) map of the	wind fam	for Aracati	i (Brazil)		with.	sensitivity	analysis of	O&M manag	1)			41.1	1.000											
Months	V <sub>NC</sub>	H .	prod												$AEF_{ava}$	d(K M n)											
,	(m/s) (kg/	()	h) yr 1	yr.,	2 yr.	3 yr	4 yı	rs y.	r6	<i>T</i> 7 )	r <sub>8</sub> y	9 yr	10 31	11 34	12 31	13 yr.	14 yr	15 yr.	6 yr	7 yr.	18 yr1	9 yr 2	0 yr2.	I yr2:	yr 23	yr24	yr 25
, January	5,8 1,.	.1665	740 1.697.72		291 3.812.	469 7.527.	755 558.	.872 8.91-	4.291 55	8.872 55	.872 4.24	.681 8.914	1.291 8.914	4.291 558	.872 3.81	2469 7.527.	.755 4.245	.081 8.914.	291 8.914	291 558.	872 3.812.	469 7.527.	755 558.8	72 3.812.4	(69 7.527.75	5 4.243.681	4.243.68
February	4,9 1,.	.1666	648 859.94.	5 6.879.	561 3.714.	421 6.879.	561 788.	321 6.87	9.561 78	8.321 78	:321 4.78	0.152 6.875	1.561 6.875	261 788	321 3.714	1421 6.879.	561 489.	171 489	71 3.336	988 4.780	.152 7.802.	526 1.594.	674 1.594.0	574 7.802.1	26 6.879.56	1 4.780.152	4.780.15
March	4,0 1,.	1671	736 555.87.	7 7.487.4	419 5.432.	002 8.866.	525 977.	212 7.48;	7.419 97.	7.212 97.	.212 6.55	.645 7.487	7.419 7.487	7.419 977	212 5.432	2002 8.866.	525 895.	822 895.4	822 1.812	134 4.220	942 1.812.	134 1.688.	623 1.688.0	523 7.817.0	899 & 866.52	5 3.792.040	6.552.64.
April	4,7 1,1	1667	712 866.360	6 6.337.1	184 6.337.	184 4.082.	151 1.633	3.098 6.33	7.184 1.65	3.098 1.65	3.098 7.241	.220 6.337	184 6.337	7.184 1.75.	2.548 6.337	7.184 4.082.	.151 945.	080 945.0	80 1.633	098 6.337.	184 1.633.	098 3.667.	352 945.0	80 7.241.2	20 6.337.18	4 1.752.548	7.241.220
Mav	6.0 1.	1670	736 1.812.06	6 5.4315	800 7.487.	140 5.431.	800 1.812	066 5.43	1.800 1.81	2.066 1.81	2.066 7.815	409 5.431	800 5.431	800 1.68	\$ 560 7.487	140 6.552.	401 1.688	560 1.688.	560 977.	176 8.866	195 977.1	176 555.	856 895.7	88 6.552.4	01 4,220.78	5 1.688.560	7.817.40
Inno	1 0 2	1686	58 YOU 3 DOV 82	5 YOO 2 C.	CUV L CS8	FUC 9 239	76.4 2 500	100 2 002 (	5 857 2 50	1720 250	1 7 20 8 205	800 2 006	857 2.006	857 250	207.7 402	281.5 2.59	616 1715	512.1 200.	077 848	COV 2 7.002	657 848	878 690	.003 2 290	1 21 2 102	19 8 1 9 8 1	6 075333	8 205 80
		0001		102210 7	1000 1000	1070 100	160-0 LOV	166-10 1071-1	10-10 TOD 10	1010 N#110	×0.00 041.0		X210 7001	1000 TO 1001	101-1 071-1	CLT:0 /00*	-1/-1 010-	1111 170	-010 /7/		1010 100	1010 - 101		104.1°C 07.	10.011.0		00.000
July	8,0 1,.	2601	/30 2.444./8	2 3.800:	902 8.88/.	260.1 C85	062-7-062	1.8/5 5.80	0.902 4.2	0.8/3 4.25	1.66 818.0	./CC C81.	.185 S.8U	1.902 5.44	4./82 8.88,	0187 085	.39/ 5.800	1902 5.800.	./cc 706	COC./ COI	1./CC +50		11 4.230.0	8/3 4.230.0	65.260.1 673	676.768 0	:81./00
August	9,6 1,.	1677	736 7.491.30	1 1.813.1	073 1.813.	073 1.813.	073 8.871	1.123 1.81.	3.073 5.45	4.819 5.45	4.819 896	286 896.	286 1.815	8.073 4.22.	3.131 1.81.	1073 1.689.	.499 5.434	(819 7.821.	753 7.821	753 896.	286 4.223.	131 7.821.	753 5.434.8	819 1.813.0	73 1.813.07	3 556.165	896.280
September	10,1 1,1	.1657	712 8.566.92.	3 1.631	564 1.631	564 3.663.	906 7.553	3.538 1.63.	1.564 6.35	1.230 6.35	1.230 944	192 944.	192 1.631	.564 6.33.	1.230 1.631	.564 3.663.	.906 6.331	230 7.234.	417 7.234	417 944.	192 5.248.	454 8.566.	923 6.331.2	230 1.631.2	64 3.663.90	6 6.331.230	944.192
Octoher	07 1	5171	736 7800.74	0.55.0	131 0751	131 5541	53.6 7.470	1703 075	031 7.47	0703 7.47	1 703 1 684	823 1 684	853 075	031 884	5 230 075	031 5541	636 7.470	703 6 528	016 6538	016 1 808	088 6 538	117 4211	2027 7 470 2	0.25.0	31 075.03	1 8 846 731	1 684 85
DUDDE	., 1,.	257	47'000'/ DC/	NC16 0.	VC16 101	1.FUC 1.CC	1/47/ 0.00	C16 C017	+-/ ICO-	1+-1 CO/10	00.1 00/.0	-00"T CC0"		+010 ICA-	C16 0017	-t-cc 100	1/4-7 0.00	00000 00/2	00000 010	0.00 1.000	00000 0000	117-4 010	10/1-1 610	0.016 m	CO.C.16 10	0.07070.01	1.004-00.1
November	9,2 1,.	.1638	696 6.179.25.	2 844.7	775 844.	775 844.	775 6.179	9.252 844	1775 7.37	2.218 7.37	2.218 1.70	872 1.708	1.872 844.	.775 7.37.	2.218 844.	775 844	775 7.372	218 5.122.	467 5.122	467 1.592	399 7.060.	758 6.179.	252 7.372.2	218 844.7	75 844.77.	5 7.372.218	1.708.87.
December	7,6 1,1	1651	736 3.785.72.	5 5549	151 554.5	351 975.	585 5.422	.956 554	.951 8.85	1.759 8.85	1.759 3.78	.725 3.785	:725 554.	.951 7.47	1.950 554.	951 975	585 8.851	759 4.213.	913 4.213	913 3.785	725 7.804.	681 5.422.	956 8.851.3	759 554.9	51 554.95	1 7.474.950	3.785.72.
Annual	7.4 1.1	1666 8	.616 49.057.05	5 48.667.	462 48.892.	652 48.537.	127 49.08	8.734 48.66	57.462 49.0	51.893 49.0	1.893 48.60	8.021 48.62	4.219 48.66	7.462 49.04	9.275 48.89	2.652 48.590	5.807 49.23.	9.932 49.380	379 49.00	(701 48.69)	7.726 48.317	889 49.064	.437 48.965.	360 48.420.	199 48.519.75	8 48.661.530	48.608.02
IBBILIA	(),T L,	) 000 <i>1</i>	1010014 010V	1000101	100 1001	100004 - 4000	00%1 /#P.	10101 L0100	11.704 7.70	V44 040100	10101 10011	10101 10108	10101 10101	1.110 TO 1.11	0004 01916	10001 B0018	1000	2208 12200	100164 610	10004 10.0	11000 DEV.		100001 1010	107 101 101	11/2 FOID 4/2	n Turning	40 10 00 VOL
Table H.2 Ener	gy productio	on map of t	he wind farm fo	or Corvo E	sland (Porti	ugal)		with	sensitivity	analysis of	O&M <sub>manag(</sub>	0															
	V <sub>WC</sub>	H	arod												AEP	(k Wh)											
Months	(m/s) (kg,	7/m <sup>3</sup> ) (	h) yr i	yr 2	2 VI	3 yr.	4 yı	r.5 V.	r6	17 )	r.8 y.	rg Vr	10 yr	ы. п.	12 VI	13 Yr	14 YT	15 YF 1	6 yr	7 yr	18 Yr I	9 VF	0 VI 2.	1 Vr2	yr 23	YF 24	YF 25
Innum	117 1	2312	TAD 14 A00	SOFFI CS.	14K7 14 40	0782 14.40	W FI CYFU	F FI CYF00	FI CYF 00.	101 677 101	71.408 10.8	W FI 80F 12	10.467 10.8	71 408 10.5	71 408 10.8	1 408 14 40	10.467 10.87	1 408 10.87	1408 1440	0.467 10.87	1.408 10.87	1 408 10 87	1408 10.871	408 10.871	408 10 871 4	08 10 821 40	8 10.871 4
Tahuan y	1 /11	3766	FUEL 1 041	COL 7 10	00.01 10.00	0001 1010	10.01 102.0	LF C 102.00	11 700 L.	101 701 101 101	02.1 302.31	LV C FOL 3	2,006 10.1	02 1 202 31	FUU F01 3	1172 10.00	0.01 2.02.0	10.01 004.1	100 F 201 2	10'01 2 201.0	LUF C 0003	10'01 004-1	1/001 007.	201 6 102	0710'01 00L	04-17-0-01 01	22 312 CT 1
reoraary	'I C'II	C+C7,	040 17:07:1	667.4 17.	40771 /CT	6071 17/7	0.21 127.20	14.0 17/26	71 060.71	71 17/760	17.1 co/.ci.	0./04 0.41	/77 0607/	1.1 00/.01	47°6 40/°C	4.1/2 1.21	77.121 0.0/-	17.71 CIO.4	67.6 00/0	004°C /CT-	116.0 067.0	CI07 060-	76071 000	./21 2.100	/0.9/0.0 /0/	7/760771 0	2/10/171
March	10,5 1,	,2329	736 10.486.2	28 3.193.	.907 13.71	7.510 13.71	7.510 13.7.	17.510 6.22	23.433 13.	717.510 13.	17.510 2.32	9.762 3.19.	3.907 13.7.	17.510 2.32	<b>29.762</b> 13.7.	17.510 13.71	17.510 6.22.	3.433 13.71	7.510 3.870	220 7.57	0.742 4.869	.967 13.71	7.510 14.424	289 2.037.	067 10.486.2	28 14.424.25	3.193.90
April	9,5 1,	,2317	712 7.316.5	97 7.316.	597 10.45	8483 1045.	8.483 10.4.	58483 7.31	16.597 10.	458.483 4.7.	16.485 3.08	6.689 7.31	6.597 13.2	57.022 3.08	6.689 13.2	57.022 4.700	5.485 4.70	6.485 13.25	7.022 3.080	689 10.13	4.212 3.086	.689 13.94	0.075 13.257	:022 3.086.	689 3.086.6	39 13.257.02	2 3.746.09
May	8,2 1,	,2282	736 4.851.6	76 10.440	5.845 10.44.	6845 1044	6.845 6.20	P0.059 10.4	146.845 10.	446.845 10.	46.845 3.86	1.662 6.20	0.059 10.4	46.845 3.80	1.662 14.3.	70.115 10.44	16.845 3.86.	1.662 10.44.	5.845 2.380	13.66	5.991 6.200	.059 2.380	1287 10.446	845 3.861.	662 14.370.1	15 10.446.84	5 4.851.67
June	7.1 1.7	.2224	696 2.994.4	61 12866	7.010 7.097	790.7 1867	7.09.7	1.01 189.77	45.990 4.5	55.858 IZ.	60.910 4.56	5.858 10.14	15.990 7.09	7.981 4.50	5.858 7.09	7.981 2.240	1.532 2.99.	4.461 7.097	906.1 1.905	861 12.86	760.7 016.0	906.1 1.905	861 7.097.	981 4.565.	858 12.860.9	10 7.097.98	5.834.80
July	6.1 1.	.2154	736 2.008.1	18 13.522	2.571 4.800	1760 6.134	1.992 10.3.	37.209 13.5	22.571 7.4	53.154 3.1-	(8.518 6.15	4.992 2.00	8.118 6.13	4.992 6.15	4.992 6.13	4.992 2.008	8.118 2.35:	5.801 6.134	.992 6.134	.992 14.21	9.306 10.337	7.209 3.821	135 6.134.	992 6.134.	992 13.522.5	71 3.821.13	5 7.463.15
Auoust	64 1	2075	736 234040	96 10.595	8.668 3.706	310 3706	5310 370	6310 13.4	34.719 6.0	75 134 37	17 17 17 17	1 668 2 34	0.406 4.76	0 571 741	4 668 4 76	9 571 10.59	8.668 1 00	5 072 4 769	571 13.43	4.719 1 00	5 (17) 13.434	1219 4 760	621 4760	571 7414	47695	71 3 128.06	8 10.270.05
Cantamhar	76 1	7900	K 099 E 612	10 1 008	773 5 801	022 4600	0917 9280	097 9280.	0 876 1 0	78772 58	1 057 0 03	5 180 0 02	5 180 3 66	20 0 202 0	992 0819	0 200 5 801	1 057 0 07	5 180 3 666	20 21 200	96 C 808 F	122 12 082	1 808 5 801	022 3,660	900 000	16 0 3 6 60 7	51 696 6 60	708001 0
October	80 1	9010	736 61210	101 9 02	070 2141	2006 822.	1 5 1 9 1 9	00 6 828 1.	12 564 2.2	VL 05705	FEI 0669.	WEI 500 10	21 005 2 14	F EI 822 L	01 002 314	1 278 7 446	07 1 0 CC 3	1002 3141	378 1064	2 787 2 14	278 2.002	1447 144	1112 000	107 21 822	A 2 2 2 6 1	20 2 00256	2 2 250 45
190100	4 × 5	0.414	01710 001	171.0 11			LT-0 L00-0	10-7 0//···		T-1 (UT-0)									100 0 010				11110 ATT				CE-0000
November	10,0 1,	+612,	C171701 060	C70.5 08	.62.2 624.	143 2.23	0.145 2.25	:77 5142	2.2 241.02	77 807.18	271 661.03	CC.4 0/6.67	4.8/0 2.23	0.143 124	C7-7 0/6/67	0.145 2.98.	.8.21 802.1	27.7 2.73	-143 9.80	./01 2:07		145 9.801	.01. 2223	145 12.829	07°C06'T 0/6	// 7.820.1/	16.679.71
December	11,5 1,	,2237	736 13.614.9	184 2.371.	.901 2.02	1842 3.170	9.035 2.02	21.842 3.17	70.035 3.5	47.249 2.6	21.842 14.2	16.481 13.6	14.984 2.02	1.842 14.5	16.481 2.02	1.842 3.84.	7.249 14.3.	16.481 2.021	.842 7.514	.158 4.83.	3.568 14.310	5.481 13.61	4.984 2.021.	842 14.316	481 6.176.9.	8 4.833.56	3 13.614.98
Annual	9,1 1,-	,2222	3.616 90.107.6	10 90.765	9.774 90.19.	0.491 90.25.	3.921 90.1:	976 816 97.6	16.328 90.	443.405 89.	28.042 90.6	S5.374 90.7A	90.678 90.0	78.677 90.6	85.374 90.5	30.336 90.47	73.134 90.24	16.888 90.07.	8.677 90.55	7.464 90.66	6.434 90.852	5.213 90.98	5978 90.162	:393 90.643	598 90.743.3	54 90.059.50	0 89.670.57
2011102	r 1/2	4 4 4 4 4			1100	C2006 16440	100			100	240000	1700 E.	0.00	200	100 H. 1000	14-06			22000 2 2 2 000				0	200		00100000 40	
Table H.3 Ener	gy productic	on map of t	he wind farm fo	or Cape Si	aint James (	Canada)		with	sensitivity	analysis of	O& M manage	()															
Mantha	V wc	H	prod												$AEP_{ava}$	u(k Wh)											
SHIHOM	(m/s) (kg,	) ( <sup>2</sup> (m <sup>3</sup> ) (	$h$ ) $yr_I$	yr.2	2 yr	3 yr	16 P.	rs y.	T 6	ir7 )	r <sub>8</sub> y.	r9 yr	10 M	<i>н</i> б 11.	12 yr	13 yr.	14 yr	15 yr,	6 yr	7 yr	18 yr 1	9 yr.	0 yr2.	I yr2	yr 23	yr 24	yr 25
January	15,4 1,	,2561	740 32.823.5	10 32.825	3.510 32.82.	3.510 32.82.	3.510 32.8.	23.510 32.8	23.510 32.	\$23.510 32.	23.510 32.5	23.510 32.8.	23.510 32.8	23.510 8.05	5.210 32.8	23.510 32.82	3.510 32.82	3.510 32.82.	3.510 32.82	3.510 32.82	3.510 32.825	3.510 40.86	5.255 32.823	510 32.823	510 28.095.9	29 8.035.21	7.120.17
February	14,7 1,	,2522	648 24.591.4	.04 14.672	2.254 7.016	1451 2659	9.864 14.6.	72.254 14.6	(72.254 26.	599.864 26	10.7 408.69	0.451 14.6.	72.254 14.6.	72.254 7.85	9.649 26.5	99.864 7.01U	3.451 17.62	3.290 7.016	451 7.010	451 7.010	0.451 7.010	.451 22.78	2600 26599	864 26.599	864 29.369.5	94 7.859.64	17.596.91
March	12.7 1.	.2495	736 18.252.3.	76 18.252	2.376 8.908	1878 27.87.	4.248 12.39	94.144 18.2	52.376 27.	874.248 27.	74.248 8.90	8.878 12.39	24.144 18.2	52.376 9.98	6.084 27.8	74.248 8.908	3.878 30.15	0.829 8.908	.878 8.90	.878 8.900	8.878 8.908	.878 23.02	4.061 27.874	248 27.874	248 31.459.3	74 9.986.08	4 18.948.10
Anril	124 1	2490	712 16.081.2	49 19315	5.677 9.656	023 24.86	5.308 9.65	6.023 19.3	15.677 24.	865.308 24.	65.308 9.65	5023 965	5.023 19.3	15.677 9.65	6.023 24.8	52.308 9.656	5 (D 3 26.95	2.947 0.656	CD 3 29.15	4.282 9.651	929 620	023 22.21	8.160 20.001	.184 24.865	308 24.956.4	59 9 656.02	8 18.165.62
Max	1 6 11	3040	736 12 224.0	095.56 19.	000 0380	98.01 00.91	2 0 0 2 0 0 0	3 36 0690	01 058 09.	10 073 10	CO O 220 CM	00 0090	6 3 C UCY C	5 67 058 05	24.061 10.8	C) 0.73 0.076	1536 0696	000 028 0.	1220 009	000 000	0000 0000	1010 009	8 078 10 863	073 10 863	073 10 116 3	20 102 01 21	101 XI 1
Inno	101	7351	V08 0 333 74	12036 20	1.495 11.59	12011	0110 023	0 % PP0 %	21 387 83.	121 001 000	511 00109	100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.04 14.0.2	23 186 15 5	11 503 17 0	201700115	1201 1201	01100112	1351 2403	11 11 22	11 1351	1 21 12 12	8 664 17 060	220 21 001	2 180 31 041	12 12 24 20	15 146 21
1.1	1 0 0 I	1007	100000 000		A COLOR DE LA C		4010 A-1012	100 000 J	10 400 14			400 400m	0.04 044 0	10 400 100	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~										0 100 11 100 100		
(mr	10,01	C/ 77'	7.1C/.8 0C/	10/67 57	9,039 10.35	7.950 IQ.53	0.5. /. 00	10.520 29.0	19.039 IO.	33/.930 IO.	10/ 066/6	3/.930 /.80	0.520 29.0	1/1 620/61	20.511 10.3	5/.930 IO.3.	1.900 /.000	0.320 10.32	19:02	5.991 10.33	/.930 10.33/	CC.CI 056.7	6000 I 1000	10.33/	930 IO./83.9	12/02/07/1 /00	202/.39
August	9,7 1,	0177	710 7.768.7.	12 12.11.	7.129 17.84	4.428 12.11	7.129 17.8	144,428 12.1	17.129 12.	117.129 12.	2/1 621.71	44.428 17.8	44.428 12.1	17.129 19.1	29.451 12.1	17.129 17.84	14.428 8.70	9.760 17.84	1.428 17.84	4.428 17.84	4.428 17.844	1.428 12.92	1.415 15.399	12.117	129 12.606.8	36 19.529.45	7.121.99
September	10,4 1,	,2234	/12 9.458.0	82 7.526	162 18.91	9.721 9.458	8.082 26.4	001433 7.52	20.165 9.4	58.082 9.4	58.082 18.5	19.721 26.4	00.433 7.52	0.165 24.	55.589 9.45	8.082 18.91	19.721 9.45.	8.082 18.91	9.721 15.75	1.596 18.91	9.721 18.919	9.721 12.33	9.146 13.294	981 9.458	082 &&55.0.	20 24.355.58	9 19.057.68
October	13,1 1,	,2327	736 19.706.9	14 8.788.	29.74	4.799 9.851	1.605 25.3	168.953 8.72	88.905 9.8	51.605 9.8	51.605 29.)	44.799 25.3	68.953 8.78	8.905 27.4	98.877 9.85	1.605 25.30	8.953 9.85	I.605 25.30	8.953 12.22	7.237 29.74	4.799 25.368	8.953 12.25	9.773 8.871.	247 9.851.	605 &134.1	57 27.498.87	7 21.626.62
November	14,3 1,-	,2429	696 24.188.6	539 9.393.	.250 26.21	9.466 8.375	7.993 28.3	60.895 9.35	13.250 8.3	79.993 &3	79.993 26.2	19.466 28.3	60.895 9.39	8.250 28.2	60.895 8.37	9.993 26.21	19.466 11.6	58.353 26.21	0.466 9.39	.250 26.21	9.466 26.215	0.466 7.520	.762 8.379.	993 8.379.	993 8.987.7.	16 28.360.85	5 22.240.11
December	15,1 1,-	,2528	736 30.229.1	53 10.012	2.025 25.75	2051 7.966	5.958 20.0.	27.814 10.6	112.025 7.9	66.958 7.9	6.958 25.7	82.051 20.0.	27.814 10.0	12.025 32.5	44.702 7.96	6.958 30.22	29.153 16.6.	74.139 30.22	9.153 10.01	2.025 25.78	2.051 30.229	0.153 6.359	397 7.966.	958 7.966	958 9.176.6.	37 32.544.76	2 42.535.34
Annual	12,5 1,	,2404	8.616 2B.5098.	B 2M.M4.	t.266 2.H.76	1434 2B.B)	7.728 2.B.6	511337 214.1	44.266 213.	197.728 213.	97.728 214.7	61.434 213.6.	11.337 214.1-	44.266 213.6	25.948 213. h	97.728 214.85	32.689 214.3.	38.805 214.83.	2.689 214.50	1.803 214.76	0.434 214.832	2.689 214.03	8.947 214.203	.964 213.197	728 214.523.4	12 213.625.94	8 214.387.65

Table H.4 Wind	l speed sei	ries simula	tions for Al	EP and in AI	acati (Brazil	D		-	vith sensitiv	ity analysis	of O&M man.	ag(A)		•												1
Months	Vwc (m/s)				. 10	247.	UP.	- 40	20.0		UP 10	Wind sp	eed data se	ries for simu	ations (m/s)				WF 10		UF ac	UP		v		
Innuan	5.8	5.8	101	76	4.0	01	1 01	101	10	7.0	101	101	10	76	50.6	70	01.01	101	10	7.6	0.6	10	76 0	2 90	10	202
February	4.9	4.9	9.7	2'5	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	2.9	9.7	4.0	4.0	7.6	8.6	1.01	6.0	6.0	101	2.0	. 0	8.6
March	4.0	4.0	9.6	8.6	1.01	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7 10	1.0	.6	0,2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	0.2	0	9.6
May	6,0	6,0	8,6	9'6	8,6	6,0	8,6	6,0	6,0	9,7	8,6	8,6	5,8	9'6	9,2	5,8	5,8	4,9	10,1	4,9	4,0	4,7	9,2	6.2	8	0,7
June	7,9	7,9	7,9	9,7	9,2	7,6	7,9	7,6	7,6	10,1	7,9	7,9	7,6	9,7	8,6	6,0	6,0	4,7	9,7	4,7	4,7	7,6	8,6	3,6	1 65	1'0
July	8.6	8.6	7.6	1.01	5.8	7.9	7.6	7.9	7.9	4.0	4,0	7.6	8,6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	.8	(7	0.4
August	9'6	9'6	6,0	6,0	6,0	10,1	6,0	8,6	8,6	4,7	4,7	6,0	7,9	6,0	5,8	8,6	9,7	9,7	4,7	7,9	9,7	8,6	6,0	5,0	0	4,7
September	10'1	10,1	5,8	5,8	7,6	9,7	5,8	9,2	9,2	4,9	4,9	5,8	9,2	5,8	7,6	9,2	9,6	9,6	4,9	8,6	10,1	9,2	5,8	2'6	2,0	6'1
October	9,7	9,7	4,9	4,9	4,0	9,6	4,9	9,6	9,6	5,8	5,8	4,9	10,1	4,9	4,0	9,6	9,2	9,2	6,0	9,2	7,9	9,6	4,9	1,9 11	10	5,8
November	9,2	9,2	4,7	4,7	4,7	9,2	4.7	9,7	9,7	6,0	6,0	4,7	9,7	4,7	4,7	9,7	8,6	8,6	5,8	9,6	9,2	9,7	4.7	4.7	7	5,0
December	7,6	7,6	4,0	4,0	4,9	8,6	4,0	10.1	10,1	7,6	7,6	4,0	9'6	4,0	4,9	10.1	7,9	7,9	7,6	9,7	8,6	10.1	4,0	1,0	0,0	2,6
Annual	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	.4	4'
																										1
Table H.5 Wind	speed ser	ies simulat	tions for AE	P wait in Co.	rvo Island (	(Portugal)		W	ith sensitivi	ty analysis c	of O&M mana	$\chi(A)$														
.	V <sub>NC</sub>											Wind spe	ed data ser	ies for simu	ations (m/s)											1
Months	(m/s)	$yr_1$	$yr_2$	yr3	yr.4	yr 5	yr 6	yr 7	$yr_8$	yr9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	97 22 yı	r23 y.	24 y	r25
January	11,7	11,7	11.7	11.7	11.7	11,7	11,7	11,7	10,6	10,6	11,7	10,6	10,6	10,6	11,7	10,6	10,6	11,7	10,6	10,6	10,6	10,6	10,6 10	10 10	1 90	9'0
Febmary	11,5	11,5	8,2	11,5	11,5	11,5	7,6	11.5	11.7	6,I	7,6	11,7	6,1	10,5	2,11	9,5	11.7	8,2	8,9	7,6	7,1	11,5	6,4 9	5. I.	5 1	1,7
March	10,5	10,5	7,1	11,5	11,5	11,5	8,9	11,5	11,5	6,4	1'1	11,5	6,4	11,5	11,5	8,9	11,5	7,6	9,5	8,2	11,5	11.7	6,1 1(	,5 I.	2	1'2
April	9,5	9,5	9,5	10,6	10,6	10,6	9,5	10,6	8,2	7,1	9,5	11,5	7,1	11,5	8,2	8,2	11,5	7,1	10,5	7,1	11,7	11,5	2,1 3	·1 Γ.	5	2',6
May	8,2	8,2	10,5	10,5	10,5	8,9	10,5	10,5	10,5	7,6	8,9	10,5	7,6	11.7	10,5	7,6	10,5	6,4	11,5	8,9	6,4	10,5	7,6 11	1.7 11	,5	8,2
June	1'1	1'1	11,5	9,5	9,5	9,5	10,6	8,2	11,5	8,2	10,6	9,5	8,2	9,5	6,4	7,1	9,5	6,1	11,5	9,5	6,1	9,5	8,2 11	5,5	5	8,9
Judy	6,1	6,1	11,5	8,2	8,9	10,5	11,5	9,5	1.7	8,9	6,1	8,9	8,9	8,9	6,1	6,4	8,9	8,9	11,7	10,5	7,6	8,9	8,9 11	5,5	,6	9,5
August	6,4	6,4	10,6	7,6	7,6	7,6	11,5	8,9	7,6	9,5	6,4	8,2	9,5	8,2	10,6	6,1	8,2	11,5	6,1	11,5	8,2	8,2	9,5 8	2,2	I I'.	),5
September	7,6	7,6	6,1	8,9	8,2	8,2	8,2	6,1	8,9	10,5	10,5	7,6	10,5	7,6	8,9	10,5	7,6	11,5	6,4	11,5	8,9	7,6	10,5	,6	4	5,1
October	8,9	8,9	8,9	7,1	6,1	7,1	6,1	6,4	9,5	11,5	11,5	7,1	11,5	7,1	9,5	11,5	7,1	10,6	7,1	6,1	9,5	2,1	1.5 6	6,4	13	5,4
November	10,6	10,6	7,6	6,4	6,4	6,4	6,4	7,1	6,4	11,5	8,2	6,4	11,5	6,4	7,1	11,5	6,4	10,5	7,6	6,4	10,5	6,4	1,5 6	, I,	1 6'	1,5
December	11,5	11,5	6,4	6,1	7,1	6,1	7,1	7,6	6,1	11,7	11,5	6,1	11,7	6,1	7,6	11,7	6,1	9,5	8,2	11,7	11,5	6,1	1,7 8	s,9	1 1	1,5
Annual	9,1	9,1	9,1	9,1	9,1	1'6	9,1	9,1	<i>1'6</i>	9,I	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,1	9,I 9		Ľ	1'0
толны 11 с Witho				с  Е		C)	3																			
TADIC 11.0 W II	h <sub>w</sub> ,	crics summi	auous ior A.	Er avait III C	apesating		(pr		MIII SEUSIUV	ny analysis	01 U&M man	ag(A) Wind sp.	eed data se	ries for simu	ations (m/s)											I
Months	( <i>m</i> / <i>s</i> )	yr 1	$yr_2$	yr 3	yr 4	yr5	yr6	yr7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22 yi	r 23 y	24 3	r25
January	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	9,7	15,4	15,4	15,4	15,4	15,4	15,4	15,4	16,6	15,4	15,4 14	1,7	5,7	9,3
Febmany	14,7	14,7	12,4	9,7	15,1	12,4	12,4	15,1	15,1	9,7	12,4	12,4	10,0	15,1	9,7	13,1	9,7	9,7	9,7	9,7	14,3	15,1	15,1 1:	5,6 11	1 0'	3,1
March	12,7	12,7	12,7	10,0	14,7	11,2	12,7	14,7	14,7	10,0	11,2	12,7	10,4	14,7	10,0	15,1	10,0	10,0	10,0	10'0	13,8	14,7	14,7 I:	5,3 11	,4 I	2,9
April	12,4	12,4	13,1	10,4	14,3	10,4	13,1	14,3	14,3	10,4	10,4	13,1	10,4	14,3	10,4	14,7	10,4	15,1	10,4	10,4	13,8	13,3	14,3 Iz	4,3 11	,4 I	6,5
May	11,2	11,2	14,3	10,4	13,1	10,4	14,3	13,1	13,1	10,4	10,4	14,3	11,2	13,1	10,4	14,3	10,4	14.7	10,4	10,4	13,4	13,1	13,1 1:	3,0 1.		<i></i> .
anne	10,4	10.04	141	711	1.21	0'07	14./	1,21	/ 71	7,11	0'07	14,/	+'71	/'71	7'11	14,7	711	C, +1 1 c 1	7'11	7'11	0'71	12.7			+ +	7.0
Auron A	0.01	0'07	1101	+'71	t, 21	1.6	1101	t'71	+'71	+'71	1,4	1'01	121	+'71	+'71	1001	+'71	1,01	+,21	1.27	7'71	C'71	1			0'r
Sentember	10.4	10.4	2'11	13.1	7'11	14.7	2'11	7,11	7'11	13.1	14.7	2.11	143	7'11	13.1	10.4	13.1	12.4	13.1	13.1	11.4	1.2	10.4 11	1 20	1	1.0
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2	15.1	14.3	11.2	1.01	10.4	.1 80		3.5
November	14,3	14,3	10,4	14,7	10,0	15,1	10,4	10,01	10,0	14,7	15,1	10,4	15,1	0'01	14,7	11,2	14,7	10,4	14,7	14,7	9,7	10,0	10'0 10	),3 1.	1 13	3,9
December	15,1	15,1	10,4	14,3	9,7	13,1	10,4	9,7	9,7	14,3	13,1	10,4	15,4	9,7	15,1	12,4	15,1	10,4	14,3	15,1	9,0	9,7	9,7 1(	0,I I.	,4 I	5,9
Annual	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5	12,5 I.	2,5 1.	,5 I	2,5

Cites .												K.	W/yr												
Siles	yr <sub>1</sub> yr	-2 yı	r3 yı	r4 y.	r5 )	yr 6	yr7	$yr_8$	yrg 3	T 10 3	W II	yr 12	yr 13	yr 14	yr 15	yr 16	yr17	yr 18	yr 19	yr 20	$yr_{21}$	yr22	yr23	yr24	$yr_2$
Aracari (Brazil) 5 (	593 5 64 <sup>.</sup>	8 567	74 563	13 569	97 56	48 51	593 51	593 51	541 51	5' 2'	548 5	693 5	5 674	5 640	5 715	5 731	5 688	5 652	5 608	5 694	5 683	5 620	5 631	5648	564.
Corvo Island 10 . (Portugal)	458 10 53.	5 1046	10 47	75 1040	58 105	-01 E9:	497 10.	429 10.	525 10:	527 IO.	454 10	1525 IC	) 507 I.	0 5 00 i	0 474	10 454	10 510	10 523	10 545	10 560	10 464	10520	10532	10452	1040.
Cape Saint James 24; (Canada) 24;	780 2485	3 2492	5 2474	13 2479	91 248	53 24:	743 24	743 24	925 24:	791 24	853 24	193 24	4 743 2	4 933 2	34 876	24 933	24 895	24 925	24 933	24 841	24 860	24743	24897	24793	2488.
×																									
able H.8 Cashflow for 25 years o	of the wind farr	n project	50 000	kw	Aracati (Braz	(liz			with	sensitivity a	malvsis of t	D& M													
In market and the second		and out a	000.00							Company of the	TO GE CHINA	Vianum monog(A	Years												
Item	0	-	2	3	4	s	9	7	8	6	10	=	12	13 1	14 1	5 14	5 17	18	19	20	21	22	23	24	25
(-) LCCCM <sub>WF</sub>	60 225 90	- 10	,	'	,	,	,	,	,	,	,	,	,	,	,	,					'	'	,	,	
$WT_{CM}$	27 686 27	- 8																			'	'			
Tar	24 219 25	, ,									,														'
LWIG <sub>CM</sub>	1 545 24	, ,																							'
TS CM	572 83	2 54																							
SICH	2 136 72													,		,									
$PO_{CM}$	1 796 87	- 0.	•	•	•	•								,								'	•	•	1
$F_{CM}$	188 55	- 6		•	•	•																	•	•	
CCC ar	12021		- 10 000 -		-	- 000.04				- 07 100				- 40 40				- 40.007				- 007 07 0	- 40 640 760		- 000 01
LLTM WF (KWILYF) (+) AAR (SM/wr)		4314824	5 4387 573	700760 04 3	4597349	4765 836	46 00/ 402	+ 060 100.6+ + 068 348 5	2 128 437 5	00 012 40	074 712 40 341 081 57	479477 56	704 017 640	83513 580	2000 492	9.44 5.679, 679, 679,	0.341 6309	140.04 10/	110 4021	567 49 0044.	35 493996	0 500711	2614046	000 100 04	5 413 05
PPAR		4 314 820	6 4 387 573	4 518 071	4597349	4765836	4843059	5 003 348	5 128 432 5	209 075 5	341 081 5.	479477 56	\$60.527 57	83513 58	92 231 6 11	9463 629	0.341 6.395	1200 6517	427 6 6 2 8 2	26 6 898 95	35				
EMP														,		,					4 939 95	0 5 007 11.	5 5 142 845	5 286 820	5 413 05
(-) O&MWFCH		3 964 70.	6 4 031 427	7 4 151 213	4 223 934	4378615	4471031	4618343	4 733 137 4	806 905 4	928 061 5 xxo 441 27	055 095 52	221459 53 106775 25	34243 54 77748 27	33856 56	12744 575 5277 386	9 641 5 890 7 895 2 890	344 6 007	676 6109.	183 63579:	99 586798 35 135050	4 594706	2 6 107 615	6 277 939	6 427 1:
O&M pixed		1 299 215	7 1 321 003	1 360 175	1383 923	1434523	1479 236	1527 531	1 565 056 1	2 0.60 17	28.620 1.	670162 17	*24.683 17	61 494 170	76 10666 93920 1866	22467 191. 22467 191.	3806 1946	264 1981	563 20146	3/0 4/2017. 306 2/09621	14 150847	7 1528319	1569.092	1 612 361	4 //0 %
(+) LRCM		863 26	8 884 850	906 971	929 646	952 887	976709	1 001 127	1 026 155 1	051 809 11	778 104 1	105 057 11	132 683 11	61 000 1 15	90.025 1.21	9.176	,	,			,	,	,	,	
(+) Depreciation		2 453 48	6 2514824	: 2 577 694	2 642 137	2708190	2775895	2 845 292	2 916 424 2	989 335 31	064 068 3	140.670 32	219187 32	99 666 33	82158 34	6712 355	3 380 3 642	214 3 733	270 3826t	501 3 922 20	57 402032	3 412083	1 4 223 852	4 329 448	4 437 68
(=) Profit before tax		3 666 87	7 3755819	3 851 524	3 945 197	4 048 298	4124632	4 231 424	4 337 875 4	443 314 4.	555 193 4	670108 45	790 938 45	09 937 50	30.558 51(	3 206 4 04	4 079 4 142	070 4 243	020 4345(	575 446320	02 309232	3 180 88	4 3 259 082	3 338 329	3 423 5(
(-) Revenue tax		1 294 44	8 1316272	1 355 421	1379205	1 429 751	1 452 918	1501 004	1 538 530 1	562 723 1	602 324 1	643 843 16	598158 15	35 054 17	67 669 18.	35 839 1 88	7 102 1 915	760 1955	228 1988	477 20696	80 148195	7 150213	4 1542854	1 586 046	1 623 9
(+) REPIM	384 768	2 046	1991	1 963	1912	1 899	1 849	1 830	1 798	1751	1 722	281	291	297	303	314	3.	29 35	34	354	362	367	377	388	397
RFP	CIC 177	- 1875	- 1766	- 1731	- 1676	- 1654	1.600	- 1573	- 1 535	1484	- 448														
OREP	163 455			'																					
$GHG.R_{CM}$	'	222	225	232	236	245	249	257	263	267	274	281	291	297	303	314 5	23 3.	29 33	5 340	354	362	367	377	388	397
(=) Profit after tax w/out intere		2 374 47(	6 2441539	2 498 065	2567905	2620446	2 673 562	2 732 250	2 801 143 2	882 342 21	954.591 3	026547 30	93.071 3.1	75180 324	63 191 3 32.	7 682 2 15	7 300 2 222	0.639 2.288	127 23575	538 23938.	76 161065	14 1 679 11	5 1716606	1 752 671	1 800 05
(-) Debt payments			3 175 718	3 255 111	3 336 489	3 419 901	3 505 399	3 593 034 5	682 860 3 5	74 931 38.	99 304 3 9	66 037 4 06	55 188 4 16	6 818 4 27(	988 4375	763								•	'
$(+) RCM_{WF}$		2 621 73	9 2 687 282	2 754 464	2 823 326	2 893 909	2966257	3 040 413	3 116 424 3	194 334 3.	274 193 3	356047 34	439 949 35	25947 36	14 096 371	14 448 375	7 060 3 891	986 3989	286 4089(	018 41912	43 429602	24 4 4 03 42	5 4513511	4 626 348	4 742 00
(+) Depreciation (=) Free net cashflow	-59 841 13	2 455 48	6 2514824 1 4467926	4 575 113	2 642 157 4 696 879	2 /08 190 4802 644	27/2 892 4910315	2845 292 5024922	2 916 424 2 5 151 132 5	989 355 5 4 291 080 5 4	064.068 5 123.547 5.	1406/0 5. 557227 56	21918/ 52 587018 58	99 666 55 33 976 591	82158 54. 38457 612	6712 555 1079 950	3 380 3 04. 7 740 9 756	2214 3755	270 58260 682 102731	501 59222 58 1050738	67 4 U2U 5. 36 9 9 2 7 0 4	23 4 120 85 2 10 203 37.	3 10 453 968	4 329 448 10 708 467	4 457 00 10 979 74
$\Sigma$ free net annual cashilo		-52 391 43.	1 47 923 505	43 348 392	-38 651 514 -	-33 848 870 -	-28 938 555 -:	23 913 633 -1	3 762 502 -13	471 421 -81	047 874 -2.	490.647 3.1	196371 90	30347 150	18 804 21 10	9 884 30 64	7 624 40 404	463 50 415	145 60 688 2	302 71 195 68	88 81 122 75	0 91 326 10	3 101 780 071	112 488 539	123 468 21
	LCOE	" 67.68	67.83	68.04	68.20	68.45	68.64	68.89	69.10	69.28 (	9.51	69.74 7	0.02 7	0.25 71	1.46 71	.79 69.	82 70.0	12 70.2	2 70.42	70.78	70.39	70.58	70.85	71.13	71.40

Table H.9 Cashflow for 25 years of th	e wind farm pi	oject	50 000 kW	Corvo	Island (Por	tugal)			with ser	sitivity analy	s is of O&M,	vanag(A)												
Item	0	-	6	6		0		~	6	01	=	Yea 12	s 13	14	15	16	17	18 1	9 20	21	22	23	24	25
(-) LCCCM <sub>WF</sub>	60 225 901										•	•	•	•									•	
WT CM	27 686 278																							
$T_{CM}$	24 219 295				,																			
LWTGCM	1 959 783		,																					,
CP CM	045 646 1																							
10 CI	700710																							
POC	1 796 870																							
For	188 559		,	,		,						,		,				,		,			,	,
CCC	120211		,	,		,						,		,				,		,			,	,
LCPM www. (k.Wh/vr)		00 107 610	0 769 774 90	190.491 90.25	3 921 90 16	10 10 223 01 01	6328 90.44	3 405 89 858	042 90.685	74 90.700.6	78 90.078.67	7 90.685 374	90 530 336	90 473 134	0.246.888 9	0.078 677 90	557 464 - 904	566.434 90.85	5213 90.98	201 00 162	393 90 643	508 00 743 3	4 90.059.500	89 670 577
(+) AAR (SM/vr)		15 046 124	5 535 609 15	822374 1622	9340 166	012 0100	4985 1751	3.916 17.83	578 18.449	87 189142	19.75412	19868.407	201330 205	20.825 386	c 179 cbc 1	C LLC 181	447 567 231	36443 23.66	36 76 815 1	201 02 02 02 02 02 02 02 02 02 02 02 02 02	1202 11 128	18 260 01	3 18 575 463	18 957 676
DAP		121 040 21	5 535 600 15	20374 1670	9340 166	0171 04045	1971 2004	3016 1783	578 18.440	C 18 014 7	21 10 254 12	201-000 (1 /	202 002 02	985 386 00	c 119 00 1	C LLC 18L	102 102 114	36.443 73.64	27 27 21 28	7 063				000 / 00 01
EMP	,		-			-		-							,	,				- 17 268	871 17 795 (	18 260 01	3 18 575 463	18 957 626
(-) Ot M		9 414 550	0 102 0 20	00 01 21 000	A 577 10.4	1 931 10.75	8477 10.06	7 807 11 156	0.08 11 543	92 11 833 6	46 12 046 18	5 12 430 378	12 719 232	13 078 853	3 3 21 057 1	2 628 511 14	043 351 147	111.633 14.80	0 558 15 10	1 336 13 212	815 13 615	13 970 91	14 212 144	14 504 416
O.E.M.		1 805 013	2 212 2012	86.5 965.801	M 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	055 12900	5150 5.60	8 0 3 5 8 0 S	200 6003	2121212	21 29 6 2 65 17	010000000000000000000000000000000000000	6615 357	6776.440	887 809	098 360	2 386 108	292 102 201	70 7 0 C 0	2132 8 007	126 8 185	1 8 48 10	8 634738	6812382
D.F.M.		1 510 607	A 665 407 4	TO A 201 10T	2570 400	91.5 05000	90.5 01.0	000 5350	120 5 520	26 5 670.0	001025 00	100 2010	6 102 990	SON CSC 3	6 207 560	1 201 000 1	730.062 66	01 2 222 210	002 1902	201.2 200.1	424 5 242	10 00 2 112	201100000000000000000000000000000000000	5 402 024
Count variable		100.010 +	+ 001000+	0 + 00+10/		DIC 00776	200 0000 200		11101 D21	100000000000000000000000000000000000000	1010/1 00	170 004 0	000 010	100 001 1	200 200 1		0 000 401	W / 70/01	67 / ±07 0	COT C CO7 1		10704 C /TC	00+1100 1	+C0760 C
(+) TWC12		007 000	004020	26 1/60/06	2 0H0 5	16 10070	010	1070 1 171 1		10/01 400	0.0011 40	200 201 1 /	000 101 1	C70 061 1	0// 6171									
(+) Depreciation		206 644 7	7 1400107	007 HDCC/C	V 7 / CO /	117 91CCC	1001 0001	167 167 2012	1067 001	2 200 C 110	200011000	COV CI7 C 7	140 467 6	200 0/ 0 0	2 400 202	- 670 000	C 710.000	70 C 716071	16 5 5000	010 0 0100	1000 0 000	20017 4 71002	0777676 0	121 064 4
(=) <i>Profit before tax</i>		101 446 8	6 967 017 6	407 028 0 0 0	26 0607	2101 6/46/	4.590 10.55	1901 5667	162 109420	6/11711/14	51 11 448 52 m c m c m c 20	0 11 /84 412	12,000,000	006 709 71	1 901 700 7	71 660 507 1	71 877 040	1971 777 109	00 51 540.6	7.21.5 8.069.	222 8 293	)/ CDC 8 - 580	065 080 8 0	8 883 33/
(-) Kevenue tax		4 213 83/	4 000 083 4	/40 / 12 4 80	8 802 4 96	CI C 1984/S	2 0 0 4 1 2 2	410 030	10/2 CCC C/0	26/00 06/	57 9/ / C / C	175 096 5 8	690 660 9	0 24/ 010	76/ 1850	527 283 0	0 0/7 45/	SU / 55601	197 / 001 8	0.91 0 680 0	222 C 100	019/15 01/2010	6607/00 +	997 / 90 C
(+) REPIM	486 675	1439	1420	1382 13	355 1	327 13	13	279 12	1 123	1211	1 180	1 167	1 144	1 123	1 100	165	170	175	1 621	84 18	19	198	201	205
$REI_{CM}$	221 313					,		,							,	,	,		,					
$REP_{CM}$	,	1 325	1 302	1262 13	232 1	201 11	83	47 11	1 10%	1 068	1 034	1 016	666	965	939	,	,	,	,	,			'	,
OREP CM	265 362	,				,		,			1	'	'		,		,		,				'	
GHGR CH		114	118	120	123	126 1	30	1 133	5 140	143	146	151	154	158	161	165	170	175	1 10	84 18	7 195	3 198	201	205
(=) Profit after tax w/out interest		4 431 752	4 551 033 4	657 307 4 77	4 648 4 80	33.377 5.07	7 207 5 14	7607 5 264	735 5408	45 5544	75 5673.26	3 5825.058	5 968 165	6116463	6265 476	5 167 976 5	306 128 5	140 964 5 55	0769 572	2 2 889	050 2 055	97.00 5 179	112 957	3 196.754
									00.0010 0000000000000000000000000000000			1 1040144	001 002 021 1	and of a	014 007 0					600 × 600 0				
(-) Dept payments			10 210 27	49.208 3.330	80/ 3#Te	66± 5 1/0 1	080.5 675	0/05 016	00 80/ 5 88	GI/ 798 5 5	587 666 5	4 UD 8 700	4 159 122	4 203 /ID	\$ 3/0.308									
$(+) RCM_{WF}$	,	2 621 739	2 687 282 2	754464 282	3 3 2 6 2 8	33.909 2.96	6257 304	0413 3116	424 31940	34 32741	33 3356.04	7 3439 949	3 525 947	3 614 096	3 704 448	3 797 060 3	891 986 33	89 286 4 06	9018 419	1 243 4 296	024 4403	425 4 513 51	1 4 626 348	4 742 007
(+) Depreciation		2 449 308	2 510 541 2	573 304 2 63	7 637 2 70	03 578 277	1167 284	0447 2911	458 2.9843	44 30588	50 313532	2 3213705	3 294 047	3 376 398	3460808	3 547 329 3	636 012 3'	726912 382	0.085 3.913	5 587 4 013	477 4 1131	814 421665	9 4 322 075	4 430 127
(=) Free net cashflow	-59 739 225	9 502 799	6 578 546 6	735 508 6 90	4804 7.00	76732 726	5 202 7 43	8 642 7 616	029 7819(	21 80148	33 8 205 34	9 8420446	8 628 438	8 843 243	9 060 425 1	2 5 1 2 3 6 5 1 2	834 126 13	57 162 13 48	9 872 13 82	839 11 198	560 11 472	195 11 758 13	3 12 061 381	12 368 389
Υ.		- 90 236 426	3 657 880 -36	10 05- 175 000	2 CC- 195 L	10.835 -15.67	5633 -8.73	000 -000	1081	80 152128	12341821	1 31 838 657	40.467.095	49 310 338	R 370 764 7	8 80 880	117 254 961	874416 1103	64 287 124 15	4 126 135 392	686 146 865	181 158 623 3	5 170 684 685	183 053 074
🖛 freenet annual cashpow		- 0.4L 0.14 00	00-000/00/0	10 00- 110 000	- mm - 100 1	10 PT- 000 PT	- nnn n	V=0-0/0	10/1/ 10/	0.414.01 000	10 10 10 10 10 10	100.000 10 1	CON INT NT	000 000 /1		0 0** 000	111 100 100	0111						
	22	2	4						2		6	5 4	2				0		4					
Table H.10 Cashflow for 25 years of t	he wind farm	roject	50 000 kW	Cape	Saint James	(Canada)			with ser	sitivity analy	sis of O&M,	vanag(A)	9											
Item	0	-	2	с 4		2		~	6	10	11	12	13	14	15	16	17	18	9 20	21	22	23	24	25
	10.444.001																							
(-) DCCCMwr	106 577 09																							
WI CM	2/7 090 77	,	,	,	,	,		,									,	,	,					,
I CM	C67.617.47										'													
$LWTG_{CM}$	1 959 783				,		,									,	,	,						,
CP CH	1 545 346				,							'	'					,					'	,
TS CM	572 832			,	,	,	,	,					'			,			,	,			•	
$SI_{CM}$	2 136 726	,	,	,		,		,			'	'	•	,	,	,	,	,	,				'	,
PO CM	1 796 870	,				,		,					•		,		,		,				'	
$F_{CM}$	188 559	,	,	,	,	,	,	,				•	'	,	,	,	,	,	,	,			'	
CCCar	120211				,	,	,	,			'	•	•			,	,		,				•	
$LCPM_{WF}$ (k Wh/yr)	,	213 509 813	214 144 266 214	47614342131	97 728 213 6	511 337 214 1-	44 266 213 1	97728 21319	728 214 761	434 213 611 3	37 214 144 26	5 213 625 948	213 197 728	214 832 689	214 338 805 2	14 832 689 2	4 501 803 214	761 434 2148	32 689 214 03	8 947 214 203	964 213 197	728 214 523 4	2 213 625 948	214 387 639
(+) AAR (SM/yr)		30 276 974	1 126 117 31	996219 3255	7331 334	36 006 34 35	7409 35.06	0 685 35 937	202 37 105 1	04 378297	72 38 872 25	5 39747 622	40 659 646	41 995 741	12 946 676 4	4 121 775 45	155 164 46	340 065 47 51	4 326 48 52	2 244 34 841	551 35 5441	828 36 659 99	5 37 419 293	38 491 531
PPAR		30 276 974	1 126 117 31	996219 3255	7331 334	36 006 34 35	7409 3506	0 685 35 937	202 371051	04 37 8297	72 38 872 25	5 39747 622	40 659 646	41 995 741	12 946 676 4	4 121 775 45	155 164 46:	340.065 47.51	4 326 48 52	2 244			'	
EMP					,							'	•							- 34.841.	551 35 5441	828 36 659 99	5 37 419 293	38 491 531
(-) O & M W F CM		20 688 790	1 268 898 21	863 324 22 24	6612 228	46 890 23 47	6361 2395	6782 24 555	577 25 353	46 25 848 4	98 26 560 68	5 27 158 681	27 781 721	28 694 515	93441373	0 146 919 30	852 873 314	562 346 32 46	4 546 33 15	3 088 29 528	360 30 1243	265 31 069 24	4 31 712 621	32 621 209
$O\&M_{fixed}$	,	11 600 929	1 926 280 12	259 661 12 47	4 651 12 81	11317 1316	4355 1343	3815 13769	654 14217	14 494 7	95 14 894 22	5 15 229 623	15 579 065	16 090 994	6 455 346 1	5 905 588 17	301 532 17	755 529 18 20	5 449 18 59	1 634 19 071	110 19 4560	054 20 066 45	3 20 482 061	21 068 961
$O\&M_{variable}$	,	9 087 862	9 342 619 9	603 663 9 77	1962 10 0	35 573 10 31	2 006 10 52	2 968 10 785	923 111363	39 11 353 7	33 11 666 46	0 11 929 059	12 202 656	12 603 521	2 888 791 1	3 241 331 13	551 341 139	06817 1425	9 097 14 56	1 454 10 457	250 10 668	211 11 002 75	1 11 230 560	11 552 248
(+) LRCM		863 268	884850	906971 92	9 646 92	52.887 97.	6709 100	1127 1026	155 1 051 3	10781	04 1105 05	7 1132 683	1 161 000	1 190 025	1219776				,				'	
(+) Depreciation		2 431 021	2 491 796 2	554.091 2.61	7943 26	83 392 275	0477 281	9239 2889	720 2961	63 3 0 3 6 0	12 311191	2 3189710	3 269 453	3 351 189	3 434 969	3 5 20 843 3	608 864 34	599.085 3.75	1563 3884	5352 3983	510 40830	098 418515	6 4 289 805	4 397 050
(=) Profit before tax	,	12 882 473	3 233 865 13	593 957 13 85	8308 142	25 394 14 60	8 2 34 14 92	4268 15297	500 157654	30 16 095 3	89 1652853	8 16911 334	17 308 377	17 842 439	8 257 283 1	7 495 699 17	911 155 18:	376 804 18 84	1 343 19 25:	5508 9296	701 9.5034	561 977592	7 9 996 478	10 267 372
(-) Revenue tax	,	9 083 092	9 337 835 9	598 866 9 76	0 01 661 //	30 802 10 30	7 223 10 51	8 205 10 781	161 11 131	41 11 348 9	31 11 661 67	7 11 924 287	12 197 894	12 598 722	2 884 003 1	3 236 533 13	546 549 139	02 019 14 25	4 298 14 550	5 673 10 452	465 10 663	148 10 997 99	9 11 225 788	11 547 459
(+) REPIM	932714	780	794	3 608	315	830 8	146	827 8	1 89	904	801	819	838	865	885	606	930	955	79 10	00 1 02	1 046	5 1079	1 101	1 133
REL	221313	,	,	,	,	,	,	,		,	,	,	,	,	,	,	,	,	,	,		,	,	,
REP		156	153	140	45	141	38	34	×1	501		,			,	,	,	,	,				,	
OREP	711.400	2	1		2 '		3 '	5 '																
CHC B	0006-111/				6	003			1	022	100	010	020	006	800	000	020		01 024		101	0001	101.1	1 1 3 3
(-) Profe allowed and an and an and		2 000 161	2 006 024 2	005 000 1 00	11001	000 000 1 00	1 057 1 4	1210 121	0/ 10/ 10	C 11 1 101	100 496766	2 1007 966	1020	002 002 5 2 4 4 5 2 2	224 165	1 200 0001	006 206 206	006 V V V V V V V V V V V V V V V V V V	01 4 400	101 100	1001 1000	201 1 22000	1011	220 026 1
(=) rioju diteriax Wout interest		101 000 0	c +70 0/0 c	40.+ 006.066	1 A 24 4 10	90420 430	1001 0010 100	104 6160	4034 117	C /th/ th 70.	00/001 700	000/064 0	170 111 0	700 100 100 1	COI +/ C C	+ C/0 007+	·+ 0cc coc	00 + 0+/ 0/+	0 17 17 17 17 17 17 17 17 17 17 17 17 17	+CI I- +CO 6	001 1- 601	66077 1- 1+/	407 977 1- 7	CC6 0/7 1-
(-) Dept payments			0,007,007,007,007	000 0000000000000000000000000000000000	2000 JUN 2000	2/10 000000	1000 LINE 100	0.410 0.049	27 3 740.30	#/20020 0	171 676 0	406/70 t	000 971 4	2 614 000	2704 440	- 101 000	- 200 100							100 010 1
(+) NOM WE		1001070	7 707 100 7	10 7 40440/	39 C 670 L			100 C 000 0	1300 000	14/70 40	10111 0 01		2000 452	040 +10 0	3 424 060	000/6/0	000 000 000 000	30 t 0 007 604	1 562 2 000	067 6 020 3	10011 013	1201 1 000	0400001 3	10074/ 4
(=) Free net cashflow	-\$0 293 187	8 852 920	5 929 263 61	079150 622	7255 638	84138 654	2230 677	9 2.37 5 6 872	1027 11020	13 72236	740590	1 7589560	7778 057	1977 PS1	8 175 905 1	- CHO 1751	866386 12	111 12 46	8.604 12.77	1409 7 124	796 7327	180 7 477 69	4 7 687 944	7 860 102
$\Sigma$ free net annual cashflow		50 440 267 -4	4 511 004 -38	431 854 -32 20	4 599 -25 8	20 461 -19 27	5 171 -12 56	8734 -5.694	516 1356	97 85798	88 15 985 78	9 23 575 349	31 353 406	39 331 393	17 507 298 5	9 085 275 70	951 661 83	115 772 95 58	4376 10836	1 805 115 486	601 122 814	383 130 292 0	7 137 980 021	145 840 124
	LCOE un	84.40	85.07	85.75 86	23 86	5.92 87.	65 85	22 88.	2 89.85	90.43	91.25	91.96	92.69	93.72	94.49	94.17	94.97	5.88 96	78 97.	57 94.0.	5 94.75	95.81	96.56	97.59

# **APPENDIX I**

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	l Inputs										Financial Ind	exes		Notes
Legend	-							Revenues	l	Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an	re updated		Г	Mater		Ī	Natas	Dense Denskerer Annound Dere	0.09791	(0.03071-)	-	мс		(6.4.57)
automatically based on user input into	yellow cells.	O&M warranty condition	ms	ivoles	Depreciation		ivoles	Power Purchase Agreement Rate	0.08581	[5/KW II]		MC A	50	[5/KW]
Yellow cells are for use input informatic	on about the project.	Costs covered by manufacturer (O&M_m)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.		Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public Inc	entive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	ARCM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI CM	70.8203	[\$/kWc]	WF CM		50 000	[kWg/yr]
Project Location	Aracati (Brazil)	Deprwr	76.9840	[\$/kW]	RM WT	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	WF car		50 000	[kW]
Turbine Model	Vestas V90-2MW	WT CM	553.7256	[\$/kW]	WF car	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N <sub>WT</sub> )	25 [-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000 [kW]	N	25	[yr]	MAA	100	[m-h]	$\psi_{iotal}$	30.00%	[%]	Nrow		5	[-]
Wind Farm Capacity (WF cap)	50 000 [kW]	ifr	2.50%	[%/yr]	CMBranger	85.00	[\$/m-h]	n ,,	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0 [m]	Depr <sub>Tec</sub>	60.1398	[\$/kW]	$N_{m_{BMT}}$	3	[-]	REP CM	0.00002627	[\$/kWeh]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7 [m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	Dmatter	2.0	[d]	AEP avail/H prod	5 696	[kW/yr]	L <sub>x</sub>		1 800	[m]
Hub height (H)	105.0 [m]	TO CM	0.000033	[\$/kW]	Cadabay	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L		2 430	[m]
Wind speed measured at $(H_0)$	10.0 [m]	Π	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	8	0.1496	[\$/kWeh]	SD <sub>3</sub>		450	[m]
Terrain rugosity factor (a)	0.14 [-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.116883	[\$/kWeh]	SD <sub>xcol</sub>		540	[m]
Betz Limit's coefficient (C PBetz)	0.5926 [-]	V <sub>0</sub>	6 100 000	[kW]	NWT	25	[-]	$n_x$	10	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25 [yr]	c <sub>0</sub>	1 457.72	[\$/kW]	M	3.0	[m-h]	OREP CM	13.0813	[\$/kW_c]	PC <sub>PM</sub>			
Production Efficiency (WF PE)	11.2% [%]	PR	0.70	[-]	CMBran	85.00	[\$/m-h]	LCCCM <sub>WFORSIGN</sub>	2.7664	[\$/kW]	AEP anail		48 979 624	[kWeh/yr]
Availability	98.2% [%]	ь	-1.94	[-]	N.,	3	[-]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	$\eta_{wes}$		20.98%	[%]
	358 [d/yr]	LRCM	16.8443	[\$/kW]	D	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{-n}}$		25.00%	[%]
					C <sub>ml m</sub>	3 500.00	[\$/d]	$\Psi_{total}$	30.0%	[%]	P&D <sub>LN</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capita	al Cost Model Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
WT CM	553.7256 [\$/kW]	O&M fuel	0.098275	[\$/kWh]	WFcm	50 000	[kW]	n	10	[yr]	Α		6 361.7	(m <sup>2</sup> )
CM WT	265.32 [S/kW]	LCCCM	1 204.5180	[\$/kW]	Nwr	25	[-]	CR	80.0%	[%]	AEP roted		438 000 000	[kW_h/yr]
RCWT	73.70% [%/\$/kW	σ	0.0000001%	[%]	AWT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	1 600.4612	[\$/tCO <sub>2</sub> ]	P&DIM			
$C_{kW}$	400.00 [\$/kW]	LLC	0.0530	[\$/kWh]	M	3.0	[m-h]	LCER <sub>co</sub>	18.6	[tCO2/MWah]	λa		7.00%	[%]
IPT	10.00% [%]	N	25	[yr]	CMar	85.00	[\$/m-h]	$\sum AEP_{could}$	48 980	[MWeh]	2 rai		0.00%	[%]
T <sub>CM</sub>	484.3859 [\$/kW]	ifr	2.50%	[%/yr]	N_	3	[-]	n	25	[yr]	λd		5.00%	[%]
Tmass	138 000 [kg]	O&M <sub>variable or</sub>	0.025839	[\$/kWh]	Dman	3.0	[d]	GHG <sub>EMS</sub>	0.00041	[tCO2/MWah]	λm		5.00%	[%]
RCT	26.30% [%/\$/kW	MLC	71.5608	[S/h]	Cmd	3 500.00	[\$/d]	GHG	0.00003	hCO <sub>2</sub> /MW.hl	LCPMwr		48 979 624	[kW_h/yr]
Cuted	0.1900 [S/kg]	ПС	124,5688	[S/h]	RVM w.r	61.0184	[\$/kW]	E	46.3820	[\$/tCO <sub>2</sub> ]				
LWTG CM	39.1957 [\$/m/kW]	Russer	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[%]	Proiect Finan	ing	Γ	Notes
WF	\$0,000 [143/3	10	2.50%	[%/vr]				Č. RELau	25.0%	(***)	Delegante		50.0%	[%]
	20/00/2 16/77	ur			WISVM	1.4442	[\$/kW]			1%	Dept ratio		14	[ve]
L -	13 950 [m]	ljr N	25	[yr]	WIS <sub>VM</sub> WF <sub>cm</sub>	1.4442 50 000	[\$/kW] [kW]	ζ <sub>2</sub> REP or	25.0%	[%]	Debt rano Debt term		1.4	174
L <sub>g</sub> CAB	13 950 [m] 2 000.00 [\$/m]	ijr N Radh	25	[yr] [h]	WIS <sub>VM</sub> WF <sub>cap</sub> ifr	1.4442 50 000 2.50%	[\$/kW] [kW] [%/yr]	$\tilde{\zeta}_2 REP_{CM}$ $\tilde{\zeta}_2 OREP_{CM}$	25.0%	[%] [%]	Debt ratio Debt term Debt gr	ace period	1	[yr]
Lg CAB cost	13 950 [m] 2 000.00 [\$/m] 30.9069 [\$/kW]	ijr N n <sub>mih</sub> R <sub>vih</sub>	25 72 90	[yr] [h] [h]	WIS <sub>VM</sub> WF <sub>cap</sub> ifr N	1.4442 50 000 2.50% 25	[\$/kW] [kW] [%/yr] [vr]	$\tilde{\zeta}_2 REP_{CM}$ $\tilde{\zeta}_3 OREP_{CM}$ $\tilde{\zeta}_4 GHG.R_{CM}$	25.0% 25.0% 25.0%	[%] [%] [%]	Debt ratio Debt term Debt gr Debt in	ace period erest rate	1	[yr] [%/yr]
Lg CAB <sub>cost</sub> CP <sub>CM</sub> EF <sub>2</sub>	13 950 [M] 2 000.00 [S'm] 30.9069 [S'kW] 400.00 [S'kW]	tyr N n <sub>sulh</sub> AAR	25 72 90 4 202 942	[yr] [h] [h] (\$M]	WIS VM WF cap ifr N WT	1.4442 50 000 2.50% 25 200 000	[\$/kW] [kW] [%/yr] [yr] [kg]	$\xi_2 REP_{CM}$ $\xi_3 OREP_{CM}$ $\xi_4 GHG.R_{CM}$ <b>REPIM</b>	25.0% 25.0% 25.0% 421.0907	[%] [%] [%] [\$/proil	Debt term Debt gr Debt in Debt value	ace period erest rate	1 5.00% 29 920 535	[yr] [%/yr] [\$]
Lg CAB cont CP cat EF c C	13 950 [m] 2 000.00 [S/m] 30.9069 [S/kW] 400.00 [S/kW] 0.08% [%]	yr N n mih AAR AEP empit	25 72 90 4 202 942 48 979 624	[yr] [h] [h] [\$M] [kWh/yr]	WIS VM WF cap ifr N WT <sub>weight</sub> C red	1.4442 50 000 2.50% 25 200 000 0.1900	[\$/kW] [kW] [%/yr] [yr] [kg] [\$/kg]	$\vec{\xi}_{2} REP_{CM}$ $\vec{\xi}_{3} OREP_{CM}$ $\vec{\xi}_{4} GHG.R_{CM}$ REPIM	25.0% 25.0% 25.0% 421.0907	[%] [%] [%] <b>(\$/proj)</b>	Debt ratio Debt term Debt gr Debt in Debt value Debt value	ace period erest rate	1 5.00% 29 920 535 3 022 691	[yr] [%/yr] [\$] [\$/vr]
$L_g$ $CAB_{cast}$ $CP_{CH}$ $EF_c$ $\zeta$ $TS_{cast}$	13 950 [kW] 13 950 [m] 2 000.00 [\$/m] 30.9069 [\$/kW] 400.00 [\$/kW] 0.08% [%]	yr N n <sub>nlh</sub> AAR AEP <sub>avell</sub>	25 72 90 4 202 942 48 979 624 0 124114	[yr] [h] [h] [\$M] [kWh/yr]	WIS VM WF cap ifr N WT <sub>weight</sub> C stred	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965	[\$/kW] [kW] [%/yr] [yr] [kg] [\$/kg] [\$/kg]	$\zeta_2 REP _{CM}$ $\zeta_3 OREP _{CM}$ $\zeta_4 GHG.R_{CM}$ REPIM Exchange rates	25.0% 25.0% 25.0% 421.0907	[%] [%] [%] [%] [\$/proj]	Debt ratio Debt term Debt gr Debt in Debt value Debt pa Fauity rati	ace period verest rate syments	1 5.00% 29 920 535 3 022 691 50.0%	[yr] [%/yr] [\$] [\$/yr]
$L_{\pi}$ $CAB_{cont}$ $CP_{CM}$ $EF_{c}$ $\zeta$ $TS_{CM}$ $T$	13 950 [m] 2 000.00 [S'm] 30.9069 [S'kW] 400.00 [S'kW] 0.08% [%] 11.4566 [S'kW] 0.0490 [S'm]	yr N n <sub>mlh</sub> AAR AEP <sub>avail</sub> O&M <sub>WFCM</sub>	25 72 90 4 202 942 48 979 624 0.124114	[yr] [h] [h] [\$M] [kWh/yr] [\$#Wh/yr]	WIS van WF cap ifr N WT <sub>weight</sub> C stord TS van WF	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965 50 000	[\$'kW] [kW] [%/yr] [kg] [\$'kg] [\$'kg] [\$'kW] [\$W]	4. KH Cu ζ <sub>2</sub> REP Cu ζ <sub>3</sub> OREP Cu ζ <sub>4</sub> GHGR CM <b>REPIM</b> Exchange rates	25.0% 25.0% 25.0% 421.0907	[%] [%] [%] [%] [%] [%] Notes	Debt ratio Debt term Debt gr Debt in: Debt value Debt value Equity rati	ace period erest rate yments o	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535	[yr] [%/yr] [\$] [\$/yr] [%]
$L_{g}$ $CAB_{cont}$ $CP_{CM}$ $EF_{c}$ $\zeta$ $TS_{CM}$ $TL_{c}$ $T$	13 950 [m] 2 000.00 [5m] 30.9069 [51W] 400.00 [51W] 0.08% [%] 11.4566 [54W] 0.0400 [5m] 1.200 [10W]	yr N n nih AR AEP <sub>anul</sub> O&M <u>wrcu</u>	25 72 90 4 202 942 48 979 624 0.124114	[yr] [h] [h] [\$M] [\$Wh/yr] [\$&Wh/yr]	WIS VM WF cap ifr N WT <sub>weight</sub> C seed TS VM WF cap ife	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965 50 000 2.50%	[\$'kW] [kW] [%/yr] [yr] [kg] [\$'kg] [\$'kg] [\$'kW] [kW] [\$'kW]	4     Interface       ξ <sub>2</sub> REP cut       ζ <sub>3</sub> OREP cut       ζ <sub>4</sub> GHGR cut <b>EEPIM</b> EUR/USD dec200 CMM(IRS) cuto	25.0% 25.0% 25.0% 421.0907	[%] [%] [%] [%] [%/proj] Notes [-] [-]	Debt ratio Debt term Debt in Debt in Debt palue Debt pa Equity rati Equity of	ace period verest rate yments o value	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00%	[yr] [%/yr] [%/yr] [\$/yr] [%] [\$] [%]
L <sub>t</sub> CAB <sub>cont</sub> CP <sub>CM</sub> EF <sub>c</sub> 5 TS <sub>CM</sub> TL <sub>c</sub> TL <sub>r</sub>	2 0000 [KW] 13 990 [m] 2 000.00 [S'm] 30.9069 [S'kW] 0.08% [%] 11.4556 [S'kW] 0.0400 [S'm] 1 200 [I/kW] 2 000 [m]	yr N naib nib AAR AAR AAR O&MwrCM	25 72 90 4 202 942 48 979 624 0.124114	[yr] [h] [sM] [kWh/yr] [s/kWh/yr] Notes [s/kWh/	WIS var WF cap ifr N WTwight C seed TS Var WF cap ifr	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965 50 000 2.50% 25	[\$'kW] [kW] [%/yr] [yr] [kg] [\$'kg] [\$'kg] [\$'kW] [kW] [%/yr] [w]	t Index ξ RPCut ζ OREPut ζ OREPut ζ OREPut <b>REPIM</b> Exchange rates EURUSD dec2010 CANUSD dec2010 PM (TO D	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5095	(%) (%) (%) (\$/proj) Notes [-] [-]	Debt tatio Debt term Debt in Debt value Debt value Equity rati Equity v	ace period erest rate yments o value tt rate	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00%	[yr] [%/yr] [\$] [\$/yr] [%] [\$] [\$] [%/yr]
L <sub>t</sub> CAB <sub>cont</sub> CP <sub>CM</sub> EF <sub>c</sub> 5 TS <sub>CM</sub> TL <sub>c</sub> L <sub>i</sub> SP		yr N n <sub>min</sub> AAR AEP <sub>small</sub> O&M <sub>WFCM</sub> O&M <sub>WFCM</sub>	25 72 90 4 202 942 48 979 624 0.124114 0.000105 20	[yr] [h] [h] [\$M] [kWh/yr] [\$kWh/yr] Notes [\$/kWh] [6]	WF var WF var ifr N WT weight C stool TS var WF var ifr N T	1.4442 50 000 2.50% 25 200 000 0.9965 50 000 2.50% 25 51 128 000	[\$'kW] [kW] [%/yr] [yr] [kg] [\$'kg] [\$'kW] [\$'kW] [\$'kW] [\$'yr] [yr] [\$co]	$ \begin{array}{c} 1 & \text{Ind}\mathcal{L}_{a} \\ \overline{\zeta}_{a} & \text{REP}_{Cat} \\ \overline{\zeta}_{b} & \text{OREP}_{cat} \\ \overline{\zeta}_{b} & \text{OHGR}_{Cat} \\ \hline \\ $	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986	[%] [%] [%] [%] <i>(\$/proj]</i> <i>Notes</i> [-] [-] [-]	Debt ratio Debt term Debt gr Debt on Debt value Debt value Equity rati Equity vali Discour	ace period erest rate yments o value tt rate	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00%	(y-1) [yr] [%/yr] [\$] [\$/yr] [%] [\$] [%/yr]
L <sub>t</sub> CAB <sub>con</sub> CP <sub>CM</sub> EF <sub>r</sub> $\zeta$ TS <sub>CM</sub> TL <sub>r</sub> L <sub>r</sub> L <sub>r</sub> SB <sub>r</sub>	13990         [m]           2000.00         [Sm]           309099         [SkW]           400.00         [SkW]           11.4556         [SkW]           0.0400         [Sm]           120.000         [m]           1300         [m]           1000         [SkW]	yr N n <sub>sib</sub> AAR AEP <sub>ousl</sub> O&M <sub>WFCM</sub> O&M <sub>WFCM</sub> SC 0M Work days	25 72 90 4 202 942 48 979 624 0.124114 0.000105 3.0	[yr] [h] [k] [\$M] [kWh/yr] [\$kWh/yr] Notes [\$/kWh] [d] [1]	$WIS_{VM}$ WF cop ifr N $WT_{volphed}$ C word $TS_{VM}$ WF cop ifr N $T_{mass}$ $T_{mass}$	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965 50 000 2.50% 25 138 000	[\$'kW] [kW] [%/yr] [yr] [kg] [\$'kg] [\$'kW] [\$'kW] [\$'kW] [%/yr] [yr] [kg]	1, 100 Ca 5, 2, RF Ca 5, OREP CA 5, ORE	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986	[%] [%] [%] [%] [%] [%] Notes [-] [-] [-]	Debt rano Debt rem Debt gr Debt jan Debt value Debt value Debt pa Equity rati Equity vali Equity vali Discour	ace period erest rate yments value ut rate Summary	29 920 535 3 022 691 50.0% 29 920 535 9 920 535 9.00% of LCOE wite	(yr) [yr] [%/yr] [\$] [\$/yr] [\$] [\$] [%/yr] <b>Notes</b>
L <sub>s</sub> CA <sub>0</sub> CP <sub>CM</sub> EF <sub>s</sub> 5 TS <sub>CM</sub> TL <sub>s</sub> TL <sub>s</sub> SB <sub>s</sub> SI <sub>CM</sub>	20000 [kW] 300969 [S1W] 40000 [S1W] 0.08% [%1W] 11.4566 [S1W] 1200 [J1W] 3000 [m] 1200 [m] 1300 [m] 1300 [m]	07 N п.а.в. лак ААР ААР ААР С&М итсы О&М итсы ОСМ (адмалац(В)) SC Сам Work days Feb Jan/Nov	25 72 90 4 202 942 48 979 624 0.124114 0.000105 3.0 9	[yr] [h] [sM] [kWh/yr] [skwh/yr] Notes [s/kWh] [d] [d] [d]	W D Synt WF corp iff N WTwight C and TS 64 W From iff N Tunes RCM WF	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965 50 000 2.50% 25 138 000 1 278.8970	[\$'kW] [kW] [%'yr] [yr] [kg] [\$'kg] [\$'kg] [\$'kW] [%'yr] [yr] [kg] <b>[\$/kW]</b>	$ \begin{array}{c} 1 & 0.0 \\ \overline{\zeta}_{2} & RP_{CM} \\ \overline{\zeta}_{2} & 0REP_{CM} \\ \overline{\zeta}_{2} & 0RER_{CM} \\ \overline{\zeta}_{4} & 0RCR_{CM} \\ \hline \end{array} \\  \begin{array}{c} \hline \end{array} \\ \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \begin{array}{c} \hline \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \begin{array}{c} \hline \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \begin{array}{c} \hline \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \end{array} \\ \begin{array}{c} \hline \end{array} \\ \end{array}$	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986	[%] [%] [%] [%] [%] [%] [%] [%] [%] [%]	Debr rano Debt zem Debt gr Debt in Debt value Debt value Debt pa Equity value Discour Initial Results 67,6693	ace period verest rate yments o value at rate Summary yr 1	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00% of LCOE was 70.7843	(5*) [yr] [%/yr] [%] [%] [%] [%/yr] Notes yr15
$L_{t}$ $CAB_{sout}$ $CP_{Cu}$ $EF,$ $\zeta$ $TL,$ $TL,$ $TL,$ $L_{t}$ $SB_{t}$ $SI_{Cu}$ $WF_{sop}$	23000 [kW] 13990 [st] 20000 [st] 30000 [st] 008% [%] 11456 [st] 1200 [sw] 1200 [s	97 N nub nub AR AR AR AR AR O&M wrcu O&M (Mananach) SC 044 Work days Feb/ManNov Hours required	25 72 90 4 20292 48579624 0.124114 0.124114 0.000105 3.0 9 72.0	[yr] [h] [k] [\$M] [\$Wh/yr] [\$/kWh/yr] Notes [\$/kWh] [d] [d] [h]	WI 3 yat WF corr df N WT <sub>volght</sub> C stud TS yat WF corr df S yat WF corr df RCM wy	1.4442 50 000 2.50% 25 200 000 0.9965 50 000 2.50% 25 138 000 1 278.8970	[S/kW] [kW] [%/yr] [yr] [kg] [S/kg] [S/kW] [kW] [%/yr] [kg] [\$/kW]	1 MOLGA <sup>2</sup> / <sub>2</sub> REP <sub>CM</sub> <sup>2</sup> / <sub>2</sub> OREP <sub>CM</sub> <sup>2</sup> / <sub>2</sub> ORER <sub>CM</sub> <sup>2</sup> / <sub>2</sub> GHGR <sub>CM</sub> <sup>2</sup> / <sub>2</sub> CHCSD <sub>decoden</sub> CAN(ISD <sub>decoden</sub> CAN(ISD <sub>decoden</sub> )           CAN(ISD <sub>decoden</sub> )	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986	(%) (%) (%) ( <i>S</i> / <i>proj</i> ) <i>Notes</i> (-) (-) (-) (-)	Debt rann Debt gen Debt gen Debt yalue Debt value Debt set gen Discour Initial Results 67.6693 67.8196	ace period ierest rate yments o value it rate Summary yr 1 yr 2	29 920 535 3 022 691 50.0% 29 920 535 9.00% 0f LCOE was 70.7843 69.8148	(5*) [yr] [%/yr] [\$] [\$/yr] [%] [%] [%/yr] <b>Notes</b> yr 15 yr 15 yr 15
L <sub>1</sub> CAB out CAB out EF. 5 TS cu TL, L, 58, SI cu WF mp WT aut	2.000 [kW] 13.999 [m] 2.000.00 [S'W] 30.9090 [S'W] 400.00 [S'W] 11.4556 [S'W] 1.200 [J'W] 3.000 [m] 1.200 [J'W] 3.000 [m] 42.7345 [S'm <sup>2</sup> AW] 42.7345 [S'm <sup>2</sup> AW]	pr N n <sub>mb</sub> AR AR AR AR Marcu O&M wrcu O&M wrcu SC and World days FebdanNov Hours required USC and	25 72 90 4 202 942 48 979 624 0.124114 0.000105 3.0 9 9 72.0 0.000229	[yr] [h] [sM] [kWh/yr] [s/k/Wh/yr] [s/k/Wh/] [d] [d] [h] [s/k/Wh/]	WIS You WF core if r N WT wight C and C and WF core if r N T mass RCM wy Hours Distribution	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965 50 000 2.50% 25 138 000 1 278.8970 FLH <sub>vf</sub> (h)	[SkW] [kW] [%/yr] [yr] [kkg] [SkW] [%/yr] [kW] [%/yr] [kg] [kkg] [kkg]	1, 10, 10, 10, 10, 10, 10, 10, 10, 10, 1	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986	(%) (%) (%) (%) (%) (%) (%) (%) (%) (%)	Debr tann Debt term Debt gr Debt m Debr value Debr value Debr pa Equity rati Equity to Discour Discour Discour G1.6693 67.8196 68.0301	ace period erest rate yments o value at rate Summary yr 1 yr 2 yr 3	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00% of LCOE w10 70.7843 69.8148 70.0062	(5-) [yr] [%/yr] [%] [%] [%] [%] [%] [%] [%] [%/yr] <b>Notes</b> yr 15 yr 15 yr 16
L <sub>1</sub> CAB out CPCu EF, 5 TS cu TL, TL, TL, SB of SIcu WF out WF out Bld out Bld out	2.0000 [kW] 13.9969 [s1] 2.000.00 [S4W] 400.00 [S4W] 0.08% [%] 11.4666 [S4W] 0.0400 [S7] 1.200 [s1] 1.200 [s1] 1.200 [s1] 1.120 [S4Wh] 42.7345 [S7m <sup>2</sup> AW 5.0000 [kW] 5.0000 [Sm <sup>2</sup> ]	pr N n <sub>mb</sub> AR AR AR AR MEN Mathematic SC obst Work days Feb Jun Nov Hours required USC obst N wr	25 72 99 4 202 942 48 979 624 0.124114 0.00015 30 9 720 0.000229 25	[yr] [h] [sM] [kWh/yr] [skwh/yr] [skwh/yr] [d] [d] [h] [s/kWh/] [-]	WIS year WF corr df N WT could C stud TS (st) WF corr df TS (st) WF corr df TS (st) WF corr df RCM up Encode Lanceton (st) Lanceton (st)	1.4442 50 000 2.50% 25 200 000 0.9965 50 000 2.50% 25 138 000 1 278.8970 FLH <sub>ef</sub> (h) 744	[SkW] [kW] [%(yr] [kg] [S'kg] [S'kW] [kW] [%/yr] [kg] [\$/kW] [\$/kW] 738		25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986 1 80.0%	[%] [%] [%] [%] [%] <b>Notes</b> [-] [-] [-] [-] <b>Notes</b> [1/0] [%]	Debr failo Debr term Debt gr Debt in Debt yalue Debr yalue Debr yalue Debr yalue Debr yalue Debr yalue Discour Jistial Results 67,693 67,8196 68,0301 68,1907	ace period erest rate yments p value at rate yr yr yr yr yr yr yr yr yr yr yr yr	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00% of LCOE wto 70.7843 69.8148 70.0062 70.2090	(5-5) (yr) (%)yr) (%) (%) (%) (%) (%) (%) (%) (%) (%) (%
L <sub>1</sub> CP <sub>Col</sub> EF, 5 TZ <sub>Col</sub> TL, TL, 5B, SI <sub>Col</sub> WF <sub>col</sub> WF <sub>col</sub> WF <sub>col</sub> Bld <sub>con</sub>	2.0000 [kW] 13.9969 [stW] 30.9069 [StW] 400.00 [StW] 0.08% [stW] 11.4556 [StW] 10.4556 [StW] 12.00 [fW] 12.00 [m²] 11.300 [sW] 42.7345 [sm²AW 50.000 [sW] 42.2338 [stW] 50.000 [sW] 30000 [sW] 3000	97 N nub 10,0 AAR AAR AEP aust O&M vscu O&M vscu O&M vscu SC out Work days Feb/Jun/Nov Hours required USC out N vsr Feb/Jun/Nov Hours required USC out N vsr Frequency	25 72 90 4 202 42 48 979 624 0.124114 0.000105 30 9 720 0.000229 25 18	[yr] [h] [sM] [kWh/yr] [skWh/yr] [skWh/yr] [d] [d] [h] [s/kWh] [-] [peryr]	WJ Synt WF corp ifr N WTwight C and TS sol WF cop ifr N Twos Twos Twos Twos Twos Tanuary January	1.4442 50 000 2.50% 25 200 000 0.1900 0.9965 50 000 2.50% 25 138 000 1 278.8970 FLH <sub>ef</sub> (h) 744 672	[SkW] [kW] [%y] [yr] [kg] [S'kW] [kW] [%/w] [%/w] [kg] <b>f/kW]</b> <b>H</b> prod [h] 738 641	<sup>1</sup>	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986 1 80.0%	[%] [%] [%] [%] [%] <i>Notes</i> [-] [-] [-] [-] [/] [/0] [%]	Debt term Debt gr Debt im Debt gr Debt m Equity rati Equity rati Equity rati Equity rati Equity rati Equity of Discour Initial Results 67.5693 67.5196 68.0301 68.1907 68.4452	ace period erest rate yments o value tt rate Summary yr 1 yr 2 yr 3 yr 4 yr 5	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00% of LCOE was 70.7843 69.8148 70.0662 70.2090 70.4052	(5-5) (yr) (%) (%) (%) (%) (%) (%) (%) (%) (%) (%
L <sub>1</sub> CAB out CPCu EF, 5 TS cu TL, TL, L <sub>1</sub> SB , SI cu WF out WF out WF out Bd out Bd out POCu POCu	2.0000 [kW] 13.9969 [S4W] 30.0069 [S4W] 400.00 [S4W] 0.08% [%] 11.4566 [S4W] 1.200 [I/4W] 3.000 [m] 113.00 [S4Wb] 42.7345 [S4W4] 50.000 [kW] 42.7345 [S4W] 50.000 [s4Wb] 12.5020 [s4Wb] 50.000 [s4Wb] 50.	pr N n <sub>m</sub> AR AR AR AR AR AR AR AR AR AR	25 72 90 4 202 942 48 979 624 0.124114 0.124114 0.000105 30 9 720 0.000229 25 1.8 2.0	[yr] [h] [sM] [kWh/yr] [skWh/yr] [skWh/yr] [d] [d] [h] [s/kWh] [-] [per yr] [h]	W15 yat WF core df N WT weight C and TS (st WF core df N Tasse RCM ay Hours Distribution January February <sup>(*)</sup> March	1.4442 50 000 2.50% 25 200 000 0.9965 50 000 2.59% 25 138 000 1 278.8970 FLH <sub>~f</sub> (h) 744 672 744	(S/kW) [kW] [%/yr] [yr] [kg] [S/kg] [S/kW] [%/yr] [yr] [kg] [s/kW] 738 641 737	<sup>1</sup> (2) ORE <sup>3</sup> <sup>2</sup> / <sub>2</sub> RP Cu <sup>2</sup> / <sub>2</sub> OREP Cu <sup>2</sup> / <sub>4</sub> GRCR Cu <b>REPIM</b> Exchange rates EURVISD accello CAWUSD accello BRL/USD accello Conditions for LCOE <sub>100</sub> ORM wich ORM wich ORM mon (%) ccm REPIM distribution	25.0% 25.0% <b>421.0907</b> 1.3252 0.9998 0.5986	[%] [%] [%] [%] [%] [/%] [/0] [%]	Debt term           Debt term           Debt gr           Debt pat           Debt value           Debt pat           Equity rati           Equity rati           G7.5693           67.5693           67.5693           68.0301           68.1907           68.4452           68.6285	ace period erest rate yments o value tt rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6	1 5.00% 29 920 535 3 022 691 50.0% 29 920 535 9.00% of LCOE was 70.7843 69.8148 70.0062 70.7843 69.8148 70.0062 70.2090 70.4052 70.7652	(y-1) [yr] [%b/yr] [%] [%] [%] [%] [%b/yr] <i>Notes</i> <i>yr</i> 15 <i>yr</i> 16 <i>yr</i> 17 <i>yr</i> 18 <i>yr</i> 19
L <sub>1</sub> CAB <sub>sent</sub> CP <sub>Cu</sub> EF, 5 SCu TL, TL, L <sub>1</sub> SB, SICu WF <sub>rap</sub> WTrau Bldaw Bldaw Bldaw FO Cu FS	13.000         [km]           13.996         [SxW]           30.006         [Sxm]           30.006         [SxW]           400.0         [SxW]           0.0400         [Sxm]           1.1456         [SxW]           0.0500         [Sx]           1.200         [Sx]           1.200         [SxW]           3.000         [m]           1.120         [SxW]           4.2733         [SxW]           50.000         [Sw]           4.2733         [SxW]           50.000         [Sw]           300.00         [m]           300.00         [m]           300.00         [m]           300.00         [m]           35.974         [SxW]	97 N n <sub>mb</sub> AR AR AR AR AR AR MANAMAGEN O&M (MANAMAGEN) SC 0644 Work days Work days Work days Work days Work days Work days National States Hours required N wr Frequency Requiring Hours required	25 72 90 4 202 942 48 979 634 0.124114 0.000105 3.0 9 720 0.000229 25 1.8 20 0.000229 25 1.8 20 0.000229	[yr] [h] [s] [kWh/yr] [kWh/yr] [kwh/yr] [d] [d] [d] [h] [s/kWh/ [-] [per yr] [h] [h] [h]	WI Synt WF corr df N WT <sub>weight</sub> C circl TS tot WF corr df M RCM wy Hours Distribution Ianuary February <sup>(*)</sup> April	1.4442 5.0000 2.50% 25 5.0000 0.9965 5.0000 2.55% 25 138.000 1.278.8970 FLH <sub>vf</sub> (h) 744 672 744 672 744	(S/kW) [kW] [%/yr] [yr] [kg] [S/kg] [S/kW] [kW] [%/yr] [kg] [%/kW] Hprod [h] 738 641 737 713	$ \begin{array}{c} & 1 \\ \zeta_{2} & RF \\ \zeta_{3} & OREF \\ \zeta_{3} & OREF \\ \zeta_{4} & OREF \\ \zeta_{5} & OREF \\ \zeta_{6} & OREF \\ CMURSD \\ MURSD \\$	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986 1 80.0%	[%]         [%]           [%]         [%]           [%]         [%]           [%]         [%]           Notes         [-]           [-]         [-]           [-]         [-]           [-]         [-]           [-]         [-]           [-]         [-]           [-]         [-]           [-]         [-]           [-]         [-]	Debt term           Debt term           Debt gr           Debt nin           Debt value           Debt value           Debt value           Debt ran           Equity value           Discour           Initial Results           67.6693           67.8196           68.0301           68.1907           68.4525           68.5776	ace period erest rate yments o value it rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6 yr 7		[yr] [%/yr] [%/yr] [%] [%] [%] [%] [%/yr] <i>Notes</i> <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 17 <i>yr</i> 18 <i>yr</i> 19 <i>yr</i> 20
L <sub>1</sub> CAB mu CPCu EF, 5 TL, TL, L, 5 SICu WF mp WT mu Bild mu Bild mu PO Cu FS DT	2.0000 [kw] 3.0000 [Sw] 3.0000 [Sw] 4.0000 [Sw] 4.0000 [Sw] 1.14566 [SkW] 0.08% [%] 1.1300 [m] 1.300 [m] 1.300 [Sw] 4.27345 [Sw] 5.0000 [Sw] 3.000 [Sw] 1.300 [Sw] 3.000 [Sw	97 N n <sub>m</sub> AR AR AR AR AR AR AR O&M word AR Word days Feb/Jun/Nov Hours required USC cast Nwr Nwr Repairing Repairing Hours required SC cost <sup>4</sup> USC cost	25 72 90 4 202 942 6.124114 0.124114 0.124114 0.124114 0.000029 720 0.000229 25 1.8 2.0 9000 162.0	[yr] [h] [\$M] [\$Wh/yr] [\$&wh/yr] [\$&wh/yr] [d] [d] [h] [\$/kWh] [-] [per yr] [h] [h] [h]	WI Synt WF orp df N WT weight C and TS OA WF orp df R N T ano RCM wy Hours Distribution January February <sup>(*)</sup> March April May	1.4442 5.0000 2.50% 25 20000 0.1900 0.9965 5.0000 2.50% 25 138.000 1.278.8970 1.278.8970 1.278.8970 7.44 672 7.44	(S/kW) [kW] [%/yr] [yr] [kg] [S/kW] [%/kW] [%/yr] [yr] [kg] [%/kW] Hprod [h] 738 641 737 713 737	$\begin{array}{c} \sum\limits_{i=1}^{n} REP _{CM} \\ \sum\limits_{i=1}^{n} REP _{CM} \\ \sum\limits_{i=1}^{n} ORGR _{CM} \\ REPIM \\ \hline \hline \\ Exclosure rates \\ EURUSD _{ac2010} \\ CAWUSD _{ac2010} \\ REUSD _{ac2010} \\ \hline \\ OAM _{CM} \\ CM _{CM} \\ REPM _{distribution} \\ \sum\limits_{i=1}^{n} REPM _{distribution} \\ \sum\limits_{i=1}^{n} REPM _{CM} \\ \hline \\ \end{array}$	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5986 1 80.0% 1 1 80.0%	[%] [%] [%] [%] [%] <i>[S(proj)</i> <i>Notes</i> [-] [-] [-] [-] [-] [-] [-] [-] [-] [-]	Debri rano Debri gen Debri gen Debri gen Debri gen Equity rati Equity Equity Equity Equity Equity rati Equity	ace period erest rate yments o value tt rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6 yr 7 yr 8	1 1 5.00% 29 920 535 3 022 e01 50.0% 29 920 535 9.00% 29 920 535 9.00% 70.7843 69.8148 70.0062 70.2090 70.4052 70.7854 70.5607	(yr) [yr] [%/yr] [%] [%] [%] [%] [%] [%] (%/yr] <i>Notes</i> <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 15 <i>yr</i> 16 <i>yr</i> 17 <i>yr</i> 18 <i>yr</i> 19 <i>yr</i> 20 <i>yr</i> 20 <i>yr</i> 21
L <sub>1</sub> CAB and CPCu EF, 5 TS cu TL, TL, TL, L, SBe SIcu WF any WT and Bild and Bild and FS DT EG	2.0000 [kW] 13.9969 [s1] 2.000.00 [S4W] 4.00.00 [S4W] 0.08% [%] 11.4566 [S4W] 0.080 [%] 11.200 [S4W] 1.200 [kW] 11.300 [kW] 11.300 [kW] 42.7345 [S4W] 5.9000 [kW] 42.7345 [S4W] 1.988 [S4W	pr N n <sub>mb</sub> AR AR AR AR MEP <sub>mul</sub> O&M <sub>(mbhamq0)</sub> SC 0.00 Work days Feb/lum/Nov Hours required USC 0.00 N wr Frequency Required Nowr Hours required SC 0.004 SC 0.004 N wr Frequency Require inter Hours required SC 0.004 SC 0	25 72 90 4 202 942 4 8979 624 0.124114 0.00015 30 9 0.000229 0.000229 25 1.8 20 0.000229 1.5 1.8 20 0.000234	[yr] [h] [SM] [KWh/yr] [SkWh/yr] Notes [S/kWh/ [d] [h] [S/kWh/ [-] [per yr] [h] [h] [h]	W15 yat WF core GF N WT codd C and TS yat WF core GF N T-must RCM wy Hours Distribution Hours Distribution January February <sup>(*)</sup> March April May June <sup>(*)</sup>	1.4442 5.0000 2.50%, 25 2.000,00 0.9945 5.000,00 2.50%, 25 1.38,000 1.278,8970 FLH - <sub>5</sub> (h) 744 672 744 720 744 720	[SkW] [kW] [gu/yr] [yr] [s/kg] [S/kg] [S/kW] [kw] [kw] [kw] [kw] [kw] [kw] [s/kW] T38 641 737 713 737 689	$ \begin{array}{c} & 1 \\ & \zeta_{2} & REP_{CM} \\ & \zeta_{3} & OREP_{CM} \\ & \zeta_{4} & GREC_{M} \\ \hline \\ & \mathcal{K}_{4} & GREC_{M} \\ \hline \\ & \textbf{Exchange rates} \\ \hline \\ & \textbf{EVERSD}_{accositio} \\ \hline \\ & \textbf{CAWUSD}_{accositio} \\ \hline \\ \hline \\ & \textbf{CAWUSD}_{acc$	25.0% 25.0% 25.0% 421.0907 421.0907 1.3252 0.9998 0.5986 1.50%	[%] [%] [%] [%] [%] [%] [-] [-] [-] [-] [-] [/0] [1/0] [1/0] [1/0] [1/0]	Debri ratio Debri serio Debri serio Debri serio Debri serio Debri serio Equity rati Equity ratio Equity ratio	ace period erest rate yments o alue at rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6 yr 7 yr 8 yr 9 yr 9	29 920 50 3 022 691 5 0,0% 29 920 535 90 700 520 70 20562 70 20562 70 20562 70 20562	(yr) (yr) (%) (%) (%) (%) (%) (%) (%) (%
L <sub>1</sub> CAB out CCost EF, 5 TS cu TL, TL, 58, SI cu WF mp WT nut Bild out Bild out Bild out EG FCu	2.000 [kW] 13.9909 [Sw] 30.0009 [Sw] 400.00 [S4W] 400.00 [S4W] 11.4556 [S4W] 3000 [m] 1100 [IAW] 42.7345 [Sw74] 42.7345 [Sw74] 42.7345 [Sw74] 3000 [m <sup>2</sup> ] 3000 [m <sup></sup>	pr N n <sub>m</sub> AR AR AR AR Martunget O&M (network) SC cost Work days Feb Jan/Nov Hours required USC cost Nor Repairing USC cost Nor Repairing SC cost SC cost	25 72 900 0.124114 0.124114 0.124114 0.000105 30 9 720 0.000229 18 18 18 18 18 0.00034	[yr] [h] [s] [s] [s] [s] [s] [s] [s] [s	WJ Synt WF orp Øf N WT oright Cand TS tot WF orp Øf N Tson WF orp Øf N Tson WF orp Øf N Tson WF orp Øf N Tson WF orp Øf N N Tson WF orp Øf N N Unight Cand TS tot N N N Son WF orp Øf N N Son WF orp Øf N N Son WF orp Øf N N Son WF orp Øf N N Son WF orp Øf N N Son WF orp Øf N N Son WF orp Øf N N Son WF orp Øf N N Son M N M Son Con M Son Son M Soon M Son M Son M Son M Son M Son M Son M Son M Son M Son N	1.4442 5.0000 2.50% 2.5 5.00000 0.1900 0.1900 2.50% 2.5 5.0000 2.50% 2.5 5.0000 1.278,8970 FLH <sub>wf</sub> (h) 744 672 744 720 744	[S/kW] [kW] [%/yr] [yr] [kg] [S/kg] [S/kg] [S/kg] [%/yr] [yr] [kg] <b>[xgkW]</b> <b>H</b> prod <b>[h]</b> 738 641 737 713 737 6689 737	$\begin{array}{c} 1 \\ \frac{1}{2}, REP_{CM} \\ \frac{1}{2}, OREP_{CM} \\ \frac{1}{2}, OREP_{CM} \\ \frac{1}{2}, OREP_{CM} \\ \frac{1}{2}, ORER_{CM} \\ \hline \hline \\ REPIN \\ \hline \\ EVRUGSD_{accord} \\ RRUUSD_{accord} \\ RRUUSD_{accord} \\ \hline \\ RRUUSD_{accord} \\ \hline \\ OAM (mcs) \\ OAM (mcs$	25.0% 25.0% 25.0% 25.0% 421.0907 421.0907 1.3252 0.95986 0.5986 1.800% 1 1 1 1 1 1	[%] [%] [%] [%] [%] [%] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-	Debt i ratio Debt i seri Debt gr Debt in Debt yalae Debt yalae Deb	ace period erest rate yments o value ti rate Summary yr 1 yr 2 yr 3 yr 4 yr 5 yr 6 yr 7 yr 8 yr 9 yr 9 yr 9 yr 9 yr 9 yr 10	29 920 535 3 022 e01 50.0% 29 920 535 9.00% of LCOE wm 70.7843 e9.8148 70.0662 70.2090 70.0522 70.7384 70.0567 70.3784 70.5667 70.3884 70.5667 70.3884	(yr) [yr] [%/yr] [%] [%/yr] [%] [%/yr] <b>Notes</b> yr 15 yr 16 yr 17 yr 18 yr 19 yr 20 yr 22 yr 22 yr 23
$L_{g}$ $CRM_{max}$ $CP_{CM}$ EF, G $TS_{CM}$ TL, TL, TL, $L_{i}$ $SB_{i}$ SIGE $WF_{max}$ $Bid_{cont}$ $Bid_{cont}$ $PO_{CM}$ FS DT EG $F_{i}$ EF, G $PO_{CM}$ FS DT EG $F_{i}$ ES DT EG $F_{i}$ ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT ES DT EG DT EG DT EG DT EG	2.0000 [kw] 13.9909 [st W] 2.000.00 [St W] 400.00 [St W] 400.00 [St W] 1.14.566 [St W] 1.200 [st W] 1.200 [st W] 1.200 [kW] 42.7345 [St W] 500.00 [kW] 500.00 [st m <sup>2</sup> ] 3.000 [st m <sup>2</sup>	pr N n <sub>mb</sub> AR AR AR AR AR AR Coss Work days Feb/lumNov Hours required USC 600 Work days Feb/lumNov Hours required USC 600 N wr Frequency Repair inter Hours required SC 600 N wr Frequency Repair inter Hours required	25 72 900 0.124114 0.124114 0.000105 300 720 0.000292 25 18 20 900 1620 0.000334	[yr] [h] [SM] [SM] [SWh/yr] [S&Wh/yr] [s&Wh/yr] [d] [d] [h] [s&Wh/ [-] [h] [h] [h] [h] [b/yr] [S&Wh/yr]	W15 yat WF corr df N WT weight C soul WF corr df r N T Sout WF corr df r N T sout RCM wy Hours Distribution January <sup>(1)</sup> Jany	1.4442 5.0000 2.50%, 25 5.00000 0.9945 5.0000 2.50%, 25 138.000 1.278,8970 FLH <sub>vf</sub> (h) 744 672 744 720 744 720 744 720	[SkW] [kW] [w] [yr] [skg] [Skg] [SkW] [kW] [kW] [w] [yr] [kg] [skW] 738 641 737 737 689 737 737	$\begin{array}{c} 1 & \text{OLCL}\\ \frac{1}{2} & \text{OLCR}\\ \frac{1}{2} & $	25.0% 25.0% 25.0% 421.0907 421.0907 1.3252 0.9998 0.5986 1.5996 1	[%] [%] [%] [%] [%] [%] <i>Notes</i> [-] [-] [-] [-] [-] [4/0] [1/0] [1/0] [1/0]	Debi tem ratio Debi sem Debi sem Debi sem Debi sum Debi sum Equity uit Equity uit Equity uit Discour Station 68,000 69,000 68,0000 68,0000 68,0000 68,0000 68,0000 68,0000 68,0000 68,0000 68,00000 68,00000 68,0000000000	ace period erest rate yments o alue ti rate Summary yr1 yr2 yr3 yr4 yr5 yr7 yr7 yr7 yr7 yr7 yr7 yr7 yr7 yr7 yr7	29 903 53 3 022 691 5 00% 29 903 535 9 00% <b>of LCOE</b> wie 0,00% <b>of LCOE</b> wie 70,784 80,8148 700062 70,2090 70,4052 70,7652 70,7652 70,3784 70,5607 70,3806 71,1149	(yr) (yr) (%) (%) (%) (%) (%) (%) (%) (%
L <sub>1</sub> CP <sub>Cu</sub> EF, 5 TC <sub>4</sub> TL, TL, SB, SI <sub>Cu</sub> WF <sub>au</sub> WF <sub>au</sub> Bild <sub>am</sub> PO <sub>Cu</sub> FS DT EG Fou WACC <sub>pren</sub>	2.000 [kW] 13.9909 [Sw] 2.0000 [Sw] 3.0009 [Sw] 4.0000 [Sw] 11.4556 [Sw] 1.1.4556 [Sw] 1.1.00 [Sw] 1.1.00 [Sw] 1.1.00 [Sw] 1.1.00 [Sw] 4.2.734 [SwW] 5.0000 [w] 3.000 [m <sup>2</sup> ] 3.000 [m <sup>2</sup>	pr N n <sub>mb</sub> AR AR AR AR Marcui O&M wrcui O&M wrcui SC onu Work days Febdua/Now Hours required USC onu N wr Repair inm Frequency Repair inm SC onu SC onu HUSC onu SC onu HUSC onu SC onu SC onu HUSC onu SC onu HUSC onu SC onu HUSC onu SC onu HUSC onu SC onu HUSC onu SC onu HUSC onu	25 72 900 420942 4397962 300 9 720 0.000229 25 18 20 900 162.0 0.00034	[yr] [h] [SM] [SM] [kWh/yr] [s&kWh/yr] [d] [d] [d] [b] [s/kWh/] [-] [per yr] [h] [h] [h/yr] [s/kWh/yr]	WJ Synt WF cop df N WT column Count TS var WF cop df N Tunner RCM wr Hours Distribution January Gebruary <sup>(*)</sup> March April May June <sup>(*)</sup> July July September	1.4442 5.0000 2.50%, 55.0000 0.9905 5.0000 2.50%, 2.55 138.000 1.278.8970 FLH- <sub>97</sub> (h) 744 672 744 720 744 720 744 720 744 720	[SkW] [kW] [g6/yr] [yr] [s/kg] [S/kg] [SkW] [kW] [w/yr] [kg] [yr] [kg] [s/kW] H <sub>prod</sub> [h] 738 641 737 737 689 737 713	$\begin{array}{c} 1 \\ \xi_{2} \\ RP \\ \zeta_{3} \\ OREP \\ \omega \\ \zeta_{4} \\ OREP \\ \omega \\ \zeta_{5} \\ OREP \\ \omega \\ \zeta_{6} \\ ORE \\ CANUSD \\ d_{nOSH0} \\ REJUSD \\ m_{nOSH0} \\ REJUSD \\ m_{nOSH0} \\ CANUSD \\ m_{nOSH0} \\ m_{nOSH0} \\ CANUSD \\ m_{nOSH0} \\ m$	25.0% 25.0%	[%] [%] [%] [%] [%] [%] [-] [-] [-] [-] [.] Notes [1/0] [%] [1/0] [1/0] [1/0] [1/0] [1/0]	Debt i raito Debt i seri Debt gr Debt in Debt y Debt in Debt value Debt y Equity value Equity va	ace period erest rate yments o alue at rate Summary yr1 yr2 yr3 yr4 yr5 yr6 yr7 yr8 yr9 yr10 yr10 yr10 yr10 yr10 yr10 yr10 yr10	29 920 352 3 022 691 5 0.0% 9 29 920 355 9 900% of LCOE +++ 70.7843 69 8148 70.0862 70.0290 70.4052 70.03784 70.5607 70.4805 71.1149 71.1149 71.17673	(yr) (yr) (%)yr) (%) (%) (%) (%) (%) (%) (%) (%
L <sub>2</sub> CAB mu CPCu EF, 5 IS cu TL, TL, L, SB, SI cu WF mp WT mu Bild mu Bid mu PO Cu FS DT EG FCu WGC proj Big.mu WF, WG mp WF, WG mp WF, WG mp WF, WG mp WF, WG mp WF, WG mp WF, WG mp WF, WG mp WF, WG mp WF, WG mp WF, WF, WF, WF, WF, WF, WF, WF,	2.3000 [km] 13.9909 [st W] 2.00000 [St W] 3.00090 [St W] 4.0000 [St W] 1.14566 [St W] 1.000 [St W] 1.000 [M] 1.000 [M] 1.000 [M] 1.000 [M] 1.000 [St Wh] 4.27345 [St W] 5.0000 [w] 3.000 [m <sup>2</sup> ] 3.000	pr N n <sub>mb</sub> AR AR AFPout O&M wrc.u O&M wrc.u SC asu Work days Feb/Jun/Nov Hours required USC asu N wτ Frequency Repair time Hours required	25 72 900 4202942 43970624 0.124114 0.000105 30 9 720 0.000234 25 25 25 20 0.000334	[yr] [h] [SM] [SM] [SM] [SMWh/yr] [s&Wh/yr] [d] [d] [h] [S&Wh/ [h] [h] [h] [h] [k] [k] [k] [k] [k] [k] [k] [k	W15 yat WF corr df N WT weight C and TS (st WF corr df N Tasse RCM ay Hours Distribution January February <sup>(*)</sup> March March Mary Anguil May Judy Judy September Oxtober	1.4442 5.0000 2.50% 25 5.0000 0.9985 5.0000 2.20% 25 <u>138000</u> 1.278.8970 744 672 744 672 744 720 744 744 744 744 744 744	[SkW] [kW] [%Y] [96/yr] [yr] [Skg] [S/kW] [kW] [kW] [kW] [yr] [kg] <b>f</b> ( <i>k</i> ] <b>738</b> 641 <b>737</b> 713 737 713 737 713 737 713 737	$\begin{array}{c} 1 \\ \zeta_{2} & RP_{CM} \\ \zeta_{3} & OREP_{Cd} \\ \zeta_{4} & ORER_{Cd} \\ \mathcal{Z}_{6} & ORER_{Cd} \\ \hline \mathcal{R} & REPIM \\ \hline \end{array} \\ \hline \begin{array}{c} Exchange rates \\ EURVISD_{dec3010} \\ ORMUSD_{dec3010} \\ \hline \\ RL/USD_{dec3010} \\ \hline \\ ORMUSD_{dec3010} \\ \hline \\ O$	25.0% 25.0% 25.0% 421.0907 421.0907 1.3252 0.9998 0.5986 1.5586 1.5586 1.5586 1.5586 1.1 1.1 1.1 1.1 1.1 0.5586 0.55	[%] [%] [%] [%] [%] [%] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-	Leen ratio Debt term Debt gr Debt m Debt y Leen Debt value Debt value Debt value Debt value Equity vit Equity vit Equity vit Escour 61.6093 63.8196 63.8196 63.8196 63.8196 63.8196 63.825 64.8	ace period erest rate yments o alue it rate Summary yr1 yr2 yr3 yr4 yr5 yr5 yr6 yr7 yr8 yr9 yr10 yr11 yr11 yr12 yr13	29 920 535 3 022 691 50,0% 29 920 535 9,00% <b>of ICOE</b> wm <b>of ICOE</b> wm	(yr) (yr) (%)yr) (%) (%) (%) (%) (%) (%) (%) (%
$ \begin{array}{c} L_{1} \\ CP_{CM} \\ CP_{CM} \\ CP_{CM} \\ EF, \\ \varphi \\ TS_{CM} \\ TL, \\ TL, \\ SB, \\ SICM \\ WF_{exp} \\ WF_{exp} \\ WF_{exp} \\ WT_{max} \\ Bdd_{exm} \\ Bdd_{exm} \\ Bdd_{exm} \\ Bdd_{exm} \\ Bdd_{exm} \\ FS \\ DT \\ EG \\ FS \\ DT \\ EG \\ FS \\ DT \\ EG \\ FS \\ CC_{exp} \\ WRCC_{pred} \\ n_{je_{1}} \\ WRCC_{pred} \\ WRCC_{pred} \\ n_{je_{1}} \\ WCC_{CM} \\ CC_{CM} \\ \end{array} $	2.000 [kW] 13990 [S4W] 20000 [S4W] 40000 [S4W] 0.088 [%] 11.4556 [S4W] 11.4556 [S4W] 11.000 [Sm] 12.00 [Sm] 12.00 [Sm] 13.00 [M] 13.00 [Sm] 13.00 [Sm] 13.00 [Sm] 13.00 [Sm] 13.00 [Sm] 13.00 [m <sup>2</sup> ] 3.000 [m <sup>2</sup> ]	97 N n <sub>mb</sub> AR AR AR AR MED <sub>mul</sub> O&M (netheams(f)) SC 0.04 Work days Feb/Jun/kov Hours required USC 0.04 Work days Feb/Jun/kov Hours required USC 0.04 N W Frequency Repair inte Hours required SC 0.04 V V C 0.04 N W	25 70 4 20 942 4 35 962 4 35 962 3 0 7 20 0.000105 7 20 0.000229 25 18 20 900 162.0 0.00034	[yr] [h] [SM] [SM] [kWh/yr] [s&Wh/yr] [d] [d] [h] [s/kWh/ [-] [per yr] [h] [h] [b] [k/yr] [s&Wh/yr]	W15 yat WF corr if r N WT weight C stud C stud TS yat WF corr if r N Tmass RCM wpr Hours Distribution Idnuary February <sup>(*)</sup> March April Mary June <sup>(*)</sup> July Angust September October November <sup>(*)</sup>	1.4442 5.0000 2.50%, 25 200.00 0.9905 5.0000 2.50%, 25 1.278.8970 FLH_{rf}(h) 744 720 74 74 720 74 74 720 74 74 74 720 74 74 720 74 74 74 74 74 74 74 74 74 74 74 74 74	[SkW] [WW] [WY] [Yr] [S4g] [S4g] [S4g] [SkW] [WV] [kW] [SkW] [WV] [kW] [WV] [kW] [SkW] [SkW] [SkW] [SkW] [S4g	$\begin{array}{c} 1 \\ \tilde{\zeta}_{2} \\ REP_{CM} \\ \tilde{\zeta}_{3} \\ OREP_{CM} \\ \tilde{\zeta}_{4} \\ ORCR_{CM} \\ \hline \end{array} \\ \hline \begin{array}{c} REPIM \\ \hline \end{array} \\ \hline \\ \hline \\ \hline \\ REPIM \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ \hline \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ \hline \\ \hline \\ \hline \\ CANUSD_{Ac2010} \\ \hline \\ $	25.0% 25.0% 25.0% 25.0% 421.0907 1.3352 0.9998 0.5998 0.5998 1.500% 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	[%] [%] [%] [%] [%] [%] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-	Debt rem Debt gen Debt gen Debt gen Debt min Debt value Debt value	ace period erest rate yments o alue trate Summary yr1 yr2 yr3 yr4 yr5 yr6 yr7 yr7 yr6 yr7 yr7 yr7 yr7 yr7 yr7 yr7 yr1 yr1 yr1 yr1 yr1 yr1 yr1 yr1	29 920 353 3 022 691 5 0.0% 9 020 355 9 0.0% 9 020 55 9 0.0% 70 7843 6 08148 70 0.062 70 0.062 70 0.050 70 0.00	(yr) (yr) (%)yr) (%) (%) (%) (%) (%) (%) (%) (%
$L_{r}$ $CAB_{out}$ $CP_{Cu}$ EF, $\xi$ SCu TL, TL, $L_{1},$ SB, SIcu $WF_{mp}$ $WT_{mu}$ $Bid_{aut}$ $Bid_{au$	2.0000 [5:4W] 2.00000 [5:4W] 3.00090 [5:4W] 4.0000 [5:4W] 4.0000 [5:4W] 1.14566 [5:4W] 3.0000 [m] 1.1200 [1:4W] 3.000 [m] 1.1300 [5:4Wh] 4.27345 [5:m²3.4W 5.0000 [5:4W] 3.0000 [5:4W] 3	97 N n <sub>cb</sub> AR AR AR AR AR AR AR AR AR AR	25 72 90 420 942 43970624 0.124114 0.024114 0.024114 0.024114 0.024114 0.024114 20 20 25 18 20 20 0.00034	[yr] [h] [SM] [&Whi/yr] [\$\$\$&Whi/yr] [d] [d] [h] [\$\$\$&Whi/ [d] [h] [b] [b] [b] [b] [b] [b] [b]	W15 yat WF or off N WT weight C and TS (a) WF or off N Tmax RCM w Tmax RCM w Tmax RCM w Tmax April March April May September October October December	14442 50000 250% 25 20000 0.9905 50000 2.50% 25 38000 1278.8970 FLH	[SkW] [kW] [kW] [%/yr] [s/kg] [S/kW] [%/yr] [kW] [%/yr] [kW] [%/yr] [kg] [s/kW] Hprod (h] 738 641 738 641 737 737 689 737 737 737 737 737 737 737	$\begin{array}{c} 1 \\ \tilde{\zeta}_{2} \ REP_{CM} \\ \tilde{\zeta}_{3} \ OREP_{CM} \\ \tilde{\zeta}_{4} \ OREP_{CM} \\ \tilde{\zeta}_{4} \ OREP_{CM} \\ \tilde{\zeta}_{4} \ OREP_{CM} \\ \hline \end{array}$ EVENUSD decision Conditions for LCOE was ORM USD decision REPUM Conditions for LCOE was ORM wince ORM wince ORM wince ORM wince ORM COE REPUM distribution $\tilde{\zeta}_{4} \ REP_{CM} \\ \tilde{\zeta}_{5} \ OREP_{CM} \\ \tilde{\zeta}_{5} \ O$	25.0% 25.0% 25.0% 421.0907 1.3252 0.9998 0.5998 1 80.0% 1 1 1 1 1 1 1 1 1 1 1 1 1	[%] [%] [%] [%] [%] [%] <i>Notes</i> [-] [-] [-] [-] [-] [-] [-] [-] [-] [-]	Levin ratio           Debt series           Debt gr           Debt min           Debt value           Debt min           Debt value           Equity rati           Equity rati           Equity rati           67.6893           67.6893           68.007           68.425           68.025           69.052           69.052           69.052           70.008           70.238           70.238           70.245           LCOE w	ace period erest rate yments o value it rate Summary yr1 yr2 yr3 yr4 yr5 yr5 yr6 yr7 yr5 yr6 yr7 yr7 yr8 yr9 yr10 yr11 yr12 yr12 yr12 yr13 yr14 yr12 yr13 yr14 yr14 yr12 yr14 yr15 yr16 yr16 yr16 yr16 yr16 yr16 yr17 yr16 yr17 yr16 yr16 yr16 yr17 yr16 yr16 yr16 yr17 yr16 yr16 yr16 yr16 yr16 yr16 yr16 yr16	5,00% 5,00% 5,00% 5,00% 5,00% 5,00% 5,00% 5,00% 70,7843 69,8148 70,0062 70,7843 69,8148 70,0062 70,7843 69,8148 70,0062 70,7843 69,8143 70,0062 70,7843 70,7843 70,7843 70,7843 70,7843 70,7843 70,7843 70,7843 70,7843 70,7852 70,7853 70,7853 70,7856 70,9856 70,7856 7	(yr) [yr] [%/yr] [%] [%] [%] [%] [%] [%/yr] <b>Notes</b> yr 16 yr 16 yr 16 yr 16 yr 16 yr 16 yr 16 yr 16 yr 17 yr 18 yr 16 yr 12 yr 12 yr 22 yr 22 yr 22 yr 23 yr 25 yr 25 y 25 y 25 y 25 y 25 y 25 y 25 y 25 y

**Figure I.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(B)}$ . Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar	ve updated			Г	Noter		Γ	Noter	Dower Durchese A ergement Date	0.16201	(\$.440.b)		MC	60	(\$/1437)
automatically based on user input into	yellow cells.		O&M warranty condition	5	ivotes	Depreciation		ivores	Power Purchase Agreement Rate	0.16291	[5/KWN]		MC <sub>A</sub>	30	[5/KW]
Tellow cells are for use input informatio	on about the project.		Costs covered by manufacturer (O&M_m)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/KWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	Г	Notes	Levelized Replacement C	ost Model	Notes	Wind Farm Removal Co	ost Model	Notes	Renewable Energy Public Ind	entive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		ARCM	16.8442	[\$/kW]	$DCM_{WF}$	1 339.9154	[\$/kW]	REI CM	70.8203	[\$/kW <sub>c</sub> ]	WF CM		50 000	[kWg/yr]
Project Location	Corvo Island (Portugal)		Deprwr	76.9840	[\$/kW]	RM <sub>WT</sub>	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	WF		50 000	[kW]
Turbine Model	Vestas V90-2MW		WICH	553.7256	[\$/kW]	WF	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (Nwr)	25	[-]	Tau	484.3859	[\$/kW]	Nwr	25	[-]	ifr	2.50%	[%/vr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	M <sub>10</sub>	100	[m-h]	Wanad	30.00%	[%]	Nrow		5	[-]
Wind Farm Capacity (WF can)	50 000	[kW]	ifr	2.50%	[%/yr]	CMBrann	85.00	[\$/m-h]	n	6	[yr]	Nonl		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr	60.1398	[\$/kW]	N	3	[-]	REP CM	0.00001039	[\$/kW_h]	D		90.0	ſml
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	YRC	15	[yr]	D	2.0	ſdī	AEP muit/H mod	10 458	[kW/yr]	L.		1 800	ſml
Hub height (H)	105.0	[m]	TOCH	0.000033	[\$/kW]	$C_{mlm}$	2 500.00	[\$/d]	ifr	2.50%	[%/vr]	L		2 430	ſml
Wind speed measured at $(H_{\alpha})$	10.0	[m]	TI	1 798 743	[\$/kW]	RM cr	20 1954	[\$/kW]	ь. Б	0.1086	[\$/kW.h]	SD.		450	[m]
Terrain meosity factor (a)	0.14	[-]	v	237 699 000	[kW]	WF	50.000	(kW)	60	0.075000	[S/kW.h]	SD.		540	[m]
Betz Limit's coefficient (C as . )	0.5926	[-]	, Va	6 100 000	[kW]	N war	25	[-]	n_	15	[vr]	FLH (		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[vr]		1 457 72	[\$/kW]	М.	30	[m-h]	ORFP at	21 2289	(\$/kW ]	PCau			(1-7-1
Production Efficiency (WF as )	20.6%	[%]	PR	0.70	[-]	C 101	85.00	[\$/m-h]	LCCCM	2 4 4 5 1	(\$/kW)	AFP		90 107 610	[kW_h/yr]
Aválability	98.4%	[%]	h.	-1 94	[-]	N	3	[-]	ICCCM w.c	1 204 5180	[\$/kW]	n		20.98%	[%]
retunations	250	[Joj]	IRCM	16 9442	101.117	D	20	61	WACC	4 00000	[0/ /me]	n		25,000	[/0]
	337	[dr j1]	LACIN	10.0445	[\$/K 11]	C	2 500.00	[0] [6/4]	W .	20.06	[06]	Parect <sub>ord</sub>		0.820225	[20]
Wind From Life Coale Conit	Cart Madal	N. 4	Wind Farm Of M Cart A	e	N. c	and Mar	1 207 2016	(a/u)	7 8040	30.0%	[70]	PaD	factor	0.839323	
wina Farm Lije-Cycle Capita	ii Cosi Model	Notes	oth	louer	Notes	SæRV	1 297.3916	[5/KW]	ıţr	2.3%	[%/yr]	N <sub>WT</sub>		23	
WI CM	553.7256	[S/KW]	Cache fuel cu	0.098275	[\$/kWh]	WF cap	50 000	[KW]	n ,,	15	[yr]	A		6 361.7	[m <sup>*</sup> ]
CM <sub>WT</sub>	265.32	[S/KW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/KW]	N <sub>WT</sub>	25	[-]	CRf	80.0%	[%]	AEP rated		438 000 000	[kW <sub>e</sub> h/yr]
RC WT	73.70%	%/\$/kW]	ω	0.000001%	[%]	Awr	43.00	[m²/wt]	GHG.R <sub>CM</sub>	825.2491	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M Ar NARY	3.0	[m-h]	$\sum AFP$	34.2	[tCO <sub>2</sub> /MW <sub>0</sub> h]	Â.a		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	C <sub>Mhr<sub>SARV</sub></sub>	85.00	[\$/m-h]	ALP and 11,11,11,11,11,11,11,11,11,11,11,11,11,	90 108	[MW <sub>e</sub> h]	× rā i		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m sam</sub>	3	[-]	n,	25	[yr]	λa		5.00%	[%]
Tmass	138 000	[kg]	O&M variable CM	0.048925	[\$/kWh]	D <sub>m saav</sub>	3.0	[d]	GHG <sub>EM<sub>F</sub>co<sub>2</sub></sub>	0.00041	[tCO <sub>2</sub> /MW <sub>0</sub> h]	λm		5.00%	[%]
RC <sub>T</sub>	26.30% [	%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	GHG <sub>EM were CO2</sub>	0.00003	[tCO <sub>2</sub> /MW <sub>0</sub> h]	LCPM <sub>WF</sub>		90 107 610	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	Ec	13.0000	[\$/tCO2]				
LWTG CM	39.1957 [	\$/m/kW]	R taxes	30.00%	[%]	$N_{WT}$	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\xi_1 REI_{CM}$	25.0%	[%]	Debt ratio		50.0%	[%]
$L_g$	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\xi_2 REP_{CM}$	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mlh</sub>	48	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 \text{ OREP }_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	100	[h]	N	25	[yr]	$\xi_4 GHG.R_{CM}$	25.0%	[%]	Debt in	terest rate	5.00%	[%/yr]
EFc	400.00	[\$/kW]	AAR	14 679 146	[\$M]	WTweight	200 000	[kg]	REPIM	229.3246	[\$/proj]	Debt value		29 869 613	[\$]
5	0.08%	[%]	AEP avail	90 107 610	[kWh/yr]	Csted	0.1900	[\$/kg]				Debt pa	yments	3 017 547	[\$/yr]
TS CM	11.4566	[\$/kW e]	O&M <sub>WFCM</sub>	0.147200	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	0	50.0%	[%]
TLs	0.0400	[\$/m]				WFcap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 869 613	[\$]
π.,	1 200	[1/kW]	O&M Of Manager (R)	Г	Notes	ifr	2.50%	[%/yr]	CAN/USD der 2010	0.9998	[-]	Discou	it rate	9.00%	[%/yr]
L.	3 000	[m]	SC ORM	0.000038	(\$/kWh]	N	25	[vr]	BRL/USD 4-2010	0.5986	[-]				
SB	113.00	(\$/VWb)	Work days	20	60	T	138.000	[ke]				Initial Results	Summary	of LCOF	Notes
SU	42 7245 (	e2 a.w.	Feb/Im/Nov	-	[4] [4]	PCM	1 278 8970	(\$/I-W)	Conditions for LCOF		Notar	72 1255	Summary	78 4712	roles
SI CM	42.7545 [5	s/m/kwj	Teorinov	49.0	[u] (L)	KC.M WF	1 2/0.0970	[\$/k 11]	Containions for ECOL was		110103	73.1235	<i>yr</i> 1	78,4712	yr 15
WP cap	30 000	[KW]	nours requirea	48.0	[n]				Odem WFCM			/5.518/	$yr_2$	77.6515	yr15
WT inst	42.5238	[\$/kW]	USC ORM	0.000138	[\$/KWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	73.7873	yr 3	78.1612	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	74.1334	yr 4	78.6268	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.0	[per yr]	February	672	648	REPIM			74.4746	$yr_5$	79.1175	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	4.0	[h]	March	744	736	REPIM distribution			74.9273	$yr_6$	79.6115	yr 19
FS	19.88	[\$/kW]	Hours required	100.0	[h]	April	720	712	$\zeta_1 REI_{CM}$	1	[1/0]	75.2253	yr 7	77.7347	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	148.0	[h/yr]	May	744	736	$\xi_2 REP_{CM}$	1	[1/0]	75.5275	$yr_8$	78.2446	yr21
EG	404.52	[\$/kW]		0.000176	[\$/kWh/yr]	June <sup>(*)</sup>	720	696	$\xi_3 \text{ OREP }_{CM}$	1	[1/0]	76.0152	$yr_g$	78.7103	yr 22
F <sub>CM</sub>	3.7712	[\$/kW]				July	744	736	$\xi_4 GHG.R_{CM}$	1	[1/0]	76.4118	yr 10	79.0644	yr23
WACC proj	4.900%	[%/yr]				August	744	736	P&D <sub>IM</sub>			76.7332	yr 11	79.4723	yr25
n <sub>fin</sub>	1.0	[yr]				September	720	712	λ <sub>a</sub>	1	[1/0]	77.2289	yr 12	76.8666	Mean
W <sub>FCM</sub>	0.30%	[%]				October	744	736	$\lambda_{xdi}$	0	[1/0]	77.6321	yr 13	2.0151	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	696	λa	1	[1/0]	78.0589	yr 14	-0.4631	$\gamma$ (skewness)
ĸ	0.20%	[%]				December	744	736	λ.,	1	[1/0]	LCOF	76.8666	US\$/MWh	valid !
LCCCM	1 204.5180	[\$/kW]	1			Total [h/yr]	8 760	8 616		p.s.: I = yes ar	nd 0=no	22002 W10	0.076867	US\$/kWh	

**Figure I.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(B)}$ . Source: Own elaboration

LCOE wso Mode	l Inputs									Financial Ind	lexes		Notes
Legend							Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and a automatically based on user input into	re updated yellow cells.	O&M warranty condition	ons Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[S/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.	Costs covered by manufacturer (O&M_orr)	80.00% [%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.		Period of warranty (nw)	5 [yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
												r	
Wind Project Information	Notes	Levelized Replacement	Cost Model Notes	Wind Farm Removal	Cost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name Project Location	Firestar Wind Farm	Depr	16.8442 [S/KW] 76.9840 [S/FW]	DCM WF RM	1 339.9154	[S/KW] [S/FW]	KEICM	1 204 5180	[\$/KW_c] [\$/FW]	WF CM WF		50.000	[KW@/yr]
Turbine Model	Vestas V90-2MW	WT CM	553.7256 [S/kW]	WF cm	50 000	[8W]	LRCM	16.8443	[\$/kW]	N <sub>WT</sub>		25	[_]
Number of Wind Turbines (N <sub>WT</sub> )	25 [-]	T <sub>CM</sub>	484.3859 [S/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000 [kW]	Ν	25 [yr]	$M_{w_{BW_{BT}}}$	100	[m-h]	$\psi_{total}$	30.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000 [kW]	ifr	2.50% [%/yr]	CMErawar	85.00	[\$/m-h]	n "	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0 [m]	Depr <sub>Yac</sub>	60.1398 [S/kW]	N <sub>mener</sub>	3	[-]	REP CM	0.00000052	[\$/kW_ch]	D		90.0	[m]
Swept Area per Turbine (A)	6.361./ [m <sup>2</sup> ]	Y <sub>RC</sub>	15 [yr] 0.000022 (\$439)	C .	2.0	[d] (\$/4)	AEP anail/H prod	24 762	[KW/yr]			1 800	[m]
Wind speed measured at (Ha)	10.0 [m]	10 CM	1 798 743 [S/kW]	PM cm	20 1954	[3/u] [\$/kW]	ip 6	0.0128	[%/y1] [\$/kW_h]	SD SD		450	[m]
Terrain rugosity factor (a)	0.14 [-]		237 699 000 [kW]	WF cm	50 000	[kW]	E <sub>0</sub>	0.009998	[\$/kW_h]	SD <sub>scal</sub>		540	(m)
Betz Limit's coefficient (C PBetz)	0.5926 [-]	$V_{\theta}$	6 100 000 [kW]	NWT	25	[-]	n <sub>e</sub>	10	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25 [yr]	C 0	1 457.72 [\$/kW]	MANTER	3.0	[m-h]	OREP CM	56.8722	[\$/kWe]	PC PM			
Production Efficiency (WF PE)	48.6% [%]	PR	0.70 [-]	$C_{Mbr_{R_{cT}}}$	85.00	[\$/m-h]	LCCCM <sub>WFORGCM</sub>	2.7664	[\$/kW]	AEP avail		212 943 465	[kWeh/yr]
Aváilability	98.2% [%]	b	-1.94 [-]	N <sub>mmcr</sub>	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wacs}$		20.35%	[%]
	358 [d/yr]	LRCM	16.8443 [\$/kW]	D <sub>m</sub> <sub>swcr</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{nncs_{(rel)}}}$		25.00%	[%]
				C <sub>md MCI</sub>	3 500.00	[\$/d]	$\psi_{sotal}$	30.0%	[%]	P&D <sub>LM</sub>	Ifactor	0.814145	-
Wind Farm Life-Cycle Capit	al Cost Model Notes	Wind Farm O&M Cost	Model Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
W1 CM	265.32 (SVW)	ICCCM	1 204 5180 [S/kWh]	WF cap	30 000	[KW]	n <sub>v</sub>	80.0%	[yr] [%]	AFP .		438,000,000	[m <sup>*</sup> ]
RC wr	73 70% [%/\$/kW	σ	0.0000001% [%]	Awr	43.00	[m <sup>2</sup> /wt]	GHG R cy	4 500 5522	[5/(CO)]	P&D.u		450 000 000	[k ( at )]
CkW	400.00 [\$/kW]	LLC	0.0530 [\$/kWh]	M	3.0	[m-h]	LCER <sub>co</sub>	80.9	[tCO2/MW,h]	λ <sub>a</sub>	1	7.00%	[%]
IPT	10.00% [%]	Ν	25 [yr]	CMhrower	85.00	[\$/m-h]	$\sum AEP_{avail}$	212 943	[MWeh]	2 141		3.00%	[%]
T <sub>CM</sub>	484.3859 [\$/kW]	ifr	2.50% [%/yr]	N <sub>maany</sub>	3	[-]	n.,	25	[yr]	λa		5.00%	[%]
Tmarr	138 000 [kg]	O&M <sub>variable cu</sub>	0.041526 [S/kWh]	$D_{m_{SARV}}$	3.0	[d]	$GHG_{IM_{F_{10}}}$	0.00041	[tCO2/MW,h]	λm		5.00%	[%]
RC <sub>T</sub>	26.30% [%/\$/kW	MLC	71.5608 [\$/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	GHG <sub>EM</sub> <sub>unr co2</sub>	0.00003	[tCO2/MW2h]	LCPM WF		212 943 465	[kWeh/yr]
C steel	0.1900 [\$/kg]	TLC	124.5688 [\$/h]	RVM WF	61.0184	[\$/kW]	Ec	30.0000	[\$/tCO <sub>2</sub> ]			,	
LWTG <sub>CM</sub>	39.1957 [\$/m/kW	R <sub>MREF</sub>	30.00% [%]	N <sub>WT</sub>	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing	<b>70.0</b> %	Notes
WF cap	13.950 [kw]	ifr N	2.30% [%/yr] 25 [yr]	WIS VM	50,000	[5/KW] [1/W]	≤1 KEI <sub>CM</sub> č pEp	25.0%	[%]	Debt term		30.0%	[%]
CAB	2 000.00 [\$/m]	n	72 [h]	ifr	2.50%	[%/vr]	$\tilde{\zeta}_2 OREP _{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069 [\$'kW]	n <sub>tih</sub>	90 [h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	25.0%	[%]	Debt in	terest rate	5.00%	[%/yr]
EF c	400.00 [\$/kW]	AAR	29 460 159 [\$M]	WTweight	200 000	[kg]	REPIM	1 157.0612	[\$/proj]	Debt value		29 646 843	[\$]
ς	0.08% [%]	AEP arail	212 943 465 [kWh/yr]	Csteel	0.1900	[\$/kg]				Debt pa	syments	2 995 042	[\$/yr]
TS CM	11.4566 [\$/kWe	O&M WFCM	0.139801 [\$&Wh/yr]	TS VM	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	0	50.0%	[%]
TL <sub>c</sub>	0.0400 [\$/m]			WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	salue	29 646 843	[\$]
TL,	1 200 [1/kW]	O&M <sub>O&amp;Mmanag(B)</sub>	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	it rate	9.00%	[%/yr]
L <sub>1</sub>	3 000 [m]	SC ORM	0.000024 [\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]			,	
SB <sub>c</sub>	113.00 [\$/kWh	Work days	3.0 [d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE wso	Notes
SI CM	42.7345 [\$/m <sup>2</sup> /kW	Feb/Jun/Nov	9 [d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE win		Notes	84.3448	yr1	94.4360	yr 15
WF cap	50 000 [kW]	Hours required	72.0 [h]				O&M WFCM			85.0205	$yr_2$	94.1138	yr 15
WTinst	42.5238 [S'kW]	USC ORM	0.000053 [\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M com	1	[1/0]	85.7100	yr3	94.9205	yr 16
Bld cont	500.00 [S/m <sup>2</sup> ]	N WT	25 [-] 1.8 (autur)	January	/44	738	(%) ccm REPIM	80.0%	[%]	86.17.54	yr4	95.8186	yr 17
Bia area PO cu	35.9374 (S/kW)	Renair time	2.0 [b]	March	744	737	REPIM distribution			87 5940	yrs yrs	90.7191	yr 18
FS	19.88 [\$'kW]	Hours required	90.0 [h]	April	720	713	REICM	1	[1/0]	88.1682	yr 5 yr 7	93.9817	yr 20
DT	87.22 [\$/kW]	SC OAM+USC OFM	162.0 [h/yr]	May	744	737	REP CM	1	[1/0]	88.8666	yrs	94.6831	yr <sub>21</sub>
EG	404.52 [\$/kW]		0.000077 [\$kWh/yr]	June <sup>(*)</sup>	720	689	OREP CM	1	[1/0]	89.7788	yr <sub>9</sub>	95.7335	yr <sub>22</sub>
F <sub>CM</sub>	3.7712 [\$/kW]			July	744	737	GHG.R CM	1	[1/0]	90.3684	yr 10	96.5076	yr 23
WACC proj	4.900% [%/yr]			August	744	737	P&D <sub>LM</sub>			91.1898	yr 11	97.5244	yr 25
n <sub>fin</sub>	1.0 [yr]	11		September	720	713	λa	1	[1/0]	91.9082	yr 12	91.7691	Mean
WFGH	0.30% [%]	11		October	744	737	λ <sub>x&amp;i</sub>	1	[1/0]	92.6296	yr 13 Yr 13	4.1987	SD Y colorest
ĸ	0.20% [S/kW]	11		November December	744	737	2	1	[1/0]	95.6712	91.7691	-0.5338	valid !
LCCCM <sub>wr</sub>	1 204.5180 [%]	41		Total [h/wr]	8 760	8 600	× m	p.s.: l = yes m	d 0=no	LCOE was	0.091740	IS\$/kWh	vunu ?
and a Cons WF	- 204.0100 [Ø/KH]	J		"Period of less hours for prod	luction	5 000	L	,		L	0.091/09		

**Figure H.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(B)}$ . Source: Own elaboration

Table I.1 Energ.	y product	ion (AEP avai	in map oi	f the wind ,	farm for A.	racati (Brazil			with sensi	tivity analy	sis of O&	M <sub>manag(B)</sub>																
Months	V wc	H	H prod												AI	7P avail (kWh	()											
	(m/s) (k	kg/m <sup>3</sup> ) (.	( <i>q</i> )	yr 1	$yr_2$	yr 3	$yr_4$	yr 5	$yr_6$	yr 7	$yr_8$	$yr_{g}$	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
January	5.8	1.1665	738 I t	593 132 8	861 068 :	3 802 165	7 507 410	557361	8 890 198	557361	557361	4 232 212	8 890 198	8 890 198	557361	3 802 165	7 507 410	4 232 212	8 890 198	8 890 198	557361	3 802 165	7 507 410	557 361 3	802 165 7	507410 4.	232 212 4	232 212
Fehrnary	4.0	1 1666	641 8	50430 6	927 203	3 673 320	5 803 436	779 508	6 803 436	779 598	770 508	4 727 258	6 803 436	6 803 436	779 598	3 673 320	6 803 436	483 758	483 758	3 300 063	4 777 258	7 716 188	077 020	1 577 020 7	716188 6	803 436 4	27.258 4	727 258
March	40	11671	737 5	56 507 7	000 207.	5438155	3 876 568	078 310	000 507 L	078 310	078 310	890.095.9	7.405 000	2.405 000	078 310	5 4 38 155	8 876 568	806.836	806.836	1 814 186	PCL 366 P	1814186	1 600 536	2 925 001	8 333 968	876 568 3	9 332 9	890 095
		11000				111111	1000000			10200	102021	00000000		10110	1 77 1 600	101100	100000	201 210	201 210		100000				0 0000000			002.07.0
nudv	÷ ,	/00//	0 01/	0 100 10	544 004	0 344 004	1 000 931	110 050 1	0 344 004	110 00 1	110 050 1	/ 249 / 00	0.544 004	0 544 004	000 4 C/ 1	0.544.004	4 080 951	/91 0#6	/01 0+6	110 050 1	0 544 004	110 000 1	0+0 1/0 5	/ /01 046	0 00/647	544 004 1	/ 000 40	00/ 647
May	0.0	1.1670	737 1.	814 119 5	5 437 953	7 495 621	5 437 953	1 814 119	5 437 953	1814119	1814119	7 826 264	5 437 953	5 437 953	I 690 473	7 495 621	6 559 824	I 690 473	I 690 473	978283	8 876 238	978283	026480	896 803 6	559824 4	225 566 1 (	90 473 7	826 264
, June	7.9	1.1686	689 3:	955 677 3	8 955 677	7 3 26 396	5 140 844	3 553 729	3 955 677	3 553 729	3 553 729	8 309 307	3 955 677	3 955 677	3 553 729	7326396	5 090 627	1 698 250	I 698 250	839 524	7 326 396	839524	839524 3	3 55 3 729 5	090 627 5	090 627 9	15 799 8	309 307
July	8.6	1.1698	737 5.	450 949 3	1 805 267	8 897 452	1 694 513	4 235 665	3 805 267	4 235 665	4 235 665	557816	557816	3 805 267	5 450 949	8 897 452	1 818 455	3 805 267	3 805 267	557816	7513536	557816	980 621 4	1235 665 4	235 665 1	694 513 8	98 946	57816
August	9.6	1.1677	737 7.	499 787 1	815 127	1815127	1 815 127	8 881 171	1 815 127	5 440 975	5 440 975	897 302	897302	1 815 127	4 227 915	1 815 127	1 691 413	5 440 975	7 830 614	7 830 614	897 302	4 227 915	7 830 614 5	5 440 975 1	815127 1	815 127 5.	56 795 8	97 302
Sentember	10.1	1.1657	713 8:	1 226 925	. 633 475	1 633 475	3 668 197	7 562 383	1 633 475	6 338 644	6 338 644	945 298	945 298	1 633 475	6 338 644	1 633 475	3 668 197	6 338 644	7 242 889	7 242 889	945 298	5 254 599	\$ 576 955 6	5 338 644 1	633 475 3	668 197 6.	338 644 6	45 298
Outohor	2.0	1 1645	737 74	,	776 125	076125	196 223	2 470 165	076 125	7 470 165	2 470 165	1 606 767	1 606 767	076 125	0 056 751	076125	196 223	2 470 165	UF 3F3 9	CUP 343 9	1 010 126	111 212 3	006.9161	1 100000	76125 0	76 125 0	1 132 330	192 303
		C+01-1	1 101	700 600	CCI 0/6	CCT 0/6	+07 000	COT 6/4 /	CCT 0/6	01 6/4 /	COL 6/4-/	70/0001	70/ 000 1	CCT 0/6	10/0000	CCT 0/6	+07 000	1016/4/	774 040 0	774 (40 0	0.01 010 1	. 774 (4/ 0	607 017	C (01 6/4			1 10/000	707 000
November	9.2	1.1638	689 6.	115 594 (	836 072	836 072	836 072	6 115 594	836 072	7 296 271	7 296 271	I 691 267	I 691 267	836 072	7 296 271	836 0/2	836 072	7 296 271	5 069 696	5 069 696	1 575 994	0 988 019	0 115 594	7 296 271 8	630 0/2 S	30 0/2 7.	296 271 I	691 267
December	7.6	1.1651	737 3.	790 014	555 580	555580	976 690	5 429 099	555 580	8 861 786	8 861 786	3 790 014	3 790 014	555 580	7 483 417	555580	976 690	8 861 786	4 218 687	4 218 687	3 790 014	7813521	5 429 099 8	861786	55580 5	55 580 7.	483 417 3	790 014
Annual	7.4	1.1666 8	8 600 48	t 979 624 4	18 549 424	48 794 102	48 399 005	49 021 215	48 549 424	48 970 644	48 970 644	48 473 266	48 496 226	48 549 424	48 968 028	48 794 102	48 470 887	49 169 824	49 318 276	48 922 388	48 589 860	48 172 649	48 991 802	48 874 151 4	8 297 112 4	8 393 836 45	547 502 4	8 473 266
न्तु ८1 वस्तु हा वस्तु				1 60 mm 70 m	Lebox	Control D					C of O	, and the second s																
T TI NODI	Vuis Prod	o dani monon	Hund			inguine is an				un furmer	O to credu	×111manag(B)				EP	( <i>u</i> )											
Months	( <i>m</i> /s)	(k a/m <sup>3</sup> )	(H)	VF 1	27.7	VF 2	VF. 4	Vre	VF 6	11 A	Ur o	Vro	VF 10	VF 11	VF 17	VF 12	NF 14	VF 15	VF 14	VF 17	VF 10	VF 10	UP 10	UL 11	VF JJ	VF 12	VLA	VFIE
Januar	v 11.7	1.2313	740	14 490 462	14 490 46	14 490 46	14 490 46	2 14 490 40	2 14 490 46	2 14 490 40	2 10 871 40	8 10 871 400	8 14 490 46	2 10 871 405	8 10 871 408	10 871 408	14 490 462	2 10 871 408	10 871 408	14 490 462	10 871 408	10 871 408	10 871 408	10 871 408	10 871 408	1 801 408 1	0 871 408	0 871 408
Februar	w 11.5	1.2345	648	12 092 721	4 293 13	7 12 092 72.	12 092 72	1 12 092 7.	1 341709	6 12 092 72	1 12 715 78	5 1 795 784	12 3 417 090	5 12 715 785	5 1 795 784	9 244 173	12 092 721	1 6674015	12 715 785	4 293 137	5 486 290	3 417 096	2 815 600	12 092 721	2 106 703 4	674 015 1	2 092 721	2 715 785
Marc	4 105	1 2 3 2 9	736	10 486 228	103 00	13 717 511	13 717 51	9 13 717 5.	0 622343	3 13 717 51	0 13 717 51	2 380 762	3 103 002	7 13 717 516	1 2 389 762	13 717 510	13 717 516	6 6 2 2 3 43	13 717 510	3 876 220	242 025 7	4 869 967	13 717 510	14 424 289	2 037 067	10 486 228	4 424 289	103 007
ant	20 17	1 2317	012	7 216 507	. 721650	7 10.458.48	10.459.49	2 10 458 4	13 7 216 50	7 10.458.45	3 4 706 49	3 2006 691	721650	7 13 357 035	2.006.600	12 757 077	1 706 495	AT ANY	12 757 07	2 006 690	CIC/21010	2 006 600	12 040 075	13 757 037	2 006 600	089 980	2 757 027	246.009
udu W	2 8.2	(1071	217	4851 676	SC 01C / .	5 10 446 84	10 446 84	5 620005	5C 01C / 0	· · · · · · · · · · · · · · · · · · ·	2 + /00 +C	5 3.861.662	2000029 4	2 10 446 845	5 3 861 662	770 107 01	10 446 845	2 3 861 665	10 446 84	2 380 787	166 599 81	6 200 050	787.085.0	10 446 845	3 861 662 .	14370.115 1	0 446 845 4	851 676
1	10 0	707717	K0K	100 100 1	10 070 41	002002 0.	7 007 00	1 700706	00 201 01 1.	10 1272 1	10 0 28 61 0	1 1 2 2 2 2 2 2	10131101 0	1007007	1 4 565 050	7 007 001	1 140 53	001000	7 007 00	1 000 002	010/020 61	1007001	1 000 001	7 007 001	020 200 7	2 010 020 01	100 200	200 100
un(	1./ ər	1.2224	060	2 994 401	12 800 91	86/60/ 0	96/60/	Y6/60/ 1			16 10 2 1 20	0 4 200 8		. 109/98	) 4 202 50 50 1	186/60/ 8	2 240 35.	2 2 994 401	186 / 60 /	108 606 1	016 008 71	186 / 60 /	108 606 1	186/60/	8 CS COC 4	/ 016.002.21	. 186 /60	854 800
Ju	170 fr	4612.1	/30	2 008 118	10 220 51 5	/1 4 800 /0	0 154 95	2 10 35/ 2	15 222 51 60	// / 4031:	4 514831	8 0154 99.	7 2 008 11	8 0154 99.	2 0 1 5 4 99.	0 154 992	2 008 114	108 665 2 8	0 134 992	0 134 992	14 219 300	10 55/ 209	CEI 128 E	0 154 992	0 134 992	5 1/5 27 5 5	CS1 178	407 I 04
Augu.	st 6.4	1.2075	730	2 340 496	10 598 64	se 379631.	3 796 31	0 37963.	10 13 434 7.	19 6 095 I.	4 379631	0 741466	8 234049.	6 476957.	1 741466	8 4 769 571	10 5 98 66	8 1 995 072	4 769 571	13 434 719	1 995 072	13 434 719	4 769 571	4 769 571	7 414 668	1 769 571 3	128 063	0 270 051
Septembe	er 7.6	I.2064	712	3 669 202	1 928 27	73 5 891 05.	7 4 609 87	6 46098,	76 4 609 87	6 19282;	3 5 891 05	7 9 926 18.	9 9 9 2 6 18.	9 3 669 202	2 9 926 185	3 669 202	5 891 05	7 9 926 189	3 669 202	12 984 898	2 262 132	12 984 898	5 891 057	3 669 202	9 926 189	1 669 202 2	262 132	928 273
Octob	er 8.5	1.2126	736	6 121 079	6 121 07	79 3 141 37.	\$ 2 003 56	4 31413.	78 2 003 56	4 235045	9 744622	9 13 491 90	5 13 491 90.	5 3 141 37	8 13 491 90:	5 3 141 378	223	9 13 491 905	3 141 378	10 643 782	3 141 378	2 003 564	7 446 229	3 141 378	13 491 905	350 459 2	003 564 2	350459
Novembe	er 10.6	1.2194	696	10 121 586	3 625 42	5 223514	\$ 223514	3 22351-	(3 2 2 3 5 14	3 2 987 25	8 2 2 3 5 14	3 12 829 97.	5 455487 <sub>1</sub>	6 2 2 35 14.	3 12 829 97	\$ 2235143	2 987 25	8 12 829 970	2 235 145	9 807 761	3 625 425	2 235 143	9 807 761	2 235 143	12 829 976	905 267 5	820 771	2 829 976
Decembe	er 11.5	I.2237	736	13 614 984	1 2 371 90	1 2 021 84.	3 170 03.	5 2 0 2 1 84	(2 3 170 05	5 384724	9 2 021 84.	2 14 316 48	1 13 614 98	4 2 021 84.	2 14 316 48.	2 021 842	3 847 245	9 14 316 481	2 021 842	7 514 158	4 833 568	14 316 481	13 614 984	2 021 842	14 316 481	176 918 4	833 568	3 614 984
Annue	al 9.1	1.2222	8616	90 107 610	(2 69 20 T	74 90 190 49.	90 253 92	1 90 198 9.	73 91 016 37	18 90 443 4	15 89 858 04	2 90 685 37.	4 90 700 67.	8 90 078 67.	7 90 685 37,	1 90 530 336	90 473 13.	4 90 246 882	90 078 677	90 557 464	90 666 434	90 855 213	90 985 978	90 162 393	90 643 598	90 743 354 9	0 02 9 5 0 0	89 670 577
Table I.3 En	tergy prod	uction map o	of the win-	d farm for C	Cape Saint	James (Can:	ida)		with ser	nsitivity and	lysis of O.	&M <sub>manag(B)</sub>																
Months	V <sub>NC</sub>		H prod												1	AEP avail(KM	(1)											
	(m/s)	$(kg/m^3)$	( <i>q</i> )	$yr_I$	yr 2	yr 3	yr 4	yr5	$yr_6$	yr 7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
Janua	ry 15.4	1.2561	738	32 734 798	8 32 734 75	98 32 734 79.	8 32 734 75	8 32 734 7.	98 3273473	a8 327347.	32 734 75	8 32 734 79.	8 32 734 79.	8 32 734 79,	8 801349.	1 32 734 798	32 734 79,	8 32 734 798	32 734 798	32 734 798	32 734 798	32 734 798	40 754 809	32 734 798	32 734 798	28 019 994 8	013 494 7	100 933
Februa	ry 14.7	1.2522	641	24 319 291	1 14 509 90	01 693287.	3 26 305 52	7 14 509 9	01 14 509 9.	11 263055.	27 26 305 52	7 693287.	8 14 509 90	1 14 509 90.	1 7772 673	26 305 527	6 932 87	8 17 428 282	6 932 878	6 932 878	6 932 878	6 932 878	22 528 524	26 305 527	26 305 527	59 044 609 7	772 679	7 402 199
Marc	ch 12.7	1.2495	737	18 273 052	2 18 273 05	52 891896	27 905 82	3 12 408 1.	\$3 18 273 0.	52 27 905 8.	3 27 905 82	3 891896	9 12 408 18.	3 18 273 05.	2 9 997 395	5 27 905 823	891896	9 30 184 987	8 918 965	8 918 969	8 918 969	8 918 969	23 050 141	27 905 823	27 905 823	81 495 010 9	997 395	8 969 625
Apr	il 12.4	: I.2490	713	16 100 080	1 1933829	əs 966733ı	1 24 894 42	5 96673.	10 1933825	15 24 894 4.	27 24 894 42	5 9 667 330	9 667 330	0 1933829.	5 9 667 33(	1 24 894 425	9 667 331	) 26 984 508	9 667 33(	29 188 421	9 667 330	9 667 330	22 244 176	20 024 605	24 894 425	24 985 682 9	667 330	8 186 892
Ma	w 11.2	1.2425	737	12 338 025	1 25 598 81	14 9 940 86	19 885 47	3 994080	8 25 598 81	1 19 885 4.	73 19 885 47	3 9 940 86	\$ 9940.86	8 25 598 81-	4 12 338 02:	19 885 473	9 940 865	8 25 598 814	9 940 868	27 748 037	9 940 868	9 940 868	21 042 787	19 885 473	19 885 473	1 666 131 61	2 338 025	6 209 586
Jun	ıe 10.4	1.2351	689	9 237 631	25 785 08	¥6 11 465 20.	8 16 884 30	9 8241 h	A 25 785 00	16 16 884 31	ig 1688430	9 11 465 20.	8 824116.	1 25 785 080	6 15 384 45:	16 884 369	11 465 200	8 16 884 369	11 465 208	23 787 904	11 465 208	11 465 208	169 100 21	16 884 369	16 884 369	16 806 455 1	5 384 455	4 990 327
$J_{III}$	ly 10.0	) I.2275	737	8 761 837	7 29 653 15	JI 16 356 44.	3 16 356 44	3 781516	12 29 653 B	1 163564.	16 356 44	3 1635644.	3 781516.	2 29 653 19.	1 17 951 122	16 356 443	16 3 56 44.	3 7815162	16 356 44	19 646 221	16 356 443	16 356 443	15 570 355	16 087 422	16 356 443	16 802 962 1	7 951 122 8	647 175
Augu.	st 9.7	1.2216	737	7 777 512	12 130 85	55 17 864 64.	12 130 85	5 17 864 6	41 12 130 8:	15 12 130 8.	12 130 85	5 17 864 64.	1 17 864 64.	1 12 130 85:	5 19 551 57.	1 12 130 855	17 864 64.	1 8719626	17 864 641	17 864 641	17 864 641	17 864 641	12 936 052	15 417 110	12 130 855	12 621 116 1	9 551 573 7	130.060
Septembe	er 10.4	I.2234	713	9 469 157	7 753497	77 18 941 87.	5 946915	7 26 431 3	17 753497	7 946915	7 946915	7 18 941 87.	5 26 431 34.	7 753497.	7 24 384 10	0 469 157	18 941 87.	5 9469157	18 941 875	15 770 041	18 941 875	18 941 875	12 353 594	13 310 548	9 469 157 8	865 389 2	4 384 108	100 080 6
$Octob\epsilon$	er 13.1	1.2327	737	19 729 237	7 8 798 86	II 29 778 49.	9 862 76	4 25 397 6	30 8 798 86	1 986270	4 986276	4 29 778 49.	3 25 397 69	0 8 798 861	1 27 530 021	9 862 764	25 397 69	0 9862764	25 397 690	12 241 087	29 778 493	25 397 690	12 273 661	8 881 296	9 862 764 2	8 143 371 2	7 530 026	21 651 123
Novembe	er 14.3	1.2429	689	23 939 450	9 296 48	12 25 949 35	\$ 293.66	4 28 068 7.	25 9 296 48	2 8 293 66	4 8 293 66	4 25 949 35	5 28 068 72.	5 9 2 96 48.	2 28 068 72:	8 293 664	25 949 35	6 11 538 250	25 949 350	9 296 482	25 949 356	25 949 356	7 443 284	8 293 664	8 293 664 8	895 126 2	8 068 725	2 011 001
Decembr	er 15.1	1.2528	737	30 263 395	5 10 023 34	56 25 811 25	\$ 797598	3 20 050 5	91 10 023 31	\$6 797595	3 797598	3 25 811 25	5 20 050 50	1 10 023 36	5 32 581 56	\$ 7.975.983	30 2 63 39.	5 16 693 020	30 263 395	10 023 366	25 811 256	30 263 395	6 366 601	7 975 983	7 975 983 9	187 032 3	2 581 568	12 583 526
Annue	al 12.5	1.2404	8 600	212 943 465	5 213 677 6	78 214 362 11.	5 212 699 28	1 213 130 3.	96 213 677 6.	78 212 699 2.	81 212 699 28	1 214 362 11.	5 213 130 30.	6 213 677 67.	8 213 240 50	1 212 699 281	214 433 45.	1 213 913 741	214 433 451	214 152 844	214 362 116	214 433 451	213 565 675	213 706 617 2	12 699 281 2	14 004 745 21	3 240 500 2.	3 962 451

Table I.4 Wind	l speed sen	es simulatior.	ns for AEP	and in Ara	cati (Brazil)			wit	h sensitivit	y analysis e	of O&M <sub>ma</sub>	ag(B)														I
Months	лис Л											Wind spe	ed data seric	es for simule	ttions (m/s)											I
,	(m/s)	yr 1	yr 2	yr3	yr 4	yr5	yr 6	yr7	yr 8	yr9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	Vr 16 )	r17 y	r 18 )	r19 yı	20 yı	r21 y	r 22 yı	23 yr.	4 yr2	55
January	5.8	5.8	10.1	7.6	9.6	4.0	1.01	4.0	4.0	7.9	1.0.1	10.1	4.0	7.6	9.6	7.9	1 1.0	0.1	0.4	2.6	9.0	0.4	2.6	. 2	6	6
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6 1	1.0	0.	5.0 1(	5 I.C	.7 8.	\$. \$.	0
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	0.0	6.2	5.0	<i>8</i> 0	5.8	9.7 10	П 7.	5	2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	· 9.	6.6	9.6	.2 6.	9.6	9
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9 II	1.0	1.9 4	5 O.1	1.7	9.2 7	.9 5.	8	7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	0.7	4.7 4	1.7	2.6	8.6 8	.6 4.	9 10.	I
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	1.0 4	6.9	. 6.2	2 6.2	.8 4.	7 4.	0
August	9.6	9.6	6.0	6.0	6.0	1.01	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	1.7	2.9	5 8	8.6	5.0 6	0 4	9 4.	7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	6.1	8.6 10	5 <i>I</i>	2.0	5.8	.6	2	6
Octoher	0.7	0.7	4 0	4 0	4.0	90	40	9.6	90	5 8	8.5	4 0	101	4 0	4.0	9.6	0 2	0 2	0.5		0	90	10	01 0	5	×
Movember	0 2	0 2	4.7	2.4	4.7	0 0	2.4	0.7	0.7	6.0	60	2.4	0.7	47	4.7	0.7	86	2 2 8	8			2.0	47	0		
D	7.6	7.6	, c + *	, c	, c	1.0	, . ; ;	1.01	1.61	0.0	0.0		20		, c,	1.01	0.0	0.0	2.6		1 2				5 6	5 4
Annual	0.1	0.7	7.4	N.4	4.4	0.0	N.4	1.01	1.01	0.7	0.7	1.4	0.4 7.4	0.4 7 A	4.4 N L	1.01	K.1	K. 1	0°-	1.1 0	01 P1	. 11		N. 1.	1 1	- I -
17111177	ţ	ţ	ţ	e.	ţ		ţ	ţ	ţ		ţ	ţ	ţ	ţ	ţ	<b>H</b> * (		ţ		ţ	t.	ţ				, I
Table I.5 Wind	speed serie	es simulation	IS for AEP.	avait in Corv	o Island (P.	ortugal)		wit	h sensitivit	y analysis o	of O&M <sub>ma</sub>	ag(B)		1	(											Т
Months	P NC											wind spe	ea aata seru	es for simule	thons (m/s)											I
	(m/s)	yr 1	yr 2	yr3	yr 4	$yr_5$	yr 6	$yr_7$	$yr_8$	$yr_9$	yr 10	yr 11	yr12	yr 13	yr 14	yr 15	Vr 16 )	r17 y	r 18 )	r19 yı	-20 yı	r21 yı	r 22 yı	23 yr.	4 yr2	52
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	10.6	11.7	10.6	1 9.0	I.7 II	0.6 1	).6 I(	91 91	).6 I(	9.6 16	.6 10.	5 10.	6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	1.7	8.2	8.9	2.6	н г.	1.5 (	5.4 5	5 II.	5 11.	7
March	10.5	10.5	7.1	11.5	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	1.5	7.6	0.5	8.2 11	5 11	1.7 0	5.1 10	US 11.	7 7.	I
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	7.1	11.5	8.2	8.2	1.5	7.1 1/	7.5	11 12	.7 11	1.5	L I.7	.н п.	5 7.1	6
May	8.2	8.2	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4 1.	1.5	8.9 6	.4 10	0.5	11 9.7	.7 10.	5 8.	2
June	1.7	7.1	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1 1.	1.5	9.5 (	5 I'	9.5	8.2 11	.5 9.	5 8.	6
July	6.1	6.1	11.5	8.2	8.9	10.5	11.5	9.5	7.1	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9 I.	1.7 1	).5 ),	3.0	8.9	8.9 11	.5 7.	5 9.	5
August	6.4	6.4	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2 1	1.5	1 13	1.5 8	5.2	8.2	9.5 8	2 7.	I 10.	5
Septeniber	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6 1	1.5	5.4 1	1.5 8	6.	2.6 1(	9.5	.6	4 6.	1
October	8.9	8.9	8.9	7.1	6.1	1.7	6.1	6.4	9.5	11.5	11.5	7.1	11.5	1.7	9.5	11.5	1 1.7	0.6	<i>I</i> .7	5 1.3	5	1 I'	1.5 6	4 6.	I 6.	4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	7.1	6.4	11.5	8.2	6.4	11.5	6.4	7.1	11.5	6.4 I	0.5	2.6	5.4 I(	.5 6	5.4 1.	1.5 6	.1 8.	9 11.	2
December	11.5	11.5	6.4	6.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2 1	1.7 IJ	.5	5.1 L.	1.7 8	.9 8.	2 11	νI
Annual	1.6	9.1	9.1	1.6	9.1	1.6	9.1	9.1	9.1	9.1	9.1	1.6	9.1	1.6	9.1	9.1	1.6	9.1	1.6	2. I.G	5 I.	5 I.G	5 I.6	.I 9.	I 9.	~
Table L6 Wind	l speed sen	ies simulation	ns for AEF	and in Cap	e Saint Jam	es (Canada	0	wit	h sensitivit	y analysis o	of O&M <sub>ma</sub>	ag(B)		•												I
Months	Р ис											wina spe	ea aata seru	es Jor sumuc	thons (m/s)											ī
	(m/s)	yr 1	yr 2	yr3	yr 4	yr5	yr 6	yr7	yr 8	yrg	yr 10	yr 11	yr12	yr 13	yr 14	yr 15	Vr 16 )	r17 y	r 18 )	r19 yı	20 yı	r21 yı	r 22 yı	23 yr.	4 yr2	5
January r 1	15.4	4.CI	1.0.4	4.CI	15.4	4.CI	10.4	4.CI	15.4	4.CI	10.4	4.CI	7.6	15.4	15.4 7.0	1.5.1	1 5.0	7.4	1 1	4.0 10	0.1		14 14	6 S	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	× -
repruary	14./	14./	12.4	1.6	1.61	4:71	4.71	1.61	1.61	1.6	4.71	4.71	0.01	1.61	7.6	1.61	7.6						CI 1.0	0. 0.		- 0
March	/ 71	1.21	1.2.1	10.01	14./	7.11	1.21	14./	14.7	0.01	7.11	1.21	+01	14./	0.01	1.01					0.0			0 0 0	-71 +	~ ~
nuder	4:71	+ 71	1.61	+.01	1.41	+ 01	1.61	1.41	1.41	+:01	+:01	1.61	4:01	1.51	+.01	1.4.2			+		0				1 2	~ ~
Inno	7.11	7.11	C-+1	t:01	1.01	+:01	C.+1	1.01	1.61	t:01	10.0	C.+1	7.11	1.01	t:01	C.+1	+ C L		+	+ C I	*		CI LC	2 2	- 17 - P	. c
Jane L.L.	4.01		1-11	7.11	1.21	0.01	1.4.1	1.21	1.21	7.11	0.01	1.71	1.71	1.41	7.11		7 7 7 5		1 2	7 1	0.5		71 FC		- 101	4 9
August	0.01	0.01	1.01	4:71 12 7	11.7	7.61	1.01	+:71	4.71	4:71 1.2.7	1.6	C 11	121	4.71	+:71 	1.001	1 L C L C L	1 1.0			7 I I				0 10	
Cancerdan	1.01	1.01	2.11	1.21	7.11	147	2.11	7.11	7.11	1.2.1	147	2.11	<i>CV1</i>	7.11	1.21		1 1 1 1									
September	10.4	10.4	1.60	1.61	10.4	14./	1.6	10.4	10.4	1.51	14./	1.6	C.41	10.4	1.61	10.4	1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		1 12		+: ·:			- 14. - 14.	12.	v v
November	14.3	14.3	10.4	14.7	10.0	15.1	10.4	+:01	10.0	14.7	15.1	10.4	14.7	10.0	14.7	11.2	4 C + J	0.4		17		11 00	0.0 10	13 15. 13	1 13.	
December	15.1	15.1	10.4	14.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	10.4	15.4	9.7	15.1	12.4	1 1.5.1	0.4 1	13 1	5 1.5	5 00	7.0	9.7 10	1 15.	4 16.	6
Annual	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	1 2.5 1	2.5	25 1	2.5 12	5 13	25 12	2.5 12	5 12	5 12	١v
		1 410							1 410		1 410	1400	1 410	1410												

Table I.7 kWh per H <sub>prod</sub>							with se.	nsitivity and	lysis of O	&M <sub>manao(R</sub>	_														
										0		KW/S	Vr												1
yr j	, yr 2	yr 3	yr 4	yr5	yı	.6 y.	r7 3	r <sub>8</sub> yı	.9 yr.	10 yr	II yr	12 yı	r 13 y.	r 14 y	r15 y.	r16 yı	'17 y	r 18 y.	r 19 )	r 20 )	r21	Vr22 y.	r <sub>23</sub> )	V 24	yr 25
Aracari (Brazil) 5 696	5 646	5 674	5 628	5 700	5 64	6 56	15 56	15 5 63	7 563	9 564	16 569	94 56.	74 56	36 57	18 57	35 56	89 56	50 56	02 5t	97 5 (	583 5	616 56	28 51	545 5	637
Corvo Island 10 458 (Portugal)	10 535	10467	10 475	10 468	10 56.	3 1045	10 4.	39 I052	5 1052	7 1045	54 10.52	25 I05.	07 105	:00 I04	74 104	54 105	10 105	23 105	45 10:	200 IO	464 10.	520 105	32 10.	452 10	407
Cape Saint James 24 762 (Canada) 24 762	24 848	24927	24 734	24 784	24 84.	8 2475	14 247.	34 2492	7 2478	4 2484	48 2473	97 247.	34 245	36 248	75 249	36 249	03 245	27 245	36 24 8	335 248	851 24	734 248	86 24	797 24	881
																									1
Table 1.8 Cashflow for 25 years of th	te wind farm p	roject	50.000 K	A W	racati (Braz	<u>1</u> ])			with	sensitivity a	nalvsis of G	\&M													
Item	0	-	2	3	4	5	9	7	~	N N	0	12	Years 13	14	15	16	17	18	19	20	21	22 23	24	25	
(-) LCCCM <sub>WF</sub>	60 225 901																								
$WT_{CM}$	27 686 278	•	,						,		,	,			'	•			,						
T <sub>CM</sub>	24219295		,	,	,		,		,	,	,			, ,		,		,	,	,		,	,		
CP CM	1 545 346																								
TS CM	572 832																								
SICH	2 136 726	,	,			,	,		,	,	,	,			'		,	,	,	,	,		,		
$PO_{CM}$	1 796 870					,				,	,				'		,				,		,		
FCM	188 559															•									
CCC Gr	112.021	-						- 040 - 440 - 040 -					- 10704			-		- 020 020 40							-
LUCIN WE (KWH/)T) (+) AAR(SM/)T)		4308.015	4376931	4508965	4584266	4 759 280	4831313	4 995 061 5	9/00++++04 119937 519	12 200 46 45	7 022 5 466	5 187 5 651	151 5771	102 404/00 356 58769	6/ 49/109/02/ 53 6/110/75(	6282430	697.799	+ 0.00 200 + + 0.00 - + 0.00 200 - + 0.	6608332 4	5888721 40	930.788 4	29/11/2 40 39/ 394386 5120	1408 5274		200
PPAR		4308 015	4376931	4 508 965	4584266	4 759 280	4 831 313	4 995 061 5	119 937 51	74 634 5 32	7 022 5 466	5 187 5 651	151 5771 (	356 58769	53 6110 750	) 6282430	6387799	6 502 991	6 608 332 (	5888721					
EMP	,	•	,	,	,	,	,	,	,		,	,			'	'		,	,	-	930788 49	994386 5129	9 498 5 274	431 5 398	025
$(-) O \& M_{WFCM}$		3 958 388	4 021 593 2 702 950	4 142 789	4211857	4 372 535	4 459 642 7 084 530	4 610 143 4 2 065 607 2 1	724747 47	93.035 4.91 16.075 2.30	4 544 5 04.	2290 5212	260 5322	943 54192 547 2620 #	32 5 634 15 75 3 774 904	8 5791793 5 2 000 040	5 888 285 2 046 029	5 993 824 4 017 105	6 090 278 i	5 348 036 5 1 2 55 4 76 4	856505 55 251297 4.	931402 6091 407510 4524	1221 6262 5744 4.654	682 6408 645 4762	06/ F
O&M meints		1 297 109	1317743	1 357 376	1379 929	1 432 493	1 475 103	1 524451 1:	561914 15	1620 162 162	3788 1665	5566 1721	276 1757	396 17887.	57 1859 262	3 1910 846	1 942 247	1976628	2 008 010 2	2092560 1	505118 1:	523 892 1 56/	1477 1608	038 1645	±1/
(+) IRCM	,	863 268	884850	176 906	929 646	952 887	976709	1 001 127 1 4	026155 1 0t	51 809 1 07	8 104 1 105	5 067 1 1 1 32	683 1161	0 061 1 000	25 1219 77(	5 -	,	,	,	,	,	,	,	,	,
(+) Depreciation		2 453 484	2514821	2 577 692	2 642 134	2 708 187	2 775 892	2 845 289 2	916421 2.9.	89332 306	4 065 3 140	) 667 3219	184 3 299	663 33821.	55 346670	9 3553376	3 642 211	3 733 266	3 826 598	3 922 263 4	020319 4	120 827 4 22	3 848 4 329	444 4437	680
(=) Profit before tax	•	3 666 379 1 202 405	3 755 009	3 850 839 1 357 680	3944188	4 047 820	4 124 272 1 440 304	4 231 334 4 1 408 518 1	337 <i>767</i> 44 335.081 15-	42.740 4.55 18.300 1.50	8 107 1 636	9 621 4790 1 856 1 605	345 1731	576 50299 357 17630	11 516307 20 1833774	5 4044013 5 1884720	4 141 725	4 242 433 1 050 807	4344652 ·	1462948 3 066616 1	094.602 3	183811 3262 408316 1535	2125 3341 8850 1587	320 1610	914 407
(+) REPIM	384 830	2.046	1 989	1 962	1910	1899	1847	1 830	1 798 1	749 17	720 25	81 29	V 29(	5 302	314	323	328	334	339	354	362	366 3	76 31	20 - 20 20 - 30	2 9
REICM	221 313	1	'	-	'	'	'	-			a 	i ; '				'	-		'	,		2 1	2 1		
$REP_{CM}$	,	1 825	1 764	1 730	1 674	1 654	1 599	1 573	1 535 1	482 14	147			,	'	'	•								
$OREP_{CM}$	163 516																								
$GHG.R_{CM}$	•	21	225	232	235	244	248	256	263	267 2	274 2.	81 25	40 29t	5 302	314	323	328	334	339	354	362	366 3	76 31	87 39	9
(=) Profit after tax w/out interest		2376021	2443919	2500111	2570818	2 621 934	2 676 725	2 734 645 2	803 583 28	86099 295	8 260 3 030	046 3095	703 3178	316 3267 L	24 3330 16.	5 2159 606	2 225 713	2 291 870	2 362 491	2 396 685 1	615728 10	885 862 1723	3 652 1 759	250 1 807	903
(-) Debt payments	•	- 107 0	3 175 715	3 255 108	3 336 486	3 419 898	3 505 395	593 030 36	82.856 377	1 927 3869	300 39661	033 40651	84 416681	3 4270984	4377758		-	- 00000			-		-	-	-
(+) KCM wF		2 621 739	268/282	2754464	2823320	2 893 909	722 906 22	3 040413 3	116424 31 Mean 200	94334 32/	4 193 3 331	5.047 3.439	2222 646	947 36140	96 37/0444	8 379/060	9861685	3 989 286	4089018 ·	191243 4	296024 4	10.925 4.512	5511 4626	748 4 /42	/00/
(=) Free net cashflow	-59 841 071	7 451 244	4470308	4577159	4 699 792	4 804 133	4 913 478	5 027317 5	153572 52	07332 5.00 14837 5.42	7218 5560	1727 5689	651 5837	U3 59923	91 6123.564	4 9510.042	9759910	10014421 1	027810710	161 0121	932.071 10.3	210114 1046	512 01 010 10 10 10 10 10 10 10 10 10 10 10	042 10 987	290
$\Sigma$ free net annual cashflow		-52 389 827 -	-47919520 -	43 342 361 ÷	38 642 568 -	-33 838 435	28 924 957 -2	3 897 640 -18	744 068 -13 4	49 230 -8 02	2 012 -2 46	1 285 3 228	366 9.065	478 15 057 8	69 21 181 43.	3 30 691 475	40 451 385	50465806 t	0743913 7.	254104 81	18 175 91	396288 10185	7 299 112 57	2 341 123 555	1566
	LCOE was	67.67	67.82	68.03	68.19	68.45	68.63	68.88	59.09 6:	9.27 69	.49 69.	73 70.6	11 70.2	4 70.45	70.78	18.69	10.07	70.21	70.41	70.77	70.38	0.56 70.	83 71	1 713	8

1 able 1.9 Cashriow for 25 years of th	e wind farm p.	nject	50 000 k	w	orvo Island	(Portugal)			wi	h sensitivity	analysis o	f O&Mmana	2(B)												
Item	0	-	6	е	4	s	9	7	80	6	10	=	rears 12	13	14	5 1	6	18	19	30	21	13	23	24	25
(-) I CCOM	100 202 091																								
WTCM	27 686 278		,	,	,																				
$T_{CM}$	24219295		,	,	,	,			,	,	,	,	,		,	,	,	,					'	1	•
LWTG CM	1 959 783					•																			•
CP CM TC	1 245 646																								
V CM	962 961 6																								
POCH	1 796 870						,								,		,	,							
$F_{CM}$	188 559					•																			,
CCC <sub>CM</sub>	120 211				•	•																	•	•	,
$LCPM_{WF}$ ( $kWh/yr$ )	1	90 107 610	90 769 774	90 190 491	90 253 921	90 198 973	91 016 328 9	0 443 405 8	9 858 042 90	685 374 90	700 678 90	078 677 90 6	585 374 90	530336 904	73134 902	16 888 90 07	8 677 90 55	7 464 90 66	5434 90 855	213 90 985 9	978 901623	93 90 643 5	8 9074335	02 6 00 02 9 2 00	89 670 577
(+) AAR (SM/yr)		15 046 124	15 535 609	15 822 374	16229340	16 624 945	17 194 985	7 513 916 1	7 835 578 18	449 787 18	914 223 19	254 127 198	868.402 20	330 295 20 8	25386 212	2 641 2178	4 277 22 44	7 567 23 03	5443 23 661	518 24 287 9	63 17 268 8	171 17795 0	3 18 260 01	18 575 46	18 957 626
PPAR		15 046 124	15 535 609	15 822 374	16229340	16 624 945	17 194 985	7 513 916 1	7 835 578 18	449 787 18	914 223 19	254 127 198	868.402 20	330 295 20 8	25386 212	2 641 2178	4 277 22 44	7 567 23 03	5443 23 661	518 24 287 9	90				
EMP		- 114 660	-	-		- 10.401 02.1	- 022.01	- 0007.000					- 01 012 021	- 120	- 13.2	- 13 6			- 14 000		- 1/2083	0 06/ /1 1/3	13 020 01	204 0/ 0 81	070/06.81
(-) OCOM WEOK		4 905 042	10202	710 000 5	17040101	104 104 01	7/1-00/01	5 600 025	1 102 100 5	11 241 124	21 040 000	71 C01 040	21 0/0004	15 252 67	12 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0.01 0010	0.11 1404	11-11 1000	200 +1 000	1200 7 000	217 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		16 0/ 6 01 10	1171711	011110011
O&M veriable		4 518 607	4 665 487	4 75 1 486	4 873 579	4 992 258	5 163 313	5 258 962	5 355 430 5	539736 5	679 068 5	781 006 55	0 221 6	103 880 62	52 405 63	2569 654	0.051 673	9 063 6 91	5 732 7 103	264 72912	205 51854	134 53433	7 5482 80	5 577 400	5 692 034
(+) LRCM	,	863 268	884850	126 906	929 646	952 887	976709	1 001 127	1 026 155 1	051809 1	078 104 1	105 057 11	32.683 1	1000 11	90.025 1.2	9.776	,		,						,
(+) Denveriation		2 449 308	2 510 541	2 573 304	2 637 637	2 703 578	2 771 167	2 840 447	0 011458 2	984.744 3	058.850 3	135 322 32	13 705 3	94.047 33	76398 34	0.808 3.52	1309 363	5 012 3 72	3912 3820	085 3915	87 40137	4113.8	4 4216.65	4 322 07	4 430 1 27
(=) Profit hefore tax		8 944 151	9 210 296	9 407 638	500 079 6	9 8 79 479	10 184 390	0 307 503 1	0.614162 10	11 129 040	217 531 11	448 320 11	21 21 22	0110	62 956 12 6	57 168 11 70	12 045 12 048	25 1 36 1	1722 12 676	045 13 009	13 8.069	33 8293 5	8 505 764	8 685 30	8 883 337
(-) Revenue tax	,	4 513 837	4 660 683	4 746 7 12	4 868 802	4 987 484	5 158 496	5 254 175	5 350 673 5	534936 5	674 267 5	776 238 59	60.521 6	99 089 62	47.616 63	87.792 6.53	5 283 673	4 270 6 91	933 7 098	455 7 286	89 51806	61 53385	9 5478 00	5 572 63	5 687 288
(+) REPIM	486 675	1 439	1420	1 382	1355	1 327	1313	1279	1 247	1 234	1 211	1 180	167	144	123 1	001	165 1	1 10	75 1	9 184	18.	193	198	201	205
REICH	221 313	,	,	,		,	,	,	,	,	,	,		,	,		,		,						,
REP	-	1 325	1 302	1260	1 232	1.201	1 183	1 147		1 094	1.068	1 034	016	000	965	02.0	,		,				,		
OP FP	765 367	-				1								2											
		114	011	2	201	901	120	133	1.25	1.40	142	146	151	154	140	191	1 29	1 02	1 22	10/1	0	10.2	100	100	200
UTUR CM (=) Deaft after tax infants		4 431 752	110	1 657 307	071 649	1 902 207	001 2002	209 144 607	5 264 735 5	408.045 5	2 244 475 5	140 512 51	101 2020	1.9 591 890	001	101 5 7/7 5 17	1 02 × 300 0	1 0/	1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	101 57731	01 2 2001	C 20 C 050	2077.05	3 112 05	202
(=) rrout ageriax woun meresi		70/10++	CCU 100 +	100100+	4 / /# 0#0	770 060 +	102 120 5	160 111 0	C CC/ #07 C	0 0 00000000000000000000000000000000000	n n/++++n	0 C C07 C/O	C 000.070	10 001000	70 00401	0/+0	0000 016 1	140 C 071 C			16007 60V	4 0067 60	-06 170 0 1	C6711 C 4	+C7 0.61 C
(-) Debt payments			3 1 70 310	3 249 568	3 330 807	3 414 077	3 499 429	5 586 915	676 588 3	768 503 3 8	62715 35	159 283 4 00	8 265 41	9 722 4 26	3 715 4 370	308									
$(+) RCM_{WF}$		2 621 739	2 687 282	2 754 464	2 823 326	2 893 909	2966257	3 040 413	3 116 424 3	194334 3	274 193 3	356 047 37	139 949 3	525 947 3 6	614.096 3.7	1448 379	7 060 3 89	1 986 3 98	9286 4089	018 41912	243 4296(	24 44034	5 451351	4 626 348	4 742 007
(+) Depreciation		2 449 308	2 510 541	2 573 304	2 637 637	2 703 578	2 771 167	2 840 447	2 911458 2	984244 3	058 850 3	135 322 32	213 705 3	294 047 33	76398 34	90.808 3.54	17 329 3 63	5 012 3 72	5912 3820	085 39155	587 40134	177 41138	4 4216 65	4 322 075	4 430 127
(=) Free net cashflow	-59 739 225	9 502 799	6 578 546	6735508	6 904 804	7 076 732	7 265 202	7 438 642	7 616 029 7	819.021 8	014 803 8	205 349 84	120 446 8	528 438 8 8	43 243 9 0	9 425 12 51	2 365 12 83	4 126 13 15	7 162 13 485	872 13 829 8	39 11 1985	60 11 472 4	5 11 758 12	12 061 381	12 368 389
2		-50 236 426 -	43 657 880 -	36 922 371 -	30.017.567	-22 940 835 -	15 675 633	8 236 990	2 296.029-	198.060 15	212.862 23	418 211 318	38.657 40	467 095 49 3	10338 583	0 764 70 85	G 128 8371	7 254 96 87	4416 11036	1 287 124 194	126 135 392	686 146 865 1	31 158 623 30	170 684 68:	183 053 074
4. free net annual cashflow	LCOE	73.13	73.52	73.79	74.13	74.47	74.93	75.23	75.53	76.02	76.41	76.73	7.23	2 63 72	200 00000	47 77	65 78.	16 78.	63 79.	2 79.61	27.77	78.24	78.71	29.06	29.47
Table I.10 Cashflow for 25 years of t	he wind farm	project	50 000 k	×	ape Saint Ja	ames (Canad	a)		wi	h sensitivity	analysis o	f O&Mmana	2(B) Vance												
Item	0	-	2	e	4	5	9	7	8	6	10	11	12	13	14	5 1	6 10	18	19	20	21	5	23	24	25
( ) ] CCCM	100 500 09																								
(-) LUCUM WF	27 686 278																								
Tor	24219295	,	,	,		,	,	,		,	,	,	,	,	,	,	,	,	,						,
LWTG CH	1 959 783	•	•	•	•	•							,			,	,	,							,
$CP_{CM}$	1545346	,	,	,		,	,	,	,	,		,		,	,		,								
TS <sub>CM</sub>	572 832	•				•							,												,
$SI_{CM}$	2 136 726	,	,	,	,	•	,	,	,	,	,	,	,	,	,	,	,	,					'	'	'
$PO_{CM}$	1 796 870					,	,		,			,		,			,						'	'	
F <sub>CM</sub>	188 559		•	•	•	•																		'	
CCC CH	120 211	,	,	,		,	,	,	,	,		,		,	,		,		,				'		,
LCPM <sub>WF</sub> (kWh/yr)	•	212 943 465	213 677 678	214 362 116	212 699 281	213 130 306	213 677 678	212 699 281	12 699 281 21	4 362 116 21	130 306 21	3 677 678 213	240 500 212	699 281 214	433 451 213	13 741 214 4	33 451 214 15	\$2 844 21436	2 116 21443	3 451 213 565	675 213 706	617 212 699 2	31 214 004 74	213 240 500	213 962 451
(+) AAR (SM/yr)	•	30 196 663	31 058 298	31 936 726	32 481 214	33 360 711	34 282 550	4 978 715 3	5 853 182 37	036811 37	744 583 38	787 558 39 (	575 905 40	564.585 41.9	17 697 42 8	506 44 00	9 781 45 08	1 704 46 25	3 902 47 426	027 48 414 9	54 347606	55 35 461 7	6 3657136	37 351 77.	38 415 192
PPAR		30 196 663	31 058 298	31 936 726	32481214	33 360 711	34 282 550	4 978 715 3	5 853 182 37	036811 37	744 583 38	787 558 39 6	575 905 40	564.585 419	17 697 42 8	51 506 44 00	9 781 45 08	1 704 46 25	3 902 47 426	027 48 414 5	54				'
EMP			- 102 000 10	- 000 000 10			- 101 007 00	- 102,000 0			- 000 000										- 347606	55 354617	56 36571 36	21 351 351 777	38 415 192
DAM		000 COD 07	10 000 11	12 236 866	240 441 77	200 061 77	13135.671	1 17/ 002 C	3 737 461 14	10/00/17	460 154 14	861 773 152	12 020 200	091 07101	7 67 001 14	2000 1600	7000 CHO 0	00 10 070 7	121 81 5150	6/0 CC 201-	590001 SCS	301000 0t	0 20010 03		20102012
O.P.M		0.052.702	0100000	0.595.754	230.047.0	000 010 01	967 060 01	1 102304.0	11 101/01/0	11 062.511	11 100 002	0 11 0 00 009	07 492 10	SCI 30070	6 CI 20008	0 1 20 1 2 2 1	6677 1252	0.012 12 00	10101 1030	246 14 520	000 10420	00101000	7 1007613	ACOIC 11 3	20100211
(+) LRCM		863 268	884.850	126 906	929.646	952 887	976709	1 001 127	1 026155 1	061809	078 104 1	105.057 1	32.683 1	11 000 11	90.025 1.2	9.776	-		-				-	-	-
(+) Depreciation		2 431 041	2 491 817	2 554 113	2 617 965	2 683 414	2750500	2 819 262	2 889 744 2	961988 3	036 037 3	111 938 31	89 737 3	269 480 33	51217 34	4 997 3 52	0 872 3 60	8 894 3 69	9117 3791	594 38863	384 39835	44 4083 L	2 4185 21	4 289 84	4 397 087
(=) Profit before tax	,	12 857 112	13 212 461	13 575 190	13 834 276	14 201 624	14 584 601	4 898 383 1	5 270 966 15	743 856 16	068 486 16	501 792 168	888 698 17	278 348 17 8	17801 182	0389 1746	9 810 17 88	7 970 18 34	9.597 18.813	459 19 221 6	9 284	151 9491 0	5 9762 49	9 986 26	10 255 819
(-) Revenue tax		9 058 999	9 317 489	9 581 018	9744364	10 008 213	10 284 765	0 493 614 1	0 755 955 11	111 043 11	323 375 11	636 267 11 9	02 772 12	169376 125	75 309 12 8	8 452 13 21	1 934 13 52	4 511 13 87	5 171 14 227	808 14 524	186 10 428	96 10 638 5	8 10.971 40	11 205 53	11 524 558
(+) REPIM	932 216	778	793	807	814	829	845	855	870	892	903	662	817	836	864	883	9 202	29 9	53 9.	166 11	1 023	1 044	1 076	1 099	1131
$REI_{CM}$	221 313		•	•		•																			
$REP_{CM}$		156	153	150	145	142	138	134	131	129	125	,	,			,								'	
$OREP_{CM}$	710 902		,	,	,	,						,	,			,								'	
$GHG.R_{CM}$	,	622	640	658	699	687	706	721	739	763	778	662	817	836	864	883	907 9	29 9	53 9.	166 11	1 023	1 044	1 076	1 099	1131
(=) Profit after tax w/out interest	,	3 798 892	3 895 764	3 994 980	4 090 726	4 194 239	4300681	4 405 624	4 515 882 4	633 705 4	746 014 4	866 323 49	986744 5	109 808 5 2	43355 53	2 820 425	8 783 436	4 388 4 47	4379 4586	628 4698	20 -1142	23 -1146 3	9 -1 207 83	-1 218 16	-1 267 608
(-) Debt payments			3 146 666	3 225 332	3 305 966	3 388 615	3 473 330	3 560 163 3	649 168 37	740 397 3 8	33 907 3 5	29 754 4 02	7 998 41	28 698 4 23	1 916 4 337	713	,						'	'	
$(+) RCM_{WF}$	•	2 621 739	2 687 282	2754464	2 823 326	2 893 909	2 966 257	3 040 413	3 116 424 3	194334 3	274 193 3	356 047 3 4	139 949 3	525 947 36	14 096 37	1448 379	7 060 389	1986 398	9286 4089	018 4 191 2	243 4296(	24 44034	5 451351	4 626 348	4 742 007
(+) Depreciation		2 431 041	2 491 817	2 554 113	2 617 965	2 683 414	2 750 500	2 819 262	2 889 744 2	961988 3	036 037 3	111 938 31	89 737 3	269 480 33	51217 34	4 997 3 52	0872 360	8 894 3 69	9117 3791	594 3886	384 3983	44 40831	2 4185 21	4 289 841	4 397 087
(=) Free net cashflow $\Sigma$	-59 293 685	8 851 672 - 442 013 -	5 928 198 44 513 816 -	6 078 224 39 435 597 -	6 226 05 1 27 709 540 .	6382 948 25 826 503 -	6544108 10282485_1	6 705 136 2 577 349	6 872 881 /	245162 8	222 337 7 567 409 15	404.555 7.2 077.053 23 4	588 431 /	776537 79 227022 393	76753 81	74.552 11.57 28.327 59.04	6715 1180 × 042 7093	5 268 12 16 1 3 10 83 09	2.781 12.46/ 2.001 05.56f	240 127/5	748 71:562 070 115 472	146 7340 E	130 303 97 130 303 97 130 303 97	138 001 00-	7 871 480
- It could write the state of the second second	LCOE	84.34	85.02	85.71	86.17	86.87	87.59	88.17	88.87	89.78	90.37	5 61.19	1610	2.63 9	3.67 9.	44 94		92 95.	82 96.	2 97.50	93.92	94.68	95.73	96.51	97.52

## **APPENDIX J**

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and av automatically based on user input into	re updated vellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[S/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
										887 464					
Wind Project Information	P	Notes	Levenzea Replacement	Jost Model	Notes	wina Farm Kemoval C	ost Model	Notes	Kenewable Energy Fublic Ind	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Aracati (Brazil)		Denr	76.9840	[5/KW] [5/FW]	DCM WF RM wr	22 3284	[5/KW] [5/FW]	ICCCM we	1 207 5681	[3/KWe] [5/FW]	WF CM		50.000	[KW@/yr]
Turbine Model	Vestas V90-2MW		WT cu	553,7256	[\$/kW]	WF	50 000	[JKW]	LRCM	16.8443	[\$/kW]	Nwr		25	[_]
Number of Wind Turbines (NWT)	25	[-]	TCM	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WTrated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	M	100	[m-h]	$\Psi_{solal}$	30.00%	[%]	N rew		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMANNE	85.00	[\$/m-h]	n ,	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>Y<sub>RC</sub></sub>	60.1398	[\$/kW]	N <sub>mentur</sub>	3	[-]	REP CM	0.00002627	[\$/kWch]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>10 1000</sub>	2.0	[d]	AEP anail/H prod	5 695	[kW/yr]	L <sub>x</sub> ,		2 880	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	[\$/kW]	C <sub>ad mar</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$	10.0	[m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	e	0.1496	[\$/kW_ch]	SD <sub>x</sub>		630	[m]
Betz Limit's coefficient (Can . )	0.14	[-]	V V	237 899 000	[KW] [VW]	WF cap	30 000	[KW]	е <sub>0</sub> п	0.116883	[S/KWen]	ELH (		540 8 760	[m] [h/sr]
Lifetime of Wind Farm (N)	0.3920	[-] [vr]	Vo	1 457 72	[KW]	M <sub>WT</sub>	3.0	[-] [m-h]	ORFP CH	13 (0797	[5/kW_]	PC BM		8 700	[II/ y1]
Production Efficiency (WF PF)	11.2%	[%]	PR	0.70	[-]	C <sub>MBr</sub>	85.00	[S/m-h]	LCCCM	2.7734	[\$/kW]	AEP mail		48 856 319	[kW_h/yr]
Availability	97.9%	[%]	b	-1.94	[-]	N., ~7	3	[-]	LCCCM WF	1 207.5681	[\$/kW]	$\eta_{max}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/kW]	D <sub>m</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{method}$		25.00%	[%]
						C <sub>nd m</sub>	3 500.00	[\$/d]	$\Psi_{solal}$	30.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost !	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>faul cu</sub>	0.098275	[\$/kWh]	WF cap	50 000	[kW]	n ,,	10	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM WT	265.32	[\$/kW]	$LCCCM_{WF}$	1 207.5681	[\$/kW]	$N_{WT}$	25	[-]	CRj	80.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.000001%	[%]	$A_{WT}$	43.00	$[m^2/wt]$	GHG.R CM	1 596.4321	[S/tCO <sub>2</sub> ]	$P \& D_{LM}$			
$C_{kW}$	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>krzaw</sub>	3.0	[m-h]	$LCER_{co_2}$	18.6	[tCO2/MWah]	a		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	C <sub>Mbrsaev</sub>	85.00	[\$/m-h]	$\sum AEP_{mal} = r_1, \dots, r_n$	48 856	[MWeh]	2		0.00%	[%]
T <sub>CM</sub>	484.3859	[S/KW]	ifr O&M	2.50%	[%/yr]	D N M XARY	3	[-]	n , GHG	0.00041	[yr]			5.00%	[%]
PC -	26 30%	[Ag] [96/\$/J/W]	MLC	71 5608	[3/KW1]	C .	3 500.00	[U] [\$/d]	GHG	0.00041	ICO AW N	ICPM		48 856 319	[70] fkW.b/srl
C	0.1900	[50/3/KW]	TIC	124 5688	[3/1] [\$/b]	RVM w.c.	61.0184	[3/u] [\$/FW]	C C C C C C C C C C C C C C C C C C C	46 3820	[800/MW/a]	LCI M WF		40 850 517	[K 17 all yi ]
I WIG and	42 2302	[\$/m/FW]	P.	30.00%	[96]	Num	25	[]	BEPIM distribution	100.0%	[01002]	Project Finan	cina	1	Notes
WF	50 000	[Jim Kir]	ifr	2.50%	[%/vr]	WTS ym	1.4442	[\$/kW]	$\tilde{\zeta}_1 RELow$	25.0%	[%]	Debt ratio	. mg	50.0%	[%]
L,	15 030	[m]	N	25	[yr]	WFcm	50 000	[kW]	č, REP CM	25.0%	[%]	Debt term		14	[yr]
CAB cent	2 000.00	[\$/m]	n <sub>mib</sub>	72	[h]	ifr	2.50%	[%/yr]	$\xi_3 \text{ OREP }_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	113	[h]	Ν	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	25.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	4 192 361	[\$M]	$WT_{weight}$	200 000	[kg]	REPIM	420.1272	[\$/proj]	Debt value		29 996 522	[\$]
ç	0.08%	[%]	AEP anail	48 856 319	[kWh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	3 030 368	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M WFCM	0.124133	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	2	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 996 522	[\$]
TL,	1 200	[1/kW]	O&M <sub>manag(STD)</sub>		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
L	3 000	[m]	SC ORM	0.000105	[\$/kWh]	Ν	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB c	113.00	[\$/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE wso	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE with		Notes	67.8128	yr <sub>1</sub>	70.9287	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			67.9643	yr 2	69.9602	yr 15
WT inst	42.5238	[\$/kW]	USC OBM	0.000287	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M ccm	1	[1/0]	68.1735	$yr_3$	70.1513	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	68.3347	yr.4	70.3512	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			68.5874	yr s	70.5480	yr 18
PO CM	33.93/4	[5/KW] (\$/LW)	Kepair time	3.0	[n] [b]	March	744	735	KEPIM distribution		(1/0)	60.0225	yr 6	70.9089	yr 19
rs DT	19.88	[31.17]	SC USC	112.5	[11]	April Man	720	725	F PEP	1	(1/0)	60.2200	37.7	70.5211	3Y 20
EC	87.22	[\$/FW]	JC O&M+USC O&M	104.5	[Nyr]	stay	744	687	Č. ORFP	1	[1/0]	69.4112	yrs	70.7039	yr 21
Fou	3 7807	[S/kW]		0.000392	(*******/	July	744	735	Š. GHG R CH		[1/0]	69.6398	VEIO	71.2576	37 22 W 32
WACC mod	4,900%	[%/yr]		Г	1	August	744	735	P&D <sub>IM</sub>		[1/0]	69.8761	yr 10	71,5190	yr 25
n fin	1.0	[yr]				September	720	711	λ.,	1	[1/0]	70.1551	yr 12	69.8318	Mean
WECH	0.30%	[%]	1			October	744	735	2	0	[1/0]	70.3807	yr 13	1.0823	SD
CCC CM	2.4103	[\$/kW]	1			November <sup>(*)</sup>	720	687	λa	1	[1/0]	70.5948	yr 14	-0.4514	Y (skewness)
ĸ	0.20%	[%]	1			December	744	735	λm	1	[1/0]	LCOF	69.8318	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 207.5681	[\$/kW]				Total [h/yr]	8 760	8 579		p.s.: 1 = yes ar	nd 0=no		0.069832	US\$/kWh	

**Figure J.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $L_{wt}(5D7D)$ . Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes	ĺ	Notes
Legend				-					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	e updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	n about the project.		Costs covered by manufacturer $(O \Delta M_{\rm cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	ĺ	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	TORS	AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI <sub>CM</sub>	70.9972	[\$/kWe]	WF CM	-	50 000	[kW_/yr]
Project Location	Corvo Island (Portugal)		Depr <sub>WTmi</sub>	76.9840	[\$/kW]	$RM_{WT}$	22.3284	[\$/kW]	LCCCM WF	1 207.5681	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	C M <sub>Mar</sub>	100	[m-h]	$\psi_{aoaal}$	30.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tjr Denr.	2.50%	[%/yr] [\$/vW]	N N	85.00	[5/m-n]	PFP out	0.00001039	[yr] (\$/FW-b)	N col		90.0	[-]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	YBC	15	[(rk(t)]	$D_{\mu}^{n_{m_{yr}}}$	2.0	[d]	AEP muit/Harod	10 451	[kW/yr]	L.		2 880	[m]
Hub height (H)	105.0	[m]	ТОсм	0.000033	[\$/kW]	C <sub>nd max</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L		2 430	[m]
Wind speed measured at (H <sub>0</sub> )	10.0	[m]	Π	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ŝ	0.1086	[\$/kW_eh]	SD <sub>x</sub>		630	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.075000	[\$/kW_eh]	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>e</sub>	15	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	c 0	1 457.72	[\$/kW]	M <sub>brance</sub>	3.0	[m-h]	OREP CM	21.2151	[S/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	20.5%	[%]	PR	0.70	[-]	C <sub>Mbracr</sub>	85.00	[S/m-h]	LCCCM <sub>WFORSIGCM</sub>	2.4513	[\$/kW]	AEP avail		89 657 257	[kWeh/yr]
Availability	97.9%	[%]	Ь	-1.94	[-]	D N m mcr	3	[-]	LCCCM WF	1 207.5681	[\$/kW]	$\eta_{wecs}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/kW]		2.0		WACC proj	4.9000%	[%/yr]	n sectore		25.00%	[%]
Wind Farm Life-Cycle Canit	al Cost Model	Noter	Wind Farm O&M Cost	Model	Noter	SA PV	1 297 3916	[\$/d] [\$/JW]	9° antal i Gu	2.5%	[%] [%/vr]	P&D <sub>LM</sub>	factor	0.839325	[-]
wr	553 7256	(S/FW)	O&M.	0.098275	(\$/FWP)	WE	50,000	[JAK11]	iji i	15	[/0/ 91] [ve]	4		6 361 7	- C-25
CMwr	265.32	[\$/kW]	LCCCM we	1 207.5681	[\$/kW]	N wr	25	[-]	CR	80.0%	[%]	AEP		438 000 000	[m] [kW_h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	A WT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	821.1245	[\$/tCO2]	P&D <sub>IM</sub>			
CkW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Mbr sam	3.0	[m-h]	LCER <sub>co</sub> ,	34.1	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mir_{sanv}}$	85.00	[\$/m-h]	$\sum AEP_{aud} = \sum_{r_1, r_2, r_3}$	89 657	[MW <sub>e</sub> h]	2,41		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub> <sub>MP</sub>	3	[-]	n <sub>v</sub>	25	[yr]	λd		5.00%	[%]
Tmass	138 000	[kg]	O&M variable cu	0.048935	[\$/kWh]	D <sub>m saks</sub>	3.0	[d]	$GHG_{IM_{FCO_2}}$	0.00041	[tCO2/MW2h]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md sav</sub>	3 500.00	[\$/d]	$GHG_{EM_{unit}CO_2}$	0.00003	[tCO2/MWah]	LCPM <sub>WF</sub>		89 657 257	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	Ec	13.0000	[\$/tCO2]			r	
LWTG CM	42.2302	[S/m/kW]	R <sub>tanes</sub>	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[KW]	tfr N	2.50%	[%/yr]	WIS VM	1.4442	[S/KW]	ζ <sub>1</sub> REI <sub>CM</sub> č prp	25.0%	[%]	Debt ratio		50.0%	[%]
CAR	2 000 00	[m] [\$/m]	JV	25	[yr] [b]	WP cap	2 50%	[KW] [%/vr]	Č ORFP ou	25.0%	[%]	Debt or	ice neriod	14	[yr]
CP cu	30.9069	[\$/kW]	R ch	113	[11] [h]	N	25	[vr]	Š <sub>4</sub> GHG.R <sub>CM</sub>	25.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
EF	400.00	[\$/kW]	AAR	14 605 780	[\$M]	WTweight	200 000	[kg]	REPIM	228.3342	[\$/proj]	Debt value		29 945 676	[\$]
ç	0.08%	[%]	AEP anail	89 657 257	[kWh/yr]	C steel	0.1900	[S/kg]			1.1 11	Debt pa	yments	3 025 231	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.147210	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	,	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 945 676	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000057	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	$[/m^2/kW]$	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	73.2318	yr i	78.5641	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			73.6301	$yr_2$	77.7428	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000156	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	73.8961	yr 3	78.2623	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	74.2410	$yr_4$	78.7162	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			74.5811	$yr_5$	79.2229	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution		64.003	75.0412	yr <sub>6</sub>	79.7123	yr 19
P3	19.88	[5/KW]	nours requirea	112.5	[n]	April	720	/11	ζ <sub>1</sub> κει <sub>CM</sub> ξ pro	1	[1/0]	75.5319	yr 7	77.8292	yr 20
DI	404.52	[\$/KW] [\$/FW]	SC O&M+USC O&M	104.5	[H/yr]	May	744	687	Č ORFP ou	1	[1/0]	76 1210	yr <sub>8</sub>	78.3423	yr <sub>21</sub>
EG F cu	3 7807	[\$/kW]		0.000214	[#KHN/yf]	June	744	735	ŠA GHG R CH	1	[1/0]	76 5181	yr 9 VF 10	79 1478	37 22 VF 23
WACC mai	4,900%	[%/vr]		Г		August	744	735	P&DIM		[1,0]	76.8318	yr II	79,5421	yr 25
n <sub>fin</sub>	1.0	[yr]				September	720	711	λa	1	[1/0]	77.3320	yr 12	76.9663	Mean
WFCM	0.30%	[%]				October	744	735	$\lambda_{xdx}$	0	[1/0]	77.7339	yr 13	2.0085	SD
CCC CM	2.4103	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	78.1605	yr 14	-0.4651	Y (skewness)
K	0.20%	[%]				December	744	735	λ.,,	1	[1/0]	LCOE was	76.9663	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 207.5681	[\$/kW]				Total [h/yr]	8 760	8 579		p.s.: 1 = yes as	nd U=no		0.076966	US\$/kWh	

**Figure J.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $L_{wt}$  (5D7D). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	15	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_m)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind During Information		Neter	I evelized Penlacement (	Cost Model	Notes	Wind Farm Removal C	ort Model	Neter	Panawahla Enargy Public In	cantina Madal	Neter	Wind Farm Life	Cycle Prod	uction Model	Natas
Project Name	Firestar Wind Farm	wotes	AR cu	16 8442	(\$/kW)	DCM we	1 339 9154	[S/kW]	Relew	70 9972	INDIES [S/kW_]	WE cu	-c,ete 170a	50.000	[kW_/yr]
Project Location	Cape Saint James (Canada)		Depr	76,9840	[\$/kW]	RMwr	22.3284	[5/kW]	LCCCM WF	1 207.5681	[5/kW]	WFam		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF car	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	(-)
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	[yr]	$M_{hr_{max}}$	100	[m-h]	$\psi_{aobal}$	30.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	$C_{Mhr_{EM_{WT}}}$	85.00	[\$/m-h]	n <sub>v</sub>	6	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>marga</sub>	3	[-]	REP CM	0.0000052	[\$/kWeh]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>m super</sub>	2.0	[d]	AEP anail/H prod	24 766	[kW/yr]	L.,		2 880	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	$C_{ml_{Mayr}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	$L_{x_{col}}$		2 4 3 0	[m]
Wind speed measured at $(H_0)$	10.0	[m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	£	0.0128	[\$/kW <sub>c</sub> h]	SD <sub>x</sub>		630	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.009998	[\$/kWeh]	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C PBetz)	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>x</sub>	10	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	C ()	1 457.72	[\$/kW]	M <sub>br</sub> <sub>mcr</sub>	3.0	[m-h]	OREP CM	56.8814	[S/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	48.5%	[%]	PR	0.70	[-]	C <sub>Mbrace</sub>	85.00	[S/m-h]	LCCCM <sub>WFORSOCM</sub>	2.7734	[\$/kW]	AEP avail		212 467 325	[kWeh/yr]
Availability	97.9%	[%]	b	-1.94	[-]	N <sub>mmcr</sub>	3	[-]	LCCCM WF	1 207.5681	[\$/kW]	$\eta_{seecs}$		20.35%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/kW]		2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{wecr_{(rel)}}}$		25.00%	[%]
						C <sub>nd mar</sub>	3 500.00	[\$/d]	$\psi_{\rm aotal}$	30.0%	[%]	$P\&D_{LM}$	factor	0.814145	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost M	lodel	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	N <sub>WT</sub>		25	[-]
WT CM	553.7256	[\$/kW]	O&M <sub>ful</sub>	0.098275	[\$/kWh]	WF cap	50 000	[kW]	n <sub>v</sub>	10	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM <sub>WT</sub>	265.32	[\$/kW]	LCCCM WF	1 207.5681	[\$/kW]	NWT	25	[-]	CRf	80.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70%	[%/\$/kW]	ω	0.0000001%	[%]	A WT	43.00	[m²/wt]	GHG.R CM	4 490.4890	[\$/tCO <sub>2</sub> ]	P&D <sub>IM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>br sur</sub>	3.0	[m-h]	$\sum_{AEP} AEP$	80.7	[tCO2/MWah]	2		7.00%	[%]
11-1	10.00%	[%]	N	25	[yr]	CMbr <sub>sanv</sub>	85.00	[S/m-h]	∠ <sup>ML1</sup> and <sub>P11-1P2</sub>	212 467	[MW <sub>e</sub> h]	14.1		3.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr O.f.M	2.50%	[%/yr]	N <sub>m</sub> <sub>un</sub>	3	[-]	n <sub>7</sub>	25	[yr]	×		5.00%	[%]
I mass	138 000	[Kg]	O'Cur variable Cur	0.041531	[SKWI]	C m SARV	3.0		CHC	0.00041	[ICO <sub>2</sub> /MW <sub>2</sub> h]	A <sub>m</sub>		3.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	/1.5608	[5/h]	C nd saw	3 500.00	[\$/d]	GHG <sub>EM</sub> <sub>uns CD2</sub>	0.00003	[tCO <sub>2</sub> /MW <sub>4</sub> h]	LCPM <sub>WF</sub>		212 40/ 325	[KW <sub>c</sub> h/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[S/h]	RVM WF	61.0184	[S/kW]	E <sub>c</sub>	30.0000	[\$/tCO <sub>2</sub> ]			r	
LWIG CM	42.2302	[5/m/kW]	R taxes	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[S/kW]	ς <sub>1</sub> REI <sub>CM</sub>	25.0%	[%]	Debt ratio		50.0%	[%]
Lg	15 030	[m]	N	25	[yr]	WF cap	50 000	[KW]	ζ <sub>2</sub> REP <sub>CM</sub>	25.0%	[%]	Debiterm		14	[yr]
CAB cost	2000.00	[5/m]	n <sub>mlh</sub>	72	[n]	ifr N	2.50%	[%/yr]	$\zeta_3 OREP_{CM}$	25.0%	[%]	Debt gr	ice perioa	1	[yr]
CP CM	30.9089	[5/KW]	n th	20.204.205	[II]	n urr	200,000	[yr]	54 GHO.K CM	25.0%	[%]	Debi in	erest rate	3.00%	[%/yr]
EF c	400.00	[5/KW]	AAR	29 394 280	[\$M]	WI weight	200 000	[Kg]	REPIM	1 154.5919	[\$/proj]	Debi value		29 722 762	[5]
9	0.08%	[%]	AEP anail	212 467 323	[KWn/yr]	C steel	0.1900	[5/kg]				Debi pa	ymenis	3 002 711	[5/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139806	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[S/kW]	Exchange rates		Notes	Equity rati		50.0%	[%]
IL <sub>c</sub>	0.0400	[\$/m]		F		WF cap	50 000	[KW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29/22/62	[5]
TL,	1 200	[1/kW]	O&M manag(STD)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_{i}$	3 000	[m]	SC OBM	0.000024	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]			r	
SB <sub>c</sub>	113.00	[\$/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE wise	Notes
SI <sub>CM</sub>	42.7345	$[/m^2/kW]$	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	84.4521	yr i	94.5243	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			85.1268	$yr_2$	94.2007	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000066	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	85.8151	yr 3	95.0057	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NwT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	86.2772	$yr_4$	95.9021	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			86.9708	$yr_5$	96.8008	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution			87.6954	$yr_6$	97.5797	yr 19
FS	19.88	[\$/kW]	Hours required	112.5	[h]	April	720	711	REI CM	1	[1/0]	88.2682	yr 7	94.0692	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	184.5	[h/yr]	May	744	735	REP CM	1	[1/0]	88.9652	$yr_8$	94.7693	yr 21
EG	404.52	[\$/kW]		0.000090	[\$/kWh/yr]	June <sup>(*)</sup>	720	687	OREP CM	1	[1/0]	89.8763	yr 9	95.8157	yr 22
F <sub>CM</sub>	3.7807	[\$/kW]				July	744	735	GHG.R CM	1	[1/0]	90.4645	yr 10	96.5815	yr 23
WACC proj	4.900%	[%/yr]				August	744	735	$P\&D_{IM}$			91.2843	yr 11	97.5952	yr 25
n <sub>fin</sub>	1.0	[yr]				September	720	711	$\lambda_{a}$	1	[1/0]	91.9934	yr 12	91.8606	Mean
W <sub>F<sub>CH</sub></sub>	0.30%	[%]				October	744	735	λ <sub>sai</sub>	1	[1/0]	92.7210	yr 13	4.1890	SD
CCC CM	2.4103	[\$/kW]				November <sup>(*)</sup>	720	687	λd	1	[1/0]	93.7613	yr 14	-0.3343	Y (skewness)
ĸ	0.20%	[%]				December	744	735	λ.,,	1	[1/0]	LCOE	91.8606	US\$/MWh	valid !
LCCCM WF	1 207.5681	[\$/kW]	L			Total [h/yr]	8 760	8 579		p.s.: 1 = yes at	nd 0=no		0.091861	US\$/kWh	

**Figure J.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $L_{wt}$  (5D7D). Source: Own elaboration

Table J.1 Ener	rgy produc	tion $(AEP_a$	vail) map of the	wind farn	n for Araca	ti (Brazil)		with	sensitivity	analysis c	of $L_{wt}$ (5D	(D)															
Months	$V_{HC}$		$H_{prod}$												$AEP_{ava}$	$_{il}(k Wh)$											
	(m/s) (	$(kg/m^3)$	(h) yr <sub>1</sub>	y,	r2 3	81.3 yı	· 4 )	vrs y	r6 3	117 3	118 y	r9 yı	10 yr	11 yr	12 yr	13 yr.	14 31	15 yr1	6 yr	7 yr1	8 yr1	19 Yr 21	0 yr 21	1 yr2.	2 yr 23	yr 24	yr 25
January	5.8	1.1665	738 16931.	32 8890	9198 380	12 165 750;	7410 55.	7361 889.	0 198 55.	7 361 55.	7 361 4 23	2 212 8 890	0198 8 890	1198 557	361 380.	3 165 7 507	7410 423	212 8890	198 8 890	198 557.	361 3802	165 7507.	410 5573	61 3 802	165 75074	10 4 232 21	2 4 232 21
February	4.9	1.1666	639 847.94	40 6785	3 520 3 60	12 567 6785	\$ 520 77.	7316 678.	3 520 77.	7316 77.	7316 471	3419 678.	3 520 6 783	1 520 777	316 366	2 567 6783	520 482	342 482.	342 3 290	403 4713	419 7693.	599 1 572 -	412 1 572 4	412 7 693 :	599 67835	20 471341	9 471341
March	4.0	1.1671	735 555 06	90 7.476	5817 543	4 310 8853	. 020 02.	5 829 7 47	5817 07	5 820 07	5820 654	3 367 7 471	5817 7476	5817 975	829 5424	1310 8.853	020 804	553 804	553 1 800	568 4214	066 1 800	2989 1 686	232 16863	232 7 8061	630 8853 6	70 3 786 67	1 654336
Anril	4.7	1 1667	711 865.00	08 6325	7 908 635	7 908 4 076	176 163	10 708 6 32	7 908 1 65	0 708 1 65	0.708 7.23	1621 632	7 908 6 327	008 1740	1 083 6 375	7 008 4 076	176 043	1270 209	02 1 630	708 6 327	008 1630	708 3 661 4	984 0436	02 7 230	621 63279	N 1 740 08	3 7230.62
W		1 1670	735 1 000 54		100 210	FUF 3 063 3.	001 001.	01200200	A 100 1 8	201 0020	002 0020		FUF 2 0013	1001 1001		002 9 002 ;	1091 101	2021 0213	160 075	20.0 0 022	0.15	100 222 002	2 100 090	013 9 00	SPICE FU	91 909 1 00	10 200 2 0
lum	0.0	1 1696	10 FFO E 289	24 C 10	1001 73/	1019 FFF9	13 C UCL.	7LC 00CC	1001 250	10 T 00C 4	10 / 000 G	440 040 040 0 7 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1007 5071	100 T COT	101 2 2010	240 2 PW 3	001 171	2091 2010	C/C 032	127 7206	012 PPF	CCC 227	127 25441	9203 130	5 920 S F92	64 013 30	199010 2
India 1	20	1 1600	0 LEF 3 36L	302 0 02	10 1 100 L		CC 0711	02 6 100 20	UL 10/1		120 LOOL	225 20C.	302 6 306	LCC LCC.	001 0001	1 010 1 1 010	102 C 300	302 6 003 3	100 000	106 7 102	100 LUF	100 020	57667 SC		10021 400	29 900 00	000000 0
Anne .	0.0	0601.1	0/04/0 /0/	-61 0 71	00 0000	X01 100 +-		5/ C 700 #7	7 + 0000	7 6 700 6	)// 700 #3	JUL 0601	26/ C D6C	-C+C NOC 0	/00 7/0/	CI0 I 100 +	· · · · · · · · · · · · · · · · · · ·	C6/ C D0C 0	000 000	+6+/ D60	. ncc /n+	10/6 060	0 477 4 (7)	+77 + 700	10601 700	CU UYO YY	<u> </u>
August	0.6	//01-1	/35 / 480 0	94 181	0 200 18.	181 0050	.88 00CL	181 100.80	0000 54	2/125 54.	2/123 89.	568 /100	01/ 1810	1200 421.	181 101	180 1 000 0	100 542.	123 / 810	0/8 / 8/0	- 668 8/0	01/ 421/	-018 / ICI	1/74 5 8/0	123 1 810	C 018 1 00C	15 555 01	10 668 8
September	. 10.1	1.1657	711 85543.	84 1 625	9176 16.	20176 3652	8 543 7 54	42 482 1 62	9176 63.	01 963 63.	01 963 94 <sup>7</sup>	810 942	810 1629	0176 6321	1 963 1 62.	9176 3658	8 543 632.	963 7223	828 7223	828 942.	810 5240	771 8 554.	384 63219	963 1 629	176 3 658 5	43 632196	3 942 81
October	9.7	1.1645	735 77892	01 973	650 97.	3 650 553	851 74t	\$0.125 975	3 650 74	10 125 7 4t	0 125 1 68	2 467 1 68.	2467 973	650 8834	4 203 973	650 553.	851 746	0 125 6 528	759 6528	759 1805	528 6528	759 4205.	556 74601	125 9736	50 9736	60 883420	3 168246
November	9.2	1.1638	687 60989.	39 833	795 83.	3 795 833	795 6 09	18 939 835	22 22	6 401 72	6 401 1 68	5 661 1 68t	5661 833	795 7276	\$ 401 833	795 833	795 7270	5 401 5 055	889 5 055	889 1 571	703 6968	989 6 098	939 72764	401 8337	795 8337	5 727640	1 1 686 66
December	2.6	11651	735 3780 30	25 554	166 55	4 166 974	204 541	12277 554	166 8.85	0 226 885	9 2 26 3 78	0365 3780	1365 554	166 7464	1366 554	166 974	204 8.830	226 4207	046 4 207	046 3 780	365 7703	630 5415	277 88303	1 256 554 1	1 22 27 1	6 7 464 36	5 3 780 36
Ammend	11	1 1666	0 570 49 956 3	110 48 48	Y 57 562 F.	04 8F 940 94	0 40 46 6	05.020 49.40	1 279 49 49	5 5V 55V VV.	2 01 201 11	TK 25.4 18 20	11 172 18 44	1 279 49 94	29 81 998 1.	CYE 87 940 9	50.07 997 5	10 07 510 2	10 01 292	403 48 462	120 49 48 1154	200 01 292.	LYL 8V 202	002 48 170	386.87 820	10 48 420 7	0 40 25K 2
TIMININ	t:/	0001-1	. DLO 04 6/10 0	44.04 610	104 070 44	(7 04 070 014	104 004 0	101 700 64	04 070 44	104 004 444	C 04 004 444	10.04 400.00	44.04 C/T 14	10 04 07C 4	1 000 40 0	00.04 070.0	10 64 007 7	C17 64 CTO C	10 04 m7	704.04 CO4	100 04 000	000.04 00/4	14/04 000	611.04 0.66	010	7/07404 04	10 000 04 0
Table J.2 Enc	argy produc	ction map o.	f the wind farm f	for Corvo	Island (Po	rtugal)		with	sensitivity	/ analysis (	of L <sub>w1</sub> (5D	(fL															
Months	V <sub>nc</sub>		$H_{prod}$												$AEP_{ava}$	$_{ii}(k Wh)$											
CHINO M	(m/s) ()	$(kg/m^3)$	$(h)$ $yr_I$	ιń	r2 )	11.3 yı	( +,	rrs y	r6 )	w7 )	'r 8 )	r9 yı	10 yr.	II yr	12 yr	13 yr.	14 yr	15 yr.	6 yr	7 yr1	.8 yr1	.9 yr 20	0 yr 21	1 yr2.	2 yr 23	yr 24	yr 25
January	11.7	1.2313	738 14 451.	298 144:	51 298 14	451 298 14 45	51 298 14.	451 298 144	51 298 14.	151 298 10.	342 026 10 5	42 026 14 4.	51 298 10 84	12 026 10 8.	42 026 10 8	42 026 14 45	1 298 10 8	42 026 10 84	2 026 14 45	1 298 10 84.	3 026 10 84	2 026 10 842	2 026 10 842	026 10 842	026 10842	026 10 842 0	6 10 842 0
Fehruary	511	1 2345	630 11 923 5	902 4 23	11 802 8.	923 902 11 92	3 902 11 5	923 902 3 36	0 302 11	723 902 12.	538 268 1 77	0714 336	0 302 12 53	18 268 1 77	0 714 011	5 121 11 92	3 902 6 58	0.843 12.53	8 268 4 23	203 5400	098 8 009	302 2 776	203 11 923	. 902 2 077	203 6580	43 11 923 9	2 12 538 2
Manah	10.5	0 2 3 2 0	735 10.471	2 1 2 1 9	21 102 0.	08 087 13 60	12 087 13	408 087 K 31	121 0131	13 187 131	12 0 787 303	× 279 219	09 21 102 0.	02 6 280 80	6 279 13 6	09 21 280 80	10 7 2 20 80	0 2 1 1 2 Y	12.0 2 2.0.0	721 7560	296 1 000	12 12 12 608	8 087 14 403	FEU C 598	127 01 681	5 11 105 8	6 2 1 9 0 2
IMPROVE AND A DESCRIPTION	207	LICCI	0100 E 11E		07 100 L	0.01 /00.000	100.07	100 000 0 F	or 070 40	11 100 000	10 2 100 000	31.0 0/000	0.07 400.4	00 7 100 04		00.01 000000	17.0 10.0	10001 0704	100 000 000 0		100 1 0001	010 ct 1/0 c		400 7 000	112.01 701		2010 0
April	C. 6	/10701	3 202 / 11/	06/ / 20	01 /99.0	4 01 C/1 C44	01 0/1 04	12 000 10	01 / 20 CI	04 0/1 04 C	1) 5 0/ C / C	12/ 1/172	77 CT / 20 CT	5/ 012 2 00	761 1/172	2/012 4 070	20.5 0.60 4 05	57 57 06C 6	010 2 010	1101 1/1:	101 2 007	16 CI 1/1 2	107 01 1/04	2002 2002	. 2005 1/1	0/27 21 1/	3 3 /400
(DIM	0.2	7077.1	2 ##0 # CC/	907 IO4	01 000 70	+ n1 ccn 7c+	10 ccn 7c	-01 097 16	01 000 704	01 000 70+	'Ω € CCN 7C+	510 46100	1 790 IN 10	C9 C CCN 70	2 47 461 0	24 /02 10 45	CD C CCN 70	0.194 IV 10	127 0003	HOCI 014	1610 0400	1167 007	7C+ 01 01+	000 0 000	64C HI 461	070+01 90/	0 4 0 4 0 4 0
June	1.7	1.2224	687 29555	541 126	03 755 76	05 728 7 00.	5728 70	05 728 10 t	14 121 45	06 515 12	693 755 4 50	96515 106	14 121 7 00.	5728 450	6515 700	15 728 221	1411 295	5 541 7 005	728 188	038 12 69.	3 755 7 005	5 728 1 885	038 7 005	728 4506	515 12 693	755 7 005 7.	8 57589
July	6.1	1.2154	735 2 005 2	275 135	03 424 47	93 962 612	6 305 10.	322 572 13 :	503 424 7 4	52 587 31	44 060 61.	26 305 2 0U	15 275 6120	6305 612	6305 612	6305 200	5 275 2 35	2 466 6 126	305 6120	305 1419	9172 1032.	2 572 3 815	724 6126.	305 6126	305 13 503	124 38157.	4 74525
August	6.4	1.2075	735 23371	182 105.	83 661 37	90 935 3 79.	0 935 37.	90 935 13.	(15 696 6 6	86504 37	90 935 74(	04 169 235	7182 476.	2817 740	4169 476	52 817 10 58	83 661 196	2 247 4 762	817 13 41	5 696 I 992	247 1341.	5 696 4 762	817 4762	817 7404	169 4762	17 3 123 6.	4 10 255 5
September	. 7.6	1.2064	711 3 663 8	832 192	5 451 58	82 434 4 60.	3129 46	03 129 4 6	33 129 15	25 451 58	82 434 99.	166 099 I i	1660 366.	3 832 9 91	1 660 3 66	3 832 5 88.	2 434 9 91	1 660 3 663	832 12 96	5 892 2 258	821 12.96.	5 892 5 882	434 3 663	832 9911	660 3663	32 2 258 8.	1 19254.
Uctober	8.9	07171	+2110 CE/	412 011	2412 31	30 930 2 00	0 /2/ 31	<i>50 930 2 0</i>	0/2/ 25	4/131 /4	-51 080 05	1/2 801 13 4	72 801 3 15	0 930 134	CI S 108 ZL	0 930 7 43.	2 080 154	72 801 - 5 150	9.30 10.02	8711 3130	930 2 000	1/2/ / 455	020 3130	930 13 472	801 2347	31 2 000 7	7 234/1.
November	10.0	1.2194	1066 6 289	034 357	78 305 22	06 092 2 20	6 092 2 2	06 092 2 20	36 092 25	48 433 2 2	06 092 12 1	563 223 4 45	15 676 2 20v	6 092 12 6	63 223 2 20	16 092 2 94k	8 433 12 6	63 223 2 206	092 968(	288 3578	305 2 206	092 9680	288 2 206	092 12 663	1 223 1 880.	04 57451	8 12 663 2
December	C11	/ 62201	06001 00/00	06.2 00/	17 740 20	10 1/4 2 10	0.2 /40.0	15 9/9 21	76 /40 00	17 100 14	10.9/9 14.	2 01 017 063	VI0.7 00/06	2 41 6/69	10.7 017.06	09/9 304	7 41 109 1	210.7 017.06	INC / 6/6	779 4 970	1.42 14 14 29.	16C CI 017 0	910.7 00/0	067 #1 6/6	2010 017	/ 079 4 2/	/ CAC CI +
Annual	1.6	1.2222	8 5 7 9 89 657.	257 903	177 375 89	783 574 89 8	46 976 89	792 106 - 90 c	881 985 90	056 935 89	381 970 90.	318 367 90 5	39 663 89 64	68 733 90 3	18 367 901	63 301 90 11	13 636 89 8	37 428 89 66	8 733 90 22	0 267 90 26	3 721 90 56	0 856 90 67,	187 89760	146 90 272	2 750 90 345	823 89 615 9	0 89 153 6
Table J.3 Energ	gy producti	ion map of t	he wind farm for	r Cape Sa	int James (	Canada)		with	sensitivity	analysis o	f L <sub>w1</sub> (5D'	(D)															
Months	$V_{\rm HC}$	Ι.	H <sub>prod</sub>												AEP avai	I(kWh)											
	(m/s) (k	$(g/m^3)$	$(h)  yr_I$	yr.	2 y.	r3 yr.	4 yı	rs yı	6 y	r7 y	r.8 yı	9 yr.	10 yr,	11 yr.	12 yr	13 yr1	14 yr.	15 yr 1.	5 yr,	7 yr1.	8 yr <sub>I</sub> .	9 yr 2t	0 yr 21	r yr 2.	2 yr 23	yr 24	yr 25
January	15.4	1.2561	738 327347.	98 32 73.	4 798 32 7	34 798 32 73.	4 798 32 7.	34 798 32 7.	34 798 32 ;	34 798 32 ;	34 798 32 7.	34 798 32 75	14 798 32 73.	4 798 8 01.	3 494 32 7.	84 798 32 73.	4 798 32 7.	4 798 32 734	798 32 73.	1 798 32 734	1 798 32 734	4 798 40 754	1 809 32 734	798 32 734	798 28 019	94 80134	4 71009.
February	14.7	1.2522	639 24 248 0.	00 I4 46.	7 424 6 91.	2 583 26 22	8 520 14 4	67 424 14 4t	57 424 26 2	28 520 26 2	28 520 6 91.	2 583 14 46	57 424 14 46.	7 424 7 745	9 925 26 21	8 520 6 912	2 583 173:	7 262 6 912	583 6912	583 6912	583 6912	583 22 462	574 26 228	520 26 228	520 28 959	584 77499	5 17 351 2
March	12.7	1.2495	735 18 226 5.	32 18 22	6 532 8 89.	6 263 27 83.	4 779 12 3.	76 594 18 22	16 532 27 8	34 779 27 8	34 779 8 89.	6 263 12 37	6 594 18 22	6 532 9 97 <sub>1</sub>	1 944 278:	14 779 8 896	5 263 30 h	8 137 8 896	263 8896	263 8 896	263 8896	263 22 991	460 27 834	779 27 834	179 31 414	6 1 2 6 6 7 1 9	4 18 9213
April	12.4	1.2490	711 16 057 7.	11 19 28.	12 404 9 64	1 890 24 82	\$ 913 964	37 61 068 1.	7 404 248	28 913 24 8	28 913 9 64	1 890 9 64,	1 890 19 28.	7 404 9 641	t 890 24 82	18913 9641	1 890 26 91	3 496 9 641	890 2911	149 6 609	890 9.641	890 22 185	126 61 689	909 24 828	913 24 919	31 9 641 8	0 18 139 0
May	11.2	1.2425	735 123066.	14 25 53.	3 644 9 91	5 560 19 83.	4 848 9 91.	5 560 25 53	3 644 19 8	34 848 19 8	34 848 9 91.	5 560 9 91:	5 560 25 53.	3 644 12 30	6 614 1985	14 848 9 915	5560 255:	8 644 9 915	560 27 67	395 9915	560 9915	560 20.989	216 19834	848 19834	848 19 089	277 12 306 6	4 161683
June	10.4	1.2351	687 92124	74 2571-	4 865 11 4.	33 985 16 831	\$ 388 821	8 718 25 71	4 865 16 8	38 388 16 8	38 388 11 4.	13 985 8212	8 718 25 71-	4 865 15 34	12 558 16 85	18 388 11 43.	3 985 168:	8 388 11 433	985 23 72	1 122 11 435	1 985 11 433	3 985 16 955	390 16 838	388 16 838	388 16760	585 15 342 5	8 14 949 5
July	10.0	1.2275	735 873953	31 29 57.	7 699 163	14 803 16 31-	4 803 7 79.	5 266 29 5	7 699 16 3	14 803 16 3	14 803 163.	14 803 7 795	5 266 29 57.	7 699 17 96	15 422 16 31	4 803 16 31-	4 803 7 79.	5 266 16 314	803 1959	205 16314	(803 16314	1 803 15 530	0715 16 046	466 16314	803 16760	185 17 905 4	2 8 625 10
August	9.7	1.2216	735 775771	12 12 09:	9 972 17 8	19 161 12 093	9 972 17 8.	19 161 12 05	9 972 12 6	99 972 12 6	99 972 17 8.	18 21 191 61	9 161 12 09	9 972 19 50	1 798 12 05	0 972 17 81	9 161 8 69.	7 428 17 819	161 17.81	161 17819	161 17819	7 161 12 903	119 15 377	861 12 099	972 12 588	985 19 501 7	8 71119
September	10.4	1.2234	711 9 444 25	38 7515	148 188	92 028 9 444	238 263	61 791 751:	5 148 9 44	4 238 9 44	4 238 18 8	12 028 26 36	1 791 7 515	148 2431	.9 940 9 44.	1 238 18 89.	2 028 9 44	4 238 18 892	028 15 72.	: 541 18 892	028 18 892	2 028 12 321	085 13 275	521 9 444	238 88420	59 243199	0 19 029 7
October	13.1	1.2327	735 196790.	10 8776	\$ 461 297.	02 682 9 837	656 253.	33 032 8 771	5461 983	7 656 9 85	7 656 29 7	12 682 25 33	3 032 8 776	6 461 27 45	10 940 9 83.	7 656 25 33.	3 032 9 83,	7 656 25 333	032 12 20	924 29 702	682 25 333	3 032 12 242	2 414 8 858 0	686 9837	656 81220	39 27 459 9	0 21 596 0
November	14.3	1.2429	687 23 874 2.	56 9271	165 258	78 688 8 271	078 27.9	92 285 9 27.	1 165 827	1 078 8 25	7 078 25 8.	78 688 27 99	12 285 9 271	165 27 99	2 285 8 27.	t 078 25 87.	15 11 889 8.	6 828 25 875	688 9 271	165 25 872	1 688 25 878	\$ 688 7 423	013 8 271 0	078 8 271	078 8 870	02 27 992 2	12 21 951 0
December	15.1	1.2528	735 301863.	50 9 997	7 848 25 7	45 545 7 955	6 61 26 9 9	99 456 9 99.	7 848 7 95	5 677 795	5 677 25 7	15 545 19 99	9 456 9 997	7 848 32 45	38 621 7 95.	5 677 30 18.	6 350 16 6.	0 529 30 186	350 9 997	848 2574:	545 30186	\$ 350 6 350	393 79550	677 7955	677 91630	44 32 498 6	21 42 475 1
Annual	12.5	1.2404	8 579 212 467 3.	25 213 20.	12 961 213 8.	87 985 212 22.	3 670 212 6.	55 974 213 20	12 961 212 2	23 670 212 2	23 670 213 8.	\$7 985 212 65	5 974 213 20.	2 961 212 76	ut 429 212 21	3 670 213 95	9 139 213 4.	0 670 213 959	139 213 67	1 613 213 88	7 985 213 959	2 139 213 105	827 213 228	530 212 223	670 213 512	714 212 704 4	9 213 419 4

Table J.4 Wind	l speed ser	ries simulatio	ons for AE	P <sub>avail</sub> in Ara	acati (Brazil			with	h sensitivit	v analysis	of L <sub>wt</sub> (5D	(D)														
Months	V we							- 414				Wind spe	ed data ser	ies for simul	ations (m/s											
	(5.0)	5 0	701	76	y14	y15 4.0	701	10	718	919	71 10	10.1	10	76	91.14	7.0	y1 16 1.0.1	71 17	yr 18 4.0	91 19 7 6	y1 20	yr 21 4.0	yr 22 7 6	yr 23 0.6	7.0	7.0
February	8.C	0.0 4 0	10.1 0.7	0./	0.7	4.0	10.1	4.0	4.0	6./ 8.6	1.01	1.01	4.0	0./	0.7	4.0	10.1	10.1	4.U 8.6	0.7	9.0	4.0	0.7	0.7	6./ 8.6	8. V
March	40	40	0.6	86	1.01	40	9.6	40	40	0.0	90	90	40	86	1.01	4.7	4.7	6.0	7.0	60	8.5	5.8	0.7	101	2.6	0.0
Anril	4.7	4.7	9.2	9.2	2.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	7.9	5.8	9.7
Inne	7.0	7.9	2.0	0.7	6.0	2.6	7.9	7.6	7.6	101	7.0	2.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.0	101
Intv	86	86	2.6	1 01	5 8	7.0	7.6	7.0	7.0	4.0	4.0	7.6	86	101	60	7.6	2.6	4.0	96	4.0	4.0	7.0	7.0	8 5	4 7	4.0
(	200	2.0			0.7	1 0 1	0.7	2 0	20			0.7	0 0		0.0	2 0				0.1		20		2.0		
August	0.7	0.7	0.0	0.0	0.0	1.01	0.0	0.0	0.0	4./		0.0	V./	0.0	0.0	0.0	7.1	7.7	4./	<i>v.</i> /		0.0	0.0	0.0	4.0	÷ -
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9	10.1	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	9.7	6.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	10.1	10.1	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9	7.9	7.6	9.7	8.6	10.1	4.0	4.0	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Toble I & Wind o			a fra A E D		a Island (De			ti.			203/ 13	Ê														
	V <sub>WC</sub>		IS INLAGE,	mail III COLV.		onugar		IIIIM	SCIISIUVILY	allalysis c		Wind spee	id data serie	es for simula	tions (m/s)											Ì
Months	(s/m	vr ,	vr.,	vr.,	vr.,	VF c	Vr «	VF-7	vr.	vr.o	VF 10	vr.,	Vr 17	vr	vrid	VF 15	VF 16	vr.,-	VF 10	VF 10	VF 2.0	VF 21	vr.,	VF 13	VF 24	Vrac
Ianuary	211	117 1	2.7	717	117	2.7	7.1	117	10.6	10.6	7117	10.6	10.6	10.6	117	10.6	90.10	11.7	9010	106	10.6	10.6	10.6	10.6	106	901
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	11.7	8.2	8.9	7.6	1.7	11.5	6.4	9.5	11.5	11.7
March	10.5	10.5	1.7	11.5	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	11.5	11.7	6.1	10.5	11.7	1.7
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	1.7	9.5	11.5	7.1	11.5	8.2	8.2	11.5	1.7	10.5	7.1	11.7	11.5	7.1	7.1	11.5	7.6
May	8.2	8.2 1	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4	11.5	8.9	6.4	10.5	7.6	11.7	10.5	8.2
June	7.1	1 1.7	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1	11.5	9.5	6.1	9.5	8.2	11.5	9.5	8.9
July	6.1	6.1 1	11.5	8.2	8.9	10.5	11.5	9.5	7.1	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9	11.7	10.5	7.6	8.9	8.9	11.5	7.6	9.5
August	6.4	6.4 I	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2	11.5	6.1	11.5	8.2	8.2	9.5	8.2	7.1	10.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	11.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	7.1	11.5	1.7	9.5	11.5	7.1	10.6	7.1	6.1	9.5	1.7	11.5	6.4	6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	7.1	6.4	11.5	8.2	6.4	11.5	6.4	1.7	11.5	6.4	10.5	7.6	6.4	10.5	6.4	11.5	6.1	8.9	11.5
December	11.5	11.5	6.4	6.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2	11.7	11.5	6.1	11.7	8.9	8.2	11.5
Annual	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Table J.6 Win	d speed se	eries simulati	ions for AE	P <sub>aveil</sub> in Ca	the Saint Ja	mes (Canad	B	wi	th sensitivit	y analysis	of L (5I															
:	V NC											Wind sp.	eed data ser	ies for simu	lations (m/s	(2										l
SHIHOM	(m/s)	yr 1	$yr_2$	yr3	yr4	yr 5	yr 6	yr 7	yr 8	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr22	yr23	yr24	yr 25
January	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	15.4	15.4	15.4	15.4	15.4	16.6	15.4	15.4	14.7	9.7	9.3
February	14.7	14.7	12.4	9.7	15.1	12.4	12.4	15.1	15.1	9.7	12.4	12.4	10.0	15.1	9.7	13.1	9.7	9.7	9.7	9.7	14.3	15.1	15.1	15.6	10.0	13.1
March	12.7	12.7	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1	10.0	10.0	10.0	10.0	13.8	14.7	14.7	15.3	10.4	12.9
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	15.1	10.4	10.4	13.8	13.3	14.3	14.3	10.4	12.9
May	11.2	11.2	14.3	10.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3	10.4	14.7	10.4	10.4	13.4	13.1	13.1	13.0	11.2	12.3
June	10.4	10.4	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7	11.2	14.3	11.2	11.2	12.8	12.7	12.7	12.7	12.4	12.2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	12.4	13.1	12.4	12.4	12.2	12.3	12.4	12.5	12.7	10.0
August	9.7	9.7	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.0	12.7	12.7	12.7	12.7	11.4	12.1	11.2	11.4	13.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1	12.4	13.1	13.1	11.4	11.7	10.4	10.2	14.3	13.2
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2	15.1	14.3	11.2	10.1	10.4	9.8	14.7	13.5
November	14.3	14.3	10.4	14.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	10.4	15.1	10.0	14.7	11.2	14.7	10.4	14.7	14.7	9.7	10.0	10.0	10.3	15.1	13.9
December	1.01	1.61	10.4	14.5	7.6	13.1	10.4	7.6	7.6	14.5	13.1	10.4	15.4	7.6	1.61	12.4	1.61	10.4	14.5	1.61	9.0	7.6	9./	10.1	15.4	10.9
Annuai	C.71	C.21	C.71	C.21	C.71	C.21	C.71	C.71	C.21	C71	C.71	C.71	C.21	0.71	C.21	C.21	C.21	C.21	C.21	12.5	C.21	C.21	C.21	C.21	12.5	C.21

Bit         International         State	Table J.7 kWh per H <sub>prod</sub>							MILLI OVER	in the same	MIT TO CTC/															
	Citae												kW/yr												
International         361         561         561         560         561         561         561         561         561         563         <	y 8911C	<i>r</i> <sub>1</sub> <i>y</i> <sub>2</sub>	yr 3	$yr_4$	yr5	$yr_{\delta}$	yr 7	yr 8	yr9	yr 10	yr 11	yr12	yr13	yr14	yr 15	yr 16	yr 17	yr 18	yr19	yr 20	yr 21	yr 22	yr 23	$yr_{2}$	yr:
Optimizing (manual)         (101)         (102) <td>Aracari (Brazil) 5 6</td> <td>95 5647</td> <td>5674</td> <td>5 629</td> <td>5 699</td> <td>5 647</td> <td>5 694</td> <td>5694</td> <td>5 637</td> <td>5 641</td> <td>5 647</td> <td>5 693</td> <td>5 674</td> <td>5637</td> <td>5 718</td> <td>5 737</td> <td>5 690</td> <td>5 649</td> <td>5 602</td> <td>5 698</td> <td>5 682</td> <td>5 616</td> <td>5 628</td> <td>5 645</td> <td>563</td>	Aracari (Brazil) 5 6	95 5647	5674	5 629	5 699	5 647	5 694	5694	5 637	5 641	5 647	5 693	5 674	5637	5 718	5 737	5 690	5 649	5 602	5 698	5 682	5 616	5 628	5 645	563
Optimulation         3100         31011         3101         3101	Corvo Island 10.4. (Portugal)	51 10 535	10466	10473	10 467	10 570	10 498	10 419	10 528	10 530	10 452	10 528	10 510	10504	10 472	10 452	10 517	10 522	10 556	10569	10 463	10 523	10 531	10 446	1039
Intell         Statisticat Statist	Cape Saint James 24 7. (Canada) 24 7.	66 24 852	24932	24 738	24 788	24 852	24 738	24 738	24 932	24 788	24 852	24 794	24 738	24940	24 879	24 940	24 908	24 932	24 940	24841	24 855	24 738	24 888	24 794	2487
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The function of the fun																									
$ I m \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	Table J.8 Cashflow for 25 years of 1	the wind farm I	rroject	50 000 kW	/ Ara	cati (Brazil)				with ser	sitivity analy	sis of L	(SD7D)												
$ \frac{1}{10^{10}} \frac{1}{10^{10}}$	Item	0	-	6	"	4	v		7 8	6	10	=	Yea 12	13	14	15	16	17	18	K 6.	16 0	<i>cc</i>	23	24	25
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	(-) I CCCM	208 407		1	2		,						1	2		3								5	ì
$ \begin{array}{ccccccc} & 31398 & \cdot & $	WT CM	27 686 278																							
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$T_{CM}$	24 219 295	,	,	,	,	,	,	,			,	'	,	,	,	,	,	,	,	,			,	
$ \begin{array}{ccccccc} C_{CC} & 155 \mmode contact cont$	$LWTG_{CM}$	2 111 508																						'	'
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CP <sub>CM</sub>	1 545 346	,			,	,	,				,	•				,		,	,	,			'	'
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$C_{01}$ [B017] $C_{01}$ [B017] $C_{01}$ <t< td=""><td>POCM</td><td>1 796 870</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	POCM	1 796 870																							
$ \begin{array}{rcccccc} CCCCccccccccccccccccccccccccccc$	$F_{CM}$	189 037					,	,				'			,				,	,	,			,	'
I = 1 + M M M M M M M M M M M M M M M M M M	CCC <sub>CM</sub>	120 516	- 010 040 04	- 000 111 01					- 40.044				- 40.041.077	- 40 - 40 - 40	-			- 07 LOT		- 40.00		- 40.170			
$ FAR = 1 \ FAR$	LLFM WF (KWRYT) (+) AAR (SM/sri)		- 610 000 84 071 700 b	48 444 328 48 4 367 456 4	5 0/0 U20 45 1 408 053 4	7.4 010 012 7.4 010 012	5 95 7 CL CK0 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	2 0 7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	42 45 45 45 44 30 102 5 106	1 C81 5 L77	05 531548	17C 464 94 C.	1 5 636 501	48 0/0 U20 5 757 880	48 302 288 5 863 796	- CIU COU 64	34 002 012 64	- 24 001 40 - 274 001 6	10.64 800 004 10 10 10 10 10 10 10 10 10 10 10 10 10	30 04 00/ 40 30 161 687	3 465 4 918	201 24 CKC	0113 181	7 196 5 88	6 48 320 5 4 5 385 0
$ \frac{B}{M} = \frac{M}{M_{100}} = \frac{1}{2} \frac$	PPAR		4 297 170	4 367 456 4	1498 053 4.	573 979 47	747 030 48	20 855 49	32 192 5 106	747 5 182 1	05 531548	3 5 454 354	1 5 636 591	5 757 889	5 863 796	6 096 233	6 269 053 6	374 091 64	186 088 6 59	92 161 687	3 465		-		
$ (JAK_{Mr/vin} = 264573 - 679167 - 77573 - 75726 - 75747 - 7571 - 7573 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 75756 - 7555 - 75556 - 756 - 756$	EMP	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	- 4918	060 4982	181 5 117 9	88 5 261 7	4 53850
$ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	(-) O&Mwfgu	•	3 949 353	4 013 810 4	4 133 691 4	203 326 4 2 975 574 7.0	362 211 44 327 474 70	455 205 4 6 70 070 2 0	03 527 4 71. 77 742 - 2 15 4	7835 4786t	82 4909 ll	0 5 036 597	2 5 204 091	5 315 304 2 555 010	5 412 299 2 607 241	5 626 056 2 765 007	5 784 761 5	880 906 51	983 464 6 0 407	80 550 6 35	9 242 5 846	(637 5 922 155 4 206	095 6 082 7 720 4 51 5 6	52 6 252 8 ve 4 e42 4	4 63985 0 47577
$ (+) LRCM , \ 85.358 \ 84.180 \ 90671 \ 92966 \ 92287 \ 976.70 \ 100117 \ 102615 \ 10517 \ 112683 \ 10567 \ 112683 \ 10507 \ 11268 \ 10262 \ 1207 \ 13283 \ 340146 \ 37731 \ 37733 \ 37733 \ 37737 \ 37733 \ 37737 \$	O&M variable		1 294 774	1 315 813 1	1 355 018 1	377 752 14	429 737 1 4	177 127 15.	25 784 1 562	150 1 585 4	47 1 625 48	2 1 667 177	1 1722 102	1 758 385	1 789 958	1 860 129	1 912 077 1	943 336 15	76710 200	08 271 2 09	3 190 1 506	483 1 525	356 1 5661	66 1 609 3	5 16463
( + Derivative = - 246713 = 5327138 = 538873 = 5468417 = 517635 = 575724 = 285532 = 441415 = 437573 = 4461464 = 337573 = 3366346 = 3372747 = 386536 = 5375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 3306949 = 3375 = 33064947 = 301952 = 3137 = 3308 = 3375 = 3306 = 3375 = 3366 = 337 = 336 = 338 = 336 = 337 = 336 = 337 = 338 = 336 = 338 = 336 = 338 = 338 = 338 = 338 = 338 = 338 = 338 = 338 = 336 = 338 = 338 = 338 = 338 = 338 = 338 = 338 = 338 = 336 = 337 = 338	(+) LRCM	,	863 268	884 850	1/6 906	929 646 9	952 887 9	776 709 1 0	01 127 1 02t	155 1 051 8	09 1 078 10	4 1105 057	7 1 132 683	1 161 000	1 190 025	1 219 776	,	,	,	,	,			'	'
( F) Regret us = 1.260 (30) (39) (33) (33) (33) (33) (33) (33) (33	(+) Depreciation		2 459 715	2 521 208 2	2 584 238 2	648 844 25	715 065 27	782 942 28	52 515 2 92.	828 2 9965	24 3 071 84 	7 3 148 64:	3 3 227 359	3 308 043	3 390 744	3 475 513	3 562 400 2	651460 3	742 747 3 8	36316 395	2 224 4 030	529 4 131	292 4 234	75 4 340 4	9 4 448 9
(FRPM (M, M, M	(=) Profit before tax		3 670 800	3 759 704 3	3 855 572 3	949 143 4 ( 277 104 1 4	052771 41	125 300 42	32 308 4 33.	895 4444	55 4 556 32 22 1 504 64	5 467146.	2 4 792 542	4 911 628	5 032 266 1 760 120	5 165 465	4 046 692 4 1 990 71 6 1	012 2012 2012 2012 2012 2012 2012 2012	245 371 43	47 927 4 46	6447 3101 2040 1476	952 3 191	378 3 269 8 664 1 575 9	10 3 349 3 06 1 570 5	9 34354 2 16166
$ \begin{split} REI_{cl} & 22186 \\ REP_{cl} & 1735 & 1765 & 1730 & 1675 & 1634 & 1599 & 1573 & 1432 & 1447 \\ REP_{cl} & 164P_{cl} & 1639 & 1573 & 1535 & 1442 & 1447 \\ REP_{cl} & 164P_{cl} & 164P_{cl} & 1590 & 1573 & 1535 & 1432 & 1447 \\ REP_{cl} & 164P_{cl} & 164P_{cl} & 1590 & 1573 & 1535 & 1432 & 1447 \\ REP_{cl} & 164P_{cl} & 164P_{cl} & 1539 & 1537 & 1538 & 1432 & 1432 & 1538 & 1432 & 1548 & 31084 & 31843 & 3222 & 333 & 339 & 353 & 361 & 365 & 375 & 386 & 317 \\ ReP_{cl} & 164P_{cl} & 164P_{cl} & 1231 & 224 & 231 & 235 & 244 & 238 & 2866 & 273 & 286 & 301 & 313 & 322 & 335698 & 2166 & 288 & 2370 & 373 & 373 & 339 & 353 & 3608 & 2166 & 288 & 289 & 286 & 301 & 313 & 322 & 335698 & 2166 & 288 & 2370 & 372 & 374 & 375 & 386 & 375 & 386 & 375 & 386 & 376 & 371 & 372 & 373 & 338 & 3386 & 386 & 3896 & 388 & 3866 & 3896$	(+) REPIM	385 363	2045	1 989	1 015 64	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 898 1	847 1.	829 170	1748	1720	280	289	296	301	313	322	327	333	339 2.0	53 31 31 31 1 1 1 1 1 1 1 1 1 1 1 1 1 1	51 36	5 375	386	395
$ RFP_{circ} = 1825 1765 1763 1634 1599 1573 1535 1432 1447 = 123 153 1432 1447 = 123 133 132 133 133 133 133 133 133 133$	RELOW	221866											•	•	•										
$ \frac{GRCP_{CM}}{GRCR_{MM}} = \frac{16347}{2} = \frac{231}{2} = \frac{235}{2} = \frac{248}{2} = \frac{256}{2} = \frac{250}{2} = \frac{250}{2} = \frac{290}{2} = \frac{290}{2} = \frac{21}{3} = \frac{221}{3} = \frac{233}{3} = \frac{333}{3} = \frac{36}{3} = \frac{35}{3} = \frac{36}{3} = \frac{35}{3} = \frac{36}{3} = \frac{35}{3} = \frac{36}{3} = \frac$	$REP_{CM}$		1 825	1765	1730	1 675 1	1 654 1	. 299 1	573 15.	35 1482	1 447	'	•	,	•	,	,		,		,			'	'
GHCAL           - 221           234           -33           -33           -33           -33           -33           -36           -474                 -36           -36            -36	$OREP_{CM}$	163 497																							
(-) The hydromination interval - 2.83 64 - 261 567 - 260 560 - 280 279 - 286 668 - 281 272 - 265 295 - 261 262 - 559 - 561 264 - 561 264 769 - 177 395 - 177 395 - 355 568 - 261 572 - 567 366 - 561 264 263 - 561 566 - 561 264 263 - 561 566 - 561 264 263 - 562 566 - 561 264 263 - 562 566 - 561 264 - 561 566 - 561 566 - 560 - 561 566 - 560	GHG.R CH	'	221	224	231	235	244	248	256 2	52 26(	273	280	289	296	301	313	322	327	333	339	23	36	375	386	395
(*) Procentification (*) Proceeding 10, 10, 10, 10, 10, 10, 10, 10, 10, 10,	(=) Profit after tax w/out interes. (_) Debt novments		2 383 694	2 45145/2	2 208 117 2	5/8 809 2 ( 44 959 3 429	020.200 2.0 % 583 3.51s	02 060 800 2 0 2098 3 602	594/9 280/	168 2 8912	1 3879127	3 976 105	5 3 101 854 4 075 508	3 184 55/ 4 177 395	5 2/5 429 4 281 830	3 330 908 4 388 876	7 100 298	- 252 /45 - 2	- 239.8/8	5/0.61/ 2.40	4 /60 1 626	1001 008	- 1 /34		2 18203
(+) Depreciation 2459715 2521208 258428 268844 2715065 2782942 282515 2953828 296924 3071847 348643 327359 3308043 3307144 347513 3562400 361460 3742747 386316 392224 4030529 4131292 424575 4300439 448 (=) Free net configure - 5993045 16574 5465148 4766167 4583445 4766167 4583445 4769516 395246 40571 15558405 5460311 556406 1315409 5463011 556406 4315495 45661 317409 5463011 556408 10255590 102527 955348 107539901 1001 (=) Free net configure - 5993045 16570 2369165 420522 515670 256946 810185 2566164 3177405 05110073 063820 44505 10259590 10254284 10757990 11001 (=) Free net configure - 5993045 165704 3405574 240522 5156706 526046 81151 556406 1317409 5463011 556408 12450 (=) 17705 10073 06382 044507 01023 06382 04562 4001922 0110573 06382 04505 110073 06382 04505 1120153 9154950 110592 1120153 91546 201932 1120153 91546 20192 11201 (=) 17705 75729 75720 7570 7570 7570 7570 7570 7570 757	$(+) RCM_{WF}$		2 621 739	2 687 282 2	2 754 464 2	823 326 28	93 909 2 9	66 257 3 0	40413 3116	424 3 194 3	34 3 274 19	3 3 356 047	1 3 439 949	3 525 947	3 614 096	3 704 448	3 797 060 3	891986 35	389 286 4 08	89 018 4 19	1 243 4 296	024 4403	425 4 513 5	11 4 626 3	8 47420
(=) <i>Freeneration</i> (mov59.93045 7465145 4476167 483445 4706070 4815991 540052 5155710 5268016 540311 5564021 568364 581151 596648 61793 9525789 9525789 9525789 102556961 102556961 102556961 102556961 102556961 102556961 102556961 102556961 102556961 102556961 102559591 1025793 952578 10251961 102559591 102519590 102519501 102519590 102519501 102519591 1025	(+) Depreciation		2 459 715	2 521 208 2	2 584 238 2	648 844 27	715 065 27	782 942 28	52 515 2 92:	828 2 996 5	24 3 071 84	7 3 148 645	3 3 227 359	3 308 043	3 390 744	3 475 513	3 562 400 3	651460 3.5	742 747 3 8	36316 393	2 224 4 030	529 4 131	292 4 234 5	75 4 340 4	9 44489
	(=) Free net cashflow $\Sigma_{constrained}$	-59 993 045 -	7 465 148 -52 527 897 -4	4 476 167 4 18 051 730 43	4 583 445 4 4 38 38 38	706 070 4 8 762 216 -33 9	810 951 45 ¥1 265 -29 0	915 791 5 0 R5 474 -24 0	30 252 5 15t 15 222 - 5 15t	5710 5 298 (	016 543031 04 -812018	1 5 564 021 5 -2 556 164	1 5 693 654 1 3 137 490	5 841 151 8 978 642	5 996 438 14 975 080	6 127 993 21 103 073 3	9 525 758 5 0 628 832 40	405 02 504	031 910 10 2 136 934 60 7	95 950 10 52 37 884 71 26	8 227 9 953	448 10 231 559 91 446	806 10 482 8 366 101 929	74 10 737 9 40 112 667 2	9 11 011 2
	<ul> <li>Jrœnerannan campo</li> </ul>	ICOL	18 23	K7 0K	1 2 8 9	(0.22 6)	0 20	8 7.8 Kt	09 201	109 11	60.64	88.09	20.16	20.28	70.50	70.02	90.09	2 31.02	02 38.0.	02 331	02 10	2.02 03	20.02 0	96 12	C3 12

Table J.9 Cashflow for 25 years of the	e wind farm p.	roject	50 000 1	kW 6	Zorvo Islanc	d (Portugal)			wi	th sensitivity	analysis o	f L <sub>w</sub> (5D7)	D)												
ltem –	0	-	2	3	4	5	9	7	8	6	10	11	Years 12	13	[4	5 10	5 17	18	19	20	21	23	23	24	25
(-) LCCCM <sub>WF</sub>	60 378 407																						1	1	
WT CM	27 686 278	•	•	•		•					,												•	•	•
T CM LWTG cu	24 219 295 295 2111 508																								
$CP_{CM}$	1 545 346									,	,		,	,	,		,					,		,	
TS CM	572 832	,		,	•	,	,		,	,		,	,	,		,	,	,	,			'	'	,	,
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PO CM	1 /96 8/0																								
CCCor	120.516			,		,	,		,			,		,			,								,
LCPM WF (k Wh/yr)	1	89 657 257	90 377 375	89 783 574	89 846 976	89 792 106	90 681 985	90.056.935 8	9 026 182 6)	0318367 90	339 663 89	668 733 90 2	318.367 90	63 301 90 1	13 636 89 8	37 428 89 66	8 733 90 22(	267 90 26	3 721 90 560	856 90 671 1	1 89 760 14	6 90 272 75	0 90345823	89 615 940	89 153 675
(+) AAR (\$M\5\r)	'	14970925	15 468 449	15750988	16156163	16549954	17 131 821	17 439 078	7741084 18	375119 18	838 939 19	166 502 19	787 994 201	47.871 20.7	42 636 21 1	96 034 21 68	5 138 22 36	982 22 93	4 122 23 584	858 24 203 5	32 17 191 8	8 17722 25	8 18 180 019	18 483 975	18 848 346
PPAR	,	14 970 925	15 468 449	15750988	16156163	16549954	17 131 821	17 439 078	7741084 18	375119 18	838 939 19	166 502 19	787 994 20.	47.871 20.7	42 636 21 1	96034 2168	5 138 22 36	982 22 93	4 122 23 584	858 24 203 5					
EMP			- 670 666	-	- 102 001 01	-	- 069.017.01		- 1001-0	107.361 11						- 12 55	- 12 001	- 14 24			2 12 15 15 15 15 15 15 15 15 15 15 15 15 15	8 17722 25	8 18 180 019 1 12 010 507	14 142 004	18 848 346
NOV M MOO (-)		4/C 00C 6	5 023 262	000 301 3	120 201 01	040 000 01	20021101	20211201	1 00/0011	11 102 (44)	130.097 6	736.666 6.0	120 003 001	77 C23	40,572 6.9	2011 12 10 20	76 51 1053	34 5 000	123 1 100 0	240 79797	4 HCT CT CC 000	1000001 1	00001211	110 005 8	000 171-11
O& M	,	4 496 901	4 646 203	4 730 927	4852484	4 970 618	5 145 234	5 237 372	5 327 931 5	518200 5	657348 5	755575 55	342.063 6(	80.016 62	28443 63	54445 651	1165 6714	853 6.88	808 7 081	137 72668	866 516315	8 532233	5 5 4 5 9 672	5 550 813	5 660 095
(+) LRCM	,	863 268	884 850	906 971	929 646	952 887	976709	1 001 127	1 026 155 1	051809 1	078 104 1	105 057 1 1	132 683 1 1	61 000 1 1	90.025 1.2	9776									
(+) Depreciation		2 455 545	2516934	2579857	2 644 354	2710463	2778224	2847680	2918872 2	991844 3	066.640 3	143 306 3 2	221 888 3 3	02436 33	84 997 3 4	59 621 3 55	6362 3.645	271 3 734	5 403 3 829	813 3925 5	58 4023 6	7 412429	0 4227 397	4 333 082	4 441 409
(=) Profit before tax	,	8 921 364	9 190 667	9 381 592	9 620 542	9857414	10 166 914	10375930	0585328 10	10 11 11 11	196 253 11	422 624 11 1	761 609 12 (	42759 123	39 692 12 6	23 933 11 67	4 133 12 017	310 12 32	2 020 12 659	184 12 986 8	35 8 060 7.	9 8 286 07	4 8 496 823	8 674 033	8 868 075
(-) Revenue tax		4 491 277	4 640 535	4725 296	4846849	4 964 986	5 139 546	5 231 723	5 322 325 5	512536 5	651 682 5	749 951 5 5	936398 61	74361 62	22.791 6.3	58.810 6.50	5 5 4 1 6 705	0 195 6 880	0 237 7 075	458 72611	79 51575	9 531667	7 5454 006	5 545 193	5 654 504
(+) REPIM	487 054	1 438	1 420	1 382	1 355	1 327	1 314	1 280	1 245	1 235	1212	1 180	1167 1	144 1	123 1	100	64 1	70 1	74 17	9 183	186	192	197	200	204
$REI_{CM}$	221 866	,	,	,	,	,	,	,	,	,	,	,	,	,	,	,	,		,			1	1	1	,
$REP_{CM}$	'	1 325	1 303	1 263	1 233	1 202	1 184	1 147	1111	1 095	1 069	1 035 1	1 017	166	966	939	,		,				'	'	,
$OREP_{CM}$	265 188		,	,		,			,	,	,	,	,	,	,	,	,		,	,			'	'	'
$GHG.R_{CM}$		113	117	611	122	125	130	132	134	139	143	145	150	153	157	161	64	20	74 17	9 183	186	192	197	200	204
(=) Profit after tax w/out interest		4431 525	4 551 552	4 657 677	4 775 048	4 893 755	5 028 682	5 145 486	5 264 248	5410110 5	545783 5	673 853 5	826378 5	69 541 61	18 025 6 2	56 223 5 16	8756 5308	285 544	1 957 5583	906 57258	39 29034	7 296958	9 3 043 015	3 129 041	3 2 13 775
(-) Debt payments			3 178 383	3 257 843	3 339 289	3 422 771	3 508 341	3 596 049	3 685 950 3	778 099 3 3	72.552 3.1	969 365 4 0	68 600 4 1	0314 427	1 572 4 38	437									
$(+) RCM_{WF}$		2 621 739	2 687 282	2 754 464	2 823 326	2 893 909	2 966 257	3 040 413	3116424	3194334 3	274193 3	356.047 3	439.949 3.	25947 36	14096 37	04 448 3 79	7 060 3 89	986 398	9 286 4 089	018 41912	243 4296 0	4 4403 42	4513511	4 626 348	4 742 007
(+) Depreciation		2 455 545	2516934	2579857	2 644 354	2710463	2 778 224	2847680	2918872	2991844 3	066.640 3	143 306 3.	221888 3.	02436 33	84.997 3.4	59 621 3 55	6362 3 645	271 3 734	5 403 3 829	813 3925 5	558 4023 6	7 412429	4 227 397	4 333 082	4441409
(=) Free net cashflow	-59 891 353	9 508 809	6577 385	6734 156	6903439	7 075 355	7 264 823	7 437 530	7613594 :	7818188 8	014064 8	203.841 8.	419615 8.	27610 88	42.545 9.0	58 857 12 52	2 178 12 84	542 13 16	7 646 13 502	736 13 842 6	540 11 223 1	8 11 497 30	3 11 783 922	12 088 471	12 397 191
2. freenet annual cashflow		-50382544	-43 805 159	-37.071.003 -	30 167 564	-23 092 209	-15 827 386	-8 389 856	-776 262	041926 15	055990 23	259 831 31	679446 40.	07 056 49 1	49 600 58 2	08 457 70 73	0 635 83 576	177 96 74.	3 823 110 246	559 124 089	199 135 312 3	37 146 809 64	0 158 593 562	170 682 033	183 079 224
	LCOE	73.23	73.63	73.90	74.24	74.58	75.04	75.33	75.62	76.12	76.52	76.83	77.33	7.73 71	8.16 21	8.56 77.	74 78.	26 78.	72 79.2	2 79.71	77.83	78.34	78.80	79.15	79.54
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(-) LCCCM <sub>WF</sub>	60 378 407				•						,		,												
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LUTIN WF (K WILLY)		C7C /06 717	106 707 617	C06 /00 CT7	010 277 717	#16 000 717	106 707 617	010 27 717	7 010 077 717	17 006 100 01	17 1/6 000 000	12 106 207 0	117 674-401 3	0 17 010 077	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	10 10 10 10 10 10 10 10 10 10 10 10 10 1	19 517 51 561 56	20 CT7 CT0 0	106 CT 206 1	201 CI7 6CI	0 077 017 170	10 077 717 00	+1/ 710 CT7 0	675 MO 217	015 615 017
(+) AAK (3MAY)		50 129 145	167 686 09	51 800 088 21 0 cc 000	52 408 585 22 400 505	25 280 405	34.200.380	34 900 500 -	5 //3 012 30	76 664 666 6	00 000 000	701.280 39.	-06 5010/C	72 000 11 0	74 9/647	20 11 / 42 AF	2308 44 98	CI 0F 5/8	122 14 162 1	124 48.511 0	014 034 082 8	25 282 65 14	1 3048/2//	118 107 19	58.51/ 694
LT AN		CHI 671 0C	167 606 00	000 000 10	COC 00+70	c0+007 cc	000 007 40	. mcm6+c	0 71001100	10 060 +060	00 000 000	. 6C 00C TOV -	0010/0	0 1+ 000 0/1	75 016 57	± c+ /1100	06 10 000 7	CT 0+ C/0	170 14 160 1	0 110 04 471			-	- LEO LEO LEO	-
EMP																					34 082 8	25 282 CC 1	1 2048/2/1	118 107 19	58.51/ 694
(-) U&M WFCM		7.00 880 07	897.0/117	887.07.17	648 041 77	/80 04/ 77 00	25.574.048	- 007 948 57	24444204 2	CZ 51/1CZ 0	1357/1 26	-444.814 2/	042400 2/	C 97. 600 CO	7.67.771.8/	21 048 30 02	27.0 20.15	-201 21 200 -	145/ 52 535	425 33 010 0	1 162 67. CQ	10/86.67 0	1 50925 /4/	00/ 0/ 012	324/4 /00
Occur fixed		007 the II	100 0/0 11	109 407 71	/00 /1471	070 + 6/ 71	69+001 01	6647/001	AL 64/00/01	FI 000601+	+I 606.67t	CT 0C/ 979	- CI / 76 COI		C 01 00C C7		277 / 1 / <del>1</del> 00	00 /1 CCL	101 01 / 10 0	5 01 0 91 0 750	7 106 91 DC	01/02/01 0	CI6 1/6 61 +	80V 060 07	609 076 07
U&M wriable		000 1110 6	764 706 6	194 000 6	761 977 6	800 1666	QCC / 07 01	/0/ 0/ 0/ 0/	1 026/6/0	11 671760	11 20/6 20/2	11 900010	2/24/2 17	C 71 19/ /#	9 71 OCI CC	QI CI +Q+ CC	NCCT C/CO	00 CT / 17 0	1 140 14 202	1664-41 000	C 01+01 C7	+C 070 01 1	+02 IC6 01 0	666 701 11	/ 06 MC 11
(+) LRCM		863 268	884 850	906 971	929 646	952 887	976709	1 001 127	1 026 155	051809 1	078 104 1	105 057 1	132 683 1	61 000 1 1	90.025 1.2	19776	,								
(+) Depreciation		2437 266	2 498 198	2560 653	2 624 669	2 690 286	2 757 543	2826482	2 897 144 2	0.969573 3	043 812 3	119 907 3	197 905 3.	77852 33	59799 34	43 794 3 52	9889 3618	136 3.70	8 589 3 801	304 38963	336 39937/	5 4093 58	9 4195 928	4300826	4 408 347
(=) Profit before tax		12 841 026	13 196 057	13 558 424	13 817 050	14184051	14566590	14 879 903	5 252 047 1:	5724560 16	048 725 16	481 535 16 (	864 345 17.	57063 177	96080 18.2	08 038 17 44	7 036 17 86	657 18 32	5 729 18 789	005 191978	896 928186	0 948851	0 9759458	9 982 003	10 251 275
(-) Revenue tax	'	9 038 743	9 296 789	9559826	9722575	9 985 940	10 261 916	10470150	0.731.904 11	086468 11	298174 11	610416 113	872.849 12.	42164 125	47 493 12 8	29835 1318	2710 13 494	562 13 84	5 479 14 196	337 144934	184 104048	57 10 614 72	9 10 946 183	11 177 363	11 495 308
(+) REPIM	932 884	777	162	806	812	827	843	853	868	890	106	197	815	834	862	881 5	05 9	27 9	51 97	5 995	1 021	1 041	1 074	1 096	1 128
REICH	221 866		,	,	,	,	,	,	,	,	,	,	,	,	,	,	,	,	,				,	,	,
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ONET CM	910 117	' (	- 0v		- 022	- 107	- 2012	- <u>-</u>	- 101	1	- 144	- 002		- 10		- 100								- 100	
GHG.R CM	'	170	038	000	808	080	50	61/	151	/01	0//	161	CI 8	834	202	881	6	6	16 10	C(K)	1 021	101	1 0/4	1 090	1 128
(=) Profit after tax w/out interest		3 803 059	3 900 059	3 999 404	4 095 287	4198939	4 305 518	4410606	4521012 4	1 638 983 4	751452 4	871917 4	992311 5	15733 52	49448 53	79 084 4 26	5 231 4 371	021 448	1 201 4 593	643 47054	107 -1 121 96	1 -1 125 17	8 -1185 651	-1 194 263	-1 242 905
(-) Debt payments		'	3 154 724	3 233 592	3 314 432	3 397 292	3 482 225	3 569 280	3 658 512 3	749 975 31	43 724 3 5	939 818 4 0.	38 313 4 1.	9 271 4 24	2753 434	1 821						'	'	•	'
$(+) RCM_{WF}$		2 621 739	2 687 282	2 754 464	2 823 326	2 893 909	2966257	3 040 413	3116424 2	3194334 3	274193 3	356047 3.	439 949 3.	25947 36	14.096 3.7	04 448 3 79	7 060 3 891	986 398	9 286 4 089	018 41912	243 4296 00	4 4403 42	5 4513511	4 626 348	4742007
(+) Depreciation		2 437 266	2 498 198	2560 653	2 624 669	2 690 286	2 757 543	2826482	2 897 144 2	0.969573 3	043 812 3	119 907 3	197 905 3.	77852 33	59799 34	43 794 3 52	9889 3618	136 3.70	8 589 3 801	304 38963	336 39937/	5 4093 58	9 4195 928	4300826	4 408 347
(=) Free net cashflow	-59 445 523	8 862 065	5 930 816	6 0 8 0 9 2 9	6228851	6385842	6547093	6708221	6876067	052915 7	225732 7	408 054 7.	591852 7	80 262 79	80 590 81	78 505 11 59	2 179 11 88	143 12 17	9 076 12 483	964 12 792 9	87 716778	3 737183	5 7523787	7 732 911	7 907 449
$\Sigma$ free net annual cashflow	'	-50 583 459 -	-44 652 643	-38 571 713 -	32 342 863	-25 957 021	-19 409 928 -	12 701 707	-5 825 640	227 275 8	453 007 15	861 060 23	452.912 31	33174 392	13764 473	92.269 58.98	4 448 70 865	591 83 04	4 667 95 528	631 108 321 6	618 115 489 4	1 122 861 23	6 130 385 023	138 117 935	146 025 383
	LCOE was	84.45	85.13	85.82	86.28	86.97	87.70	88.27	88.97	89.88	90.46	91.28 5	2 06 IL	2.72 9.	3.76 9.	1.52 94.	20 95.	01 95.	90 96.8	97.58	94.07	94.77	95.82	96.58	97.60

## **APPENDIX K**

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend		[		_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \delta M_{\rm out})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
WE IN SILE OF	i	N	I	Card Madal	N .	Wind From BrownellC		N. 4	Bananakia Enamen Bakia In	889 675	N .	Wind Farm Life	Cuala Prod	untion Model	N .
Wind Project Information	Elector Wind Low	Notes	Levenzea Kepiacement	Lost Model	Notes (\$AM)	DCM	1 220 0154	Notes	Renewable Energy Public In	centive Model	Notes	WE	<ul> <li>Cycle Frod</li> </ul>	so ooo	Notes
Project Name Project Location	Aracati (Brazil)		Depr	76 9840	[\$/kW] [\$/kW]	DCM <sub>WF</sub> RM <sub>wT</sub>	22 3284	[5/kW] [5/kW]	ICCCM we	1 210 6183	[5/KW]	WF CM		50.000	[KW2/yr]
Turbine Model	Vestas V90-2MW		WT cu	553,7256	[\$/kW]	WF	50 000	[JKW]	LRCM	16.8443	[\$/kW]	Nwr		25	[-]
Number of Wind Turbines (N <sub>WT</sub> )	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	Mhama	100	[m-h]	$\Psi_{astal}$	30.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMITTER	85.00	[\$/m-h]	n ,,	6	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>Tac</sub>	60.1398	[\$/kW]	N <sub>manyor</sub>	3	[-]	REP CM	0.00002627	[\$/kW_h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>m super</sub>	2.0	[d]	AEP avail/H prod	5 695	[kW/yr]	L.,		3 960	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	[\$/kW]	$C_{ml_{Mayr}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	$L_{x_{col}}$		2 430	[m]
Wind speed measured at $(H_0)$	10.0	[m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	3	0.1496	[\$/kW_eh]	SD <sub>x</sub>		810	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.116883	[\$/kW_h]	$SD_{x_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926		$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>x</sub>	10	[yr]	FLH <sub>vf</sub>		8 760	[h/yr]
Lifetime of Wind Farm(N)	25	[yr]	c <sub>0</sub>	1 457.72	[\$/kW]	M <sub>10</sub> m <sub>cr</sub>	3.0	[m-h]	UCCCM	13.0797	[S/KW <sub>e</sub> ]	PC PM		10.055 210	nav s ()
Production Efficiency (WF PE)	11.2%	[%]	PR	0.70		N N	85.00	[S/m-h]	LCCCM <sub>WFORSOCM</sub>	2.7805	[\$/kW]	AEP anail		48 856 319	[kW ch/yr]
Availability	97.9%	[%]	b	-1.94	[-]	D Nama	3	[-]	LCCCM <sub>WF</sub>	1 210.0185	[5/KW]	n n		20.98%	[%]
	337	[d/yr]	LKCM	10.8443	[\$/KW]	C <sup>m<sub>mcr</sub></sup>	2.0		WACC proj	4.9000%	[%/yr]	Twees and		25.00%	[%]
Wind Farm Life Cycle Canit	al Cort Model	Matan	Wind Farm Of M Cost	Madal	Natas	S & PV	1 207 2016	[5/d] (\$//W)	9 Astal	30.0%	[%]	P&D <sub>LM</sub>	factor	0.839525	
wr	552 7256	(CONV)	OAM	0.009275	(\$/JAVb)	Jakv	50,000	[36.07]	ip	2.3%	[70/ y1]	14 WT		6 261 7	(-1)
CM	265 22	(\$/LAV)	LCCCM	1 210 6192	(\$7.527)	WP cap	30 000	[6.97]	n <sub>7</sub>	80.06	[91] (91)	AFR		128 000 000	[m]
PC	73 70%	[96/\$/FW]	m	0.0000001%	[96]	A	43.00	(-2)	CHG R	1 596 4321	[%](C)_1	R & D		4.0000000	[411 242 31]
Curr	400.00	[5/kW]	ис	0.0530	[%]	M <sub>WT</sub>	30	[m/wt]	LCER	186	DCO-MW M	1 & D IM		7.00%	[%]
IPT	10.00%	[%]	N	25	[vr]	C.e.	85.00	[S/m-h]	$\sum AEP_{max}$	48 856	[MW.h]	à.e.		0.00%	[%]
Tex	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N	3	[-]	n.,	25	[yr]	24		5.00%	[%]
Tmass	138 000	[kg]	O&M variable	0.025858	[\$/kWh]	D <sub>m</sub>	3.0	[d]	GHG	0.00041	[tCO2/MW,h]	λ.,		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md sarr</sub>	3 500.00	[\$/d]	GHG <sub>FM</sub>	0.00003	[tCO2/MW,h]	LCPM WF		48 856 319	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	E.	46.3820	[\$/tCO2]				
LWTG CM	45.2647	[\$/m/kW]	Rtanes	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing	Ī	Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\xi_1 REI_{CM}$	25.0%	[%]	Debt ratio		50.0%	[%]
Lg	16 110	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\xi_2 REP_{CM}$	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mih</sub>	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 OREP_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	113	[h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	25.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	4 192 361	[\$M]	WTweight	200 000	[kg]	REPIM	420.1715	[\$/proj]	Debt value		30 072 499	[\$]
ç	0.08%	[%]	AEP anail	48 856 319	[kWh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	3 038 043	[\$/yr]
TS CM	11.4566	$[S/kW_e]$	O&M <sub>WFCM</sub>	0.124133	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	2	50.0%	[%]
TLc	0.0400	[\$/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	30 072 499	[\$]
TLr	1 200	[1/kW]	O&M manag(STD)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000105	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	67.9653	yr i	71.0812	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			68.1169	$yr_2$	70.1127	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000287	[\$/kWh]	Hours Distribution	FLH wf [h]	H prod [h]	O&M con	1	[1/0]	68.3260	yr 3	70.3038	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	68.4872	$yr_4$	70.5037	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			68.7399	$yr_5$	70.7005	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution			68.9291	$yr_6$	71.0614	yr 19
FS	19.88	[\$/kW]	Hours required	112.5	[h]	April	720	711	$\xi_1 REI_{CM}$	1	[1/0]	69.1760	yr 7	70.6736	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	184.5	[h/yr]	May	744	735	$\xi_2 \operatorname{REP}_{CM}$	1	[1/0]	69.3913	$yr_8$	70.8564	yr 21
EG	404.52	[\$/kW]		0.000392	[\$/kWh/yr]	June <sup>(*)</sup>	720	687	$\xi_3 OREP_{CM}$	1	[1/0]	69.5637	yr 9	71.1272	yr 22
F <sub>CM</sub>	3.7903	[\$/kW]		-		July	744	735	$\xi_4 GHG.R_{CM}$	1	[1/0]	69.7923	yr 10	71.4101	yr 23
WACC proj	4.900%	[%/yr]				August	744	735	P&D <sub>IM</sub>			70.0286	yr 11	71.6715	yr 25
n fin	1.0	[yr]				September	720	711	λ	1	[1/0]	70.3076	yr 12	69.9843	Mean
WF <sub>CH</sub>	0.30%	[%] (\$/1432)				October	744	735	A	0	[1/0]	70.5332	yr 13	0.4514	SU X (dama )
K	2.4164	[5/KW] [96]				November' '	720	735	1	1	[1/0]	10.14/3	yr 14 69 98/12	-0.4514	1 (skewness) valid !
LCCCM	1 210 6192	[%]				Total [h/m]	8 760	8 570	×.,,	1	[1/0]	LCOE wro	09.9843	US\$/MWB	vana !
LCCCM WF	1 210.0183	Lo/K mj	1			Total [h/yr]	0 /00	0 3/9		p.s., 1 – yes al	J-RU	ļ	0.069984	C03/KWB	

**Figure K.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $L_{wt}(5D10D)$ . Source: Own elaboration

LCOE wso Mode	l Inputs									-		Financial Ind	exes		Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated vellow celle		O& M warranty condition	95	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	in about the project.		Costs covered by manufactures (O&M)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC mai	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	E
						· · · ·									
Wind Project Information		Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	Cost Model	Notes	Renewable Energy Public Inc	entive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR <sub>CM</sub>	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI <sub>CM</sub>	71.1740	[\$/kW_c]	WF CM		50 000	[kWe/yr]
Project Location Turking Model	Corvo Island (Portugal)		Depr <sub>W7</sub>	76.9840	[\$/KW]	KM WT	22.3284	[\$/KW]	LCCCM <sub>WF</sub>	1 210.6183	[\$/KW]	WF cap		50 000	[kW]
Number of Wind Turbines (N)	vestas v50-2MW	£1	WI CM	494 2950	(\$/1/32/)	WP cap	30 000	[ ]	LAC.M	2 500	[3/KW] [0(/m)]	WWT .		2000	1-1
Turbine Size	2000	[-]	1 CM N	404.3039	[3/KW]	M.	100	[=] [m-h]	1)/ W	30.00%	[96]	W1 rated		2000	[_]
Wind Farm Capacity (WF con)	50 000	[kW]	ifr	2.50%	[%/vr]	C <sub>Mbran</sub>	85.00	[S/m-h]	n e	6	[vr]	N cal		5	- E
Rotor Diamenter (D)	90.0	[m]	Depr	60.1398	[\$/kW]	N <sub>n</sub>	3	[-]	REP CM	0.00001039	[\$/kW_h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	D <sub>m mar</sub>	2.0	[d]	AEP avail/H prod	10 451	[kW/yr]	$L_x$		3 960	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	[\$/kW]	C <sub>mdmax</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L, ~.		2 430	[m]
Wind speed measured at $(H_0)$	10.0	[m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ε	0.1086	$[kW_{c}h]$	SD <sub>x</sub>		810	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.075000	$[S/kW_{e}h]$	SD <sub>scol</sub>		540	[m]
Betz Limit's coefficient (C PBetz)	0.5926	[-]	Vo	6 100 000	[kW]	$N_{WT}$	25	[-]	n <sub>z</sub>	15	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	c <sub>0</sub>	1 457.72	[\$/kW]	$M_{hr_{BU_{CT}}}$	3.0	[m-h]	OREP CM	21.2151	[\$/kWe]	PC PM			
Production Efficiency (WF PE)	20.5%	[%]	PR	0.70	[-]	C <sub>Mbr<sub>acr</sub></sub>	85.00	[\$/m-h]	LCCCM <sub>WFORDCM</sub>	2.4575	[\$/kW]	AEP avail		89 657 257	[kWeh/yr]
Availability	97.9%	[%]	b	-1.94	[-]	N <sub>mmcr</sub>	3	[-]	LCCCM <sub>WF</sub>	1 210.6183	[\$/kW]	$\eta_{wec}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443 [	\$/kW]	$D_{m_{BM_{CT}}}$	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{\rm NMCA_{\rm Ord}}}$		25.00%	[%]
	<b>.</b> .			<b>F</b>		C ml ancr	3 500.00	[\$/d]	$\psi_{total}$	30.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capite	al Cost Model	Notes	Wind Farm O&M Cost !	Iodel	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	Oam fuel ce	0.098275	\$/kWh]	WF cap	50 000	[kW]	n ,	15	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM <sub>WT</sub>	265.32	[\$/kW]	LCCCM <sub>WF</sub>	1 210.6183	[\$/kW]	NWT	25	[-]	CRf	80.0%	[%]	AEP rated		438 000 000	[kW_ch/yr]
RC WT	73.70%	[%/\$/kW]	ω UC	0.000001%	[%] easuri	Awr	43.00	[m*/wt]	GHG.R <sub>CM</sub>	821.1245	[\$/tCO <sub>2</sub> ]	P&DIM		7.000	(W.)
	400.00	[\$/KW]	N	0.0530	5/KWIIJ fuel	C and a second	3.0	[m-n]	$\sum_{AEP}$	20.657	[ICO2/MWah]	2		7.00%	[%]
# 1 T	484 3859	[70] [\$/VW]	ife	2 50%	[94] [96/ve]	C Mirsanv	30.00	[3/11/11]		37007	[NI Well]	2.141		5.00%	[70]
T	138 000	[kg]	O&M	0.048935	5/kWh]	D <sub>m</sub>	3.0	[d]	GHG <sub>rw</sub>	0.00041	hCO/MW.bl	2-		5.00%	[%]
RCz	26 30%	[%/\$/kW]	MIC	71 5608	[\$/h]	C_d	3 500 00	[\$/d]	GHG	0.00003	ICO-MW-M	LCPMwr		89 657 257	[kW.h/yr]
Court	0.1900	[\$/ke]	TIC	124 5688	[\$/h]	RVM w.s	61 0184	[5/kW]	E EM were co.	13,0000	[\$/tCO-]				[0.110.75]
LWTG CH	45.2647	[\$/m/kW]	R	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	inø	Г	Notes
WF	50 000	[kW]	ifr	2.50%	[%/vr]	WTS vie	1.4442	[\$/kW]	ζι RELOW	25.0%	[%]	Debt ratio		50.0%	[%]
L	16 110	[m]	N	25	[yr]	WF car	50 000	[kW]	$\xi$ , REP <sub>CM</sub>	25.0%	[%]	Debt term		14	[yr]
CAB cont	2 000.00	[\$/m]	n <sub>mlb</sub>	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_{3}^{2}$ OREP CM	25.0%	[%]	Debt gr	ice period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tib</sub>	113	[h]	N	25	[yr]	$\xi_4 GHG.R_{CM}$	25.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EFc	400.00	[\$/kW]	AAR	14 605 780	[\$M]	WTweight	200 000	[kg]	REPIM	228.3784	[\$/proj]	Debt value		30 021 653	[\$]
ς	0.08%	[%]	AEP arail	89 657 257 [1	Wh/yr]	Csteel	0.1900	[\$/kg]		-		Debt pa	yments	3 032 907	[\$/yr]
TS CM	11.4566	$[S/kW_e]$	O&M <sub>WFCM</sub>	0.147210 [\$	/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	,	50.0%	[%]
TLc	0.0400	[S/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	30 021 653	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000057 [	\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]			_	
SB c	113.00	[\$/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]		-		Initial Results	Summary	of LCOE was	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE was		Notes	73.3843	yr i	78.7166	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			73.7826	$yr_2$	77.8953	yr 15
WT inst	42.5238	[\$/kW]	USC OAM	0.000156	\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	74.0486	yr 3	78.4148	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	74.3935	yr 4	78.8687	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	per yr]	February <sup>(*)</sup>	672	639	REPIM			74.7336	$yr_5$	79.3754	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution			75.1937	yr 6	79.8648	yr 19
FS	19.88	[\$/kW]	Hours required	112.5	[h]	April	720	711	$\xi_1 REI_{CM}$	1	[1/0]	75.4844	yr 7	77.9817	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	184.5	[h/yr]	May	744	735	$\xi_2 REP_{CM}$	1	[1/0]	75.7743	$yr_8$	78.4948	yr 21
EG	404.52	[\$/kW]		0.000214 [\$	/kWh/yr]	June (*)	720	687	$\xi_3 OREP_{CM}$	1	[1/0]	76.2744	yr 9	78.9550	yr 22
F <sub>CM</sub>	3.7903	[\$/kW]		-		July	744	735	$\hat{\varsigma}_4 GHG.R_{CM}$	1	[1/0]	76.6706	yr 10	79.3003	yr 23
WACC proj	4.900%	[%/yr]				August	744	735	P&D <sub>LM</sub>		(1.00)	76.9843	yr 11	79.6946	yr 25
n fin	1.0	[yr]	1			September	720	711	λ	1	[1/0]	77.4845	yr 12	77.1188 /	Mean
W <sub>FCM</sub>	0.30%	[%]	1			October	744	735	A	0	[1/0]	77.8864	yr 13	2.0085 3	SD Xul
K	2.4164	[5/KW]				November' '	720	687	2	1	[1/0]	/8.3130	yr 14 77 1199	-0.4651	1 (skewness) valid !
1000M	1 210 6182	[70]	1			Total [[h/we]	8 760	8 579	A 10	ns: l= yer er	(1/0) nd ()=no	LCOE NED	0.077120	IS\$/kWb	vana :
Loccin WF	1 210.0103	Lang the second	L			Contract and	0700	3 31 7	1	p.a., 1 - yes ut		L	5.077119	559/K 111	

**Figure K.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $L_{wt}$  (5D10D). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes	ĺ	Notes
Legend				_					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	on about the project.		Costs covered by manufacturer $(O \Delta M_{\rm cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	ĺ	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI <sub>CM</sub>	71.1740	[S/kWe]	WF CM	-	50 000	[kW_/yr]
Project Location	Cape Saint James (Canada)		$Depr_{WT_{inst}}$	76.9840	[\$/kW]	RM WT	22.3284	[\$/kW]	LCCCM WF	1 210.6183	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	C M Mar	100	[m-h]	$\psi_{aoaal}$	30.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tfr Denr.	60.1398	[%/yr] [\$/vW]	N Milwana ar	85.00	[5/m-n]	PFP out	0.00000052	[yr] [\$/FW b]	N col		90.0	[-]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Yec	15	[(rk(t)]	$D_{\mu}^{n_{HI}}$	2.0	[d]	AEP muit/Harod	24 766	[kW/yr]	L.		3 960	[m]
Hub height (H)	105.0	[m]	TOCM	0.000033	[\$/kW]	$C_{nd_{max}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L. ~~		2 4 3 0	[m]
Wind speed measured at (H <sub>0</sub> )	10.0	[m]	TI	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ŝ	0.0128	[\$/kW <sub>e</sub> h]	SD <sub>x</sub>		810	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.009998	$[kW_{o}h]$	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>e</sub>	10	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	C ()	1 457.72	[\$/kW]	M <sub>brance</sub>	3.0	[m-h]	OREP CM	56.8814	[\$/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	48.5%	[%]	PR	0.70	[-]	C <sub>Mbracr</sub>	85.00	[S/m-h]	LCCCM <sub>WFORSIGCM</sub>	2.7805	[\$/kW]	AEP avail		212 467 325	[kWeh/yr]
Availability	97.9%	[%]	Ь	-1.94	[-]	D N M MCT	3	[-]	LCCCM WF	1 210.6183	[\$/KW]	$\eta_{wecs}$		20.35%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/kW]	C <sup>m</sup> <sub>MCT</sub>	2.0		WACC proj	4.9000%	[%/yr]	n sectore		25.00%	[%]
Wind Farm Life-Cycle Canit	al Cost Model	Noter	Wind Farm O&M Cost	Model	Noter	S& PV	1 297 3916	[\$/d] [\$/JW]	9° antal i Gr	2.5%	[%] [%/97]	P&D <sub>LM</sub>	factor	0.814145	[-]
WI ou	553 7256	[\$/kW]	O&M	0.098275	[\$/kWh]	WF	50.000	[JAW]	i)) 1	10	[vr]	A		6 361 7	[m <sup>2</sup> ]
CMwr	265.32	[\$/kW]	LCCCM we	1 210.6183	[\$/kW]	Nwr	25	[-]	CR	80.0%	[%]	AEP		438 000 000	[m] [kW_h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	AWT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	4 490.4890	[\$/tCO2]	P&D <sub>IM</sub>			
CkW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Mbruny	3.0	[m-h]	LCER <sub>co</sub> ,	80.7	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	Ν	25	[yr]	$C_{Mbr_{sARY}}$	85.00	[\$/m-h]	$\sum AEP_{aud} = \sum_{r_1, r_2, r_3}$	212 467	[MW <sub>e</sub> h]	2,41		3.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub>	3	[-]	n <sub>v</sub>	25	[yr]	λd		5.00%	[%]
Tmass	138 000	[kg]	O&M variable cu	0.041531	[\$/kWh]	D <sub>m</sub> <sub>saw</sub>	3.0	[d]	$GHG_{IM_{FCO_2}}$	0.00041	[tCO2/MW2h]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md sarv</sub>	3 500.00	[\$/d]	$GHG_{EM_{unit}CO_2}$	0.00003	[tCO2/MW,h]	LCPM <sub>WF</sub>		212 467 325	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	Ec	30.0000	[\$/tCO <sub>2</sub> ]			r	
LWTG CM	45.2647	[S/m/kW]	R <sub>taner</sub>	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing	50.00	Notes
WF cap	50 000	[KW]	ıfr N	2.50%	[%/yr]	WIS VM	1.4442	[S/KW]	ζ <sub>1</sub> REI <sub>CM</sub> č nrn	25.0%	[%]	Debt ratio		50.0%	[%]
CAR	2000.00	[m] [\$/m]	N	23	[yr] [b]	WP cap	2 50%	[KW] [%/vr]	Č ORFP ou	25.0%	[%]	Debt or	ice neriod	14	[yr]
CP cu	30.9069	[5/kW]	R alla	113	[h]	N	25	[vr]	ζ, GHG R cu	25.0%	[%]	Deht in	erest rate	5.00%	[%/yr]
EF.	400.00	[\$/kW]	AAR	29 394 286	[\$M]	WT	200 000	[kg]	REPIM	1 154.6361	[\$/proil	Debt value		29 798 739	[\$]
ç	0.08%	[%]	AEP anail	212 467 325	[kWh/yr]	Csteel	0.1900	[S/kg]			1.1 11	Debt pa	yments	3 010 387	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139806	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates	1	Notes	Equity rati	,	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 798 739	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)	Γ	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000024	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[\$/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	$[/m^2/kW]$	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	84.6046	yr i	94.6768	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			85.2793	$yr_2$	94.3532	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000066	[\$/kWh]	Hours Distribution	FLH wf [h]	H prod [h]	O&M ccm	1	[1/0]	85.9676	yr 3	95.1583	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	86.4297	$yr_4$	96.0547	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			87.1233	$yr_5$	96.9534	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution		F# 103	87.8479	yr <sub>6</sub>	97.7322	yr 19
P3	19.88	[5/KW]	nours requirea	194.5	[n]	April	720	/11	REICH	1	[1/0]	88.4207	yr 7	94.2217	yr 20
DI	404.52	[\$/FW]	SC O&M+USC O&M	104.5	[H/yr]	May	744	687	OREP CM	1	[1/0]	89.11/8	yr <sub>8</sub>	94.9218	yr <sub>21</sub>
EG F cu	3 7002	[\$/kW]		0.000090	[#KHN/yf]	June	744	735	GHG R cy	1	[1/0]	90.6170	yr 9 VF 10	96 7340	37 22 VF 23
WACC mai	4,900%	[%/vr]		Г		August	744	735	P&DIM		[1/0]	91.4368	yr II	97,7477	VT 25
n <sub>fin</sub>	1.0	[yr]				September	720	711	λa	1	[1/0]	92.1460	yr 12	92.0131	Mean
W <sub>F<sub>CM</sub></sub>	0.30%	[%]				October	744	735	$\lambda_{xdi}$	1	[1/0]	92.8735	yr 13	4.1890	SD
CCC CM	2.4164	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	93.9138	yr 14	-0.3343	Y (skewness)
K	0.20%	[%]				December	744	735	λ.,,	1	[1/0]	LCOE was	92.0131	US\$/MWh	valid !
LCCCM WF	1 210.6183	[\$/kW]	L			Total [h/yr]	8 760	8 579	L	p.s.: 1= yes ar	nd U=no		0.092013	US\$/kWh	

**Figure K.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $L_{wt}$  (5D10D). Source: Own elaboration

Table K.1 Ener	gy product	tion (AEP and	$u_{il}$ ) map of the v	wind farm t	for Aracati	i (Brazil)		with s	ensitivity :	nalysis of	L <sub>wr</sub> (5D10)	0															ļ
Months	$V_{HC}$	H	prod												$AEP_{avail}(k)$	(UII)											
	(m/s) (k	(() () ()	h) yr1	yr 2	yr.	3 yr4	, yr:	5 yr <sub>6</sub>	yr yr	, yr,	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
, January	5.8	1.1665	738 169313.	2 8 890 15	98 3802	165 7507+	410 5573	361 8890.	198 557.	61 5573	61 42322.	12 8 890 19	8 8 890 195	\$ 557361	3 802 16:	5 7 507 416	4 232 212	8 890 198	8 890 198	557361	3 802 165	7 507 410	557361	3 802 165 7	507410 42	32 212 4	232 212
February	4.9	1.1666	639 847 940	9 678352	20 3 662.	567 67832	520 777 3	316 6783:	520 777 :	16 777 5	16 47134	19 678352	0 6783520	0 777 316	3 662 56	7 6783520	482 342	482 342	3 290 403	4 713 419	7 693 599	1 572 412	1 572 412	7 693 599 6	783 520 47	13 419 4	713 419
March	4.0	1.1671	735 555 090	9 74768	17 5 424	310 88535	170 975 8	\$29 74762	817 975 2	29 9758	29 654330	57 7 476 81	7 7 476 817	7 975 829	5 424 310	1 8 853 976	894 553	894 553	1 809 568	4 214 966	1 809 568	1 686 232	1 686 232	7 806 630 8	853 970 37	86 671 6	543 367
Anril	47	1.1667	711 865.098	8 6327 01	98 6327	908 4 076	1 630	708 63270	08 1 630	1 630	72306	1 6327 90	8 6327 905	1 740 083	6 327 008	3 4 076 176	073 607	073 607	1 630 708	6 327 908	1 630 708	3 661 984	209 870	7 230 621 6	327 008 1 2	40 083 7	1 20 62 1
Mav	60	1.1670	735 1800500	1 2 424 11	90 7476	230 5 424	008 1 001	200 5 424	100 1 800	200 1 800	7E 908 2 00.	10 5 424 10	9 5 424 100	1 686 169	7 476 536	0 6543 124	1 686 169	1 686 169	075 702	8 853 641	075702	555 069	894 520	6 543 124 4	214 800 14	2 091.98	306 340
Inne	2.0	1 1686	687 2044 00	4 304401	24 7 206	LACIA NAN	1993 2 00.	051 30440	001 3 2 4 4	151 3 5441	2000 / 000	70 2 044 00	1 2 044 004	1 2 544 051	7 206 449	1 5.076 764	207 000 1	1 602 675	837.737	1 306 444	837 737	837 237	130 883 8	5 19L 9L0 5	0 192 920	13 305 8	045.670
annt a		0001-1	06 +++6 C / 00		nnc / +n	4710 444	++C C 071	+++< c 100	#CC 106	##C C 100	0.007.0 10	16 ##K C _ K		+ 0.04400	++ ooc /	+ 10/0 /0	C70 C60 T	C70 CK0 1	107 100	++++ nnc /	/ 67 / 60	107 100	- TCO ++C C	C +0/0/0C			6/0.00
July	8.0	1.1098	/32 243/0/.	2 2 /9/2	80 88/4	801 1 090.	199 4 2 24	. 66/ 5 788	580 4 224	882 4 224	50CC 78	45 0CC 01	)8C CV/ E 0	0 545/0/2	2 8 8/4 80.	1 813 822	086 66/ 5	086 661 8	065 000	/ 494 40/	065 000	C71 8/6	4 774 887	4 774 887 1	661 069	.c 8c0 0	065.00
August	9.6	1.1677	735 7480 69.	4 18105	06 1810	506 1810.	506 8858	561 1810.	506 5427	123 5 427	123 895 0,	7 895 01	7 181050t	6 4217151	1 810 500	5 1687100	5 427 123	7 810 678	7 810 678	895017	4 217 151	7 810 678	5 427 123	1 810 506 1	810 506 52	5378 8	95 017
September	10.1	1.1657	711 855438.	4 1 629 1.	76 1629	176 3 658.	543 7542.	482 I 629.	176 6321	963 6 321	42 81 942 81	0 942.81	J 1 629 17t	5 6321963	3 1 629 176	5 3 658 545	6 321 963	7 223 828	7 223 828	942810	5 240 771	8 554 384	6 321 963	1 629 176 3	658543 65	21 963 9.	42 810
October	9.7	1.1645	735 778920	1 973 65	50 973 t	550 553 b	51 7460	125 973 6	50 7460	125 7 460.	25 1 682 4	57 1 682 46	7 973 656	) 8834205	3 973 656	0 553 851	7 460 125	6 528 759	6 528 759	1 805 528	6 528 759	4 205 556	7 460 125	973 650 9	073 650 88	34 203 10	582 467
November	0.0	1 1638	687 6 008 030	0 83376	75 8333	795 8337	8009 50.	030 8337	.02 7.276.	101 7 276.	1 1 686 64	1 686 66	1 833 705	1 7 276 401	833705	\$ 833.705	7 276 401	5 055 880	5 055 880	1 571 703	6 968 989	020 030	7 276 401	833705 5	833795 73	1 107 92	886 66 1
Dacambar	16	1 1651	735 2790 364	2 554 16	122 22	166 0742	04 5415	1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	920 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	176 9 920	12 12 2 20 24	55 2 790 2K	221122 2	7 464 266	224166	NOC 120 3	966 028 8	1 207 046	4 207 046	3 790 265	7 702 630	226 216 2	201126	5 991 155	2 991 122	64 366 2	390 365
December	0.1	10011	1000010 CC1	11 + 11 - 1	100 00	74/2 007	014.0 4.0	1400 117	6000 00	600 0 077	C 00/ C 075	1000/0 00	101-100 0	1101101	101 400 0	107 116 0	077 600 0	046 /07 4	046 /07 4	COC 00/ C	000 067 7	117 014 0	077 600 0	001400	5/ 007±0/	- nnc +n	00000
Annual	7.4	1.1666	8 579 48 856 31.	9 48 444 3.	128 48 676	5 026 48 290	403 48 895	032 48 444	328 48 844	485 48 844	485 48 356 3	54 48 391 15	3 48 444 32;	8 48 841 860	5 48 676 02v	6 48 362 282	49 053 015	49 213 265	48 817 403	48 463 568	48 054 765	48 883 303	48 747 993	48 179 078 4	8 285 240 48	430 728 48	356 354
Table K.2 Energy	· productio	n map of the	> wind farm for (	Corvo Islaı	nd (Portug	(al)		with se.	nsitivity ar	alvsis of L	(5D10D	÷															
	V <sub>WC</sub>	H	pu											V	VEP avail(k B	(U)											
Months	m/c) (Par	/3 \ /h				. 40	. 10	. 40	- 40		. 40	AU	400				11 P. 1.	A.V.		M.	N.P	110.00					
,	1103) (KB	m ( m)	711	y1 2	y13	y14	315	y1 6	y1 7	y1 8	919	yr 10	71 11	y1 12	yr 13	y1 14	yr 15	yr 16	71.17	yı 18	91.19	y1 20	yr 21	yı 22	yı 23	1 24	y1 25
January	11./ T.	2313	138 14 451 298	14 451 25	14 451 .	298 14 451 2	14 421 ·	298 14451	298 14 451	298 10 842	20 10 842 0.	20 14 451 25	8 10 842 020	0 10 842 021	> 10 842 020	14 451 298	10 842 020	10 842 026	14 451 298	10 842 026	10 842 020	10 842 026	10 842 020	10 842 020 1	10 842 020 16	842 020 1	0 842 026
February	11.5 1.	2345 (	639 11 923 902	4 233 20.	3 11 923	902 11 923 9	02 11 923	902 3 369 5	92 11 923	902 12 538.	68 177071	4 3 369 39.	2 12 538 268	8 1 770 714	4 9 115 121	11 923 902	6 580 843	12 538 268	4 233 203	5 409 699	3 369 392	2 776 293	11 923 902	2 077 293 6	580 843 11	923 902 1	2 538 268
March	10.5 1	2329	735 10 471 380	318938	13 6981	987 13 698 6	13 698 i	987 6 214 6.	20 13 698	387 13 698 t	87 238637	8 318938.	1 13 698 087	7 2386378	13 698 087	7 13 698 087	6 214 620	13 698 087	3 870 731	7 560 022	4 863 071	13 698 087	14 403 865	2 034 182 1	10 471 380 14	403 865 3	189 384
April	9.5 1.	2317	711 7305887	7 305 88.	7 10 443 1	175 10 443 1	75 10 443.	175 7 305 8.	87 10 443	75 4 699 5	96 3 082 17	1 7 305 88.	7 13 237 618	3 082 171	13 237 615	4 699 596	4 699 596	13 237 618	3 082 171	10 119 379	3 082 171	13 919 671	13 237 618	3 082 171 3	1 12 12 13	237618 3	740 614
Mav	8.2 1.2	2282	735 4844807	10 432 05.	3 10 432 (	153 10 432 0	53 61912	80 104326	10 435 - 10 432 -	153 10 432 C	53 3 856 19	4 6 191 280	1 10 432 053	3 856 194	. 14 349 768	10 432 053	3 856 194	10 432 053	2 377 416	13 646 640	6191280	2 377 416	10 432 053	3 826 194 1	14 349 768 16	432 053 4	844 807
Inno	21 12	1 7000	182 2 055 541	12 603 75	2 200 2 5	7 2005 7.	2 2005 2	1 10 01 86.	9057 10.	15 12 69 21	15 905 7 55	2 10 01 12	2005 728	5159057	862 200 2	1171166	175 550 6	7 005 728	1 885 038	12 603 755	7 0.05 728	1 885 038	7 005 728	7 505 515	12 603 755 71	2 802 200	758 070
Inte	1 19	1510	725 2005 275	13 503 42	4 4 702 0	12 961 9 69.	1 200 1 202 -	577 12 502.4	CSFL FG	0 J 2 1440	05 613630	2000 5	302 961 9 .	1000101	308 961 9 .	326 300 6 .	2 257 466	202 902 9	202 202 1	C21 001 F1	10 222 572	2 915 77A	6 126 205	1 302 902 4	2 402 424 2	2 PCL 510	153 587
Auoust	1 19	2075	135 2 337 197	10 583 66	2000	0.001.5 25.	25 2 700.0	125 134154	1 YOU Y YOU	0.007 2 700.0	25 740416	0 2 337 19	218 6 32 8 4	10000TO .	218 092 8 .	. 10 683 991	The COO I	218 C32 F	13 415 606	71C COD 1	13 415 606	L18 C3L F	218 071 0	F 091 F0F 2	2 219 032	102 624 1	0.255 500
isugusi	-1 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2		201 / 00 2 2 2 1 1 2	10 COC AT	506/C 1	.606/ C CC	506/ C CC	1014-01 00	. 000 0 000	506/0 40	11 #0# / CC	01/007 6	/10 70/ 4 3	507 404 / 0	10 70/ 4		147 766 1	/ 10 70/ 4	0400 CT+ CT	147 766 1	040 CT+ CT	/10 70/ #	/10 70/ +	+ 401 40+ /	C /10 70/	- +cn c7	40C CC7 /
September	-1 0./	2004	/11 3 003 832	CF C7 6 1	4 7 9 9 7 7 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	154 4 0U5 I.	29 4 005 1	1 200 4 003 1	- 676 1 67	5799 C IG	54 991100	001166 0	2 00 2 832	100 116.6	5 003 834	2 882 434	000 1 16 6	5 005 852	768 006 71	178 867 7	768 006 71	2 882 454	5 005 852	5 000 116.6	003 832 2	1 178 867	104 076
October	8.9 1.	0717	/32 0 112 412	011241.	5 120 5	130 2 000 /.	2/ 51305	120 2 000 1	2/ 234/	1 1 4 5 5 1	80 154/28	11 15 4/2 80	1 5 150 950	15 4/2 80.	1 5 150 951	/ 455 086	13 4 / 2 801	5 150 950	11/ 870 01	5 150 950	77 000 7	/ 455 080	5 150 950	13 4/2 801 2	34/131 20	7 /7/ 00	54/ 151
November	10.6 1	2194	687 9 990 034	3 5 7 8 30.	5 22066	192 2 206 0	92 22060	92 2 206 6	92 2 948 -	(33 2 206 C)	92 12 663 2.	3 4 495 67.	5 2 206 092	12 663 22:	3 2 206 092	2 948 435	12 663 223	2 206 092	9 680 288	3 578 305	2 206 092	9 680 288	2 206 092	12 663 223 1	880 504 5	745 118 1	2 663 223
December	11.5 1	2237	735 13 595 706	2 368 54.	(2 2 018 5	779 3 165 5.	47 2 018 5	779 3 165 5	47 3841	201 20185	79 14 296 2.	0 13 595 70	5 2 01 8 979	14 296 211	2 018 975	3 841 801	14 296 210	2 018 979	7 503 518	4 826 724	14 296 210	13 595 706	2 018 979	14 296 210 6	168172 4	826 724 1	3 595 706
Annual	9.1 1	2222 8.	579 89 657 257	90 377 37	75 89 783 :	574 89 846 5	76 89 792.	106 90 681 5	385 90 056	935 89.381	70 9031831	67 90 339 66.	3 89 668 733	3 90 318 367	7 90 163 301	90 113 636	89 837 428	89 668 733	90 220 267	90 263 721	90 560 856	90 671 187	89 760 146	90 272 750 9	90 345 823 89	615 940 8	9 153 675
Tahla K 3 Huar	ve avoduct	ion man of f	he wind farm for	r Cane Saii	) semel to	Canada)		with s	ancitativ s	natueie of	TOLOS)	-															
Table C.A. SILIT	V	H H		u cape car		Callana)		S III N	elisiimily :	ularysis or	UIDC) 101	6			AEP and (k)	(1/1)											
Months	(m/s) (k	o/m <sup>3</sup> ) (	h) Vri	VF3	vr	2 VF	VL	2 VF	VL	vr.	Vra	VF 10	VF 11	VF 17	VF 12	VF 14	VP 15	VF 16	VF 17	VF 1.0	VF 10	or 20	VF11	VF 22	VF 12	LC TU	VFIS
January	15.4	1.2561	738 32 734 75	32 734 7	798 3273.	4 798 32 734	798 32 734	1798 32734	798 32 73.	798 32 734	798 32 734 7	198 32 734 7.	32 734 79	8 8013 49	4 3273479	8 32 734 79	8 32 734 798	32 734 798	32 734 798	32 734 798	32 734 798	40 754 809	32 734 798	32 734 798	28 019 994 8	013 494 7	100 933
February	14.7	1.2522	639 24 248 05	20 14 467 4	424 6 912	. 583 26 228	. 520 14 46	7 424 14 467	424 26 22	. 520 26 228	520 69125	83 14 467 4.	24 14 467 42	4 774992	5 26 228 52	0 691258	3 17 377 262	6 912 583	6 912 583	6 912 583	6 912 583	22 462 574	26 228 520	26 228 520	28 959 584 7	749 925 1	7 351 256
March	12.7	1.2495	735 18 226 53	32 18 226 5	532 8 896	263 27 834	779 12 376	5 5 94 18 226	532 27 83-	779 27 834	779 8 896 2	63 12 376 5	14 18 226 53	76 126 6 2.	4 27 834 77	9 8 896 26.	3 30 108 137	8 896 263	8 896 263	8 896 263	8 896 263	22 991 460	27 834 779	27 834 779	31 414 830 9	1 644 1	8 921 332
Anril	7 7	1 2490	711 16.057 71	1 19 287 4	107 0 101	800 24 828	179 0 810	800 19 287	404 24.825	913 24 825	013 0 641 8	00 0 041 80	0 19 287 40	4 0.641.80	9 24 828 91	3 0.641.80	7 26 913 49	0 641 800	29 111 609	0 641 800	0 641 800	22 185 639	10 071 000	24 828 913	24 919 931 9	1 800 1	8 139 0.32
May	611	30701	735 12 306.61	1225 56 Fi	510 0 775	PEN 01 095.	510 0 015	283 25 233	28 01 10 83	848 10 834	5 5 10 0 878	45 200 US	TY 223 56 U.	19 902 61 7.	10 834 84	795 510 0 X.	7 25 55 64	0955100	205 677 305	0 015 560	0 015 560	91 0 080 07	878 728 61	878 728 01	1 22 280 277	306.614	075 831 5
Inne	701	1 2 3 5 1	687 021247	SEL 20 F.	455 11 43-	3 0.85 16 838	810 8 885	718 25714	28.91 598.	388 16.835	388 11 433 6	12 8 2 18 7 1	8 25714.86	35 CPE 51 5.	8 16 838 38	80 11 433 08	5 16.838.389	11 433 085	CC1 8C2 8C	11 433 085	11 433 085	16 955 200	16 838 388	16 838 388	1 589 092 91	1 855 CFE	202 070
2006	1.01	10071	14717 6 100				0170 oors	11 / 10 / 11 / 1			004.11 000	./0170 m	0 11/ CT 0			00 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		000 004 11 J	ant fail tak	006 004 11	006 004 11		000 000 0T	000 000 01		1 000 mm	
July	10:0	C/27.1	/35 873955	51 29 577 1	699 1631	4 803 16 314	267 7 208 1	200 29.57	699 1631	1803 1631-	803 16 314	803 7 795 24	0 29 577 65	99 17 905 42	2 1631480	16 16 314 80	3 7 795 266	16 314 803	19 596 205	16 314 803	16 314 803	15 530 715	16 046 466	16 314 803	16 760 185 1	905 422 8	625 161
August	9.7	1.2216	735 775771	12 12 099	972 1781	9 161 12 099	972 17.81:	9 161 12 093	972 12 09	972 12 09.	972 17 819	161 178191	61 12 099 9;	72 19 501 75	8 12 099 9;	2 17 819 16	1 8 697 428	17819161	17 819 161	17 819 161	17 819 161	12 903 119	15 377 861	12 099 972	12 588 985 15	501 798 7	806 111
September	10.4	1.2234	711 944425	38 75151	148 1889.	2 028 9 444	238 2636.	1 791 7 515	148 9444	238 9 444	238 18 892 1	128 26 361 7	91 751514	18 2431994	0 944425	8 18 892 02	8 9444238	18 892 028	15 728 541	18 892 028	18 892 028	12 321 085	13 275 521	9 444 238 8	842 059 24	319 940 1	029793
October	13.1	1.2327	735 19 679 01	10 8 776 4	461 2970.	2 682 9 837	656 25 33.	3 032 8 776	461 9837	656 9 837	656 29 702	582 25 333 0	32 8 776 46	cl 27 459 94	0 983765	6 25 333 03	2 9837656	25 333 032	12 209 924	29 702 682	25 333 032	12 242 414	8 858 686	9 837 656 8	8 122 639 27	459 940 2	1 596 003
November	14.3	1.2429	687 238742.	56 9 271 1	165 25 87.	8 688 8 271	078 27 99.	2 285 9 271	165 8 271	078 8 271	078 25 878	588 27 992 2	85 9 271 16	5 27 992 28	5 8 271 07	8 25 878 66	8 11 506 822	8 25 878 688	9 271 165	25 878 688	25 878 688	7 423 013	8 271 078	8 271 078 8	8 870 902 2	992 285 2	951 058
December	1.61	1.2528	7.5 30 186 3.	50 9 997 8	948 2574.	5 545 7 955	677 19.99.	9 4 56 9 9 9 7	848 7955	677 7 955	677 25 745.	545 19 999 4	56 9 997 84	8 32 498 62	1 7 955 67	7 30 186 33	0 16 650 523	30 186 350	9 997 848	25 745 545	30 186 350	6 350 393	7 955 677	7 955 677 9	163 644 32	498 621 4	2 475 115
Annual	12.5	1.2404	8 579 212 467 32	25 213 202 ;	961 213 88	7 985 212 225	670 212 65:	5 974 213 202	961 212 22	670 212 22.	670 213 887 :	985 212 655 9	74 213 202 96	\$1 212 704 42	9 212 223 6;	0 213 959 13	9 213 437 670	213 959 139	213 678 613	213 887 985	213 959 139	213 109 827	213 228 530	212 223 670 2.	13 512 714 212	704 429 21	3 419 415

Table K.4 Win	d speed se	ries simulatio.	ons for AE.	P <sub>avai</sub> in Ara	tcati (Brazi	(1		wit	h sensitivi	y analysis	of L <sub>wt</sub> (5L	)10D)	:													
Months	$\frac{V_{wc}}{(m/s)}$	yr ,	$VF_2$	yr 3	Vr 4	₩ 5	Vr6	VF.7	Vr.8	Vr o	VF 10	Vr 11	eed data ser	vr 13	VF 14	s) VF 15	VF 16	VF 17	VF 18	VF 10	VF 2.0	Vr 21	WF 22	Vr 22	VF 24	VF 25
January	5.8	5.8	10.1	7.6	9.6	4.0	10.1	4.0	4.0	7.9	10.1	10.1	4.0	7.6	9.6	7.9	10.1	10.1	4.0	7.6	9.6	4.0	7.6	9.6	7.9	7.9
Febmary	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6	10.1	6.0	6.0	10.1	9.7	8.6	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7	10.1	7.6	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	7.9	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.9	10.1
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	5.8	4.7	4.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	7.9	9.7	8.6	6.0	6.0	4.0	4.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
Octoher	07	07	07	07	40	9.6	07	9.6	9.6	5.8	5.8	40	101	07	4.0	9.6	0.0	0 2	60	0.7	7.0	9.6	07	07	101	5 8
November	. 0	0.0	4.7	4.7	4.7	0.0	47	0.7	0.7	6.0	60	4.7	0.7	4.7	4.7	0.7	86	86	5.8	0.6	60	0.7	4.7	4.7	0.7	6.0
December	15	7.6			i o t	7.0		1.01	1.01	3 1	2.6		,		, o 7	101	0.0	0.0	2.6	5.0	7.6	101				200
December	0./	0./	4.0	4.0	4.4	0.0	4.0	1.01	10.1	/.0	0./	4.0	0.6	4.0	4.9	10.1	6./	<i>Y.1</i>	0./		0.0	10.1	4.0	4.0	9.0	0./
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Table K.5 Wind	speed ser,	ies simulation:	s for AEP	avait in Corv	o Island (F	<sup>o</sup> ntugal)		with	sensitivity	analysis c	$f L_{wt}$ (5D)	(OD)														
Months	Р ис											Wind spe	ed data serie	es for simula	tions (m/s)											
1	(m/s)	yr 1 🔅	yr 2	yr 3	$yr_4$	yr5	$yr_6$	yr 7	yr 8	yr 9	yr 10	yr 11	yr 12	yr13	yr 14	yr 15	yr 16	yr 17	Vr 18	119	Vr 20	yr 21	yr 22	yr 23 )	124	yr 25
January	11.7	11.7 1.	1.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	10.6	11.7	10.6	10.6	11.7	0.6	0.0	0.0	10.6	10.6	0.6	0.6	10.6
February	<i>C.11</i>	C.11	8.2	C11	C11	C11	7.0	5.11	11.7	0.1	7.0	11.7	0.1	2.01	C11	5.6	11.7	8.2	8.9	7.0	17	C.11	6.4	1 0.6	<i>C.1</i>	11.7
March	10.5	10.5	7.1	11.5	11.5	11.5	8.9	11.5	11.5	6.4	1.7	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	1.5	11.7	1.9	0.5 1	1.7	7.1
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	7.1	11.5	8.2	8.2	11.5	7.1	0.5	7.1	1.7	11.5	7.1	7.1 1	1.5	7.6
May	8.2	8.2 Iv	0.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4	1.5	8.9	6.4	10.5	7.6	1.7 1	0.5	8.2
June	7.1	7.1 1.7	1.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1	1.5	9.5	6.1	9.5	8.2	1.5	9.5	8.9
July	6.1	6.1 1.	1.5	8.2	8.9	10.5	11.5	9.5	7.1	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9	1.7	0.5	7.6	8.9	8.9	1.5	7.6	9.5
August	6.4	6.4 Iv	0.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2	11.5	6.1	1.5	8.2	8.2	9.5	8.2	7.1	10.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	1.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	1.7	6.1	6.4	9.5	11.5	11.5	1.7	11.5	7.1	9.5	11.5	7.1	10.6	7.1	6.1	9.5	7.1	11.5	6.4	6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	7.1	6.4	11.5	8.2	6.4	11.5	6.4	7.7	11.5	6.4	10.5	7.6	6.4	0.5	6.4	11.5	6.1	8.9	11.5
December	C11	C-11	0.4	0.1	1.1	1.0	1.1	/.0	0.1	11./	C11	1.0	/11	0.1	0./	11./	1.0	C.4	0.2	17	C7	1.0	11./	٥.۶	0.2	
Annual	9.1	9.1	9.1	9.1	1.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	1.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Table K.6 Winc	d speed se	ries simulation	ns for AE	P <sub>avai</sub> in Cap	e Saint Jar	mes (Canad	a)	wit	h sensitivit	y analysis	of L <sub>wr</sub> (5L	(DD)														
Monthe	V wc											Wind sp.	eed data ser.	ies for simu.	lations (m/s	(5										
CHARLOW	(m/s)	yr 1	$yr_2$	yr 3	yr 4	yr 5	$yr_6$	yr7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr21	yr 22	yr 23	yr 24	yr 25
January	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	15.4	15.4	15.4	15.4	15.4	16.6	15.4	15.4	14.7	9.7	9.3
Febmary	14.7	14.7	12.4	9.7	15.1	12.4	12.4	15.1	15.1	9.7	12.4	12.4	10.0	15.1	9.7	13.1	9.7	9.7	9.7	9.7	14.3	15.1	15.1	15.6	10.0	13.1
March	12.7	12.7	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1	10.0	10.0	10.0	10.0	13.8	14.7	14.7	15.3	10.4	12.9
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	15.1	10.4	10.4	13.8	13.3	14.3	14.3	10.4	12.9
May	11.2	11.2	14.3	10.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3	10.4	14.7	10.4	10.4	13.4	13.1	13.1	13.0	11.2	12.3
June	10.4	10.4	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7	11.2	14.3	11.2	11.2	12.8	12.7	12.7	12.7	12.4	12.2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	12.4	13.1	12.4	12.4	12.2	12.3	12.4	12.5	12.7	10.0
August	9.7	9.7	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.0	12.7	12.7	12.7	12.7	11.4	12.1	11.2	11.4	13.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1	12.4	13.1	13.1	11.4	11.7	10.4	10.2	14.3	13.2
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2	15.1	14.3	11.2	10.1	10.4	9.8	14.7	13.5
November	14.3	14.3	10.4	14.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	10.4	15.1	0.01	14.7	11.2	14.7	10.4	14.7	14.7	9.7	10.0	10.0	10.3	15.1	13.9
December	15.1	15.1	10.4	14.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	10.4	15.4	9.7	15.1	12.4	15.1	10.4	14.3	15.1	9.0	9.7	9.7	10.1	15.4	16.9
Annual	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5

												k	W/yr												
82110	yr <sub>1</sub> yr <sub>2</sub>	yr3	yr 4	yr 5	y,	(e )	r7	yr 8	yr9	W 10	yr 11	yr 12	<i>yr</i> 13	$yr_{14}$	yr 15	yr 16	yr 17	yr18	yr 19	yr 20	yr21	yr22	<i>yr</i> 2:	yr.2	4 )
Aracari (Brazil) 5 (	595 5647	5 674	5 629	5 699	5 64	7 56.	94 56	94 50	137 5	541 5	647	5 693	5 674	5 637	5718	5 737	5 690	5 649	5 602	5 698	5 682	5616	5 628	5 64.	5 50
Corvo Island (Portugal)	451 10 535	10466	10 473	10467	10.57	0 104.	98 104	;01 61.	28 10	530 10	452 II	1 528 I	0 510	10 504	10472	10 452	10 517	10 522	10 556	10 569	10 463	10523	10 531	10 44	9 IO:
Cape Saint James 24. (Canada) 24.	766 24852	24 932	24 738	24788	24 85.	2 247.	38 247	38 245	32 24	788 24	852 24	1794 2	4 738	54 940	24879	24 940	24 908	24 932	24 940	24 841	24 855	24738	24 888	24 79.	1 24
Table K.8 Cashflow for 25 ye	ars of the wind f.	rm project	50.00	0 kW	Aracati (B	razil)				with sensitiv	rity analysis	s of L <sub>w</sub> (51	D10D) Years												
Item	0	-	2	3	4	5	9	7	8	6	10	11	12	13	14	15	16	17	18 1	9 2(	9 21	22	23	24	25
(-) LCCCM WF	60.530			,	'	'	,		,			,			,	,									
WT CH	27 686	278 -																							
LCM LWTG cu	24.219	E																							
CP CH	1545.	46 -			,	'					,					,									
$TS_{CM}$	572	32 -	•			•		•	•																
SI <sub>CM</sub>	2 136	726 -			'	'																			
F out	180	- 17																							
CCCCM	120	- 02			,						,					,		,							
$LCPM_{WF}$ ( $kWh/yr$ )		· 48 856 31	19 48 444 328	8 48 676 026	48 290 400	3 48 895 03.	2 48 444 328	48 844 485	48 844 485	48 356 354	48 391 173 .	48 444 328	48 841 866 4	8 676 026 4.	8 362 288 45	053 015 45	213 265 48	817403 484	63 568 48 0:	54 765 48 88.	3 303 48 745	993 48179	078 48 285.	240 48 430';	28 48350
(+) AAR (SM/yr)		4 297 1.	70 4 367 450	6 4498 053	4573975	9 4 747 03	9 4 820 855	4 982 192	5 106747	5 182 105	5315483	5 454 354	5 636 591	5 757 889	5 863 796 6	096 233 6	269 053 6.	374.091 64	86 088 65	92 161 687.	3465 4918	8 060 4 982	181 5117	988 5 261.	44 538
PPAR FMP		- 42971	70 4 367 45	6 4498 053 -	457397	9 474703	0 4820855	4 982 192	5 106 747	5 182 105	5315483	5 454 354	5 636 591	5 757 889	5 863 796 (	- 096 233 (	5 269 053 6 -	374.091 6-	B6 (B8 65 -	92 161 687. -	3465 - 4918	- 4982	- 181 5117		5385 2.85
$(-) O \& M_{WFCM}$		3 949 35	53 4 013 810	) 4133691	4 203 326	5 4 362 21	1 4 455 206	4 603 527	4 717 835	4 786 683	4 909 110	5 036 592	5 204 091	5 315 304	5 412 299 5	626 056 5	784 761 5	880 906 55	83 464 6 08	\$0.550 6.335	9242 5846	i 638 5922	095 6082	753 6 252 8	34 6396
$O\& M_{fixed}$		. 26545'	79 2 697 99%	7 2778 672	2825574	4 2 932 47:	5 2 978 078	3 077 743	3 154 685	3 201 236	3 283 628	3 369 414	3 481 989	3 556 919	3 622 341 3	765 928 3	872 685 3	937570 4(	06 755 40.	72 279 4 24	6052 4340	155 4396	739 4516.	587 4 643 4	49 4752
$O\& M_{variable}$		12947	74 131581	3 1355 018	137775.	2 1 429 73	7 1477 127	1 525 784	1 563 150	1 585 447	1 625 482	1 667 177	1 722 102	1 758 385	1 789 958 1	860 129 1	912 077 1	943 336 1 5	76710 20	98 271 2 09.	3190 1500	5483 1525	356 1566	166 1 609	85 164
(+) LKCM (+) Devectation		- 803.24 2465.0a	05 884 80 102 102 103 103 103 103 103 103 103 103 103 103	1 2500783	H0 676	28706 0	20/ 0/6 /02	2859740	2 021 234	3 000 514	3079.677	1 100 CU 1	3 235 533	3316.422 3	1 0200611	219 //0	- 707 31			- 16.033 3.947	- 2 183 - 4 046	- 4141	- 756 4.745	- 4351 A	33 446
(=) Profit before tax		36770	30 3766090	3862117	3 955 852	2 4 059 64	7 4132 348	4 239 532	4 346 300	4 451 746	4564104	4 679 437	4 800 717	4 920 006	5 040 854 5	174 268 4	055 715 4	153 894 42	54 851 43:	57 643 4470	6406 3112	161 3201	842 3280.	536 3 360 5	42 3446
(-) Revenue tax		1 289 1:	51 1 310 23;	7 1349416	1372194	4 1 424 109	) 1446 256	1 494 658	1 532 024	1 554 632	1 594 645	1 636 306	1 690 977	1727 367	1 759 139 1	828 870 1	880 716 1	912 227 1 5	45 827 19.	77 648 206.	2 040 1 475	1418 1494	654 1 535.	396 1 5785	23 1615
(+) REPIM	385 91	5 2 045	1 989	1 961	1 910	1 898	1 847	1 829	1 797	1748	1 720	280	289	296	301	313	322	327	333	339 3	333 3.	61 36	6 37.	5 38t	6
REI CH	222 41	·		' our -	-		' oor								,	,	,	,	,	,	,	,			
NEP CM	163.40	C791 .	1/00	nc/ 1	C/0 T	+c0 I		c/c 1	cc c 1	1 482	1														
GHGRCH		221	224	231	235	244	248	256	262	266	273	280	289	296	301	313	322	327	333	339 3	25	51 36	5 37	386	<del>ارم</del> .
(=) Profit after tax w/out in	terest	2389.92	34 2 457 842	2 2514 663	258556	\$ 2 637 430	5 2 687 939	2746704	2 816 073	2 898 863	2 971 179	3 043 411	3 110 029	3 192 935	3 282 017 3	345 711 2	175 321 2:	241 994 23	09.357 2.38	30 334 241	4720 1 635	103 1707	553 1745.	515 1 7822	05 1831
(-) Debt payments			3 191 844	3 271 640	3 353 431	3 437 267	3 523 199	3 611 279	3 701 561	3 794 100	3 888 952	3 986 176	4 085 830	1 187 976 4	292 676 4.	399 992				,					
$(+) RCM_{WF}$		- 26217.	39 2 687 28. 	2 2754 464	1 282332	5 2 893 90.	9 2966257	3 040 413	3 116 424	3 194 334	3 274 193	3 356 047	3 439 949	3 5 25 947	3 614 096 3	704 448	797 060 3	891986 35	89 286 40.	89.018 419	1243 4290	5 024 4403	425 4513	511 4 626.	148 474.
(=) Free net cashflow	-60 144	24039. 14776(	46.120.2 CF	4 4588 270	4711015	5 4816020	1 4 920 987	5 035 578	5 162 170	5 303 612	5 436 047	5 569 900	5 699 680	5 847 328 (	5 002 769 6	134 483 9	543 804 9	000 /09 5. 794 689 10 C	52 22 23	40 0.00 5 5 94. 15 384 10 54	2180 4 040 8 146 9 973	1866 10252	734 10504:	325 10 7595	86 11 035
Ŀ		00 00 000	01 01 10 ETC	TACOUNT T	120 00 00 .	1012010 .	150 021 00 .	24111646	371 CAO 91	12 6.48 865	0100100	010010		1001000			OF LET AUX	102 200000	102 20L VL	100 LL 000 11	0.000				
Table K.9 Cashflow for 25 years of th	e wind farm pi	roject	50 000 kV	V Co	rvo Island (	Portugal)			with	sensitivity a	nalysis of I	L (5D10D													
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Item	0	-	2	6	4	s	6	7	8	-	0	1 12	Years 13	14	15	16	17	18	19	20	21	22	23	24	25
(-) LCCCM we	60 530 914																								
WT <sub>CM</sub>	27 686 278																•								
$T_{CM}$	24 219 295															•	•	•							
LWTG CAL	2 263 233																								
12 CT QI	01-0 01-0 01-0															• •		• •	• •						
SICH	2 136 726																								
POCH	1 796 870															•	•	•							
$F_{CM}$	189 5 14		,				,		,			,				•	•	•							
CCC ar	120 820	•				,										•	•	•							
LCPM wr (kWh/yr)		89 657 257	90 377 375 8	9 783 574 8	9 846 976 8	89 792 106 5	0.681.985 90	056 935 89	381 970 903	8 367 90 3	9 663 89 66	8 733 90 318	367 90 163	901 90 113 6	36 89 837 42	8 89 668 733	90 220 267	90 263 721	90 560 856	90 671 187 8	89 760 146 9	0 272 750 9	0 345 823 89	615 940 89	153 675
(+) AAR (5M/yr)		14 970 925	15 468 449 1	5 750 988 1	6 156 163 1	6 5 49 954 1	7 131 821 F.	439.078 17	741 084 183	5119 188	8 9 39 19 16	6 502 19 787	994 20247	571 20 742 6	36 21 196 03	4 21 685 138	22 363 982	22 934 122	23 584 858	24 203 932	17 191 828 1	7 722 258 1	8 180 019 18	483 975 18	848 346
PPAR		14 970 925	15 468 449 1.	5 750 988 1	6 156 163 1	6 549 954 1	7 131 821 I.	439.078 17	741 084 183	5119 188	8 9 39 19 16	6 5 02 19 787	994 20 247	571 20.742.6	36 21 196 03	4 21 685 138	22 363 982	22 934 122	23 584 858	24 203 932	- 000 101 21				
LINE M.		269 275	- 0 620 262 4		- 0010	0.255 000 1	- 019 012 0		100.792 11.46		7.420 11.00	- 11 12 200	- 12 669		- 13.761.40	- 13567367	12 001 012	- 14 240 505	- 755 407		1 2154 7.47	1 007 771 /	2 01 0 502 14	01 0/6 004	040 240
(-) OCM WEOK	,	CIC 00C 6	102 210 2	1 077 000 6	1 220 601 0	1 0/00 0000 0	N 040 617 0	11 006 1164	100/001	21 9 191 0C //	66 11 064 /	0271 1477	000 71 006	21/671 040	20 107 CT C0	2 7056207	CH6 166 CT	7 467 607	104 001 41	002 340 2	0921002	0.720.125	41 C6C 016 C 41 C6C 016 C	6 11C C05	100 175
D&M		4 496 901	4646303	1730.977	1852 484	4 970 618	5 145 234 5	2 212120	377931 55	8200 5.6	7348 575	5575 5942	0000 200	16 67784	43 6364.44	2010001 0	6714853	6 885 808	7.081.137	2010/001	5 163 178	5 377 330	5 459 677 5	550.813 5	200.025
(+) LRCM	,	863 268	884.850	906 971	929 646	952,887	1 602.926	001 127 1	101 251 201	1 809 1 00	8 104 1 10	6.057 1.132	683 1161	000 1 1000	72 1 21 9 77										
(+) Demeciation		2 461 776	002 202 2	2 586 403 5	010 129 1	0 2 1 7 340	0 285 273 2	854 905 2	01 01010	0.435 3.07	212 UCP7	1281 3230	0.63 3310	14 33035	247842	4 3565385	3 654 520	3 745 883	3 830 530	3 035 518	4.033.906	4 134 754	4 738 177 4	344.075 4	LL9 CSF
(-) Profit helore tox		8 977 504	0 197 050	010007	0562.091	1 000 17 2	0173963 10	383 155 10	202 734 10 9	X 11 200 6X	4.033 11.43	692 11 865 0	783 12/051	12 12 348.7	80 12 632 73	6 11 683 156	12 026 558	12 331 500	10 668 901	10 006 704	280,000 8	825 906 8	8 507 540 8	8 2201289	870 343
(-) Revenue tax	,	4 491 277	4 640 535	1725.296	1846.849	4 964 986	5 130 546 5	231 723 5	322 325 55	2536 56	1 682 574	9 951 5 936	308 6.074	6 6 222.7	01 635881	0 6505541	6 7 (19 19 5	6 880 237	7 075 458	6/L1 19/L /	5 157 549	5316677	5 454 006 5	545193 5	654 504
(+) REPIM	487 607	1 438	1 420	1 382	1 3 55	1327	1314	1 280	1 245	235	11 212	80 116	7 114	1123	1100	164	921	174	<u>8</u> .1	183	186	192	197	200	204
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(=) Buoße after tex infants interest		227.756.6	11/	1 664 377	221 757	1 000 621	5 035 721 5	112 021	271.654 5.40	22 0022	2562 569	1 0 0 0 0 0 1	557 5 077	101 8 000	101 6.775.00	401 S 2	5 2 17 5 2 2	5 451 427	5 502 637	5 725 700	2 012 675	200000	2 062 740 2	140.024 2	205.044
(=) Frojn djjer lax W/out mierest		00/ /00++	2 196 449 2	4 004 222 3	5 10/ 10/ +	1 CD /06 +	- TC/ CC/ C	C 11/7C1	2/1 004 201 2720	CC 100//1	00 0 00 000 0	1 020 1 020 1 020 1	1160 700	10710 070	539 C 05 F	6111110 0	ccc /1c c	/c+ 1c+ c	770 CKC C	06/ 00/ 0	C70 C16 7	700.006.7	c n#/ conc	c +cn.0+1	++O C77
(-) the payments			0.007.000	200 109 5	10/ 10/		5 247 75 5	0.00.000	92.50 205.257	7885 080	110 011	4.30 4.0/8/9	22 4 180 8	011 C 27 1 C	4 202 202 4		- 001 00 0	- 000 000	- 000 0 10						
(+) K C M WF		66/ 170 7	797 / 90 7	10111017	075 578 7	606 669 7	107 0067	c c1+0+0	1 6 474 011		CC C C C C F I +	664 6 / 140.0	C7C C 646	14105 /#	H+++0 C 06	000/6/5 8	096 169 0	007 606 5	4 089 018	642 181 4	470 0K7 4	- C74 C04 4	+ IICCIC+	4 956 070	100.74/
(+) Depreciation		2 461 776	2 523 320	2 586 403	2 65 1 063	2717340	2785273 2	854 905 2	926278 29.	9435 300	4420 315	1281 3230	063 3310	814 3 393 5	85 347842	4 3565385	3 654 520	3 745 883	3 839 530	3 935 518	4033906	4 134 754	4 238 122 4	344 075 4	452 677
(=) Free net cashfrow	-60 043 307	9 521 269	6 582 092	6 738 981	5 908 384	7 080 425	7 270 019 7	442 856 7	619 053 78.	23 784 8 01	9799 820	9720 8425	641 8 633	86 88488	76 9 065 34	6 12 540 224	12 864 039	13 186 605	13 522 170	13 862 559 1	11 243 555 1	1 518 231 1	1 805 373 12	110 458 12	419 728
$\Sigma$ freen et ann nal cashflore	r .	50 522 038	43 939 946 -3	7 200 965 -3(	0 292 580 -2	3 212 156 -1	5 942 137 -8	499 281	880.228 69	3 556 14 90	3 356 23 17	3 076 31 598	717 40 232	503 49 081 3	79 58 146 72	5 70 686 949	83 550 987	96 737 593	110 259 763	124 122 322	135 365 877	146 884 108 1	58 689 481 17	799 939 18	3 219 667
	$LCOE_{vro}$	73.38	73.78	74.05	74.39	74.73	75.19	75.48	75.77 74	27 76	67 76.	¥-77 86.	8 77.8	78.31	78.72	77.90	78.41	78.87	79.38	79.86	77.98	28.49	78.96	05.97	79.69
119- 30-9 81-0 of A -11-11			100 0 U	ć					2	-		do Fort	,												
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(-) LCCCM wF	60 530 914																								
W1 CM	9/7 090 /7																•	•							
$T_{CM}$	24 219 295																	•							
LWTG CH	2 263 233		,														•	•							
$CP_{CM}$	1 545 346	,	,	,		,	,	,	,	,		,			'	'	'	•	,		,	,	,		
TS CM	572 832	,	,							,		,			'	'	,					,	,		
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1 CM	+IC 601			,														•					,		
CCCOL	120 8.20			,		,	,	,	,						,			•	,			,	,		
LCPM WF (KWh/yr)		212 467 325	213 202 961 2	13 887 985 2	12 223 670	212 655 974	213 202 961 2.	12 223 670 21	2 223 670 213.	87.985 212.6	55 974 213 20	02 961 212 704	429 212 223	670 213 959	39 2134376	0 213 959 139	213 678 613	213 887 985	213 959 139	213 109 827	213 228 530	212 223 670 2	13 5 12 7 14 21	2 704 429 21	3419415
(+) AAR(SM/yr)		30 129 143	30 989 297 3.	1866088 3.	2 408 583 3	3 286 465 3	4 206 386 34	1900 500 35	773 012 36 9.	54 893 37 66	0.580 38.70	1386 39576	163 40 473	80 41 824 5	78 42 766 11	7 43 942 368	44 981 873	46 151 597	47 321 124	48 311 614	34 682 891 3	5382431 3	6487277 37	257 877 38	317 694
PPAR		30 129 143	30 989 297 3.	1866088 3.	2 408 583 3	3 286 465 3	4 206 386 34	1900 500 35	773 012 36 9.	54 893 37 66	0.580 38.70	1386 39576	163 40 473	80 41 824 9	78 42 766 11	7 43 942 368	44 981 873	46 151 597	47 321 124	48 311 614					
EMP	,	,	,	,		,	,	,	,			,			'	'	'	•	,		34 682 891 3	5 382 431 3	6 487 277 37	257 877 38	317 694
(-) O&M WFCM		20 588 653	21 176 289 2	1775289 2	2 145 849 2	2 745 588 2	3 374 048 25	848 206 24	444 264 25 2	51 714 25 75	3772 2644	4815 27042	406 27 655	570 28 578 7	23 29 221 64	9 30 025 221	30 735 353	31 534 457	32 333 424	33 010 055 2	29 394 777 2	9 987 510 30	0 923 748 31	576701 32	474 767
$O\&M_{fixed}$	,	11 544 287	11 873 857 L	2 209 802 1.	2417658 1	2 754 020 1	3 106 490 13	372 439 13	706744 141;	9 585 1442	9 9 69 14 82	8 7 56 15 163	928 15 507	89 16 025 5	67 16 386 16	5 16836848	17 235 136	17 683 317	18 131 424	18 510 931	18 984 266 1	9 367 164 19	9 971 914 20	393 708 20	973 810
O& Municiple	,	9 044 366	9 302 432	9 565 487 5	3 728 192	9 991 568 1	0 267 558 16	475 767 10	737 520 11 0	02 1 29 11 30	3 802 11 61	6 058 11 878	478 12 147	781 12 553 1	56 12 835 48	4 13 188 373	13 500 217	13 851 140	14 202 000	14 499 125 1	10410511 1	0.620.346 10	0 951 834 11	182 993 11	500 957
(+) I RCM		863 768	884.850	006 971	979 646	952 887	1 000 926	001 127 1.	01 551 900	1 809 1 00	8 104 1 10	6 057 1 132	1911 289	00 1 1900	77 0101 20	. 9			,	,			,	,	,
(+) Demociation		7 AA 3 A07	2 504 584	2 567 100	0/21 220	2 607 163	C COS 191 C	C LUL 833 TUL 2	201550 20	7163 3.06	1 507 3 17	200 2 2306	3266	3 368 3	87 3.457.50	7 3 5 38 01 7	3 677 384	3 7 18 060	3 811 021	3 006 206	4 003 054	4 104 053	7 PS9.200.1	311.820	110 616
(-) Duode hofeno ere		350 270 01	1 2002 442	2 564 060 15	1 012 750	1 100.001	1 572 620 14	31 201 200	231 02100	11110	01 202 2	0120 16 0120	396.21 013	17 00.4	10 21 0 12	0 17 456 050	17 072 005	10.225.000	102 002 01	220 200 01	0.200.060	0.409.072	0 220 102 0	01 200 000	212 212
		0000000		T INCLOSE		1 170 001 000	1 10001010	CT / TT /00/				7/0 01 010 0	007 11 010				COV 010 11	007 007 01	17/02/01			00000000		11 0/0 #00	00000
(-) Kevenue tax		9 058 /45	68/ 967 6	078 600 6	CIC771 6	1 046 086 6	10 701 616 107 0	01 001 0/10	1.11 404 127	0 408 11 2	81/4 11 01	0410 11 8/2	241 IT 147	6/tC71 t0	52 672 71 56	01/ 781 61 6	13 494 202	P15 847 4/9	14 190 557	14 495 484	1040430/1	0.014 /2/ IV	11 581 046 0	1// 305 11	806 664
(+) REPIM	933 437	111	162	806	812	827	843	823	808	068	10	97 81	~ 8	862	881	905	726	951	975	366	1 021	1 041	1 074	1 096	1 1 28
$REI_{CM}$	222 419			,			,	,	,			,						•				,	,		
$REP_{CM}$	,	156	153	150	145	142	138	134	131	129	125	,			'	'	,	,	,	,	,	,	,	,	,
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GHGROW	,	621	638	656	668	686	705	719	737		76 7	97 81	5 83	862	881	905	927	951	975	506	1 02 1	1 041	1 074	1 096	1 1 28
(-) Profit after tax w/out interest		3 800 780	3 006 444	1.005 040 4	101 005	4 205 815	4312566 4	417.831 4	528.417 4.6	IK 573 479	0.737 4.87	0.801 5.000	485 5124	111 5.258.0	36 5 387 88	6 4774753	092 082 7	4 400 680	4.603.350	4715366	02.2 111 1-	1114715	1 300 171 1	183 270 -1	731.637
(-) rugu dher aa woma meresi		607 600 C			C 101 +	010.007.4	- 0007104	100 101 1	04 /14 070	1+ C/CO	10+ 7076	000 C 160 6	1710 001	10070 11	00/0CC 0C	0 44/44	107 007 1	1000 024 4	600 0M +	00000114			1- 076 +/11	1- 0/7 001	100.107
(-) Dept payments	,		5 102 / 58 5 5	2 1 20 1 2	- 50K 77S	. 0/6 CDE C	c 07116+c	010 110 010	01.804 5.12	002 0 100	1446 DCC	555 4 0 45 0 4 0 42 5 40 0	20 4 1 4 A 20	10000 +	856 607 F		- 00100	- 000 0	- 000 0 000						
(+) K C M W F		2 021 /39	7 08 / 787	2 /24 404	7 825 520	2 895 909	1/27.006.7	040413 3	110.424 51	H 534 - 52	4195 335	0.04/ 3.459	5255 (the	M/ 30140	90 3 /04 44	8 379/000	2 891 980	2 989 280	4 089 018	4 191 245	4.290.024	4 405 425	4 115511 4	020.548 4	/42.007
(+) Depreciation	THE POST OF	244549/	1001 2001	661/007	6/5 1 50 2	2 09/ 105	7 766 907 7	2222707 2	904.550 29	1105 50C	1 5 2 2 2 1 2	1 882 5 200	0.07 5 280	230 2 208 2	6270F2 /8	1 5558912	5 0/2/ 584	690 81/ 5	170 118 5	967.906.5	4 005 954	4 104 055	4 200 054 4	511820 4	419 616
(=) Free net cashflow	-59 597 477	8 874 524	5 935 523 ·	6 085 754 ·	6 233 796 7 000 - 0	6 390 911	6 5 5 2 2 8 9 (	713 547 6	881 526 7 0	8510 72	1467 741	3 9 52 7 597	8/7 7/86	1986 7 986 5	21 8 184 99	4 11 610 225	11 899 640	12 198 035	12 503 397	12 812 906	/ 188 199	1 392 762	7 545 238 7	754.898 7	929 985
<ol> <li>free net annual cathflore</li> </ol>		- 50 722 955 -	44 787 430 -5	c- 0/0 10/ 8	2 467 880	1- 606 9/19	9 524 080 -1.	811 154 -5	929 608 11	28 902 8 30	0369 1577	4301 25372	oci 16 . 671	517 39 145 5	ST 47 550 55	00/ 066 82 1	CKC 0#8 0V	83 038 45u	95 541 82/	108 354 755	115 542 935	122 935 095 1	30 480 935 15	8 235 831 146	5 165 817
	LCOE un	84.60	85.28	85.97	86.43	87.12	87.85	88.42	89.12 91	103 96	62 91.	44 92.1	5 92.8	93.91	94.68	94.35	95.16	96.05	96.95	97.73	94.22	94.92	95.97	96.73	97.75

# **APPENDIX L**

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend		[		_			-		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{\rm out})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
WE IN SILE OF		N	I line d B la	Contractor	N .	Wind From Brownel C		N. 4	Bananakia Enamen Bakia In	894 834	N	Wind Farm Life	Cuala Prod	nation Model	N .
Wind Project Information	Einsten Wind From	Notes	Levenzea Kepiacement	Lost Model	Notes	Wina Farm Kemoval Co	1 220 0154	Notes	Renewable Energy Public In	centive Model	Notes	WE	<ul> <li>Cycle Frod</li> </ul>	so ooo	Notes
Project Location	Aracati (Brazil)		Depr	76 9840	[3/kW]	RM wr	22 3284	[3/kW]	LCCCMws	1 217 7353	[3/kW]	WF		50.000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF.cm	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (NWT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	[yr]	$M_{hr_{max}}$	100	[m-h]	$\Psi_{astal}$	30.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	$C_{Mhr_{EM}_{WT}}$	85.00	[\$/m-h]	n <sub>v</sub>	6	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>manyo</sub>	3	[-]	REP CM	0.00002627	$[kW_{o}h]$	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>m swar</sub>	2.0	[d]	AEP avail/H prod	5 695	[kW/yr]	L <sub>x</sub> ,		4 680	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	[\$/kW]	C mf may	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 790	[m]
Wind speed measured at $(H_0)$	10.0	[m]	TI	1 798 743	[\$/kW]	RM CT	20.1954	[S/kW]	3	0.1496	[\$/kW <sub>c</sub> h]	SD <sub>1</sub>		990	[m]
Terrain rugosity factor (a)	0.14		V	237 699 000	[KW]	WF cap	50 000	[KW]	δ <sub>0</sub>	0.116883	[\$/kW_h]	5D <sub>xcol</sub>		630	[m]
Lifetime of Wind Form (N)	0.3928	[-]	Vo	1 457 72	[KW] (\$4492)	N WT M	23	[=] [m.h]	OPER	12 0707	(yr)	PLD of		8 /00	[n/yr]
Production Efficiency (WF )	11.2%	[yr] [96]	C ()	1 437.72	[\$/KW]	C.,	3.0	[m-n] [\$/m-h]	LCCCM	2 7968	[S/KW_c] [S/VW]	AFP		48 856 310	[kW h/sr]
A vailability	07.0%	[96]	PR	-1.94	[-]	N Morece	30.00	[3'm'n] [_]	LCCCM WPOBSIGM	1 217 7353	[3/KW] [\$/VW]	n n		20.98%	[KW ett/yr]
revaluoliny	357	[/v] [d/ve]	IRCM	16 8443	(\$/I-W)	D	20	60	WACC	4 900096	[96/vr]	n		25.00%	[%]
	551	[0, 31]	LACM	10.8445	[\$/k 11]	C_1	3 500.00	[0] [\$/d]	W	30.0%	[96]	P&D		0.839325	[~]
Wind Farm Life-Cycle Canit	al Cost Model	Notes	Wind Farm O&M Cost	Model	Notes	S& RV	1 297 3916	[3/4]	i fr	2.5%	[%/yr]	Num	factor	25	
WI ou	553 7256	[S/kW]	O&M	0.098275	[\$/kWh]	WF	50.000	(ww)	.,,,	10	[vr]	A		63617	[m <sup>2</sup> ]
CMWT	265.32	[\$/kW]	LCCCM	1 217.7353	[\$/kW]	N wr	25	[-]	CR /	80.0%	[%]	AEP		438 000 000	[kW_h/yr]
RCWT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	AWT	43.00	[m <sup>2</sup> /wt]	GHG.R CH	1 596.4321	[\$/tCO <sub>2</sub> ]	P&DIM			
CRW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Martin	3.0	[m-h]	LCER	18.6	[tCO2/MWah]	λ <sub>a</sub>		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMbr	85.00	[\$/m-h]	$\sum AEP_{and}$	48 856	[MWeh]	2,41		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N.,	3	[-]	n.,	25	[yr]	λd		5.00%	[%]
Tmaxx	138 000	[kg]	O&M variable or	0.025858	[\$/kWh]	D <sub>m saw</sub>	3.0	[d]	GHG <sub>EM g co.</sub>	0.00041	[tCO2/MWah]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[S/h]	C <sub>md sate</sub>	3 500.00	[\$/d]	GHG <sub>EM</sub>	0.00003	[tCO2/MWah]	LCPM WF		48 856 319	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[S/h]	RVM WF	61.0184	[\$/kW]	E <sub>c</sub>	46.3820	[\$/tCO2]				
LWTG CM	52.3452	[S/m/kW]	Rtauer	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	$WTS_{VM}$	1.4442	[\$/kW]	$\xi_1 \operatorname{REI}_{CM}$	25.0%	[%]	Debt ratio		50.0%	[%]
$L_g$	18 630	[m]	Ν	25	[yr]	WF cap	50 000	[kW]	$\xi_2 \operatorname{REP}_{CM}$	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n mih	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 OREP_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	113	[h]	N	25	[yr]	$\hat{\zeta}_4$ GHG.R <sub>CM</sub>	25.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	4 192 361	[\$M]	$WT_{wright}$	200 000	[kg]	REPIM	420.2746	[\$/proj]	Debt value		30 249 779	[\$]
ç	0.08%	[%]	AEP anail	48 856 319	[kWh/yr]	C <sub>steel</sub>	0.1900	[S/kg]		,		Debt pa	yments	3 055 953	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.124133	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	2	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]		F		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	30 249 779	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000105	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]			r	
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]		,		Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	68.3211	yr i	71.4370	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			68.4727	yr <sub>2</sub>	70.4686	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000287	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	68.6819	yr 3	70.6597	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	Nwr	25	[-]	January	744	738	(%) ccm	80.0%	[%]	68.8431	$yr_4$	70.8595	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February	672	639	REPIM			69.0958	yr 5	71.0563	yr 18
FU CM	35.9374	[\$/KW] (\$/LW)	Repair time	3.0	[h] (b)	March	744	735	KEPIM distribution	1	(1/0)	69.2849	yr <sub>6</sub>	71.4172	yr 19
F 5	19.88	[\$/KW] [\$/LW]	SC USC	1125	[n]	Apru	720	711	E PEP	1	[1/0]	60,7472	yr 7	71.0294	yr 20
DI	401 52	[\$/KW] [\$/LW]	SC O&M+USC O&M	104.5	[n/yr]	May (*)	744	697	COPER	1	[1/0]	69.1472	yr <sub>8</sub>	71.2123	yr 21
EG	404.52	[\$/KW] [\$/LW]		0.000392	[\$KWII/yr]	June"	720	725	CHCRCM	1	[1/0]	70.1492	yr9	71.4850	yr 22
F CM WACC	3.8126	[\$/KW]		г		July	744	735	54 GHG.R <sub>CM</sub> P&Dave	1	[1/0]	70.1482	yr 10	71.7659	yr 23
nac C proj	4.200%	[vr]	1			September	720	711	he he	1	[1/0]	70.6635	9711 WE 10	70.3401	Mean
We We	0.30%	[%]				October	744	735	λ	0	[1/0]	70.8890	yr 12 W 12	1.0823	SD
CCC CM	2.4306	[\$/kW]				November <sup>(*)</sup>	720	687	λd	1	[1/0]	71.1032	yr 14	-0.4514	Y (skewness)
ĸ	0.20%	[%]				December	744	735	λ,,	1	[1/0]	1.005	70.3401	US\$/MWh	valid !
LCCCM WF	1 217.7353	[\$/kW]				Total [h/yr]	8 760	8 579		p.s.: 1= yes ar	nd 0=no	LCOE wie	0.070340	US\$/kWh	
-						(*) Burde de efferen harren der men der									

**Figure L.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $L_{wt}$  (6D12D). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend		ĺ					_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
				E											
Wind Project Information	F	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal Co	ost Model	Notes	Renewable Energy Public Inc	centive Model	Notes	Wind Farm Life	<ul> <li>Cycle Prod.</li> </ul>	iction Model	Notes
Project Location	Corvo Island (Portural)		Depr	76.9840	\$/VW]	DC M WF PM ww	22 3284	[5/KW] [5/FW]	ICCCM we	1 217 7353	[5/KWe] [5/VW]	WF CM		50.000	[KW@yr]
Turbine Model	Vestas V90-2MW		WT CM	553,7256	\$/kW]	WF	50 000	[JKW]	LRCM	16.8443	[\$/kW]	Nwr		25	[-]
Number of Wind Turbines (N <sub>WT</sub> )	25	[-]	T <sub>CM</sub>	484.3859	\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	$M_{he_{Bher}}$	100	[m-h]	$\Psi_{anal}$	30.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMbranger	85.00	[\$/m-h]	Π.,	6	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	\$/kW]	N <sub>mmur</sub>	3	[-]	REP CM	0.00001039	[\$/kW <sub>e</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>mmur</sub>	2.0	[d]	AEP anail/H prod	10 451	[kW/yr]	L <sub>x</sub>		4 680	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	\$/kW]	C mf may	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 790	[m]
Wind speed measured at $(H_0)$	10.0	[m]	77	1 798 743	[\$/kW]	RM <sub>CT</sub>	20.1954	[\$/kW]	e	0.1086	[\$/kW_h]	SD <sub>x</sub>		990	[m]
Betz Limit's coefficient (C as . )	0.14	[-]	V V	237 699 000	[KW] [VW]	WF cap	25	[KW]	а <sub>0</sub>	0.075000	[5/KWon]	FIH (		8 760	[m] [b/sr]
Lifetime of Wind Farm (N)	0.3920	["] [vr]	V <sub>0</sub>	1 457 72	[KW] [\$/kW]	M <sub>w</sub>	30	[=] [m-h]	OREP au	21 2151	[5/kW ]	PC nu		8 700	[II/y1]
Production Efficiency (WF RE)	20.5%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[S/m-h]	LCCCM	2.4720	[\$/kW]	AEP		89 657 257	[kW_h/yr]
Aváilability	97.9%	[%]	b	-1.94	[-]	Nmm	3	[-]	LCCCM WF	1 217.7353	[\$/kW]	$\eta_{max}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443	\$/kW]	D, 100	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wear_{-n}}$		25.00%	[%]
						C <sub>nd</sub> ma	3 500.00	[\$/d]	$\Psi_{anal}$	30.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost 1	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>fula</sub>	0.098275	\$/kWh]	WF cap	50 000	[kW]	n <sub>v</sub>	15	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM <sub>WT</sub>	265.32	[\$/kW]	LCCCM WF	1 217.7353	\$/kW]	NWT	25	[-]	CRf	80.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	821.1245	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530 [	\$/kWh]	M <sub>br sur</sub>	3.0	[m-h]	$\sum_{AEP} AEP$	34.1	[tCO2/MW2h]	2		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mhr_{SARY}}$	85.00	[S/m-h]	L ALL and PLICE	89 657	[MW <sub>e</sub> h]	×		0.00%	[%]
T <sub>CM</sub>	484.3839	[\$/KW]	ijr O&M	0.049925	[%/yr] \$/1/8/b]	D N <sub>m</sub> un	30	[=] 60	n <sub>*</sub> GHG	0.00041	[yr]	~ ~ ~		5.00%	[%]
PC -	26 206	[8] [6] (\$ (1/32)]	MIC MIC	71 5609	(\$%)	C	2 500.00	[U] (\$/4)	GHG	0.000041	ICO2MW[8]	LCPM	-	80 657 257	[70]
RC T	28.30%	[%/\$/KW]	MLC	124 5698	[5/1]	PVM	5 500.00	[5/d] (\$//W)	GHO <sub>EM</sub> <sub>um co<sub>2</sub></sub>	12,0000	[RC02/MW,h]	LCT M WF		89 037 237	[K Wen/yr]
LWIG out	52 3452	[3/ kg] [S/m/kW]	R.	30.00%	[96]	N wa	25	[3KW]	6 <sub>c</sub> REPIM distribution	100.0%	[%]	Project Finan	rina	Г	Notes
WF	50.000	[Jan Ku ]	ifr	2 50%	(%/vr]	WTS	1 4442	[S/kW]	$\tilde{\zeta}_1 RELau$	25.0%	[%]	Deht ratio	ung	50.0%	[%]
L.	18 630	[m]	N	25	[vr]	WF	50 000	[kW]	Č. REP cu	25.0%	[%]	Debt term		14	[vr]
CAB cont	2 000.00	[\$/m]	n mih	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 OREP_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	113	[h]	N	25	[yr]	$\xi_4$ GHG.R <sub>CM</sub>	25.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	14 605 780	[\$M]	WTweight	200 000	[kg]	REPIM	228.4816	[\$/proj]	Debt value		30 198 933	[\$]
9	0.08%	[%]	AEP anail	89 657 257 [k	Wh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	3 050 816	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.147210 [\$	&Wh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	,	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	30 198 933	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)	ii	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC OBM	0.000057 [3	k/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]			,	
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE wis	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	73.7401	$yr_1$	79.0725	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			74.1385	$yr_2$	78.2512	yr 15
WT inst	42.5238	[\$/kW]	USC OBM	0.000156 [3	k/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	74.4044	yr 3	78.7707	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	74.7494	$yr_4$	79.2246	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5 [	per yr]	February <sup>(*)</sup>	672	639	REPIM			75.0894	$yr_5$	79.7313	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h] (h)	March	744	735	REPIM distribution		(1/0)	75.5496	yr <sub>6</sub>	80.2207	yr 19
PS DT	19.88	[5/KW] (\$/MW)	SC USC	184.5	[n]	Apru	720	711	ζ <sub>1</sub> REI CM <sup>×</sup> PEP	1	[1/0]	75.8405	yr 7	78.3373	yr 20
EC	404 53	[3'KW] [\$/FW]	DE DEMTUSC DEM	0.000214	wyr j wwb/we	June <sup>(*)</sup>	720	687	Č ORFP ou	1	[1/0]	76.6302	37.8 NT 0	79.3100	37 21 NT 43
Fou	3,91%	[3'KW] [\$/FW]		0.000214 [\$	a nuyij	June	744	735	Či CHG R au	1	[1/0]	77.0265	37.9 XT.10	79.6561	37 22 NF 32
WACC	4 900%	[%/yr]		<b>–</b>		August	744	735	P&DIM	1	[1/0]	77 3401	VF 11	80.0505	37 25 VE 25
nice e proj	1.0	[yr]				September	720	711	λe	1	[1/0]	77.8404	VT 12	77.4747	Mean
W <sub>F<sub>cu</sub></sub>	0.30%	[%]				October	744	735	λ <sub>sdi</sub>	0	[1/0]	78.2423	yr 13	2.0085	SD
CCC CM	2.4306	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	78.6689	yr 14	-0.4651	Y (skewness)
ĸ	0.20%	[%]				December	744	735	λ	1	[1/0]	LCOF	77,4747	US\$/MWh	valid !
LCCCM WF	1 217.7353	[\$/kW]				Total [h/yr]	8 760	8 579		p.s.: 1= yes ar	nd 0=no		0.077475	US\$/kWh	

**Figure L.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $L_{wt}$  (6D12D). Source: Own elaboration

LCOE wso Mode	l Inputs									Financial Ind	exes		Notes
Legend					-		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and a	re updated	O& M warranty conditio	Note	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[S/kWh]		$MC_A$	50	[\$/kW]
Vellow cells are for use input information	on about the project	Concerning contained	80.00% (%)	Depreciation rate per ver	4.00%	[96./sce]	Expected Market Price	0.09584	(S/FWb)		WACC	4 9000%	[96/sce]
Grov cells are not used		Daried of memory (n)	5 (m)	Bariad of dampaintian	25	fored	DRAR and EMP ratio	70.008	(0.1.1.1)		UCPE	0.070242	1.0
only cent are not and.		Period of wairanty $(n_w)$	5 [19]	renou or depreciation	20	[y1]	FFAR and EMF fatto	70.00%	[70]		CCM	0.070243	[-]
Wind Project Information	Notes	Levelized Replacement	Cost Model Note	Wind Farm Remova	Cost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	AR CM	16.8442 [\$/kW	DCM WF	1 339.9154	[\$/kW]	REI CM	71.5867	[\$/kWe]	WF CM		50 000	[kW <sub>o</sub> /yr]
Project Location	Cape Saint James (Canada)	Depr <sub>WTmu</sub>	76.9840 [S/kW	] RM <sub>WT</sub>	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 217.7353	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW	WT <sub>CM</sub>	553.7256 [S/kW	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	N <sub>WT</sub>		25	[-]
Number of Wind Turbines (N <sub>WT</sub> ) Turbing Size	25 [-]	T <sub>CM</sub>	484.5859 [5/kW	N <sub>WT</sub>	25	[-] [m.h]	ifr	2.50%	[%/yr]	WI rated		2 000	[KW]
Wind Farm Capacity (WF)	50 000 [kW]	ifr	2.50% [%/y	C <sub>Mbr</sub>	85.00	[S/m-h]	Ψ total Π -	50.00%	[vr]	N raw		5	- E-
Rotor Diamenter (D)	90.0 [m]	Depr	60.1398 [\$/kW	Nmmm	3	[-]	REP CM	0.00000052	[\$/kW_h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7 [m <sup>2</sup> ]	Y <sub>RC</sub>	15 [yr]	Damar	2.0	[d]	AEP anait/Hprod	24 766	[kW/yr]	L.,		4 680	[m]
Hub height (H)	105.0 [m]	TO CM	0.000033 [S/kW	C <sub>nd<sub>mur</sub></sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	$L_{x_{out}}$		2 790	[m]
Wind speed measured at $(H_0)$	10.0 [m]	TI	1 798 743 [\$/kW	RM CT	20.1954	[\$/kW]	3	0.0128	$[kW_{c}h]$	SD <sub>xee</sub>		990	[m]
Terrain rugosity factor (a)	0.14 [-]	V	237 699 000 [kW	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.009998	[\$/kWeh]	$SD_{s_{cal}}$		630	[m]
Betz Limit's coefficient (C PBerz)	0.5926 [-]	Vo	6 100 000 [kW	N <sub>WT</sub>	25	[-]	n <sub>z</sub>	10	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25 [yr]	<i>c</i> <sub>0</sub>	1 457.72 [\$/kW	) M <sub>M</sub> <sub>M</sub>	3.0	[m-h]	OREP CM	56.8814	[\$/kWe]	PC PM		212 467 225	0.001.0.0
Aválabilav	48.5% [%]	PR	-1.94 [-]	N N	83.00	[5/m-n]	LCCCM <sub>WFORGCM</sub>	1 217 7353	[5/KW] [5/FW]	ALP avail		212 407 525	[KW_en/yr]
Availability	357 (d/or)	IRCM	16 8443 (\$4-1	7 D.	20	[=] [4]	WACC	4 9000%	[3/KW] [96/97]	η <sub>wacs</sub>		20.33%	[%]
	307 [@91]	LACM	10.0445 [3/K	C	3 500 00	[0] [\$/d]	Winter proj	30.0%	[%]	P&D		0.814145	[-]
Wind Farm Life-Cycle Capit	al Cost Model Notes	Wind Farm O&M Cost	Model Note	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	Nwr	Jactor	25	[-]
WT <sub>CM</sub>	553.7256 [\$/kW]	O&M fuel	0.098275 [\$/kW	WF cm	50 000	[kW]	n.,	10	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM WT	265.32 [\$/kW]	LCCCM <sub>WF</sub>	1 217.7353 [\$/kW	] N <sub>WT</sub>	25	[-]	CRf	80.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70% [%/\$/kW	J 00	0.0000001% [%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	4 490.4890	[\$/tCO2]	$P\&D_{LM}$			
$C_{kW}$	400.00 [\$/kW]	LLC	0.0530 [\$/kW	1] M <sub>Arxan</sub>	3.0	[m-h]	LCER <sub>co<sub>2</sub></sub>	80.7	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00% [%]	N	25 [yr]	$C_{Mhr_{SARV}}$	85.00	[\$/m-h]	$\sum AEP_{avail} = \dots = $	212 467	[MWeh]	λ		3.00%	[%]
T <sub>CM</sub>	484.3859 [S/kW]	ifr O f M	2.50% [%/y	N <sub>m3407</sub>	3	[-]	n , CUC	25	[yr]	2.4		5.00%	[%]
I mars	138 000 [kg]	WC NUC	0.041531 [SkW	D <sub>m saw</sub>	3.0	[d]	GHG <sub>IM</sub> <sub>Fing</sub>	0.00041	[tCO2/MW,h]	LCDM		5.00%	[%]
RC T	26.30% [%/\$/kw	J MLC	124 5699 [5/h	DVM	5 300.00	[\$/d] (\$/JW)	GHG <sub>EM</sub> and CO	0.00003	[RCO/MW/h]	LCTM <sub>WF</sub>		212 407 323	[K W <sub>e</sub> n/yr]
LWDC	52 2452 [\$/w]/M	P	20.00% (%)	NVM WF	01.0184	[3.6.14]	6 c PEDIM distribution	100.00	[a/iCO <sub>2</sub> ]	During the Firmer		r	Natas
WF	50.000 RW1	ifr	2.50% [96/y	1 WTS int	1 4442	[\$/kW]	Č. PFLou	25.0%	[%]	Deht ratio	ung	50.0%	[%]
Le	18 630 [m]	N	25 [yr]	WF.cm	50 000	[kW]	Ča REP CM	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00 [\$/m]	n <sub>mlb</sub>	72 [h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069 [\$/kW]	n <sub>ith</sub>	113 [h]	N	25	[yr]	$\xi_4 GHG.R_{CM}$	25.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
EF c	400.00 [\$/kW]	AAR	29 394 286 [SM	WTweight	200 000	[kg]	REPIM	1 154.7393	[\$/proj]	Debt value		29 976 018	[\$]
ς	0.08% [%]	AEP anail	212 467 325 [kWh/	r] C steel	0.1900	[\$/kg]				Debt pa	yments	3 028 296	[\$/yr]
TS CM	11.4566 [\$/kWe	O&M WFCM	0.139806 [\$&Wh	rf TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	2	50.0%	[%]
TL <sub>c</sub>	0.0400 [\$/m]			WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 976 018	[\$]
TL <sub>r</sub>	1 200 [1/kW]	O&M <sub>manag(STD)</sub>	Note	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
	3 000 [m]	SC OLM	0.000024 [\$/kW	y N	25	[yr]	BRL/USD dec2010	0.5986	[-]		c	crear I	N
SB c	113.00 (\$/kWh	Work days	3.0 [d]	T <sub>mass</sub>	138 000	[kg]	0 FC 6 100F		N. (	Initial Results	Summary	OJ LCOE waso	Notes
SI <sub>CM</sub>	42.7345 [\$/m²/kW	] Feb/Jun/Nov	9 [d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE win		Notes	84.9604	yr i	95.0326	yr 15
WF cap	50000 [KW]	nours requirea	/2.0 [n]	J Harris Distribution	ELII (h)	11 (1.)	Odem WFCM		(1.40)	83.6332	yr <sub>2</sub>	94.7090	yr 15
WI int	42.3238 [SKW]	N	25 []	Interview	744	729	(8/) mm	1 80.0%	[1/0]	86.3233	yr3	95.5141	yr 16
Bld cost	300.00 [S/m <sup>2</sup> ]	N WT Frequency	25 [-]	January E-hmore <sup>(*)</sup>	672	639	(%) ccm REPIM	80.0%	[70]	80.7830	yr4	90.4105	yr 17
PO cu	35.9374 [\$/kW]	Revair time	3.0 [h]	March	744	735	REPIM distribution			88,2038	37 3 NT 6	98.0881	yr 18 YF 10
FS	19.88 [\$/kW]	Hours required	112.5 (h)	April	720	711	REI CM	1	[1/0]	88.7765	yr 7	94.5776	yr 20
DT	87.22 [\$/kW]	SC O&M+USC O&M	184.5 [h/yr	May	744	735	REP CM	1	[1/0]	89.4736	yr s	95.2777	yr21
EG	404.52 [\$/kW]		0.000090 [\$*#Wh	r] June <sup>(*)</sup>	720	687	OREP CM	1	[1/0]	90.3846	yr 9	96.3240	yr 22
F <sub>CM</sub>	3.8126 [\$/kW]	1		July	744	735	GHG.R CM	1	[1/0]	90.9728	yr 10	97.0898	yr 23
WACC proj	4.900% [%/yr]			August	744	735	P&D <sub>IM</sub>			91.7927	yr 11	98.1035	yr 25
n <sub>fin</sub>	1.0 [yr]	11		September	720	711	λa	1	[1/0]	92.5018	yr 12	92.3690	Mean
W <sub>F<sub>CM</sub></sub>	0.30% [%]	11		October	744	735	xă i	1	[1/0]	93.2294	yr 13	4.1890	SD
ĸ	2.4.506 [S/kW]	11		November'	720	687 735	×	1	[1/0]	94.2096	97 3600	-0.3343	1 (skewness) valid !
LCCCM	1217 7353 (\$/+W	41		Total (b/we)	8 760	8 579	×	$n s \cdot l = var a$	[1/0] nd 0=no	LCOE NED	94.3690	US\$/kWb	vana ?
Locom WF	1217.7355 [\$/KW]	J [		Dial [Wyr]	0700	3 31 9	L	p.s., 1 - yes u		L	0.092369	553/K 111	

**Figure L.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $L_{wt}$  (6D12D). Source: Own elaboration

Table L.1 Energ.	y producti	ion $(AEP_{an})$	$_{\it ul})$ map of the	wind fam	n for Aracati (	(Brazil)		with sent	sitivity ana	lysis of Lw1	(6D12D)															
Months	V <sub>nc</sub>	Ч	Iprod											AEI	$P_{avail}(k Wh)$											
-	(m/s) (k,	(g/m <sup>3</sup> ) (	(h) yr <sub>1</sub>	yr	2 yr3	3 yr 4	yr 5	yr 6	yr 7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15 3	Vr 16	or 17 y.	118 yr	r 19 yı	20 yr 2	21 yr:	22 yr 2.	3 yr 24	yr 25
, January	5.8	1.1665	738 16931.	132 8 890	198 3 802 1	165 75074.	10 55736	51 8 890 19	8 55736	I 557361	4 232 212	8 890 198	8 890 198	557361 5	3 802 165 7.	507 410 4.	232 212 88	98 861 06.	90 198 55.	7361 380.	2165 750.	7410 557.	361 3802	165 75074	410 423221	2 4 2 3 2 21.
Febmary	4.9 1	1.1666	639 84794	40 6783	520 3 662 5	567 67835.	20 77731	6 6783520	0 77731	6 777 31t	4713419	6 783 520	6 783 520	777316 3	3 662 567 6.	783 520 4.	82 342 45	2342 32	90 403 471	13419 769.	3 599 1 57.	2 412 1 572	412 7693	599 6783	520 471341	9 471341
March	4.0	1.1671	735 555 05	90 7476	817 5 4243	310 88539;	70 97582	39 74768I	7 97582	9 975 825	6 543 367	7 476 817	7476817	975 829 5	5 424 310 8.	853 970 8.	94 553 89	14 553 15	09 568 4 21	14 966 180	9 568 1 68	6 232 1 686	232 7806	630 88539	70 378667	1 654336
April	4.7	1.1667	711 865 05	98 6327	908 63275	908 4 076 1.	76 1 630 76	<b>38 632790</b> k	8 1 630 76	8 1 630 700	230 621	6 327 908	6327908	1 749 983 6	5327908 41	076 176 9.	43 697 94	3 697 16	30 708 6 32	27 908 1 63.	0 708 3 66.	1 984 943 (	697 7230	621 63279	08 1749 98	3 7230 62.
May	6.0 1	1.1670	735 1809 50	500 5424	: 109 7 476 5	539 5424 h	99 1 809 56	70 5 424 105	9 1 809 56	0 1809500	7 806 340	5 424 109	5 424 109	1 686 169 7	74765396.	543 124 10	586169 1 6	86 169 97	5 792 885	53 641 975	\$ 792 555	069 894	520 6543	124 42148	809 1 686 16	9 780634
, June	7.9 1	1.1686	687 3 944 9	104 3 944	904 7 306 4	444 61241	20 354405	51 3 944 904	4 3 544 05	1 3 544 051	8 286 679	3 944 904	3 944 904	3 544 051 7	7 306 444 5 (	076 764 10	593 625 1 6	93 625 83	7 237 7 36	16 4 44 837	237 837	237 3544	051 5 076	764 5 076	764 91330	5 8 286 67
July	8.6	1.1698	735 5437 0	172 3 795	580 88748	801 1 690 1	39 4 224 88	92 3 795 580	0 4 224 88	2 4 224 882	. 556396	556 396	3 795 580	5 437 072 8	3 874 801 1	813 825 3:	795 580 37.	95 580 55	6 396 745	14 407 556	396 978	125 4 224	882 4 224	882 1 690	199 896 65	8 556390
August	9.6	1.1677	735 7480 69	(04 1810	506 1 810 5	506 1 810 50	36 888856	51 1810500	5 5 427 12	3 5 427 123	. 895 017	895 017	1 810 506	4 217 151 1	1 810 506 1	687 106 5 -	127 123 78	10 678 78	10 678 89	5 017 421	7 151 7 810	0 678 5 427	123 1810	506 1810	506 55537	8 895 01:
Sentember	101	1.1657	711 8 554 30	1 1 629	1 76 1 629 1	176 3 658 54	43 7 542 48	42 1 629 174	5 632196	3 6321965	942.810	942 810	1 629 176	6 321 963 1	, 629 176 31	658 543 6	321 963 7 2	23 828 72	23 828 942	2810 524	0 771 8 55-	4 384 6 321	963 1 629	176 3 658	543 632196	3 942.810
October	07	1 1645	125 7790 3	101 073	650 0736	50 552.85	21 246013	25 073 651	1 7 460 12	5010912 3	237 689 1	234 683 1	073.650	200 200 1	073.650 5	2 138 23.	10125 65	2 750 65	06 1 052 60	15 5 70 6 53	06 1 06 8	2 556 7 460	125 073	650 0736	20 2 2 2 2 7	31 682 46
October		C+01-1	7 60/ / (()	C/6 107	0.076 000 2000 202	10 CCC DCC	1004/ 10	100 016 07	1004/ 0	. 21004/ 0	/04/2001	104 700 1	000 016	CU2 #C0 0	0 102000	/ 10000	C 0 C7100+	CD 60/07	10 I 6C/ 07	700 0700	07 4 60/0	1047 0CCC	C16 C71	0 C/6 000	17 +COO AC	04-700-1 6
November	7.7	1.1038	087 00989.	939 833	1858 661	1/ 558 (6/	.6 860 9 66	39 833 79.	5 7 276 4	1 727640.	1 686 661	1 686 661	C6/ 558	7 276 401	6 CU/ 558	.7 66/ 55	276401 56	05 889 5 C	55 889 I 57	71 703 696	8 989 6 09	8 939 7 276	401 833	1.558 661	95 727640	1 1 686 66.
December	7.6	1.1651	735 3780 3	365 554	166 5541	166 97421	94 54152;	77 554 160	6 8 839 24	6 8 839 221	3 780 365	3 780 365	554166	7 464 366	554166 9	74204 8.	839226 42	07 946 42	07 946 378	80365 779	3 630 5 41.	5 277 8 839	226 554	166 5541	66 746430	6 378036
Annual	7.4 1	1.1666	8579 488563	319 48 44	4 328 48 676 (	026 48 290 4	03 48 895 0.	32 48 444 32,	8 48 844 4;	5 48 844 48.	1 48 356 354	48 391 173	48 444 328	48 841 866 4	48 676 026 42	8 362 288 45	053 015 49.	213 265 48	817 403 48 4	<i>463 568 48 0</i> .	54 765 48 8	83 303 48 747	7 993 48 179	9 0 78 48 285	240 48 430 7.	8 48 356 35
Table L.2 Ene	rgy produ	iction map o	of the wind farn	m for Corv.	o Island (Port	tugal)		with se	nsitivity ar	alysis of L <sub>w</sub> .	, (6D12D)															
Months	V <sub>NC</sub>		$H_{prod}$											AE	$SP_{avail}(kWh)$											
SHIDIOM	(m/s)	$(kg/m^3)$	(h) yı	r1	yr2 y.	11.3 yı	.4 yr.	5 yr6	yr.	7 yr 8	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17 )	yr 18 y	r 19 y.	r 20 yr	21 yr	22 yr2.	3 yr24	yr 25
January	. 11.7	1.2313	738 144.	(51 298 14	451 298 144	451 298 14 4:	51 298 14 45.	1 2 98 14 451	298 14 45.	298 10 842	026 10 842 0.	6 14 451 298	2 10 842 026	10 842 026	10 842 026	14 451 298	10 842 026 1.	0 842 026 1	4 451 298 10	842 026 10	842 026 10.	842 026 10 84	42 026 10 84	42 026 10 842	026 10 842 0	26 10 842 02
February	11.5	1.2345	639 119.	123 902 42	233 203 11 5	923 902 11 92	23 902 11 92.	3 902 3 369.	392 11 92.	2 902 12 538	268 1 770 71	4 3 369 392	12 538 268	I 770 714	9 115 121	11 923 902	5 580 843 1.	2 538 268 4	233 203 54	409 699 33	69 392 27.	76 293 11 92	23 902 2 07.	7 293 6 580	843 11 923 9	02 12 538 20
March	10.5	1.2329	735 104.	(71380 31	189384 136	598 087 13 65	38 087 13 69	8 087 6 214 (	620 13 69.	087 13 698	087 238637	8 3189384	13 698 087	2 386 378	13 698 087	13 698 087 (	5 214 620 1.	3 698 087 3	870 731 75	560 022 48	03 071 13 v	08 087 14 40	03 865 2 03-	4 182 10 471	380 14 403 8	65 3 189 38
April	9.5	1.2317	711 730.	15 887 73	305 887 10 4	443 175 10 44	(3 175 10 44.	3175 7305	887 10 44.	175 4 699	596 3 082 15	1 7 305 887	13 237 618	3 082 171	13 237 618	4 699 596	4 699 596 1.	3 237 618 3	082 171 10	119379 30	82 171 13	919 671 13 23	37 618 3 08.	2 171 3 082	171 13 237 0	18 374061
May	8.2	1.2282	735 484	(4 807 10	1432 053 10 4	432 053 10 45	12 053 6 191	280 10432	053 10 43.	053 10 432	923 3 856 15	4 6 191 286	10 432 053	3 856 194	14 349 768	10 432 053	3 856 194 1	0 432 053 2	377416 13	646 640 61	91 280 23.	77416 1043	32 053 3 850	6194 14349	768 10 432 (	53 4 844 80
June	1.7	1.2224	687 295.	15 541 12	693 755 7 06	95 728 7 00:	5 728 7 005	728 10.014	121 4 506	515 12 693	755 4 506 51	5 10 014 121	7 005 728	4 506 515	7 005 728	2 211 411	2 955 541 7	005 728 1	885 038 12	693 755 7 0	05 728 1 8	85 038 7 00	5 728 4 50	6515 12 693	755 7 005 7	28 575897
July	6.1	1.2154	735 200.	15 275 13	503 424 4 76	93 962 6120	5 305 10 32	2 572 13 503	424 7 452	587 31440	160 612630	5 2 005 275	6 126 305	6 126 305	6 126 305	2 005 275	352466 6	126 305 6	126 305 14	199 172 10.	322 572 3 8.	15 724 6 120	6 305 6 120	6 305 13 503	424 38157	24 7 452 58
August	6.4	1.2075	735 233.	17 182 10	1 283 661 3 79	90 935 3 790	1 935 3 790	1935 13415	696 6 086	204 3 790	135 7 404 16	9 2 337 182	4 762 817	7 404 169	4 762 817	10 583 661	i 992 247 4	762 817 1.	3 415 696 15	992 247 13.	415 696 4 70	62 817 4 76	2 817 7 40	4 169 4 762	817 3 123 6	34 10 255 50
September	7.6	1.2064	711 3 66.	1 2832 15	925 451 5 88	82 434 4 60:	3 129 4 603	129 4603.	129 1 925	451 5882 4	(34 991160	0 991166	3 663 832	0991166	3 663 832	5 882 434	£ 099116t	663 832 1.	2 965 892 2 2	258 821 12	965 892 5 8,	82 434 3 66	3 832 9 91.	1 660 3 663	832 22588	21 1 925 45
October	. 8.9	1.2126	735 611.	2412 61	112 412 3 15	36 930 2 00	9727 3136	5930 2000.	727 2347	131 7435 (	86 13 472 80	1 13 472 801	3 136 930	13 472 801	3 136 930	7 435 686	13 472 801 3	136 930 1	9 628 711 3 1	136 930 2 0	00 727 74.	35 686 3 130	6 930 13 45	72 801 2 347	131 2 000 7	27 2 347 13
November	. 10.6	1.2194	687 9.99	10 034 3 5	578 305 2 26	06 092 2 2 0t	5 092 2 206	092 2 206 0	092 2 948	433 2 206 t	192 12 663 22	3 4495676	2 206 092	12 663 223	2 206 092	2 948 433	12 663 223 2	206 092 9	680 288 3 5	578 305 22	06 092 9 6	80 288 2 200	6 092 12 66	63 223 1 880	504 57451	18 12 663 22
December	. 11.5	1.2237	735 135	:95 706 2 3	368 542 2 01	18 979 3 16.	5 547 2 018	1979 3165	547 3841	801 2 018 5	79 14 296 24	0 13 595 706	2 018 979	14 296 210	2 018 979	3 841 801	14 296 210 2	018 979 7	503 518 4 2	826724 14.	296 210 13.	595 706 2 018	8 979 14 29	96 210 6 168	172 48267	24 13 595 70
Annual	1.6	1.2222	8 5 7 9 8 9 6:	\$57.257 90	377 375 89 7	783 574 89 84	16 976 89 792	2 1 06 90 681	985 90 05	935 89.381	970 9031830	7 90 339 663	89 668 733	90 318 367	90 163 301	90 113 636	89 837 428 8	9 668 733 9	9 220 267 90	1263 721 90.	560.856 90.4	671 187 89 76	50146 9023	72 750 90 345	823 89 615 9	40 89 153 65
Toble I 3 Ene		tion man	f the wind form	n for Cane	Saint Tamas	(Canada)		with co		alveie of I	(delay)															
TADIE LO EIK	agy prout	action map c	u ure wind lan.	mior cape	Same James	(callada)		WILLI SC	distrivity a.	Ialysis of L <sub>8</sub>	(07100)			A E	(9m 4) d2											
Months	· 140	( Parton 3 )	(h)			10	Nr.	. 40	. 40	Nr.o	040	WF 10		0F 10	availing a		21.10	0F.10		0F 10	P. 10	P.00 DP	Vr	W.	UPAC .	20.00
January	15.4	1.2561	738 327.	34 798 32	734 798 32 7.	734 798 32 73	14 798 32 734	4798 32734	798 32 734	798 32 734	798 32 734 75	8 32 734 798	32 734 798	8 013 494	32 734 798	32 734 798	32 734 798 3.	2 734 798 3.	2 734 798 32	734 798 32	734 798 40	754 809 32 73	34 798 32 75	22 71 22 34 798 28 019	994 80134	94 7 100 93
February	14.7	1.2522	639 242	FI 660.87.	162 424 6 91	12 583 26 22	38 520 14 46	7 424 14 467	424 26 228	520 26 228	520 691258	3 14 467 424	14 467 424	7 749 925	26 228 520	6912583	17 377 262 6	912 583 6	912 583 65	912 583 69	12 583 22 -	462 574 26 22	28 520 26 22	28 520 28 959	584 77499	25 17 351 25
March	12.7	1.2495	735 182.	26 532 18	226 532 8 89	96 263 27 85	14 779 12 376	6 5 94 18 226	532 27 834	1779 27 834	779 8 896 26	3 12 376 594	18 226 532	9 971 944	27 834 779	8 896 263	30 108 137 8	896 263 8	896 263 88	896 2 63 8 8.	. 6 263 22	991 460 27 83	34 779 27 8:	34 779 31 414	61266 088	44 18 921 33
April	12.4	1.2490	711 16 0.	10 112 10	287 404 9 64	41 890 24 82	18913 9641	890 19287	404 24 828	913 24 828	913 9 641 85	0 9 641 890	19 287 404	9 641 890	24 828 913	9 641 890	26 913 496 9	641 890 2	9 111 609 96	96 068 185	41 890 22.	185 639 19 97	71 909 24 82	28 913 24 919	931 96418	90 18 139 0
May	11.2	1.2425	735 1230	06 614 25	233 644 9 91	15 560 19 85	14 848 9 915	560 25 533	644 19 834	848 19834	848 991556	0 9915560	25 533 644	12 306 614	19 834 848	9 915 560	25 533 644 9	915 560 2	7 677 395 9 5	015 560 99	15 560 20:	989 216 19 83	34 848 19 8	34 848 19 089	277 12 306 6	14 16 168 32
June	10.4	1.2351	687 921.	2 474 25	: 714 865 11 4	433 985 16 85	18 388 8 218	1718 25714	865 1683	388 16 838	388 11 433 90	5 8218715	25 714 865	15 342 558	16 838 388	11 433 985	16 838 388 1	1 433 985 2	3 723 122 11	433 985 11	433 985 16	955 390 16 83	38.388 16.85	38 388 16 760	685 15 342 5	58 14 949 50
July	10.0	1.2275	735 873	19 531 29	577 699 16 3	314 803 16 31	14 803 7795	5 266 29 577	609 16 31-	803 16314	803 1631480	U 7795266	\$ 29 577 699	17 905 422	16 314 803	16 314 803	7 795 266	6 314 803 1	9 596 205 16	314 803 16.	314 803 15.	530 715 16 04	16 466 16 31	14 803 16 766	185 17 905 4	22 8 625 16
August	9.7	1.2216	735 775	57712 12	099 972 17 8	819 161 12 05	18 11 226 6c	9 161 12 099	972 12 09	972 12 099	972 17 819 h	101 618 21 10	12 099 972	19 501 798	12 099 972	12 819 161	8 697 428 1	7 819 161 1	7 819 161 17	819 161 17.	819 161 12:	903 119 15 37	77 861 12 09	99 972 12 586	105 61 586	96 111 90
September	- 10.4	1.2234	711 9.44	14 238 75	515 148 18 8	892 028 9 44.	4 238 26 36.	1 791 7 515.	148 9444	238 9444.	238 18 892 0.	162 192 26 361 791	7 515 148	24 319 940	9 444 238	18 892 028	9 444 238 1.	8 892 028 1	5 728 541 18	892 028 18	892 028 12.	321 085 13 27	75 521 9 44	4 238 8 842	029 24 319 9	40 19 029 75
October	. 13.1	1.2327	735 196.	\$ 010 62	776 461 29 7	702 682 9 83.	7 656 25 33.	3 032 8 776.	461 9837	656 98371	556 29 702 6k	2 25 333 032	8 776 461	27 459 940	9 837 656	25 333 032	9 837 656 2	5 333 032 1	2 209 924 29	702 682 25.	333 032 12.	242 414 8 858	8 686 9 83.	7 656 8 122	639 27 459 9	40 21 596 00
November	14.3	1.2429	687 238.	174 256 9 2	271 165 258	878 688 8 2 7.	1 078 27 99.	2 285 9 271	165 8 271	078 8271 (	178 25 878 64	8 27 992 285	9 271 165	27 992 285	8 271 078	25 878 688	11 506 828 2.	9 888 828 5	271 165 25	878 688 25	878 688 74.	23 013 8 27	1 078 8 27.	1 078 8 870	902 27 992 2	85 21 951 02
December	15.1	1.2528	735 301.	86 350 95	997 848 25 7	745 545 795.	5 677 19 99:	9456 9997.	848 7955	677 7955 c	577 25 745 5-	5 19 999 456	9 997 848	32 498 621	7 955 677	30 186 350	16 650 529 3.	0 186 350 9	997 848 25	: 745 545 30	186 350 63.	50 393 7 95:	5 677 7 95.	5 677 9 163	644 32 498 0	21 42 475 11
Annual	12.5	1.2404	8 579 212 4	167 325 213	1 202 961 213 8	887 985 212 22	23 670 212 65.	5 974 213 202	961 212 22.	1 670 212 223	670 213 887 9.	12 212 655 974	1 213 202 961	212 704 429	212 223 670 2	213 959 139 2	13 437 670 21	3 959 139 21	3 678 613 213	1 887 985 213	959 139 213	109 827 213 22	28 530 212 22	23 670 213 512	714 212 704 4	29 213 419 41

Table L4 Wind	1 speed sei	ies simulation	ns for AEP.	avait in Arac	ati (Brazil)			with	sensitivity	analysis of	L <sub>w1</sub> (6D12D															1
Months	(m/s)	yr 1	Vr2	VF3	Vr 4	₩5	$VF_6$	<i>VF</i> 7	$_{VL_{R}}$	Vr o	VF 10	Vr 11	ea aara seri. vr 12	es jor simui. Vr 13	Vr 14	VF 15	VF 16	VF 17	VF 18	VF 10	VF 20	VF 2.1	VF 22	<i>W</i> 23	VF 24	VF 25
January	5.8	5.8	1.01	7.6	9.6	4.0	1.01	4.0	4.0	7.9	10.1	101	4.0	7.6	9.6	7.9	10.1	1.01	4.0	7.6	9.6	4.0	7.6	9.6	7.9	7.9
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6	10.1	6.0	6.0	1.01	9.7	8.6	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7	10.1	7.6	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	7.9	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.9	10.1
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	5.8	4.7	4.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	7.9	9.7	8.6	6.0	6.0	4.0	4.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9	1.0	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	9.7	6.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	1.01	1.01	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9	7.9	7.6	9.7	8.6	10.1	4.0	4.0	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
		-	4			4																				
	V <sub>wc</sub>	ICS S IIIIII and	TTV IOI SI	avail III COL		oungan		ITA	SCHEMINTLY	allary sis UI	171(10) IM-7	Wind sper	ed data serie	es for simule	tions (m/s)											
Months	( <i>m</i> / <i>s</i> )	Vr ,	Vr,	Vr 3	Vr.4	Vr 5	Vr6	VF.7	$VF_{S}$	Vr o	VF 10	VLII	VF 12	VF 13	VF 14	VLIS	VLIG	VF 17	VT 18	Vr 10	VF 20	Vrai	VF 22	VF 23	VF 24	VF 25
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	10.6	11.7	10.6	10.6	11.7	10.6	10.6	10.6	10.6	10.6	10.6	0.6	10.6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	11.7	8.2	8.9	7.6	7.1	11.5	6.4	9.5	1.5	11.7
March	10.5	10.5	7.1	11.5	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	11.5	11.7	6.1	10.5	1.7	7.1
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	7.1	11.5	8.2	8.2	11.5	7.1	10.5	7.1	11.7	11.5	1.7	7.1	1.5	7.6
May	8.2	8.2	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4	11.5	8.9	6.4	10.5	7.6	11.7	10.5	8.2
June	1.7	7.1	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1	11.5	9.5	6.1	9.5	8.2	11.5	9.5	8.9
July	6.1	6.1	11.5	8.2	8.9	10.5	11.5	9.5	7.1	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9	11.7	10.5	7.6	8.9	8.9	11.5	7.6	9.5
August	6.4	6.4	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2	11.5	6.1	11.5	8.2	8.2	9.5	8.2	1.7	10.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	11.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	7.1	11.5	7.1	9.5	11.5	7.1	10.6	7.1	6.1	9.5	7.1	11.5	6.4	6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	7.1	6.4	11.5	8.2	6.4	11.5	6.4	7.1	11.5	6.4	10.5	7.6	6.4	10.5	6.4	11.5	6.1	8.9	11.5
December	11.5	11.5	6.4	6.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2	11.7	11.5	6.1	11.7	8.9	8.2	11.5
Annual	1.6	9.1	1.6	1.6	9.1	9.1	1.6	1.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	1.6	9.1	9.1	9.1	9.1	9.1	9.1
Table L6 Wind	l speed ser	ies simulation	1s for AEP <sub>c</sub>	avait in Cape	Saint Jame	ss (Canada)	_	with	sensitivity	analysis of	L <sub>wr</sub> (6D12D)	_														
M	Vwc								•			Wind spe	ed data seri	es for simule	tions (m/s)											
SHITHOTAL	(m/s)	yr 1	yr2	yr3	yr 4	yr 5	$yr_6$	yr7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr21	yr 22	yr 23	yr 24	yr 25
January	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	15.4	15.4	15.4	15.4	15.4	16.6	15.4	15.4	14.7	9.7	9.3
Feb mary	14.7	14.7	12.4	9.7	15.1	12.4	12.4	15.1	15.1	9.7	12.4	12.4	10.0	15.1	9.7	13.1	9.7	9.7	9.7	9.7	14.3	15.1	15.1	15.6	0.0	13.1
March	12.7	12.7	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1	10.0	10.0	10.0	10.0	13.8	14.7	14.7	15.3	10.4	12.9
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	15.1	10.4	10.4	13.8	13.3	14.3	14.3	10.4	12.9
May	11.2	11.2	14.3	10.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3	10.4	14.7	10.4	10.4	13.4	13.1	13.1	13.0	1.2	12.3
June	10.4	10.4	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7	11.2	14.3	11.2	11.2	12.8	12.7	12.7	12.7	12.4	12.2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	12.4	13.1	12.4	12.4	12.2	12.3	12.4	12.5	12.7	10.0
August	9.7	9.7	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.0	12.7	12.7	12.7	12.7	11.4	12.1	11.2	11.4	13.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1	12.4	13.1	13.1	11.4	11.7	10.4	10.2	4.3	13.2
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2	15.1	14.3	11.2	10.1	10.4	9.8	14.7	13.5
November	14.3	14.3	10.4	14.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	10.4	15.1	0.01	14.7	11.2	14.7	10.4	14.7	14.7	9.7	10.0	10.0	10.3	1.5.1	13.9
December	15.1	15.1	10.4	14.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	10.4	15.4	9.7	15.1	12.4	15.1	10.4	14.3	15.1	9.0	9.7	9.7	10.1	5.4	16.9
Amual	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5

													k W/yr												
Sites	yr 1	yr 2	yr 3	yr 4	yr5	$yr_{6}$	yr7	$yr_8$	yr 9	$yr_{10}$	$yr_{II}$	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	<i>yr</i> 22	yr 23	yr 24	Ś
Aracari (Brazil)	5 695	5 647	5674	5 629	5 699	5 647	5 694	5 694	5 637	5 641	5 647	5 693	5674	5 637	5 718	5 737	5 690	5 649	5 602	5 698	5 682	5 616	5 628	5 645	56
Corvo Island (Portugal)	10 451 1	) 535 i	.0466	10473	10467	10570	10498	10419	10528	10530	10452	10528	10510	10 504	10 472	10 452	10 517	10 522	10 556	10 569	10 463	10 523	10 531	10 446	10 3
Cape Saint James (Canada)	24 766 2	4852 2	4 932	24738	24788	24852	24738	24738	24932	24788	24852	24794	24738	24 940	24 879	24 940	24 908	24 932	24 940	24 841	24 855	24 738	24 888	24 794	24 8
(																									
L.8 Cashflow for 25 years	of the wind fa	m project	50.0	00 kW	Aracati (]	Brazil)				with sensitiv	ity analysis.	of L <sub>w2</sub> (6D12	(D												
Item	0	-	6	~	4	5	9	2	~	6	10	11	Years 12	13	14	15	16	17 18	8	20	21	22	23	24	25
CCCM <sub>WF</sub>	60 886 3	. 8				'	'												,						
$WT_{CM}$	27 686 ;	. 8/2						'															'	'	
$T_{CM}$	24 219					•	•	'	'	•	•	•												•	
LWTG <sub>CM</sub>	2 617	16																							
TS CM	572 (					'	'	'	'	,												'		'	
SICM	2 136	726						'															'	'	
FU <sub>CM</sub>	96/1	0.0					•																		
CCCou	121	1 8																							
M <sub>WF</sub> (k Wh/yr)		48 8565	19 48 444 3	28 48 676 (	26 48 290 4	03 48 895 03.	2 48 444 328	48 844 48	48 844 485	48356354	48 391 173	48 444 328	48 841 866 4	8 676 026 48	362288 49	053 015 49.	213 265 488	17 403 48 46	3 568 48 05	4765 48883	303 487475	93 481790	78 48 285 24	0 4843072	3 48 356
AAR (SM/yr)		4 297 1	70 43674	56 4498(	63 45739	79 474703	0 4 820 855	4 982 19.	5 106 747	5 182 105	5 315 483	5 454 354	5 636 591	5 757 889	5 863 796 6	096 233 6.	269 053 6.	74 091 6 48	16 088 6 59	2161 6873	465 4918(	060 4982 1	81 5 117 98	8 526174	4 5 385
PPAR		4 297.	170 43674	56 4498(	<b>5</b> 3 45739	79 474703	0 4820855	498219.	5 106 747	5 182 105	5 315 483	5 454 354	5 636 591	5 757 889	5 863 796 t	096 233 6.	269 053 6.	74 091 6 48	86 088 659	2 161 6873	465				
EMP &M ween		3 9493	54 40138	10 4 133 6	 	26 4362211	- 455 206	4 603 527	- 4 717 836	- 4786.683	- 4 909 110	5 036 592	5 204 091	5 315 305 5	- 5412.299 5	626 057 5.		- 206.08	- 3 465 6 080	- 1550 6339	- 49180 243 58466	38 592204	81 5 11/98 96 6 082 75	s 5261/4	4 5.38: 5 6.398
O&M <sub>fixed</sub>		2 6545	80 26979	98 2778t	¥73 28255	74 2 932 47:	5 2 978 079	3 077 74	3 154 685	3 201 236	3 283 628	3 369 415	3 481 990	3 556 919	3 622 342 3	765 928 33	372.685 35	37 571 4 00	V6 755 4 07.	2279 4246	052 43401	55 43967-	40 451658	7 464344	9 4752
$O\&M_{variable}$		1 294	74 13158	(13 1 355 (	018 13777	52 1 429 73.	7 1477127	1 52578	1 563 150	1 585 447	1 625 482	1 667 177	1722 102	1 758 385	1 789 958 1	860 129 1	912 077 19	43 336 1 97	16 710 2 00	8 271 2 093	190 1506	183 15253.	56 1 566 16	5 160938	5 1 646
LRCM		- 863.	268 8848 97 75474	50 9065 or 7 and 0	9296 86 76713	46 952.88	076709 0 2 976709	7 001 12	7 046 55	2 003 376	2 007 707	2 175 227	1 1 32 683 2 7 54 607	1 161 000 2 225 077 - 3	1 190 025 1	219776 504 956 - 24			- 742 N	2,005 2,005	- 40645	- 11661	- 170.20	- 4277.00	1 406
Profit before tax		3 6915	66 37809	90 38773	21/02 000	06 4075 695	6 2 000130 3 4 148 795	4256390	4 363 580	4 469 457	4 582 258	4 698 045	4819 790	4 939 556	5 060 893 5	194 808 4(	776768 41	75474427	6 970 4 38.	0316 4499	645 31355	81 32262	57 330556	2 338599	1 3472
) Revenue tax		1 289 1	51 13102	37 1 349 4	16 13721	94 1 424 105	9 1 446 256	1 494 65	1 532 024	1 554 632	1 594 645	1 636 306	1 690 977	1 727 367	1 759 139 1	828 870 13	380716 15	12 227 1 94	5 827 1 97	7648 2062	040 14754	18 1494.6	54 1 535 39	5 157852	3 1 615
+) REPIM	387 20:	204:	: 1989	1961	1 910	1 898	1847	1 829	1797	1 748	1 720	280	289	296	301	313	322	327 2	333 3	35	3 361	365	375	386	3
$REI_{CM}$	223 70(					1	'	'	1	1	'			,	,	,		,					'	'	
REP CM	162 405	182	0 1 765	173(	1 675	1 654	1 599	1 573	1 535	1 482	1 447														
GHGR CH		221	24	231	235	244	248	256	262	266	273	280	289	296	301	313	322	327 3	33 3	39 35	3 361	365	375	386	36
<sup>9</sup> rofit after tax w/out inte	rest	2 4044	161 24727	42 2 529 5	35 26012	22 2 653 48.	2 2 704 385	276356	2 833 353	2916574	2 989 333	3 062 019	3 1 29 1 02	3 212 486	3 302 056 5	366 251 2	196374 22	63 574 2 33	11 477 2 40	3 006 2 437	959 1 6605	123 1731 94	99 177054	1 180785	7 1857
(-) Debt payments			3210.66(	3 290 92	7 3373200	3 457 530	3 543 968	3 632 568	3 723 382	3 816 466	3 911 878	4 009 675	4 109 917	1 212 665 4	317 981 4	425 931				-					
(+) KCM <sub>WF</sub>		2.021	139 208/2	1961 2 282	55232 40t 28233	06 2892 02	107.006.7 A	304041	5 110 424 2 049 512	3194334	3 2/4 195 2 007 707	2 175 277	3 4.39 949 2 754 607	5 225 0TD 22 5	5 014 090 2	5 /04 448 3	19/ 060 51	91.980 3.9% Prove 3.77	59.280 4.08 14.247 - 2.96	9018 4 191 2705 2065	243 42904 402 40645	50 41661	1021010 10	1 462034	8 4 /42
ree net cashflow	-60 499 .	58 7 5066	81 44918	58 4 599 5	29 47225	56 4 827 84	9 4 933 112	504800	5 174 908	5316668	5 449 430	5 583 618	5713741	5 861 740	5017542 6	149 625 9:	86 116 585	37 849 10 09	5 109 1036	0729 10 594	625 100215	06 103015	56 10 554 37	8 1081129	0 11 086
5 6			0105 0V LL	VIO 72 001 V	401 - 30 178 G	24 24 251 001	579715 PC 2	-2436996.	-19 195 (69	-13 878 391	-8 428 961	245343	2000 2000	9 720 120 1.	X 109 LVL	20. 20.	107 LICEN	21 066 50 41	CLU9 541 7.	5 CM 71 371	EDD 01 2031				A 10414.

Item	0	-	ç	5	4	v	y	L		0	01		Years	3		91	61	81	2	00	10	6	50	24	30
	000000	-	a	2	r	2	>		-		2	-	4							Na 1	4	-	3	5	à
(-) LCCUMWF WTCH	27 686 278																								
$T_{CM}$	24219295		,	,	,		,	,	,	,	,		,	,	,	,									'
$LWTG_{CM}$	2 617 258	,	,						,																
CP <sub>CM</sub>	1 545 346																								
ID CM	2682/0																								
POCH	1 796 870																								
$F_{CH}$	190.628	,	,		,	,					,		,												
CCCCM	121 530	,	,	,	,	,	,		,	,	,	,	,		,	,			,					'	,
LCPM <sub>WF</sub> (kWh/yr)	•	89 657 257	90 377 375 89	0 783 574 8	9 846 976 8	9 792 106 9	0 681 985 90	0.056.935 89	381 970 90	318367 90	339 663 89	668 733 90	18 367 90 1	53 301 90 11	3 636 89 8	7 428 89 668	733 90 220	267 90 26	3 721 90 560	856 90 671	187 897601	46 90 272 7	50 903458	23 89 615 94	89 153 675
(+) AAR $($M/yr)$		14 970 925	15 468 449 15	5750.988 10	5 156 163 1	6549954 I	7 131 821 17	7 439 078 17	741 084 18	375119 18	838 939 19	166 502 19	87 994 20 2	17871 2074	2 636 21 19	6 034 21 685	138 22 36	982 22 93	1122 23 584	858 24 203	932 17 191 8	28 17 722 2	58 181800	19 18 483 97	18 848 346
PPAR	'	14 970 925	15 468 449 15	5 750 988 10	5 156 163 1	6549954 I	7 131 821 17	7 4 3 9 0 7 8 1 7	741 084 18	375119 18	838 939 19	166 502 19	87 994 20 2	17871 2074	2 636 21 19	6 034 21 685	138 22 36	982 22 93	1122 23 584	858 24 203				- 10 101 01	- 10 0 40
1 LOLAN		310 09 0 0	0 0000	1 200 200	1000 600 1	0.266 001 1/	1 0.0017	11 2201100	10 102 001	10 00 200	11 067 101	.01 07000	0 U L L D VO	TO C1 053 03	1056 13 7	1 400 13 667	12 00	014 14 246		CF1 31 00P	C 121 CT 23 2	777/ /1 07	2010101 00	14 14 142 00	040210401
O&M nucl		4 871 475	5 033 364	5 125 299	5 257 138	5 385 273	574 607	5 674 584	772 852	979161 6	130 083 6	236.667 6-	38 894 65	88 533 674	9 523 6 8	7 054 7 056	202 727	091 7 462	2 608 7 674	350 7 875	790 79915	69 8 238 1	35 84505	21 8 592 21	8 761 585
$O \& M_{variable}$	,	4496901	4 646 203 4	1730 927	4 852 484	4 970 618	5 145 234	5 237 372 5	327 931 5	518200 5	657 348 5	755575 51	42 063 6 0	30.016 6.22	8 443 6 30	445 6511	165 6714	1853 6885	5 898 7 081	137 7 2664	366 51631	78 5 322 3	39 54596	72 555081	5 660 095
(+) LRCM		863 268	884850	906 971	929 646	952 887	976709	1 001 127 1	026155 1	051809 1	078 104 1	105 057 1	32 683 11	61 000 119	0 025 1 21	9776									
(+) Depreciation		2476313	2 538 220	5 601 676	2 666 718	2 733 386	801 720	2871763 2	943 557	017146 3	092 575 3	169 889 3	49 137 3 3	30365 341	3 624 3 4	8 9 65 3 586	439 3676	9 100 3 768	3 002 3 862	202 3 958	757 40577	26 4 159 1	70 42631	49 436972	4478971
(=) Profit before tax		8 942 130	9 211 952	1403 409	9 642 905	9 880 336 10	0 190410 10	7400013 10	610013 10	946713 11	222 187 11	449.206 11 -	88 856 12 0	10.687 12.36	8 319 12 6	3276 11704	209 12 048	138 12 35	5619 12691	573 13 0200	033 80048	07 8 3209	53 8 5 3 2 5	74 871067	8 905 636
( -) NEVETILE 10A	199 907	1 4 3 5	1420	1 382	1 355	1 377	1314	0801	1 245	1.235	1 200 100	10011	1 241	770 10040	10 1617	0000 0100	140	1 000	CID 1 1071	107 / 004	2011 2011	0010 0 64	201		100
REI	273 708	-	-		-	-		-		-					- -	3	- t '		; ;					-	5
REP CM		1 325	1 303	1 263	1 233	1 202	1 184	1 147	1111	1 095	1 069	1 035	017	5 166	99	39									,
OREP CH	265 188																								
$GHG.R_{CM}$	1	113	117	119	122	125	130	132	134	139	143	145	150	153 1	57	161 16	4	70 1	74 17	9 18	3 186	192	197	200	204
(=) Profit after tax w/out interest	,	4452291	4 572 837	1679 495	4 797 411	4 9 16 677	5 052 177	5 169 569 5	288 933 5	435411 5	571717 5	700436 51	53 625 59	7470 614	6 651 6 29	5 566 5 198	832 533	113 5 473	3556 5616	294 5 759 (	037 29374	45 3 0044	168 3 0 7 8 7	56 316568	3 251 336
(-) Debt payments	•	•	3 205 264 3	285 395 3	367 530 3	451718 3	538 011 3	626 462 3	717 123 3	10 051 3 9	05 303 4 0	02 935 4 10	3 008 4 20	584 4 310	723 4415	491								1	•
$(+) RCM_{WF}$	1	2 621 739	2 687 282	2754 464	2 823 326	2 893 909	966 257	3 040 413 3	116424 3	194334 3	274 193 3	356.047 3-	39 949 35	25947 361	4 096 3 70	4 448 3 797	090 3 891	986 3 989	0286 4089	018 4 1913	243 42960	24 44034	25 45135	11 4 6 2 6 3 4	4742007
(+) Depreciation		2476313	2 538 220	5 601 676	2 666 718	2 733 386	801720	2 871 763 2	943 557 3	017146 3	092 575 3	169 889 3.	49 137 33	30365 341	3 624 3 45	8965 3586	439 3 670	100 3 768	8 0 02 3 8 62	202 3 958'	757 40577	26 4 159 1	70 42631	49 436972	4 478 971
(=) Free net cashflow	-60 397 866	9 550 342	6 593 076 6	5750.240	5 919 924	7 092 253	7 282 143	7 455 284 7	631.791 7	836841 8	033 182 8	223 437 8.	39.702 8.6	18 198 886	3 648 9 08	0488 12582	331 12.90	199 13 23(	844 13 567	515 13 909 (	038 11 291 1	96 11 567 0	062 11 855 4	25 12 161 76	12 472 314
4. freenet annual cathflow	1001	47C / 49 OC-	21 14	24 40	7- 107 10C C	1- 100 764 0	75 55	- +00+c/ c	26 13 21	76.62	77.03	- TC /HO 0/6	0 0b 650 01-	02 76 76 90 70	N 90 061 7	2000/ 0007	014 05 49,	02 217.06	2 0Z 0TT 0CO 0	2/1 1/2 00 J	F 100 CT 600	30 07 20 27	1 C 1 6 8 C 1 90 8	20 20 21 16	00.05
Table L 10 Cashflow for 25 years of t	he wind farm	project	50 000 kW	ů,	pe Saint Jan	nes (Canada)			wit	n sensitivity	analysis of <i>i</i>	L <sub>w1</sub> (6D12D)													
Item	0	-	2	3	4	5	9	7	8	6	10	=	rears 12	3 1	-	5 16	17	18	61	20	21	13	23	24	25
(-) ICCCM	577 A88 0A	,						,	,					,	,										
WTCH	27 686 278																								
Tat	24219295			,	,			,		,		,	,	,	,									,	
LWTG <sub>CM</sub>	2 617 258	,		,	,		,	,	,	,	,	,	,	,	,	,	,							'	,
$CP_{CM}$	1 545 346	,	,													,			,					,	
TS CM	572 832											,		,	,										
SICM	2 136 726	•	,	,	,	,	,	,	,	,	,	,	,	,	,									,	'
$PO_{CM}$	1 796 870	,	,													,			,					'	
$F_{CM}$	190 628											,		,	,										
CCC CM	121 530		,								,		,		,									'	'
$LCPM_{WF}$ ( $kWh/yr$ )	'	212 467 325	213 202 961 2	13 887 985 2	12 223 670 2	12 655 974 2	13 202 961 2	12 223 670 21	2 223 670 2	3 887 985 21	655 974 21	3 202 961 212	704 429 212	23 670 213 9.	59 139 2134	37.670 213.93	0 139 213 67	8 613 213 88	7 985 213 959	139 213 109	827 213 228 5	530 212 223 6	670 213 512	14 212 704 42	213 419 415
(+) AAR(SM/yr)		30 129 143	30 989 297 31	866 088 3	2 408 583 3	3 286 465 3	1 206 386 3	1900500 35	773 012 36	954 893 37	660 580 38	701386 39	76 163 40 4	73 880 41 82	4 978 42 70	6117 43 942	368 44 98	873 46 15	597 47 321	124 48 311 0	514 34 682 8	91 35 382 4	31 364872	17 37 257 87	38 317 694
PPAR		30129143	30 989 297 31	800 088 3	2 408 583 3	3 286 465 3	1 206 386 3	1900.500 32	773.012 36	954 893 37	660 580 38	701 386 39	76 163 40 4	3880 4182	4 978 42 70	6117 43 942	368 44 98	873 46 15	597 47 321	124 48 311 6	514 -			-	-
EMP		- 20 588 655	- 100 21 10	- 10C 3LL 1	- 145.851 2	- 745 580 7	- 050702	- 306 378 5	- 336.04				- 20 CP		- 20 20 2	- 30.024	- 20.73	- 354 31 537	- 37 333		- 54 050 - 55 050 - 55 00 - 55 050 - 55 00 - 55 00 - 55 00 - 55 00 - 55 00 - 55 00 - 55 00 - 55 00 - 55 00 - 55	5 780 0C 87	2/04/02 10	12/02/22/2 10	B9L 7L 7 CC
D&M		11 544 288	1 873 850 1	1 208 602 0	1 059117	1 000 051 0	1 106.491	3372.441 15	706746 14	159587 14	420 071 14	21 824 878	5 51 606 E9	77.890 16.02	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	16831 9919	849 1773	137 17 68	3319 18131	18 510	18984 7	1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	917991 33	15 2039371	20 973 811
O&M	,	9 044 366	9 302 432	565 487	261 822 6	9 991 568 10	0 267 558 10	0475767 10	737 520 11	092.129_11	303 802 11	616.058 113	78 478 12 1	17781 12.55	3 156 12 8	5484 13188	373 13 500	217 13 851	140 14 202	000 14 499	125 104105	11 10 6203	46 10 951 5	34 11182.99	11 500 957
(+) LRCM	,	863 268	884850	906 971	929 646	952 887	976709	1 001 127 1	026155 1	051809 1	078 104 1	105 057 1	32 683 11	51 000 119	0 025 1 21	9776									
(+) Depreciation		2 458 034	2 519 484	2582 471	2 647 033	2 713 209	2 781 039	2 850 565 2	921 829 2	994875 3	069 747 3	146 491 3.3	25 153 33	5782 338	8 426 3 47	3137 3555	965 3648	965 3740	189 3833	693 3 929	536 40277	74 4 128 4	68 42316	80 433747	4445909
(=) Profit before tax	•	12 861 791	13 217 341 13	3 580 240 I	3 839 411 1	4 206 972 1	1 590.084 1-	4 903 984 15	276730 15	749 861 16	074 658 16	508117 163	91 591 17 2	34 990 17 82	4 705 18 2	7379 17477	111 17 895	483 18 357	7327 18821	392 19 231 (	93158	87 95233	87 97952	08 1001864	10 288 835
(-) Revenue tax	1	9 038 743	9 296789	559 826	9 722 575	9 985 940 10	261916 10	0470150 10	731 904 11	086468 11	298 174 11	610416 113	72 849 12 1	12164 1254	7 493 12 8	9835 13182	710 13 49	562 13 845	5479 14196	337 14 493	484 10 404 8	67 10 6147	29 10 9461	83 1117736	11 495 308
(+) REPIM	934 726	<i>LLL</i>	162	806	812	827	843	853	868	890	901	197	815	834 8	62	881 90	5 9	27 9.	51 97	5	5 1 021	1 041	1 074	1 096	1128
$REI_{CM}$	223 708										,														
$REP_{CM}$	•	156	153	150	145	142	138	134	131	129	125					,								1	•
$OREP_{CM}$	711 018		,								,		,												'
$GHG.R_{CM}$		621	638	656	668	686	205	719	737	761	776	197	815	834 8	62	881 90	5 9	27 9.	51 97	566	5 1 021	1 041	1 074	1 096	1128
(=) Profit after tax w/out interest		3 823 824	3 921 343	1021 220	4 117 649	4 221 859	329 012	4434687 4	545 695 4	6642834	777 385 4	898 498 51	19 557 51	13 660 5 27	8 073 5 4(	8425 4295	306 440	848 4512	2798 4626	030 4738	504 -1 087 9	60 -1 0903	01 -1 149 5	02 -115762	-1 205 346
(-) Debt payments	'	•	3 181 604 3	261144 3	342 673 3	426 239 3	511 895 3	599 693 3	589 685 3	81 927 38	76475 39	73 387 4 0	2 7 2 2 4 1 7	540 4 278	904 4385	876									'
$(+) RCM_{WF}$		2 621 739	2 687 282	2754 464	2 823 326	2 893 909	2 966 257	3 040 413 3	116424	194334 3	274 193 3	356047 3-	39,949 35	25947 361	4096 374	4 448 3 797	000 389	986 3989	0.286 4.089	018 4 191	243 42960	24 44034	125 45135	11 4 626 34	4742.007
(+) Depreciation	20,057,027	2 458 034	2 519 484 5 5 046 506	1/4 282 2/1	2 047 035	607.517.7	6.018/.2	2 000 0082	2 628 126	9948/5 3	744 840 7	146 491 31	25 551 53 9 2 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	0000 0700	8420 34	313/ 3235	321 11 0.4	200 12 24(	0189 3833	2020 5 5 660	0.30 402/1	74 41284	08 42310 02 75057	50 433/4/	1000 24445 5005
(=) Free net cashpow $\Sigma$ from a number of the second conditions	10070660-	- 048 440 - 51 048	- 000 0446 C	004 923 -3	CCC CH7 C	0 402/2040	204412	- CIVC21C	172 201	/ 0011/0 809365 8	244 849 7	42/049 / 1	83 800 30 9	NJ 849 38 98	1 092 0 47 18 6 342 47 18	0 154 11 058 838 6 476 58 838	807 7078	605 83 023	8878 95572	/41 12 007. 619 108 432	002 115 667 8	39 / 441 123 109 /	20701 561 561	23 138 510 22	1 146 493 495
🛥 preenes annuas casagram	1001	0100	10 101 101 0		- 100 00 -			0.000 00 00	10 M	077 JUL 0					10 10 10		20 10				0.4.50	00.30	10.00	02.00	01 00
	LCOE was	84.90	85.64	86.32	86.79	87.48	88.20	88.78	89.47	90.38	90.97	01.79	2.50 %	.23 94.	27 %	.03 94.)	.c6 L	51 90.	41 97.5	1 98.03	86.84 0	92.28	75.04	97.09	98.10

### APPENDIX M

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend							_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{cm})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[S/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information		Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI CM	69.0930	[\$/kW_c]	WF CM		50 000	[kWo/yr]
Project Location	Aracati (Brazil)		$Depr_{WT_{inst}}$	76.9840	[\$/kW]	RM wT	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cup		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	$N_{WT}$		25	[-]
Number of Wind Turbines (N <sub>WT</sub> )	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	$N_{WT}$	25	[-]	ifr	2.50%	[%/yr]	WTrated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	M <sub>14mar</sub>	100	[m-h]	$\psi_{solid}$	25.00%	[%]	N rew		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	C Miranar	85.00	[\$/m-h]	<i>n</i> ,	5	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>r<sub>sc</sub></sub>	60.1398	[\$/kW]	D N Maring	3		REP CM	0.00002484	[\$/kWeh]	D I		90.0	[m]
Swept Area per Turbine (A)	0.301.7	[m <sup>*</sup> ]	Y <sub>RC</sub>	0.000022	[yr]	C .	2.00	[0] (\$/4)	ALP anail/ II prod	2 50%	[KW/yr]			2 420	[m]
Wind sneed measured at (Ha)	100.0	[111]	TI TI	1 798 743	[3/KW] [5/FW]	PM	2 300.00	[3/0] [5/FW]	ljr C	0.1415	[%/yi] [\$/vW h]	SD SD		2430	[11]
Terrain measured at (118)	0.14	[m] [_]	<i>n v</i>	237 699 000	[3/KW] [//W]	KM CT WF	50,000	[3/KW]	е 5-	0.1415	[\$/VW h]	SD		400 540	[11]
Betz Limit's coefficient (Caras)	0.5926	[-]	V.	6 100 000	[kW]	N wr	25	[_]	n_	12	[ork(rrpit]	FIH.d		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[vr]	C 0	1 457.72	[S/kW]	M	3.0	[m-h]	OREP CH	20.7491	[\$/kW_]	PC nu			(
Production Efficiency (WF PE)	11.2%	[%]	PR	0.70	[-]	C <sub>M00-</sub>	85.00	[\$/m-h]	LCCCM <sub>WFormer</sub>	4.3886	[\$/kW]	AEP mail		48 856 319	[kW_h/yr]
Availability	97.9%	[%]	b	-1.94	[-]	N <sub>m</sub>	3	[-] ·	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{uuu}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443	\$/kW1	$D_m$	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{mer}$		25.00%	[%]
						C <sub>nd</sub>	3 500.00	[\$/d]	$\varphi_{\text{solut}}$	25.0%	[%]	P&DIM	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
WTCH	553.7256	[\$/kW]	O&M find	0.098275	\$/kWh]	WFcm	50 000	[kW]	n	12	[yr]	A		6 361.7	[m <sup>2</sup> ]
CM WT	265.32	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	NWT	25	[-]	CR	60.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	$[m^2/wt]$	GHG.R CM	2 427.4170	[\$/tCO2]	P&D <sub>LM</sub>			
$C_{kW}$	400.00	[\$/kW]	LLC	0.0530 [3	\$/kWh]	MARTAN	3.0	[m-h]	$LCER_{CO_2}$	31.4	[tCO2/MW2h]	λ <sub>a</sub>		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mhr_{SARY}}$	85.00	[\$/m-h]	$\sum AEP_{avail} \sum_{r_1, r_2, r_3}$	48 856	[MW <sub>e</sub> h]	λ		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m sam</sub>	3	[-]	n "	25	[yr]	Âd		5.00%	[%]
Tmarr	138 000	[kg]	O&M <sub>variable cu</sub>	0.025858	\$/kWh]	D <sub>m<sub>saw</sub></sub>	3.0	[d]	GHG <sub>IM F co<sub>1</sub></sub>	0.00069	[tCO2/MW2h]	λm		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	$GHG_{EM_{unit}CO_1}$	0.00005	[tCO2/MWah]	LCPM WF		48 856 319	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	$RVM_{WF}$	61.0184	[\$/kW]	Ec	41.7438	[\$/tCO2]				
LWTG <sub>CM</sub>	39.1957	[\$/m/kW]	R <sub>barnes</sub>	30.00%	[%]	N <sub>WT</sub>	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	ring		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS $_{VM}$	1.4442	[\$/kW]	$\zeta_1 REI_{CM}$	50.0%	[%]	Debt ratio		50.0%	[%]
Lg	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\tilde{\zeta}_2 REP_{CM}$	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n mih	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 OREP_{CM}$	25.0%	[%]	Debt gr	ice period	1	[yr]
CP CM	30.9069	[S/kW]	n <sub>ifh</sub>	113	[h]	N	25	[yr]	$\zeta_4 GHG.R_{CM}$	0.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	4 192 361	[SM]	WTweight	200 000	[kg]	REPIM	39.7338	[\$/proj]	Debt value		29 551 437	[\$]
5	0.08%	[%]	AEP arail	48 856 319 k	Wh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	2 985 403	[\$/yr]
TS CM	11.4566	[\$/kW <sub>e</sub> ]	O&M WFCM	0.124133 (\$	&Wh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	·	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 551 437	[\$]
TL <sub>r</sub>	1 200	[1/kW]	O&M manag(STD)	1	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
L <sub>1</sub>	3 000	[m]	SC OLM	0.000105 [5	5/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[\$/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]		1		Initial Results	Summary	of LCOE wso	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE with		Notes	67.6603	yr1	70.7762	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			67.8118	$yr_2$	69.8077	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000287 [5	5/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	68.0210	yr3	69.9988	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	68.1822	$yr_4$	70.1987	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5 [	per yr]	February <sup>(*)</sup>	672	639	REPIM			68.4349	$yr_5$	70.3955	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution			68.6241	$yr_6$	70.7564	yr 19
FS	19.88	[S/KW]	riours required	112.5	[h]	April	720	/11	ζ <sub>1</sub> KEI <sub>CM</sub>	1	[1/0]	68.8710	yr 🤊	70.3686	yr 20
DT	87.22	[S/KW]	SC O&M+USC O&M	184.5 [	n/yrj	May (*)	/44	735	ζ <sub>2</sub> KEP <sub>CM</sub>	1	[1/0]	69.0863	yr <sub>8</sub>	70.5514	yr 21
EG	404.52	[\$/kW]		0.000392 [\$	¢₩h/yr]	June	720	687	$\zeta_3 OREP_{CM}$	1	[1/0]	69.2587	yr 9	70.8222	yr 22
F CM	3.7712	[\$/kW]		-		July	744	735	54 GHG.R CM	1	[1/0]	69.4873	yr 10	71.1051	yr 23
WACC proj	4.900%	[%/yr]				August	744	735	reD <sub>LM</sub>	1	(1/0)	69.7236 70.0025	yr 11	71.3664	yr 25 Mann
n <sub>fin</sub>	0.20%	[yr] [96]				September October	720	735	×	0	[1/0]	70.0026	yr 12	1.0822	mean SD
WF <sub>CH</sub>	2,4042	[30]				November <sup>(*)</sup>	720	687	2.	1	[1/0]	70.4423	yr 13 Nr 14	-0.4514	Y (sheaners)
ĸ	0,20%	[%]				December	744	735	2_	1	[1/0]	10.4423	69,6792	US\$/MWb	valid !
LCCCM <sub>wr</sub>	1 204 5180	[\$/kW]				Total [h/wr]	8 760	8 579	·· m	p.s.: 1 = yes a	1d 0=no	LCOE was	0.069670	IS\$/kWh	
Inter Com WF	1 204.0200	[	L			Cilleria da filma harra da	0,00	5517	L	,		L	0.0070/9		

**Figure M.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $E_{pi}(Case_{1})$ . Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
						WELE B 10				c 14 14		W-10	C		
Wind Project Information	Elector Wind Low	Notes	Levenzea Kepiacement	Lost Model	votes	DCM	1 220 0154	Notes	Renewable Energy Public In	centive Model	Notes	wina Farm Lije	<ul> <li>Cycle Frod</li> </ul>	so ooo	Notes
Project Location	Corvo Island (Portugal)		Deprov	76 9840	5/kW] 5/kW]	DCM <sub>WF</sub> RM <sub>wT</sub>	22 3284	[\$/kW] [\$/kW]	ICCCM we	1 204 5180	[5/KW]	WF CM		50.000	[KW Jyr]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	\$/kW]	WF com	50 000	[kW]	LRCM	16.8443	[\$/kW]	N <sub>WT</sub>		25	[-]
Number of Wind Turbines (NWT)	25	[-]	T <sub>CM</sub>	484.3859	\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	[yr]	$M_{hr_{max}}$	100	[m-h]	$\Psi_{hotal}$	25.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	$C_{Mhr_{EM_{WT}}}$	85.00	[\$/m-h]	n <sub>v</sub>	5	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	\$/kW]	N <sub>nmur</sub>	3	[-]	REP CM	0.0000983	[\$/kW_eh]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	D <sub>m<sub>stoper</sub></sub>	2.0	[d]	AEP anail/H prod	10 451	[kW/yr]			1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	\$/kW]	C mf migr	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Tampin magnitum factor $(\pi)$	10.0	[m]	Π	1 /98 /43	(\$/KW]	RM cr	20.1954	[\$/KW]	E C	0.102/	[\$/KW_h]	SD		450	[m]
Betz Limit's coefficient (Cas. )	0.5926	[-]	V V	5 100 000	[KW] [FW]	WP cap N mm	25	[-]	n	0.007.500	[3/KW dl]	FIH (		8 760	[hij]
Lifetime of Wind Farm(N)	25	[vr]	v 0 C 0	1 457.72	S/kW1	M <sub>w</sub>	3.0	[m-h]	OREP	33.6547	[\$/kW_]	PC RM		0 100	[10] [1]
Production Efficiency (WF PF)	20.5%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[\$/m-h]	LCCCM	3.8789	[\$/kW]	AEP avail		89 657 257	[kW_h/yr]
Aváilability	97.9%	[%]	Ь	-1.94	[-]	N	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{max}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443 [	\$/kW]	D <sub>m</sub> <sub>BMC</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{out}}$		25.00%	[%]
						C <sub>nd</sub> ma	3 500.00	[\$/d]	$\Psi_{astal}$	25.0%	[%]	$P\&D_{LM}$	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost 1	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>faul</sub>	0.098275	\$/kWh]	WF cap	50 000	[kW]	n ,,	17	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180	\$/kW]	NWT	25	[-]	$CR_f$	60.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	1 248.5415	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530 [	\$/kWh]	M <sub>br surr</sub>	3.0	[m-h]	$\sum_{A \in P} A \in P$	57.6	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMbr <sub>sanv</sub>	85.00	[\$/m-h]	Z PER and Proven	89.657	[MW <sub>e</sub> h]	A		0.00%	[%]
T <sub>CM</sub>	484.3839	[5/KW]	ogen	0.048935	[%/yr] \$/WWh1	D N <sub>m</sub> <sub>un</sub>	30	[-]	n, GHG	0.00059	[yr]	2		5.00%	[%]
PC =	26 30%	[%5]	MIC MIC	71 5608	(\$/5)	C .	3 500.00	[6]	GHG	0.00005	ICO-MW-M	ICPM		89 657 257	[w]
Canal	0.1900	[%/\$rkfr]	TIC	124 5688	[5/h]	RVM w.s	61 0184	[S/kW]	E EM WILL COL	11 7000	[\$/tCO <sub>2</sub> ]	Der m wr		07 007 207	[k (( fa ) f )
LWTG cu	39,1957	[\$/m/kW]	R	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	ring	Г	Notes
WF	50 000	IkW1	ifr	2.50%	%/vrl	WTS vu	1.4442	[\$/kW]	ζ, RELOV	50.0%	[%]	Debt ratio		50.0%	[%]
L	13 950	[m]	Ň	25	[yr]	WF car	50 000	[kW]	$\xi$ , REP <sub>CM</sub>	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mlh</sub>	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n rih	113	[h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	0.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	14 605 780	[\$M]	WTweight	200 000	[kg]	REPIM	42.9602	[\$/proj]	Debt value		29 470 778	[\$]
ç	0.08%	[%]	AEP anail	89 657 257	Wh/yr]	C <sub>steel</sub>	0.1900	[\$/kg]				Debt pa	yments	2 977 255	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.147210 (\$	&Wh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	2	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 470 778	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000057 [	k/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]			,	
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	73.0793	yr i	78.4116	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			73.4776	$yr_2$	77.5903	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000156	s/kWhj	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	73.7436	yr 3	78.1098	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	74.0885	$yr_4$	78.5637	yr 17
Bld area	300.0	[m*]	Frequency	1.5	per yrj	February'	6/2	639	REFIN			74.4286	yr <sub>5</sub>	79.0704	yr 18
FC CM	35.9374	[\$/KW] (\$/14W)	Repair time	112.5	[n] (b)	March	744	735	EFIM distribution		[1/0]	74.8887	yr <sub>6</sub>	79.3398	yr 19
DT IS	19.88 87.77	[5/kW]	SC or u+USC or ··	184.5	h/vrl	Max	744	735	E REP au	1	[1/0]	75.4693	yr 7	78 1898	yr 20 Yf ai
FG	404 57	[\$/kW]	DEM COCOEM	0.000214	wWh/wr	June <sup>(*)</sup>	720	687	Č, OREP.CH		[1/0]	75 9694	77 8 NT 0	78 6500	37 21 NT 22
EG	3 7712	[\$/kW]		0.000214 [*		July	744	735	Š. GHG R.cv		[1/0]	76 3655	yr 10	78 9953	37 22 VE 23
WACC mai	4,900%	[%/vr]		Г		August	744	735	P&D <sub>IM</sub>		[1,0]	76.6792	yr II	79,3896	VT 25
n fin	1.0	[yr]				September	720	711	λa	1	[1/0]	77.1795	yr 12	76.8138	Mean
WFree	0.30%	[%]				October	744	735	$\lambda_{sdi}$	0	[1/0]	77.5814	yr 13	2.0085	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	78.0080	yr 14	-0.4651	Y (skewness)
ĸ	0.20%	[%]				December	744	735	λ.,,	1	[1/0]	LCOF	76.8138	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]	L			Total [h/yr]	8 760	8 579		p.s.: 1 = yes as	nd 0=no	w1a	0.076814	US\$/kWh	

**Figure M.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $E_{pi}$  (*Case* 1). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns N	otes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{cos})$	80.00%	%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
						WELE B 10				e 14 14		W-10	C I. B		
Wind Project Information	Finance Wind From	Notes	Levenzea Kepiacement	Lost Model N	otes	DCM	1 220 0154	Notes	Renewable Energy Public In	centive Model	Notes	WE	•Cycle Frod	so.000	Notes
Project Location	Cape Saint James (Canada)		Deprov	76 9840 [S	kW]	DCM <sub>WF</sub> RM <sub>wT</sub>	22 3284	[5/kW] [5/kW]	LCCCM we	1 204 5180	[5/kW]	WF CM		50.000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256 [\$	kW]	WF com	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859 [\$	kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	yr]	$M_{hr_{max}}$	100	[m-h]	$\Psi_{astal}$	25.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50% [9	/yr]	$C_{Mhr_{Edyr}}$	85.00	[\$/m-h]	n ,,	5	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398 [\$	kW]	N <sub>nmur</sub>	3	[-]	REP CM	0.00000049	[\$/kW <sub>e</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	yr]	D <sub>m<sub>stoper</sub></sub>	2.0	[d]	AEP anail/H prod	24 766	[kW/yr]			1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033 [\$	kW]	C mf migr	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Tampin magnitum factor $(\pi)$	10.0	[m]	Π	1 /98 /43 [5	KW J	RM cr	20.1954	[S/KW]	E	0.0121	[\$/kW_h]	SD		450	[m]
Betz Limit's coefficient (Cas. )	0.5926	[-]	V V	5 100 000 B	-w] -w]	WP cap N mm	25	[_]	n	0.003558	[3/K// ell]	EIH (		8 760	[hij]
Lifetime of Wind Farm(N)	25	[vr]	v 0 C 0	1 457.72 [\$	kW1	M <sub>w</sub>	3.0	[m-h]	OREP CH	90,2343	[\$/kW_]	PC BM		0100	[17]
Production Efficiency (WF PF)	48.5%	[%]	PR	0.70	-1	C <sub>Mm</sub>	85.00	[\$/m-h]	LCCCM	4.3886	[\$/kW]	AEP avail		212 467 325	[kW_h/yr]
Aváilability	97.9%	[%]	Ь	-1.94	-1	N <sub>mmm</sub>	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{max}$		20.35%	[%]
	357	[d/yr]	LRCM	16.8443 [\$/	kW]	D <sub>m</sub> <sub>max</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{out}}$		25.00%	[%]
						C <sub>sed story</sub>	3 500.00	[\$/d]	$\Psi_{astal}$	25.0%	[%]	P&D <sub>LM</sub>	factor	0.814145	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost 1	Model N	otes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>faul</sub>	0.098275 [\$/	(Wh]	WF cap	50 000	[kW]	n "	12	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180 [\$	kW]	NWT	25	[-]	CRf	60.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.000001%	%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	6 827.9067	[\$/tCO <sub>2</sub> ]	P&D <sub>IM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530 [\$/	(Wh]	M <sub>br surr</sub>	3.0	[m-h]	$\sum_{AEP} AEP$	136.4	[tCO2/MWah]	2		7.00%	[%]
IPT	10.00%	[%]	N	25	yr]	CMbr <sub>sanv</sub>	85.00	[S/m-h]	Z rand wat where we	212 46/	[MW <sub>e</sub> h]	A		3.00%	[%]
T <sub>CM</sub>	484.3839	[5/KW]	ogen	0.041531 [5/	whi	D N <sub>m</sub> <sub>un</sub>	30	[-]	n, GHG	0.00059	[yr]	2		5.00%	[%]
PC =	26 30%	[%5]	MIC MIC	71 5608	стиј (љ.)	C .	3 500.00	[u] [\$/d]	GHG	0.00005	ICO AW N	ICPM		212 467 325	[/w]
C	0.1900	[%/3/KW]	TIC	124 5688	501 5751	PVM min	61.0184	[3/4] [\$/JW]	C C C C C C C C C C C C C C C C C C C	27,0000	[8/(CO <sub>2</sub> )	LCI M WF		212 407 525	[K W du yi ]
LWTG cu	39,1957	[\$/m/kW]	R	30.00%	%1	Nwr	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cinø	Г	Notes
WF	50 000	IkW1	ifr	2.50% [9	/vrl	WTS vu	1.4442	[\$/kW]	ξ, RELOU	50.0%	[%]	Debt ratio		50.0%	[%]
L	13 950	[m]	Ň	25 [	yr]	WF car	50 000	[kW]	$\xi$ , REP CM	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mlh</sub>	72	h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n rih	113	h]	N	25	[yr]	$\xi_4 GHG.R_{CM}$	0.0%	[%]	Debt in	terest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	29 394 286 [5	5M]	WTweight	200 000	[kg]	REPIM	57.1051	[\$/proj]	Debt value		29 117 155	[\$]
ç	0.08%	[%]	AEP anail	212 467 325 [kV	/h/yr]	C <sub>steel</sub>	0.1900	[S/kg]				Debt pa	yments	2 941 531	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139806 [\$A	Wh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	o	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	ralue	29 117 155	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)	N	otes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	it rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000024 [\$/	Wh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	84.2996	yr1	94.3718	yr 15
WF cap	50 000	[kW]	Hours required	72.0	h]				O&M WFCM			84.9743	$yr_2$	94.0482	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000066 [\$/	Whj	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	85.6626	yr 3	94.8532	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	-1	January	744	738	(%) ccm	80.0%	[%]	86.1247	$yr_4$	95.7496	yr 17
Bid area	300.0	[m*]	r requency Paraia time	1.5 [pi	r yr]	rebruary'''	6/2	639	REATM REDIM distributio			86.8183	yr <sub>5</sub>	96.6483	yr 18
FS FS	35.9374	[5/KW] [5/FW]	Hours required	112.5	n] b]	Anril	744	735	REFIM distribution	1	[1/0]	87.3429	yr <sub>6</sub>	97.4272	yr 19
DT	19.88 87.77	[5/kW]	SC or u+USC or ··	184.5 /h		Max	744	735	REP out	1	[1/0]	88.8127	37.7 XF.o	94.6168	37 20 NT 41
FG	404 52	[5/kW]	SC O&MTOSC O&M	0 00000 154	Wh/wrl	Jung <sup>(*)</sup>	720	687	OREP CH	1	[1/0]	89 7238	37.8 XF.0	95.6632	37 21
Fou	3 7712	[\$/kW]		0.000030 [#k		July	744	735	GHG R cy		[1/0]	90 3120	VE 10	96.4289	37 22 VE 23
WACC arei	4.900%	[%/yr]				August	744	735	P&D <sub>IM</sub>		[1/0]	91.1318	yr 11	97.4427	yr 25
n fin	1.0	[yr]				September	720	711	λe	1	[1/0]	91.8409	yr 12	91.7081	Mean
W <sub>F<sub>CM</sub></sub>	0.30%	[%]				October	744	735	$\lambda_{sdi}$	1	[1/0]	92.5685	yr 13	4.1890	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	93.6087	yr 14	-0.3343	Y (skewness)
ĸ	0.20%	[%]				December	744	735	λ.,.	1	[1/0]	LCOE	91.7081	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]	L			Total [h/yr]	8 760	8 579		p.s.: 1= yes at	nd 0=no		0.091708	US\$/kWh	

**Figure M.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $E_{pi}(Case_{1})$ . Source: Own elaboration

Table M.1 Ene	rgy produci	tion (AEP <sub>av</sub>	uit) map of the	s wind fan	m for Aracs	tti (Brazil)		wit	h sensitivi	ty analysis	of $E_{pi}(Ca$	(I a)																
Months	V wc	Η	prod												AE	P avail(k Wh,	~											
	(m/s) (k,	g/m <sup>3</sup> ) (	(h) yr1	yr	2 y.	r3 >>	r4 .	yr 5	$yr_6$	yr 7	$yr_8$	$yr_9$	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	Yr 24	yr 25
, January	5.8	1.1665	738 16931.	32 8 890	198 380.	2165 756	7410 55	57361 8.	; 861.068	\$57 361	557361	(232 212	8 890 198	8 890 198	557361	3 802 165	7 507 410	4 232 212	8 890 198	8 890 198	557361	3 802 165	7 507 410	557361	3 802 165	7 507 410	4 232 212	4 232 212
February	4.9	1.1666	639 847 94	40 6783	520 366.	2567 678	3 520 77	77316 6.	783 520 3	777 316	777 316 .	(713419 (	6 783 520	6 783 520	777 316	3 662 567	6 783 520	482 342	482 342	3 290 403	4 713 419	7 693 599	1 572 412	I 572 412	7 693 599	6 783 520	4713419	4 713 419
March	4.0	1.1671	735 555 05	90 7476	817 5 42	4310 885	3 970 97	75 829 7.	476 817 5	175 829	975 829	543 367	7 476 817	7 476 817	975 829	5 424 310	8 853 970	894 553	894 553	1 809 568	4 214 966	1 809 568	1 686 232	I 686 232	7 806 630	8 853 970	3 786 671	6 543 367
April	4.7	1.1667	711 865 05	98 6327	908 632.	7908 407	6176 16	30 708 6.	327 908 1	630 708	630 708	7 230 621 (	6 327 908	6 327 908	1 749 983	6 327 908 .	4 076 176	943 697	943 697	1 630 708	6 327 908	1 630 708	3 661 984	943 697	7 230 621	6 327 908	1 749 983	7 230 621
May	6.0	1.1670	735 180950	00 5 424	109 7470	5539 542	4109 18	09 500 5.	424 109 1	809 500	809 500	806 340	5 424 109	5 424 109	1 686 169	7 476 539 6	6 543 124	1 686 169	1 686 169	975792	8 853 641	975 792	555 069	894 520	6 543 124	4 214 809	1 686 169	7 806 340
June	7.9	1.1686	687 3 944 90	04 3 944	904 730	5444 612	4120 35	14 021 31	344 904 3	544 051	244 051	1 286 679	3 944 904	3 944 904	3 544 051	7 306 444	5 076 764	1 693 625	1 693 625	837237	7 306 444	837 237	837 237	3 544 051	5 076 764	5 076 764	913 305	8 286 679
Inte	86	1608	735 543703	70 3 7 05	580 8.87	1801 160	9100 42	24 882 3	705 580 4	224 882 4	(224 882	556 306	556 306	3 705 580	5 437 072	8 874 801	1 813 825	3 705 580	3 705 580	556 306	7 404 407	556 306	978 125	4 224 882	4 224 882	001 009 1	806658	256 306
Anous	9.0	1677	735 748060	01 1810	181 905	181 9050	1506 88	2 195 85	5 905078	200 LT	201 207 -	210 208	805017	1 810 506	151 210 5	905 018 1	1 687 106	5477123	7 810 678	7 810678	805 017	121 717 4	7810.678	200 144 1	1 810 506	1 810 506	555 378	805 017
Cantandar	1.01	1657	111 0 55 Y	0091 10	101 921	397 9210	0 5 4 3 2 5	t toror	9 921 0CS	690106	00100	013 640	018 670	921 009 1	6 20 1 06 2	921.069.1	2 650 542	201023	2112 010	0100101	018 670	122 086 3	FOC F35 0	6 201 062	9210091	2 650 542	6 201 063	013 670
Januardac		2011	-C #CC 0 11/	670 1 10	701 0/1.	20 0 0/16	0.40 (40 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1 704.74	0 0/1670	06 170	CD6 17C 0	010 746	010746	0/1 670 1	COK 17C 0	0/1 670 1	0.00 040 C	CD6 17C 0	070 077 /	070 077 /	010 746	1// 047 0	#0C #CC 0	201 077 2	0/1 670 1	C#C 0C0 C	COK 17C 0	010 746
October		C#01.1	7 68/ / CC/	5/6 ID	5/6 DCO	.00 000	4/ ICS 5	6 071.00	/ 000 5/	. 071 004	CT 004 /	082 40/	1 082 40/	000 5/6	8 854 205	000 5/6	100 500	/ 400 12	66/ 870 0	60/ 870 0	87C CN8 1	66/ 876 0	4 200 000	(21 004 /	000 5/6	000 5/6	8 854 205	1 082 40/
November	9.2	1.1638	687 60989.	39 833	795 835	795 83.	\$ 795 66	08 939 8	33 795 7	276 401	7 276 401	686 661	1 686 661	833 795	7 276 401	833 795	833 795	7 276 401	5 055 889	5 055 889	1 571 703	6 968 989	6 098 939	7 276 401	833 795	833 795	7 276 401	1 686 661
December	7.6	1.1651	735 37803.	65 554	166 554	166 97.	1204 54	115 277 5	54166 8	839 226	8 839 226	3 780 365	3 780 365	554 166	7 464 366	554 166	974 204	8 839 226	4 207 946	4 207 946	3 780 365	7 793 630	5 415 277	8 839 226	554 166	554 166	7 464 366	3 780 365
Annual	7.4	1.1666	8 579 48 856 3	19 48 44.	4 328 48 6;	76 026 48 2	90 403 48.	895 032 48	3 444 328 4	8 844 485	48 844 485	48 356 354	48 391 173	48 444 328	48 841 866	48 676 026	48 362 288	49 053 015	49 213 265	48 817 403	48 463 568	48 054 765	48 883 303	48 747 993	48 179 078	48 285 240	48 430 728	48 356 354
Table M.3 Ent	rgy produc	tion map of	the wind farm.	for Cape 5	Saint James	(Canada)		wi	th sensitivi	ity analysis	of $E_{pi}(Ca$	(1 as																
Months	$V_{HC}$	H	prod												AE	P avail(k Wh.	~											
CHING BAT	(m/s) (k,	g/m <sup>3</sup> ) (	(h) yr1	yr	2 y.	r3 >>	r4 .	yr 5	$yr_6$	$yr_7$	$yr_8$	$yr_{g}$	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	$yr_{18}$	yr 19	yr 20	yr 21	yr 22	yr 23	Yr 24	yr 25
January	15.4	1.2561	738 32 734.	798 32 73	14 798 32 7	34 798 32	734 798 32	2 734 798 3.	2 734 798	32 734 798	32 734 798	32 734 798	32 734 798	32 734 798	8013494	32 734 798	32 734 798	32 734 798	32 734 798	32 734 798	32 734 798	32 734 798	40 754 809	32 734 798	32 734 798	28 019 994	8 013 494	7 100 933
February	14.7	1.2522	639 24 248 t	099 14 46	57 424 6 91	2 583 26	28 520 14	(467 424 I.	4 467 424	26 228 520	26 228 520	6 912 583	14 467 424	14 467 424	7749925	26 228 520	6 912 583	17 377 262	6 912 583	6 912 583	6 912 585	6912583	22 462 574	1 26 228 520	26 228 520	28 959 584	7 749 925	17 351 256
March	12.7	1.2495	735 18 226 :	532 18 22	6 532 8 89	¥6 263 27 8	34 779 12	376 594 1.	8 226 532	27 834 779	27 834 779	8 896 263	12 376 594	18 226 532	9 971 944	27 834 779	8 896 263	30 108 137	8 896 263	8 896 263	8 896 265	8 896 263	22 991 460	27 834 779	27 834 779	31 414 830	9 971 944	18 921 332
April	12.4	1.2490	711 16 057 ;	711 19 28	17 404 9 64	1 890 242	28 913 96	1 068 149	9 287 404	24 828 913	24 828 913	9 641 890	9 641 890	19 287 404	9 641 890	24 828 913	9 641 890	26 913 496	9 641 890	29 111 609	9 641 890	9641890	22 185 639	606 126 61 0	24 828 913	24 919 931	9 641 890	18 139 032
May	11.2	1.2425	735 123064	614 25 53.	166 #198.	361 0922.	34 848 95	915 560 2.	5 533 644	19 834 848	19 834 848	9 915 560	9 915 560	25 533 644	12 306 614	19 834 848	9 915 560	25 533 644	9 915 560	27 677 395	9 915 560	9915 560	20 989 210	19 834 848	19 834 848	19 089 277	12 306 614	16 168 320
June	10.4	1.2351	687 92124	(74 257)	4 865 11 4	3 982 16 8	38 388 82	218 718 2.	5 714 865	16 838 388	16 838 388	11 433 985	8 218 718	25 714 865	15 342 558	16 838 388	11 433 985	16 838 388	11 433 985	23 723 122	11 433 985	11 433 985	16 955 390	16 838 388	16 838 388	16 760 685	15 342 558	14 949 503
July	10.01	1.2275	735 87395	31 29 57	7 699 16 3	14 803 16 5	14 803 77	795 266 2	9 577 699	16 314 803	16 314 803	16 314 803	7 795 266	29 577 699	17 905 422	16 314 803	16 314 803	7 795 266	16 314 803	19 596 205	16 314 80.	16 314 803	15 530 715	16 046 466	16 314 803	16 760 185	17 905 422	8 625 161
Anonst	0.7	1 2216	735 77577	12 12 09	9 972 17 8	19 161 12 6	12 22 12	1 191 618.	2 000 972	12 000 972	12 099 972	17 819 161	17 819 161	12 099 972	19 501 798	12 099 972	17 819 161	8 607 428	17 819 161	17 819 161	17 819 16	17819161	12 903 115	15 377 861	12 099 972	12 588 985	19 501 798	7 111 908
Sentember	10.4	1 2234	711 94442	38 7.515	5 148 188	92 028 9 44	14 238 26	361 791 7	515148 9	1 444 238	9 444 238	18 892 028	26 361 791	7 515 148	24319940	9 444 238	18 892 028	9 444 238	18 892 028	15 728 541	18 892 028	18 892 028	12 321 085	13 275 521	9 444 238	8 842 059	24 319 940	19 029 793
October	13.1	1.2327	735 19 679 6	910 8776	5 461 29 7	a 682 9 85	7 656 25	333 032 8	776 461 9	337 656	9 837 656	29 702 682	25 333 032	8 776 461	27 459 940	9 837 656	25 333 032	9 837 656	25 333 032	12 209 924	29 702 682	25 333 032	12 242 414	8 858 686	9 837 656	8 122 639	27 459 940	21 596 003
November	14.3	1.2429	687 23 874 2	256 9271	165 258	78 688 827	71 078 27	7 992 285 9	271 165 8	271 078	8 271 078	25 878 688	27 992 285	9 271 165	27 992 285	8 271 078	25 878 688	11 506 828	25 878 688	9 271 165	25 878 685	25 878 685	7 423 015	8 271 078	8 271 078	8 870 902	27 992 285	21 951 058
December	15.1	1.2528	735 301863	20 9 997	7 848 257	45 545 79	5 677 19	999.456 9	997 848 7	7 955 677	7 955 677	25 745 545	19 999 456	9 997 848	32 498 621	7 955 677	30 186 350	16 650 529	30 186 350	9 997 848	25 745 545	30 186 350	6350395	7 955 677	7 955 677	9 163 644	32 498 621	42 475 115
Annual	12.5	, 2404 N	8 579 212 467 5	25 213 20	2 961 213 8	87 985 212 2	23 670 212	655 974 21.	3 202 961 2	12 223 670 2	12 223 670	13 887 985	212 655 974	213 202 961	212 704 429	212 223 670	213 959 139	213 437 670	213 959 139	213 678 613	213 887 985	213 959 139	213 109 825	213 228 530	212 223 670	213 512 714	212 704 429	213 419 415
Table M.2 Ene	rgy product	tion map of	the wind farm f	for Corvo	Island (Po.	rtugal)		wit	h sensitivi	ty analysis	of E <sub>pi</sub> (Ca	(1 as																
	V <sub>NC</sub>	H	prod												AE	P avail (k Wh.)	_											
SHIHOM	(m/s) (k,	g/m <sup>3</sup> ) (	(h) yr 1	уr	2 y.	r3 )	r4 .	yr s	$yr_6$	yr 7	yr 8	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
January	11.7	1.2313	738 14 451.	298 14 45	1 298 144	(51 298 14 ·	(51 298 14	451 298 1	4 451 298	14 451 298	10 842 026	10 842 026	14 451 298	10 842 026	10 842 026	10 842 026	14 451 298	10 842 026	10 842 026	14 451 298	10 842 020	10 842 026	10 842 020	10 842 026	10 842 026	10 842 026	10 842 026	10 842 026
February	11.5	1.2345	639 11 923;	902 4 23.	3 203 11 5	11 23 902 11	13 902 11	923 902 3	369 392	11 923 902	12 538 268	1 770 714	3 369 392	12 538 268	1 770 714	9 115 121	11 923 902	6 580 843	12 538 268	4 233 203	5 409 695	3 369 392	2 776 295	11 923 902	2 077 293	6 580 843	11 923 902	12 538 268
March	10.5	1.2329	735 10471.	380 3189	9384 136	98 087 13 t	598 087 13	3 698 087 6	214 620	13 698 087	13 698 087	2 386 378	3 189 384	13 698 087	2 386 378	13 698 087	13 698 087	6 214 620	13 698 087	3 870 731	7 560 022	4 863 071	13 698 087	14 403 865	2 034 182	10 471 380	14 403 865	3 189 384
April	9.5	1.2317	711 73058	887 730:	5 887 104	48 175 10+	(43.175 10	0 443 175 7	305 887	10 443 175	4 699 596	3 082 171	7 305 887	13 237 618	3 082 171	13 237 618	4 699 596	4 699 596	13 237 618	3 082 171	10 119 379	3 082 171	13 919 671	13 237 618	3 082 171	3 082 171	13 237 618	3 740 614
May	8.2	1.2282	735 48448	807 1043	12 053 104	32 053 10 -	(32 053 6 1	191 280 1	0 432 053	10 432 053	10 432 053	3 856 194	6 191 280	10 432 053	3 856 194	14 349 768	10 432 053	3 856 194	10 432 053	2 377 416	13 646 640	6 191 280	2 377 416	10 432 053	3 856 194	14 349 768	10 432 053	4 844 807
June	1.7	1.2224	687 29555	541 12 69	3 755 7 00	15728 700	15 728 71	005 728 1.	0 014 121 4	4 506 515	12 693 755	4 506 515	10 014 121	7 005 728	4506515	7 005 728	2 211 411	2 955 541	7 005 728	1 885 038	12 693 755	7 005 728	1 885 038	2 7 005 728	4 506 515	12 693 755	7 005 728	5 758 970
July	6.1	1.2154	735 20052	275 13 56	3 424 4 75	3 962 61.	26 305 10	1322 572 1.	3 503 424	7 452 587	3 144 060	6 126 305	2 005 275	6 126 305	6126305	6 126 305	2 005 275	2 352 466	6 126 305	6 126 305	14 199 172	10 322 572	3 815 724	6 126 305	6 126 305	13 503 424	3 815 724	7 452 587
August	6.4	1.2075	735 23371	182 10.55	3 661 375	0 935 3 7:	30 935 3:	790 935 1	3 415 696 6	\$ 086 504	3 790 935	7 404 169	2 337 182	4 762 817	7404169	4 762 817	10 583 661	1 992 247	4 762 817	13 415 696	I 992 247	13 415 696	4 762 817	4 762 817	7 404 169	4 762 817	3 123 634	10 255 509
September	7.6	1.2064	711 36638	832 1 92:	5 451 5 85	12 434 4 61	13 129 40	603 129 4	603 129	925 451	5 882 434	0991166	0991166	3 663 832	0991166	3 663 832	5 882 434	0991166	3 663 832	12 965 892	2 258 821	12 965 892	5 882 434	1 3 663 832	099 116 6	3 663 832	2 258 821	1 925 451
October	8.9	1.2126	735 61124	412 611.	2412 315	86 930 2 0K	0 727 3	136 930 2	000 727 2	347 131	7 435 686	13 472 801	13 472 801	3 136 930	13 472 801	3 136 930	7 435 686	13 472 801	3 136 930	10 628 711	3 136 93(	2 000 727	7 435 686	3 136 930	13 472 801	2 347 131	2 000 727	2 347 131
November	10.6	1.2194	687 99900	134 3572	8 305 2 20	16 092 221	36 092 21	206 092 2	206 092	2 948 433	2 206 092	12 663 223	4 495 676	2 206 092	12 663 223	2 206 092	2 948 433	12 663 223	2 206 092	9 680 288	3 578 305	2 206 092	9 680 285	2 206 092	12 663 223	I 880 504	5 745 118	12 663 223
December	1 1 0	1.2237 8	7520 80 657 2	706 2 36	542 201 7375 897	8 574 80 A	55 547 21	018 979 3	165 547	3 841 801	2 018 979 80 381 070	14 296 210 90 318 367	00 330 663	2 018 979 80 668 733	14 296 210	2 018 979	3 841 801 90 113 636	80 837 428	2 018 979 80 668 733	7 503 518 90 220 267	4 826 724	14 296 216 90 560 856	13 595 700	2 018 979	14 296 210	0.168.172	4 826 724 80 615 940	13 595 706 89 153 675
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Table M.4 Wind	d speed se	eries simula	tions for A	EP avail in Au	racati (Brazi			witl	h sensitivity	/ analysis ol	$E_{pi}(Case$		:													1
Months	$\frac{v_{we}}{(m/s)}$	$yr_I$	$yr_2$	<i>yr</i> 3	yr 4	$yr_5$	$yr_6$	yr 7	$yr_8$	$yr_{g}$	yr 10	Wind spe yr 11	ed data seri. yr 12	es for simuli yr 13	yr 14	yr 15	W 16 91	17 yr	16 81.	r 19 yr	20 yr	21 yı	r 22 yr	23 yr.2	4 yr 2:	5
January	5.8	5.8	101	7.6	9.6	4.0	10.1	4.0	4.0	2.9	101	101	4.0	7.6	9.6	7.9	91 10.	1 4	(0)	7.6 9	5 90	10 2	2.6 9	6 7	0 2 0	0
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0 7	. 8	10 IC	9 I'U	. 0	0 10	0 I.0	2 8	5 8.6	0
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7 6	2 0	, 6.7	5.0 5	5 5	5.8	9.7 10	Υ L	5 9.2	7
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9 5	8	2 21	5.8 7	.6 4	6.9	9.6 9	.2 6.	9.6	9
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8 4	9 10	5 I'I	4.9 4	4 0.1	1.7 5	9.2 7	.9 5.	8 9.7	7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0 4	.7 9.	1.7 4	4.7 4	(.7 7	5 9.7	8.6 8	.6 4.	10.1	I
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6 4	9 0.	5 9'i	4.0 4	6.9	2 6.2	7.9 5	.8 4.	7 4.0	0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7 5	.7 4	(7 )	7.9 5	.7 8	3.6 6	5.0 6	.0 4.	) 4.7	7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6 5	.6 4	3 63	8.6 16	6 I'I	2 5	5.8 7	.6 9.	2 4.9	6
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2 5	2 6	5 03	9.2 7	9 6.	5 4	1.9 4	9 10.	1 5.8	~
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6 8	.6 5	5.8	9.6 5	2.0	.7 4	4.7 4	.7 9.	7 6.0	0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	10.1	10.1	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9 5	. 2	5 9.2	9.7 8	10 10	4 I.G	4.0 4	.0 0.	5 7.6	9
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4 7	7 4.7	.4	7.4 7	.4 7	7.4 7	7.4 7	.4 7.	4 7.4	4
																										1
Table M.5 Wind	d speed se	sries simula	tions for A.	EP avail in Cc	orvo Island ,	(Portugal)		with	h sensitivity	/ analysis oi	$E_{pi}(Case)$	(1														
14 14	V NC											Wind spe.	ed data seri.	es for simule	ttions (m/s)											1
MONINS	( <i>m</i> /s)	$yr_I$	$yr_2$	yr3	yr 4	yr5	$yr_6$	yr 7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	VT 16 31	17 yr	18 JI	r 19 yı	-20 yr	'21 yı	r 22 yr	23 yr 2	4 yr 22	55
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	10.6	11.7	10.6	0.6 11	.7 10	10 11	2.6 IL	9.6 10	91 JC	0.6 10	·01 9	5 10.6	9
Feb mary	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	1.7 8	.2	; 63	7.6 7	H F.	.5 6	5.4 9	5 11.	5 11.7	7
March	10.5	10.5	1.7	11.5	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	1.5 5	.6 9	2.5 2	8.2 14	.5 11	1.7 6	5.1 10	5 11.	1.7 7.1	I
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	7.1	11.5	8.2	8.2	1.5 ;	01 I.	1.5 ;	11 I'-	11 27	.5	7.1.7	П II.	5 7.6	6
May	8.2	8.2	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5 6	4 11	1.5 2	8.9 ¢	.4 10	15 7	7.6 11	.7 10.	5 8.2	2
June	7.1	1.7	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5 6	11 E	1.5 5	9.5 ¢	6 I'	5 8	8.2 11	.5 9.	5 8.9	6
July	6.1	6.1	11.5	8.2	8.9	10.5	11.5	9.5	1.7	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9 8	11 6.	1.7 11	9.5 ;	.6 8	3 83	8.9 11	5 7.	5 9.5	5
August	6.4	6.4	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2 Ii	.5 6	5.1 I.	1.5 &	8.2	5.2	9.5 8	2 7.	1 10.5	5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6 11	.5	5.4 1.	1.5 &	6.9	.6 10	).5 7	.6 6.	t 6.1	I
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	7.1	11.5	7.1	9.5	11.5	7.1 16	.6 7.	γ Γ.	5.1 5	5 7	H F2	1.5 6	4 6.	1 6.4	4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	7.1	6.4	11.5	8.2	6.4	11.5	6.4	7.1	11.5	6.4 It	5.7	7.6 (	5.4 IL	5 6	5.4 11	1.5 6	.I 8.	9 11.5	5
December	11.5	11.5	6.4	6.1	1.7	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1 \$	.5 8	8.2 1.	1.7 11	5 6	11 II	1.7 8	.9 8.	2 11.5	5
Annual	1.6	1.6	1.6	9.1	9.1	1.6	9.1	9.1	1.6	9.1	9.1	9.1	9.1	9.1	1.6	9.1	9.1 5	6 I.	5 I't	9. I . 6	6 I.	5 I'C	9.1.9	.I 9.	1.6 1	~
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Table M.6 Win	d speed se	eries simula	tions for A.	EP avait in C	ape Saint Ja.	mes (Canad	la)	wit	h sensitivity	y analysis o	f E <sub>pi</sub> ( Case	( ]	ad data and	for four of north	the main and and and and and and and and and an											i
Months	<sup>7.46</sup>											adennu	1 lac mm na	co hor orthmet	(call) chotte											I
	(m/s)	yr1	yr2 15 4	yr3 15 1	yr 4 15 4	yr5 15 4	yr6 15 1	yr 7 1 - 1	yr8 17 4	yr9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16 y	17 yr	18 y.	r 19 y	20 yr	21 yr	722 yr	23 yr2	4 yr 23	52
January Fehruary	4.01	4.CI	12.4	9.7	15.1	12.4	12.4	15.1	15.1	9.7	12.4	12.4	10.0	15.1	9.7	13.1	0.7 9.7 9	.cl 4. .7	1 1.	2.4 II 2.7 I4	c1 01	CI 4.0	5.1 15	6 10	, 9.3 13.1	n -
March	12.7	12.7	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1 1	0.0 10	0 10	10 10	2.0 IS	.8 14	1.7 14	4.7 15	3 10.	4 12.9	6
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	0.4 15	01 1.	11 11	9.4 15	.8 13	13 14	4.3 14	3 10.	4 12.9	6
May	11.2	11.2	14.3	10.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3 i	0.4 14	.7 10	14 10	9.4 15	.4 13	8.I I.S	3.1 13	0 11.	2 12.3	ŝ
June	10.4	10.4	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7 1	1.2 14	3 11	1.2 1.1	1.2 12	.8 12	2.7 12	2.7 12	7 12.	4 12.2	2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	'2.4 Iš	.1 12	2.4 12	2.4 12	12 12	23 12	2.4 12	5 12.	7 10.0	0
August	9.7	9.7	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.01	12.7 12	.7 12	2.7 12	2.7 11	.4 12	II I I I	1.2 11	4 13.	1 9.4	4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1 12	.4 13.	1 I'	3.1 11	11 4.	1.7 IC	0.4 10	2 14.	3 13.2	5
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3 11	.2 15.	·I I:	4.3 11	.2 10	01 IC	0.4 9	8 14.	7 13.5	2
November	14.3	14.3	10.4	14.7	0.01	15.1	10.4	10.0	0.01	14.7	15.1	10.4	15.1	10.0	14.7	11.2	(4.7 II	.4 14	1.7	4.7 5	10 10	00 IC	0.0 10 2 2 10	.3 I5.	1 13.9	<i>6</i> (
I	201	1.01	2 01	2 01	1.6	2 01	10.1	1.6	1.6	2.41	1.01	10.5	1.01	3.1	2 01	1 501	11 20	÷ ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;	1 21	2 1.0	v v.		01 1.	CI 2	2 10.2	<u>,</u>
manury	14.0	14.0	14.0	14.0	14.7	14.0	14.7	14.0	14.0	14.0	14.0	14.2	14.7	14.7	14.7	14.0	** (-7	ت 1 س		4.J 1.			44 C.2		14.0	5

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	<ul> <li>yr<sub>1</sub>;</li> <li>5 690</li> <li>2 10515</li> <li>2 10515</li> <li>0 24906</li> </ul>	<u>7 yr.</u> 0 564!	<u>8 yr</u> 1 9 5.60:	19 yr 2	<u> </u>	21 yr2	22 yr	23 yr	
15 JY1 8 573 2 1045 9 2494 15 15	6 yrn 7 5 690 2 10 515 0 24 908	7 yr <sub>li</sub> 0 5649	8 yr <sub>1</sub> 9 560:	19 yr2 12 569	<u>o yr 2</u> 8 5 68: 9 10 46. 1 24 85	21 yr2	22 yr:	23 yr.	
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8 1860129	1 912 077	1 943 336	1 976 710 2	008271 20	93 190 1 50	06483 1525	25 356 1 566	5166 1609	385 16
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6089664	9419719	9 667 505 5	9920 509 10	181766 10-	111 182 9 85	33479 10106	78 842 10 356	\$835 10 608	807 10 8
1 21462514	30 882 234 4	40 549 739 50	047024760	0 652 014 71 0	03 196 80 8	96 674 91 005	<b>35 516</b> 101 36.	2 351 111 971	1158 122:
9413803 1537285	9 413 803 15 372 851 21 462 514	9413 803 15 372 851 21 462 514 30 882 234	2 804 9/1 2 9/9/048 0 0/89/064 9/41/1 9/00/20 9/413 803 15 372 851 21 462 514 30 882 234 40 549 739 5/	011 000 000 000 000 000 001 010 010 00	0.011 2) 2020 048 0.005 069 9412/19 9162/202 9920/202 10:181/06 10: 9413 803 15 372 851 21462 514 30 882 234 40 5497 39 50 470 247 60 652 014 710	2804.6/1 2559/48 008/064 9419/17 906/202 924.00/10181/06 10411.182 97	2844.6/1 2292948 0082064 9412/19 960.202 9242050 1921168 19611.182 955349 101 9413.803 15372851 21462514 30882254 40549739 50470.247 60.652014 71065196 80.896674 9100	2844.6/1 2292448 0.099064 9419/1/2 906/201 92/0/201 0.181/06 10411.02 95245/9 10106542 10.20 9413.803 15.372851 21462514 30.882224 40549739 50470.247 0.662.014 71063196 80.896674 91085516 10136	2844 01 2 2020 48 0 009 064 9 419 /12 900.500 2 920.700 10 161 06 1041 152 9 83 479 10 108 64 10 206.50 1008 9
2146	2514	2514 30882234 - 78 60.87	2514 30882234 40549739 5 78 60.81 70.00	2514 30882234 40549739 50470247 60 78 6081 70.00 70.70	2514 30882234 40549739 50470 247 60 652014 71( 78 60.81 70.00 70.30 70.40 7	2514 30 882 234 40 549 739 50 470 247 60 652 014 71 063 196 80 8 25 64 80 70 70 70 70 70 40 70 70 70 70 70 70 70 70 70 70 70 70 70	2514 30 882 234 40 549 739 50 470 247 60 652 014 71 063 196 80 896 674 91 0. 28 60 80 70 40 70 20 70 70 70 70 70 70 70 70 70 70 70 70 70	2514 30 882 234 40 5497 39 50 470 247 60 662 014 71 063 196 80 80 6674 91 005 516 101 36 28 60 81 20 00 20 20 20 20 20 20 20 20 20 20 20	2514 30 882 234 40 549739 50 470 247 60 652 014 71 063 196 80 80 6674 91 005 516 101 362 351 111 97. 25 668 20 70 00 70 70 00 70 70 00 70 70 70 70 70

Table M.9 Cashflow for 25 years of th	ie wind fam pr	oject	50 000 kW	V Corr	vo Is land (F	ortugal)			with s	ensitivity an	alysis of $E_{p_i}$	(Case 1)	Vanue												
ltem –	0	-	2	3	4	ŝ	6	7	8	I	II	1 12	15415	14	15	16	17	18	19	20	21	22	23	24	25
(-) LC CCM WF	60 225 901	,					,	,	,										,	,					
WT CM	27 686 278				,		,		,		,	,	,		,		'	'	,					,	
T CAL	24 219 295 1 959 783																								
CPor	1 545 346		,		,		,	,	,	,	,		,	,				,	,		,	,		,	,
TS CM	572 832				,													'	•					,	
SICM	2 136 726				,											'	'	'	•	•				,	
FUCH	1 /90 6 50				,		,	,		,	,										,				,
CCCov	120211																								
LCPM WF (KWh/yr)	80 -	9 657 257 90	037737585	3 783 574 89 1	846976 89	792.106 90	681 985 90	056935 893	81 970 90 31	8 367 90 33	9 663 89 668	8 733 90 318	1367 90163	301 90 113	636 898374	28 89 668 73.	3 90 220 26	90 263 721	90 560 856	90 671 187	89 760 146 9	90 272 750 5	034582389	615 940 89	153 675
(+) AAR $(SM/yr)$	-	4 970 925 1:	5 468 449 15	5 750 988 16	156163 16	549 954 17	131821 17	439 078 17	41 084 18 37	5 119 18 83	8 939 19 16	6 502 19 787	994 20247	871 20742	636 21 196 0	84 21 685 13	\$ 22 363 98	22 934 122	23 584 858	24 203 932	17 191 828	17722 258 1	8 180 019 18	483 975 18	848346
PPAR		4 970 925 1.	5 468 449 1.	5750988 16	156163 16	549.954 15	131821 17	439 078 17	41 084 18 37	5 119 18 85	8 939 19 16	6 502 19 787	7994 2024	871 20742	636 21 196 (	34 21 685 13.	\$ 22 363 98	2 22 934 122	23 584 858	24 203 932	- 000 101 21	- 030 00000	- 10/0/01 0		- 010 246
EMP		0.269.274	0 995 0C9 C	- 01 - 502 - 50 - 5	- 109 001		710.920 10		0111 Cal 00	7 261 11 70	7.470 11 000	- 17 200	- 12 669	- 12 072		- 12 567 364	- 12 001 07	- 14 249 504	- 755 407	- 142 655	12 154 746	1 227 077 11	2 010 507 14	61 C/4 C84	00029107
O&M and		4871 474	5 033 363 5	5 125 297 51	257137 5	385 272 5	574606 5	674.583 52	72.851 5.97	9 160 6 130	0.081 6 23(	6666 6438	883 6588	532 6749	522 6897.0	52 7056201	001121	7 462 607	7 674 349	7 875 789	2 991 568	8 238 134	8 450 920 8	592.210 8	1761 584
O&M warkable		4 496 901 4	4 646 203 4	4 730 927 4	852 484 4	1 970 618 5	145 234 5	237372 5:	27 931 551	8 200 5 65	7 348 5 75:	5 575 5 942	063 6080	016 6228	443 63644	45 651116	5 671485	8685898	7 081 137	7 266 866	5 163 178	5 322 339	5 459 672 5	550813 5	660 095
(+) LRCM	,	863 268	884 850	906 971	929 646	952 887	976709 1	001 127 14	26 155 1 05	1 809 1 07.	8 104 1 102	5 057 1 132	5683 1161	000 1190.	025 12197		'	'	•	•	,		,	,	
(+) Depreciation		2416 604 2	2 477 019 2	2 538 944 2 1	602418 2	067 478 2	734165 2	802.519 21	72 582 294	4 397 3 01	8 007 3 095	3 457 3 170	1794 3.250	063 3331.	315 34145	98 349996.	3 3 587 46	2 3 677 148	3 769 077	3 863 304	3 959 887	4 058 884	4160356 4	264365 4	1 370 974
(=) Profit before tax		8 882 422	9 150 752 5	9 340 679 9.	578 606 5	3814430 1C	122856 10	330770 10.	39 039 10 87	3 965 11 14	7 620 11 37.	2775 11710	514 11 990	387 12 286	011 12 568 5	10 11 617 73.	4 11 959 50	1 12 262 766	12 598 449	12 924 581	7 996 969	8 220 669	8 429 783 8	605316 8	197 640
(-) Revenue tax	,	4 491 277	4 640 535 4	4 725 296 4.	846849 4	1964986 5	139546 5	231723 5.	22 325 551	2 536 5 65	1 682 5 745	9 951 5 936	5398 6074	361 6222	791 6358 8	10 650554.	1 670919	6 880 237	7 075 458	7 261 179	5 157 549	5316677	5 454 006 5	545193 5	654504
(+) REPIM	1 284 346	1 253	1 232	1 194	1166	1136	1120	1 085	050 1.(	36 1(	11 0	36 6L	62	16 14	3 888	865	849		•		,		,		
$REI_{CM}$	863 662	•	•	1	•	•	•	•		•							1	'	•	•					
REPCH		1 253	1 232	1 194	1166	1136	1120	1 085	050 1.1	36 1(	9 10	5 6	6 6	87 91	3 885	865	849								
$OREP_{CM}$	420 684								,																
GHG.R CM	,	- 000 000 1				- 040 4	- 007 700						- 0.00			00					- 000	- 000 000			-
(=) Projit after tax w/out interest		4 592 598	4 211 449 4	4 0/00/04	152922 4	1 850580 4	1984429 5	2001131 5.	21/ /04 530	2 404 5 45 107 5 011	0.045 2.02	3805 5775	JI6C 8/00	902 0.064	155 62105	90 STI S 88	21102.0 2	67.07.95 0 0	166 779 9	104 500 5	7 8.59 420	166 506 7	5 111 0167	000124 3	143 15/
(-) Dept payments		0621090		20 011 007	00 307 0. 212 216 1	C 000 200.	C L3C 20/704	2 C 170 000	01.2 00001	100 001	1102 2.254	410 4004	10.40 2.575	047 2614	2016 2 704 4	2 2 2 2 0 2 0 4	2 001 00	- 2 000 - 2	1 000 010	4 101 242	- 100 200 1	- 400 ADE	- 1136134		242.000
(+) KCM WF (+) Damacintion		- 60/ 170 7	- 707 /007	7 1011077	c 817 cm	<ul> <li>C BLV L99.</li> </ul>	C 391 PEL	C CIE060	72 582 794	1307 3.01	2007 2005	3.457 3.170	200 3250	94/ 2014	315 3/1/5	00/6/2 01 50 00/6/2 00	2 2 587 46	007 606 C 0	3 760 077	3 963 30M	3 050 927	004 004 4 0 0 50 8	4 110 010 4	076.0365 A	100.241
(=) Free net cashflow	-58 941 555	9 430 740	5547771 6	5 703 807 61	372.334 7	043 477 7	232149 7	404 043 7 5	79 274 778	3 012 7 97,	3011 8 160	6891 8381	743 8588	794 8802	761 9018.0	82 12410.080	0 12 730 60	3 13 048 963	13 381 086	13 7 17 949	11 095 331	113663001	1 649 644 11	950 837 12	256118
$\Sigma$ free set annual callflow	4	9510815 42	2963 043 -36	5 259 236 -29	386 902 -22	343 426 -15	111277 -7	707 234 -1	27 959 7 65.	5 053 15 63.	3064 23 795	9955 32 181	698 40 770	491 49 573	252 58 591 3.	34 71 001 414	4 83 732 01	86 780 981	110 162 067	123 880 016	134 975 347	146 341 647	157 991 290 16	9 942 128 18	32 198 245
	$LCOE_{ww}$	73.08	73.48	73.74	74.09	74.43	74.89	75.18	5.47 75	.97 76.	37 76.	68 77.1	18 77.2	8 78.0.	1 78.41	77.59	11.87	78.56	79.07	79.56	77.68	78.19	78.65	79.00	79.39
Table M.10 Cashflow for 25 years of	the wind farm p	roject	50 000 kW	v Cap	e Saint Jam	es (Canada)			with s	ensitivity an	alysis of $E_{p_l}$	(Case 1)	Variation												
ltem –	0	-	2	3	4	5	9	7	8 9	Ĭ	II	1 12	1cats 13	14	15	16	17	18	19	30	21	22	23	24	25
(-) <i>TCCCM m k</i>	60 225 901	,	,		,	,	,	,	,						,	,			,	,		,	,	,	,
WT CH	27 686 278																								
Tar	24 219 295																	'	•	•					
LWTG CM	1 959 783	,		,	,							,					'	'	•	,		,		,	
$CP_{CM}$	1 545 346			,	,											'	'	'	•	•				,	
$TS_{CM}$	572 832						,										'	'	'	•				,	
SICM	2 136 726														,		'	'	•	•					
POCH	1 796 870			,	,		,		,	,						'	'	,							
$F_{CM}$	188 559	,	,		,	,	,	,	,	,	,	,	,			'	'	'	,	,	,	,	,	,	,
CCC CM	120211									,							'	'	'	•					
$LCPM_{WF}$ ( $kWh\Delta r$ )	1	212 467 325 2	13 202 961 2	13 887 985 211	223 670 21	12 655 974 2.	13 202 961 21	2 223 670 212	223 670 213 8	87 985 212 6.	55 974 213 20	02 961 212 70	4 4 29 2 12 22	3 670 213 959	139 213 437 (	570 213 959 13	9 213 678 61	3 213 887 985	213 959 139	213 109 827	213 228 530	212 223 670	213 512 714 21	2 704 429 21	3419415
(+) AAR $(SM/yr)$	~ i	0 129 143 30	0.989.297 31	1 866 088 32	408.583 33	3 286 465 34	206386 34	900.500 35	73 012 36 95	4 893 37 66	0.580 38.70	1386 39576	5163 40475	880 41 824	978 427661	17 43 942 36.	8 44 981 87	3 46 151 597	47 321 124	48.311.614	34 682 891	35 382 431 3	6 487 277 37	257877 38	317 694
PPAK	- 3	0129143-30	5 167.6860	1 800 088 32	408.585 32	5 280 400 34	200.380 .34	000006	73 012 30 92	4 893 3/ 00	0/ 85 0800	1 380 39 5/6	0.165 40.472	880 41 824	9/8 42/00	17 43 942 30	8 44 981 87	/6616106-6	4/ 521 124	48.311.614	- 100 007 10				
(-) O & M were		0.588 652 21	- 1176 288 21	1775 288 22	145 848 22	745 587 23	374 047 23	848 205 244	- 44 263 25 25	1 713 25 73.	3770 26 444	- 4813 27042	405 27 655	- 668 28.578		47 30 025 220	30 735 35	31 534 456	32 333 422	33.010.054	29 394 775	5 105 200 CC	0.923746 31	576700 32	474 765
$O\&M_{\beta xed}$		15442861	1 873 856 12	2 209 801 12 -	417 656 12	3754019 15	106489 13	372 438 13.	06 743 14 15	9 584 14 42	9 968 14 828	8 755 15 163	927 15 507	888 16025	565 163861	64 16 836 847	7 17 235 13	1 17 683 316	18 131 422	18510929	18 984 265	193671631	9 971 913 20	393 707 20	973 809
$O \& M_{uxiable}$		9 044 366	9 302 432 5	9 565 487 9	728 192 5	991568 10	1267 558 10	475 767 10".	37 520 11 09	2 129 11 30	3 802 11 610	6 058 11 878	8478 12147	781 12553	156 128354	84 13 188 37.	3 13 500 21'	7 13 851 140	14 202 000	14499125	10410511	10 620 346 1	0.951 834 11	182 993 11	500 957
(+) LRCM	,	863 268	884 850	906 971	929 646	952 887	976709 1	001 127 14	26 155 1 05	1 809 1 07	8 104 1 10;	6 057 1 132	2 683 1161	000 1190	025 1219 7		'	'	'	,	'	,	·	,	•
(+) Depreciation	-	2 387 607	2 447 297	2 508 479 2	571191 2	2 635 471 2	2 201 358 2	768.892 2.	58 114 290 00 010 15 20	9.067 2.96	1794 3 054	6338 3132 7.000 17.000	2747 3211	066 3 291	342 3373(	26 345796	5 3 54441	3 633 026	3 723 852	3816948	3912 372	4 010 181	4110435 4	213196 4	1318 526
( =) rroju vejore tuv		0.020 7/12 6	1 /01/0410	.0 9000550	1 7/CC0/	01 07 6714	51 00+01C	CT CTC 770	21 004 11 00	5 460 11 30 4	14 01 00/0	CENTE 11 0110	CF1C1 090.	17/11 117	0,000,01 500	25 12 197711	25 404 51 0	10 10 20 10 10	CCC 11/ 01	14 402 494	104-007-6	1 002 01-0	11 20121010	01 4/0460 II	005 300
(+) REPIM	1 991 590	148	144	141	137	134	131	127	124 1	22 1	18 1	16 11	13						-						
REICM	863 662		,	,	,	,	,	,	,	,	,		,			'	'	'	,	,		,	,	,	,
$REP_{CM}$		148	144	141	137	134	131	127	124 1	122 1	18 1	16 11	13			1	'	'	•					,	
$OREP_{CM}$	1 127 928									,							'	'	'	•					
$GHG.R_{CM}$				•		•													•	•	•				
(=) Profit after tax w/out interest	,	3 752 771	3 848 512	3 946 566 4	041134 4	143431 4	248 621 4	352 291 4.	61 238 457	7710 468	8 652 4 80	7 667 4 926	5451 5048	113 5180	130 5 308 (	B6 419240	4 29637	5 4 404 688	4515216	4 625 024	-1 204 380	-1 209 627	1 272 217 -1	282 989 -1	333 853
(-) Debt payments		2 621 730 3	090446 3 7687387 7	167 707 32 2 754 464 - 2 5	46 899 3. 273.376 7	528 072 3. . 803 000 7	411274 3- 066757 3	040.413 35	3969 3673	569 3705 1324 377	408 3859.	543 3956 C 6 0 47 3 430	152 4 0545 00/0 3 575	32 4 156 30 0.47 3.614 i	96 4 260 21. 306 3 704 4.	49 3707064	2 801 08	- 3 060 7 96	1.080.019	- 101 743	1.005.004	- 1403.475	4 5 1 3 5 1 1 4		200 CV2
(+) Depreciation		2387 607 2	2 447 297 2	2 508 479 2	571191 2	635471 2	701358 2	768.892 28	38 114 2 90	9.067 2.98	1794 3056	6338 3132	747 3211	066 3291	342 33736	26 3457960	5 3 5444	5 3 633 026	3 723 852	3 8 16 9 48	3 912 372	4010 181	4 110 435 4	213 196 4	1318.526
(=) Free net cashflow	-58 234 310	8 762 117 5	5 892 645 4	5 041 803 6	188 752 6	344739 6	504962 6	665 040 61	31 807 7 00	7 542 7 17	9 230 7 36(	0510 7543	1115 7730	193 7929	263 81258	97 11 447 430	0 11 732 77	12 026 999	12 328 086	12 633 215	7 004 016	7 203 979	7 351 729 7	556555 7	726680
$\Sigma$ free net annual cathflow	. 4	9472 193 4.	3 5 79 548 -3.	7 537 745 -31	348 993 -25	004 254 -18	499 292 -11	834 252 -51	02 446 2 00	6 097 9 18	4 327 16 54	4837 24087	952 31818	145 39747	408 47 873 3	05 59 320 73.	5 71 053 51	2 83 080 511	95 408 597	108 041 812	115 045 828	122 249 807	129 601 536 13	7 158 092 14	14 884 772
	$LCOE_{ww}$	84.30	84.97	85.66	96.12	86.82	87.54	88.12 2	8.81 89.	72 90.	31 91.	3.19 51.5	92.2	7 93.6.	1 94.37	94.05	94.85	95.75	96.65	97.43	93.92	94.62	95.66	96.43	97.44

## APPENDIX N

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				-			-		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ıs	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[S/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
WE IN SALE OF	г	N	I make a Replacement	Cont Madad	N .	Wind From Brownel C	and Madel	N	Bananahla Franse Bublis In	337 039	NA	W-1P	0		N. c
Wind Project Information	Einstein Wind Form	Notes	Levenzea Replacement C	.051 Model	Notes	wina Farm Kemovai C	1 220 0154	Notes	Renewable Energy Fublic In	centive Model	Notes	Wind Farm Life	-Cycle Prod	so ooo	Notes
Project Location	Aracati (Brazil)		Depr <sub>wr</sub>	76.9840	[3/kW]	RM wr	22.3284	[3/kW]	LCCCM we	1 204,5180	[\$/kW]	WF		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cm	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	[yr]	$M_{\mu_{m_{HT}}}$	100	[m-h]	$\psi_{sotal}$	20.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMBrawar	85.00	[\$/m-h]	n ,,	4	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>mmur</sub>	3	[-]	REP CM	0.00002465	[\$/kWch]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]		2.0	[d]	AEP anait/H prod	5 695	[kW/yr]			1 800	[m]
Hub height (H)	105.0	[m] ()	TO CM	0.000033	[S/KW]	C and garger	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
wind speed measured at $(H_0)$ Terrain measure factor $(a)$	0.14	(m) ()	II V	237 699 000	[5/KW] [J/W]	KM CT	20.1934	[5/KW] [//W]	Б С.	0.1404	[\$/KW_en] [\$/VW_b]	SD		430	[m]
Betz Limit's coefficient (Can . )	0.5976	61	v.	6 100 000	[kw]	WF cap	25	[_]	n_	14	[vr]	ELH (		8 760	[h/sr]
Lifetime of Wind Farm(N)	25	[vr]	5 g	1 457.72	[\$/kW]	Mw	3.0	[m-h]	OREP CM	23.6992	[\$/kW_]	PCPM		0100	[17]
Production Efficiency (WF PE)	11.2%	[%]	PR	0.70	[-]	$C_{Mbr_{e-}}$	85.00	[\$/m-h]	LCCCM <sub>WF</sub>	5.0125	[\$/kW]	AEP avail		48 856 319	[kWeh/yr]
Availability	97.9%	[%]	b	-1.94	[-]	N.,	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wes}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/k W]	D <sub>m</sub> m	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{\rm NMCA_{\rm (ref)}}}$		25.00%	[%]
				_		C <sub>nd</sub> <sub>BUT</sub>	3 500.00	[\$/d]	$\psi_{sotal}$	20.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost M	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M fuel ce	0.098275	[\$/kWh]	WF cap	50 000	[kW]	n "	14	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM WT	265.32	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	$N_{WT}$	25	[-]	CRf	40.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	2 910.3377	[S/tCO <sub>2</sub> ]	$P\&D_{LM}$			
C kW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>krzaw</sub>	3.0	[m-h]	$\sum_{AEP} LCER_{CO_2}$	39.8	[tCO2/MW,h]	2		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMbrsan	85.00	[S/m-h]	ALP and y <sub>1</sub> ,,y <sub>n</sub>	48 856	[MW <sub>e</sub> h]	2,41		0.00%	[%]
T CM	484.3839	[SKW] [ke]	$O_{M}^{gr}$	0.025858	[%/yr] [%//Wb]	D N <sub>m saw</sub>	30	[-]	n, GHG	0.00089	IVED ANW N	2		5.00%	[%]
PC =	26 30%	(%) (%/\$/VW)	MIC	71 5608	[5/h]	C .	3 500.00	[0] [\$/d]	GHG	0.00008	ICO-MW N	ICPM	-	48 856 319	fk W h/sel
C	0.1900	[5/kg]	TIC	124 5688	[\$/b]	RVM min	61.0184	[\$/FW]	c c	39.4247	[K/(COs)]	LOI M WF		40 000 010	[1 11 21 21 21 21
LWTGen	39,1957	[\$/m/kW]	R	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	ing	Г	Notes
WF cm	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\xi_1 REI_{CM}$	10.0%	[%]	Debt ratio		50.0%	[%]
L	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\xi$ , REP <sub>CM</sub>	50.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mlb</sub>	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_{3}$ OREP CM	20.0%	[%]	Debt gr	ice period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	113	[h]	Ν	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	20.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	4 192 361	[\$M]	WTweight	200 000	[kg]	REPIM	593.5482	[\$/proj]	Debt value		29 977 602	[\$]
ç	0.08%	[%]	AEP anail	48 856 319	[kWh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	3 028 456	[\$/yr]
TS CM	11.4566	$[kW_{e}]$	O&M WFCM	0.124133	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	,	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 977 602	[\$]
TL <sub>r</sub>	1 200	[1/kW]	O&M <sub>manag(STD)</sub>		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
L	3 000	[m]	SC ORM	0.000105	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB c	113.00	[\$/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE wso	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE win		Notes	67.6603	yr i	70.7762	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			67.8118	$yr_2$	69.8077	yr 15
WTinst	42.5238	[\$/kW]	USC ORM	0.000287	[\$/kWh]	Hours Distribution	$FLH_{wf}[h]$	H prod [h]	O&M ccm	1	[1/0]	68.0210	$yr_3$	69.9988	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	Nwr	25	[-]	January	744	738	(%) ccm PEDIM	80.0%	[%]	68.1822	$yr_4$	70.1987	yr 17
Bld area	300.0	[m <sup>*</sup> ]	Frequency	1.5	[per yr]	February'	6/2	639	REFIM DEDIM Jisteihution			68.4349	yr s	70.3955	yr 18
FC CM	19.88	[3KW]	Hours required	112.5	[11] [b]	Anril	720	711	Č. RELess	1	[1/0]	68 8710	yr6 yr a	70.7504	yr 19 Yr 20
DT IS	87.22	[S/kW]	SC osu+USC osu:	184 5	[h/vr]	Max	744	735	E REP CH		[1/0]	69.0863	37.7 VF 0	70 5514	3* 20 NF 31
EG	404 52	(\$/VW)	DC DEM TO DC DEM	0 000392	(S&Wh/er)	Juna <sup>(*)</sup>	720	687	Č. OPFP au		[1/0]	69.2587	77.0	70.8222	77.23
For	3 7712	[S/kW]		0.000392	(******)/]	July	744	735	Š. GHG R.cv		[1/0]	69.4873	VF 10	71 1051	yr 22 Wr 23
WACC prei	4.900%	[%/yr]		Г		August	744	735	P&D <sub>LM</sub>		[1/0]	69.7236	yr 11	71.3664	yr 25
n fin	1.0	[yr]				September	720	711	λa	1	[1/0]	70.0026	yr 12	69.6792	Mean
W <sub>FOI</sub>	0.30%	[%]				October	744	735	$\lambda_{xki}$	0	[1/0]	70.2282	yr 13	1.0823	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	70.4423	yr 14	-0.4514	Y (skewness)
ĸ	0.20%	[%]				December	744	735	λm	1	[1/0]	LCOE	69.6792	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	L			Total [h/yr]	8 760	8 579		p.s.: 1 = yes ar	nd 0=no		0.069679	US\$/kWh	

**Figure N.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $E_{pi}(Case_2)$ . Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend									Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty conditio	ns Not	s Depr	eciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_m)	80.00% [%	Depre	ciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5 [yr	Period	l of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
										c 14 14		W-18	C		
Wind Project Information	F	Notes	Leveuzea Kepiacement	Cost Model Not	s wina	Farm Kemoval C	ost Model	Notes	Kenewable Energy Public Ind	centive Model	Notes	wina Farm Lije	-Cycle Frod	tenon Model	Notes
Project Location	Corvo Island (Portugal)		Depr.m	76.9840 [\$/k]		.Mwr	22 3284	[5/kW] [5/kW]	LCCCM we	1 204 5180	[5/KWe] [5/kW]	WF CM		50.000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256 [\$/k	n	WForm	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859 [\$/k]	ġ.	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25 [yr		$M_{hr_{mbyT}}$	100	[m-h]	$\Psi_{astal}$	20.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50% [%/	r]	$C_{Mhr_{2M_{WT}}}$	85.00	[S/m-h]	n <sub>v</sub>	4	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398 [\$/k)	ŋ	N <sub>manar</sub>	3	[-]	REP CM	0.0000951	[\$/kW <sub>c</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15 [yr		D <sub>m<sub>swar</sub></sub>	2.0	[d]	AEP anail/H prod	10 451	[kW/yr]			1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033 [\$/k]	0	C ad Bager	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Tampin magnitum factor $(\pi)$	10.0	[m]	т 	1 /98 /43 [5/k]		M cr	20.1954	[S/KW]	E E	0.0994	[\$/kW_ch]	SD		450	[m]
Betz Limit's coefficient (Cas. )	0.5926		V V	6 100 000 ILW	1	WF cap N was	25	[_]	n	0.003730	[SKWell]	EIH (		8 760	[hij]
Lifetime of Wind Farm(N)	25	[vr]	v 0 C 0	1 457.72 [\$/k]	'n	Mu	3.0	[m-h]	OREP CH	39,4006	[\$/kW_]	PC BM		0 100	[17]
Production Efficiency (WF PF)	20.5%	[%]	PR	0.70 [-	·	C <sub>Mine</sub>	85.00	[\$/m-h]	LCCCMWF	4.5411	[\$/kW]	AEP anall		89 657 257	[kW_h/yr]
Aváilability	97.9%	[%]	Ь	-1.94 [-		N	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{max}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443 [\$/k]	V]	D <sub>m</sub> m <sub>cr</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{out}}$		25.00%	[%]
						C <sub>md mer</sub>	3 500.00	[\$/d]	$\psi_{actal}$	20.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost	Model Not	s 5	& RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>fuel</sub>	0.098275 [\$/kV	'h]	WF cap	50 000	[kW]	n ,.	18	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180 [\$/k*	7]	$N_{WT}$	25	[-]	CRf	40.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.000001% [%		$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	1 496.9316	[\$/tCO <sub>2</sub> ]	P&D <sub>IM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530 [\$/kV	'h]	Mirsur	3.0	[m-h]	$\sum_{AEP} AEP$	73.1	[tCO2/MW2h]	2		7.00%	[%]
IPT	10.00%	[%]	N	25 [yr		CMbrsanv	85.00	[S/m-h]	ALL and <sub>P12-2P2</sub>	89.657	[MW <sub>e</sub> h]	× 141		0.00%	[%]
T <sub>CM</sub>	484.3839	[S/KW]	O&M	0.048935 (\$/\V	rj (h)	D N <sub>m</sub> Mar	30	[-]	n, GHG	0.00089	IVI INCO ANVIN	2.3		5.00%	[%]
PC =	26 30%	[%5]	MIC	71 5608 (\$4	1	C .	3 500.00	[u] [\$/d]	GHG	0.00008	ICO AW N	ICPM		89 657 257	[/w]
C	0.1900	[%/\$/KW]	TIC	124 5688 [\$4	1	M we	61.0184	[3/4] [\$/JW]	C C C C C C C C C C C C C C C C C C C	11.0500	[8/(CO <sub>2</sub> )]	LCI M WF		87 057 257	[K W du yi ]
LWTG cu	39,1957	[\$/m/kW]	R	30.00% [%	,,	Vwr	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	ring	Г	Notes
WF	50 000	[kW]	ifr	2.50% [%/	rl V	WTS vie	1.4442	[\$/kW]	Š. RELOU	10.0%	[%]	Debt ratio		50.0%	[%]
L	13 950	[m]	Ň	25 [yi	í l	WF car	50 000	[kW]	$\xi$ , REP CM	50.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n mih	72 [h		ifr	2.50%	[%/yr]	$\tilde{\zeta}_{3}$ OREP CM	20.0%	[%]	Debt gri	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	113 [h		Ν	25	[yr]	$\xi_4 GHG.R_{CM}$	20.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	14 605 780 [\$N	ŋ	WTweight	200 000	[kg]	REPIM	314.0072	[\$/proj]	Debt value		29 899 095	[\$]
ç	0.08%	[%]	AEP anail	89 657 257 [kWh	[yr]	C steel	0.1900	[S/kg]				Debt pa	yments	3 020 525	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.147210 [\$#W	/yr] ]	TS VM	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	2	50.0%	[%]
TLc	0.0400	[\$/m]			_	WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 899 095	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)	Not	5	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC OBM	0.000057 [\$/kW	'h]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]			,	
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0 [d		Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9 [d	RC	M <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	73.0793	yr i	78.4116	yr 15
WF cap	50 000	[kW]	Hours required	72.0 [h					O&M WFCM			73.4776	$yr_2$	77.5903	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000156 [\$/kV	h] Hour	s Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	73.7436	yr 3	78.1098	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25 [-	Ja	nuary	744	738	(%) ccm	80.0%	[%]	74.0885	$yr_4$	78.5637	yr 17
Bld area	300.0	[m*]	Frequency	1.5 [per	r] re	bruary'	6/2	639	REFIN			74.4286	yr <sub>5</sub>	79.0704	yr 18
FS FS	35.9374	[5/KW] [5/kW]	Hours required	112.5 Di	Ma Arr	ncn	744	735	č. RELey	1	[1/0]	75 1794	yr <sub>6</sub>	77.6767	yr 19 X7 20
DT	87.77	[\$/kW]	SC or u+USC or	184.5 /h/v	-] M.	av.	744	735	E REP ou		[1/0]	75.4693	3777 NT 0	78 1898	37 20 X7 au
FG	404 57	[5/kW]	DC DEM TO DC DEM	0 000214 154-00	/wr]	ng <sup>(*)</sup>	720	687	Ča OREP cu	1	[1/0]	75 9694	77 8 NT 0	78 6500	37 21 NT 22
EG	3 7712	[5/kW]		0.000214 [3411	59 JU 1.0	ve Iv	744	735	ŠA GHG R CH	1	[1/0]	76 3656	yr 10	78 9953	37 22 VF 23
WACC mai	4,900%	[%/vr]			Au		744	735	P&D <sub>IM</sub>	1	[1/0]	76.6792	yr11	79,3896	yr 25
n fin	1.0	[yr]			Se	ptember	720	711	λ.,	1	[1/0]	77.1795	VF 12	76.8138	Mean
WFree	0.30%	[%]			Oc	tober	744	735	$\lambda_{sdi}$	0	[1/0]	77.5814	yr 13	2.0085	SD
CCC CM	2.4042	[\$/kW]			No	wember <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	78.0080	yr 14	-0.4651	Y (skewness)
ĸ	0.20%	[%]			De	cember	744	735	λ.,,	1	[1/0]	LCOF	76.8138	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]			Ta	tal [h/yr]	8 760	8 579		p.s.: 1 = yes as	nd 0=no		0.076814	US\$/kWh	

**Figure N.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $E_{pi}$  (*Case* <sub>2</sub>). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				-					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	on about the project.		Costs covered by manufacturer $(O \delta M_{\rm cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	ĺ	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	TORS	AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI <sub>CM</sub>	67.4078	[S/kWe]	WF CM		50 000	[kW_/yr]
Project Location	Cape Saint James (Canada)		Depr <sub>WTmi</sub>	76.9840	[\$/kW]	RM WT	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	C M Mar	100	[m-h]	$\psi_{aoaal}$	20.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tjr Denr.	2.50%	[%/yr] [\$/vW]	N Milwana ar	85.00	[S/m-n]	PFP out	0.00000048	[yr] [\$/FW b]	N col		90.0	[-]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Yac	15	[(rkf)]	$D_{\mu}^{n_{HI}}$	2.0	[d]	AEP muit/Harod	24 766	[kW/yr]	L.		1 800	[m]
Hub height (H)	105.0	[m]	ТОсм	0.000033	[\$/kW]	C <sub>nd max</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L		2 430	[m]
Wind speed measured at (H <sub>0</sub> )	10.0	[m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ŝ	0.0120	[\$/kW <sub>e</sub> h]	SD <sub>x</sub>		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.008498	$[kW_{o}h]$	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>e</sub>	14	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	C ()	1 457.72	[\$/kW]	M <sub>brance</sub>	3.0	[m-h]	OREP CM	103.0635	[\$/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	48.5%	[%]	PR	0.70	[-]	C <sub>Mbracr</sub>	85.00	[S/m-h]	LCCCM <sub>WFORSIGCM</sub>	5.0125	[\$/kW]	AEP avail		212 467 325	[kWeh/yr]
Availability	97.9%	[%]	Ь	-1.94	[-]	D N M MCT	3	[-]	LCCCM WF	1 204.5180	[\$/KW]	$\eta_{wecs}$		20.35%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/kW]	C <sup>m</sup> <sub>MCT</sub>	2.0		WACC proj	4.9000%	[%/yr]	n sectore		25.00%	[%]
Wind Farm Life-Cycle Canit	al Cost Model	Noter	Wind Farm O&M Cost	Model	Noter	S& PV	1 297 3916	[\$/d] [\$/FW]	9° antal i Gu	20.0%	[%] [%/97]	P&D <sub>LM</sub>	factor	0.814145	[-]
wr	553 7256	(S/FW)	O&M.	0.098275	(\$/VWb)	WE	50,000	(JAW)	iji i	14	[107]	4		63617	6.25
CMwr	265.32	[\$/kW]	LCCCM we	1 204,5180	[\$/kW]	Nwr	25	[-]	CR	40.0%	[%]	AEP		438 000 000	[m] [kW_h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	AWT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	8 186.2796	[\$/tCO2]	P&D <sub>IM</sub>			
CkW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Mbruny	3.0	[m-h]	LCER <sub>co</sub> ,	173.2	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mbr_{sARY}}$	85.00	[\$/m-h]	$\sum AEP_{aud} = \sum_{r_1, r_2, r_3}$	212 467	[MWeh]	2,41		3.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub>	3	[-]	n <sub>v</sub>	25	[yr]	λd		5.00%	[%]
Tmass	138 000	[kg]	O&M variable cu	0.041531	[\$/kWh]	D <sub>m</sub> <sub>saky</sub>	3.0	[d]	$GHG_{IM_{FCO_2}}$	0.00089	[tCO2/MW2h]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md sarv</sub>	3 500.00	[\$/d]	$GHG_{EM_{unit}CO_2}$	0.00008	[tCO2/MW,h]	LCPM <sub>WF</sub>		212 467 325	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[S/kW]	Ec	25.5000	[\$/tCO <sub>2</sub> ]			r	
LWTG CM	39.1957	[S/m/kW]	R tanes	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[KW]	ifr N	2.50%	[%/yr]	WIS VM	1.4442	[S/KW]	ζ <sub>1</sub> REI <sub>CM</sub> č nrn	10.0%	[%]	Debt ratio		50.0%	[%]
CAR	2 000 00	[m] [\$/m]	N	25	[yr] [b]	WP cap	2 50%	[KW] [% /vr]	Č ORFP ou	20.0%	[%]	Debt or	ace neriod	14	[yr]
CP cu	30.9069	[5/kW]	n atta	113	[h]	N	25	[vr]	ζ <sub>3</sub> GHG R <sub>CV</sub>	20.0%	[%]	Deht in	erest rate	5.00%	[%/yr]
EF.	400.00	[\$/kW]	AAR	29 394 286	[\$M]	WT	200 000	[kg]	REPIM	1 664,6094	[\$/proil	Debt value		29 580 781	[\$]
ç	0.08%	[%]	AEP anail	212 467 325	[kWh/yr]	Csteel	0.1900	[S/kg]			1.1 11	Debt pa	yments	2 988 368	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139806	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	o	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 580 781	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)	Г	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	at rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000024	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	$[/m^2/kW]$	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	84.2996	$yr_1$	94.3718	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			84.9743	$yr_2$	94.0482	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000066	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M ccm	1	[1/0]	85.6626	yr 3	94.8532	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	86.1247	$yr_4$	95.7496	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			86.8183	$yr_{5}$	96.6483	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution		F# 103	87.5429	yr <sub>6</sub>	97.4272	yr 19
F5	19.88	[\$/KW] [\$/14W]	SC USC	112.5	[n]	Apru	720	711	REICH	1	[1/0]	88.1136	yr 9	93.916/	yr 20
DI	404.52	[\$/KW] [\$/FW]	SC O&M+USC O&M	104.5	[N/yr]	May	744	687	OREP CM	1	[1/0]	80.512/	yr <sub>8</sub>	94.0108	yr <sub>21</sub>
EG F cu	3 7712	[\$/kW]		0.000090	(wa mu/yfj	June	744	735	GHG R cy	1	[1/0]	90.3120	97 9 VF 10	96.4289	37 22 VT 23
WACC mai	4,900%	[%/vr]		Г		August	744	735	P&DIM		[1/0]	91.1318	yr II	97,4427	VT 25
n <sub>fin</sub>	1.0	[yr]				September	720	711	λa	1	[1/0]	91.8409	yr 12	91.7081	Mean
W <sub>F<sub>CM</sub></sub>	0.30%	[%]				October	744	735	$\lambda_{xdi}$	1	[1/0]	92.5685	yr 13	4.1890	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	93.6087	yr 14	-0.3343	Y (skewness)
K	0.20%	[%]				December	744	735	λ.,,	1	[1/0]	LCOE was	91.7081	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 579		p.s.: 1= yes as	nd U=no		0.091708	US\$/kWh	

**Figure N.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $E_{pi}(Case_2)$ . Source: Own elaboration

Table N.1 Ene	rgy product	ion (AEP ana	ii) map of th	ne wind fau	rm for Araci	ati (Brazil)		with	n sensitivit	y analysis	of $E_{pi}$ (Ca	se 2)															
Months	V <sub>WC</sub>	$H_{I_{p}}$	bord												$AEP_{an}$	$_{ail}(k Wh)$											
	(m/s) (k	$g/m^{5}$ ) (1	<li>yr.</li>	7 y	12 )	113 y.	r4 )	Vrs :	Vr 6	yr 7	Vr.8	179 y	r 10 y	<i>T</i> II )	r12 y.	r 13 yr.	14 yr	15 yr1	5 yr.	7 yr1	8 yr 15	9 yr 2t	yr 21	yr 22	yr 23	yr 24	yr 25
, January	5.8	1.1665	738 1693.	132 889.	0 198 3 80	12 165 7 50.	7410 55.	7361 88	30 198 55	5361 55	7361 42.	32 212 885	30 198 8 89	90 198 55	7361 380	165 7507	7410 423.	2 212 8 890	198 8 890	198 557.	361 38021	165 75074	10 55736	1 3 802 16:	5 7507410	4 232 212	4 232 212
February	4.9	1.1666	639 8475	940 678	3 520 3 66	12 567 678.	3 520 77.	7316 67	83 520 77	7316 77	7316 47.	3419 678	83 520 672	83 520 77	7316 366	2 567 6783	\$ 520 482	342 482	42 3 290	403 4713	419 7 693 5	599 15724	12 1 572 41	2 7693599	9 6783520	4 713 419	4 713 419
March	4.0	1.1671	735 5556	747.	6817 542	4310 885.	3 970 97.	5 829 74.	76 817 97	5829 97	5829 654	(3 367 74)	76 817 74;	76 817 97	5 829 5 42	4310 8853	\$ 970 894	553 894	53 1809	568 4214	2608 1 809 2	568 1 686 2	32 168623	2 7806630	0 8853970	3 786 671	6 543 367
April	4.7	1.1667	711 865 6	198 632	7 908 6 32	7 908 4 070	6176 165	30 708 63.	31 806 16	30 708 1 6.	30 708 72:	10 621 632	7 908 632	27 908 17-	49 983 632	7 908 4 076	5176 945	697 943 (	97 1 630	708 6327	908 1 630 7	2 199 8 901 5	84 943 69	7 7 230 621	I 6327908	I 749 983	7 230 621
May	6.0	1.1670	735 1809.	500 542	4 109 747	76 539 5 424	4109 186	19 500 542	\$1 601 #2	00 500 18	19 500 7 80	6 340 542	24 109 542	24 109 1 6	96 169 747	6539 6543	124 168	5 169 1 686	169 975	792 8853.	641 9757.	'92 555 0v	59 894 52	0 6543124	4 4214809	1 686 169	7 806 340
, June	7.9	1.1686	687 3944	904 394	4 904 7 30	6 444 6 124	4120 354	4 051 3 94	14 904 35	44 051 35	14 051 8 28	6 679 3 94	14 904 3 94	44 904 35	44 051 736	6 444 5 076	5 764 1 69.	3 625 1 693	525 837.	237 7306-	444 8372.	37 8372.	37 3 544 05	1 5 076 76	4 5 076 764	913 305	8 286 679
July	8.6	1.1698	735 54371	072 379.	5 580 887	)69 I 108 F.	9199 422	74 882 3 75	15 580 42	24 882 42.	14 882 550	5396 55t	5396 375	95 580 5 4.	37 072 8 87	4 801 1813	1 825 3 79.	5 580 3 795	580 556.	396 7494.	407 5563.	96 9781.	25 4 224 88	2 4 224 882	2 1 690 199	896 658	556 396
August	9.6	1.1677	735 74800	694 181	0 506 1 81	0 206 1 810	1506 885	58 561 1 81	0.506 54	27 123 5 4.	7 123 89.	5 017 89:	5 017 181	10 506 42.	12 151 181	0.506 1.687	106 542	7 123 7 810	578 7 810	678 895 6	117 42171	151 78106	78 5 427 12	3 1810500	6 1810506	555 378	895 017
September	10.1	1657	711 8554	384 1 62	9176 162	9176 3658	8 543 7 54	12 482 1 62	9 176 63	21 963 63	1 963 94	2810 942	2810 162	29 176 63	1 963 1 62	9176 3658	543 632	1 963 7 223	828 7 223	828 942 8	310 52407	71 85543	84 632196	3 1 629 170	6 3 658 543	6 321 963	942 810
Octoher	0 7	5791	735 7780	20 100	2 650 075	255 0592	851 7.46	20 361 02	1 2 2 2 4	4 2 2 4 105	591 56105	891 297 6.	20 234 6	3 650 88	11 202 07	235 039	851 7.46	865 9 5610	865 9 052	750 1 805	2 8 6 5 2 8 7	2 206 1 202 5	26 7.460.12	5 073 651	0 073.650	8 824 202	1 682 467
CUIDDET		11010	. 40/ / CC/	-//2 IN7	-12 DCD 0		01 / 100 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140 - 140	16 07100		F/ C7100	10 I C71 OC	07 F 104 70	.16 104-70	2 200 0 000	16 007 40		04/ 100	07C 0 C7L	07C 0 6C	CD0 1 6C/	120 0120.	-007 + 601	71004/ 00			CU12 #CO 0	104 700 1
November	7.6	1.1038	960 0 / 20	959 85.	5 / 93 83.	555 (4/5	100 06/1	98 959 85	7/ 66/ 5	7/ 100-0/	/0 401 10	0 1 1 00 00	50 001 83.	2/ 66/ 5	/0 401 85.	2 / 93	17/ 66/	CCU C 10+ C	CCU C 689	1/01 688	105 0 908	5 2660 0 6266	59 12/040	1 833 /92	C6/ 558 C	104 0/7 /	1 000 000
December	7.6	1.1651	735 3780.	365 554	4 166 554	4 166 974	1204 541	15 277 55	4166 85	39 226 88	39 226 3 7	30 365 3 72	\$0.365 55	4166 74	64 366 55-	4 166 974	204 883	9 226 4 207	946 4207	946 3780	365 7793 (	530 54152	77 883922	6 554160	6 554166	7 464 366	3 780 365
Annual	7.4	1.1666 8	579 48 856	319 484	44 328 48 6	76 026 48 29	90 403 48 5	895 032 48 4	144 328 48	84 482 48	844 482 48 2	56 354 48 5	1173 484	444 328 48.	941 866 48 6	76 026 48 36.	2 288 49 0.	3 015 49 213	265 48 815	403 48 463	568 48 054	765 48 883 .	03 48 747 99	3 48 179 07	8 48 285 240	48 430 728	48 356 354
Table N.2 Ene.	rgv product	ion map of th	ve wind farm	for Corvo	Island (Por	tugal)		with	1 sensitivit	v analvsis v	of E., (Ca.	( · <i>a</i> s															
:	V <sub>nc</sub>	H	por												AEP av	$u_{II}(k Mh)$											
Months	(m/s) (k	g/m <sup>3</sup> ) (l.	(1) yr	1 3	r2 y	r3 yı	r4 )	Urs )	or 6	yr 7	ors )	r9 y.	r 10 y	111 )	T 12 y.	r 13 yr.	14 yı	15 yr1	5 yr.	7 yr1.	8 yr 19	> yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
January	11.7	.2313	738 14451	1 298 14 4	151 298 14 4	151 298 14 4.	51 298 14 -	451 298 14	451 298 14	451 298 10	842 026 10	942 026 14	451 298 10	842 026 10	842 026 10 2	742 026 14 45	51 298 10 8	42 026 10 84	026 14 45	1 298 10 842	2 026 10 842	026 10 842	026 10 842 0	26 10 842 02	26 10 842 020	10 842 026	10 842 026
February	11.5	1.2345	639 11923	3 902 4 25	33 203 11 5	23 902 11 9.	23 902 11 5	923 902 3 3.	69 392 11	923 902 12	538 268 17	70714 330	69 392 12.	538 268 17	70714 91	15 121 11 92	13 902 6 58	0 843 12 53	268 4 235	203 5409	699 3369	392 27762	293 11 923 9	02 2 077 29	3 658084	11 923 902	12 538 268
March	10.5	0220	735 10471	×1.5 085 1	121 120	508 087 13 6	08/087	698.087 6.2	81 00971	51 280 809	608/087 2-3	86 378 3 15	121 782 08	6 08 087 2 3	86 378 137	08.087 13.60	16 2 2 1	09 81 0 0 9 7	087 3.870	731 7 560	022 4.863	071 13.608	087 14 403 8	65 2 034 18	10 471 381	14 403 865	5 180 384
10.000			111 200		10 100 10 10 10 10 10 10 10 10 10 10 10	101 201 000			01 000 10				or 000 0						200 6 012	2000 / 10/	000 L 000 L	010 01 120	2 LOV CT 122			012 200 01	1000010
Mav		11071	000 111	201 208	- 07 000 00	FOI C/IC++	01 C/164	C/ C/T CH4	11 100 CO	14 01 044	95 066 669	C/ 1/170	CT /00 CD	3 6 010 / 67	CT 1/1 70	20 4 0 10 10 10 10 10 10 10 10 10 10 10 10 1	20 4 040 4	2701 0606	700 C 010	1101 111	200 6 6/66	414 CT 1/1	0.07.01 911	11700 C of	92 0FE FI FC	250 627 01 2	+10 0+/ C
(nm	4 - 0 t	7077.1	101 1 011			401 000 TO	10 000 10	or 007 16	1 COD 704	VI 000 704.	20 000 70	10 46100	01 007 16	20 000 70 20				104.01 46T.0	//C7 CC0	500 CT 014	1610 0400	//67 007	0 704.01 014				100 440 4
June	17	+777-I	202 / 202	541 121	993 755 7 0V	00 / 82/ 00	0 / 28 / 0	01 827 20	014 121 4.	210 212 12	693 755 4 5	00 212 10	014 121 7 0	. 4 . 7 . 20	0 212 70	05 728 221.	1411 29.	2 241 7 002	728 1 883	038 12 69.	3 755 7 000	1 887 1 82/	7 000 / 850	28 4 506 51	12 693 75.	7 000 7 28	0/6 867 6
yluly .	1.0	1.2154	735 2 005	275 13:	503 424 47:	93 962 612	26 305 10.	322 572 13	503 424 7.	452 587 3.	44 060 61	26 305 2 6	05 275 61	26 305 6 4	26 305 61.	26 305 2 00.	5 275 23.	2 466 6 126	305 6126	305 14 19	9172 10322	572 3815	724 0 120 30	)5 612630 	15 13 503 42	3815724	7 452 587
August	0.4	C/07-1	/927 (22/	187 10	282 001 3 /.	2/ 5 556.06	1 5 5 5 1	51 056.06	10 060 CI+	180 204 3.	9/ 026.06	04 109 23	3/182 4/	5/ /18 70.	04 109 47	icni /19.70	1 I I I I I I I I I I I I I I I I I I I	7 24/ 4/07	81/ 1341	766 1 060 0	CIE SI 187 ;	0/0 4 /07	81/ 4 /02 8.	1/ / 404 10	1870/8/0	5 125 054	605 557 01
September	7.6	1.2064	711 3 663	832 19.	25 451 5 8.	82 434 4 60	13 129 46	03 129 46	03 129 1	925 451 5 (	82 434 9 9	11 660 99	11 660 36	63 832 95	11 660 36	63 832 5 88.	2 434 9 91	1 660 3 663	832 12.96	5 892 2 258	821 12 965	892 5882	134 3 663 8.	32 991166	90 3 663 83	2 258 821	1 925 451
October	8.9	07171	711 0 (2)	412 01	12 412 51.	20 930 2 00	N/2/ 31	30 930 2 6	00 /2/ 7.	54/ 151 /-	57 000 05	4/2 801 15	4/2 801 5 1	50 950 15	4/2 801 3 1.	50 950 / 45.	5 0 0 0 C	12 801 5 150	930 I0 07	s /11 3 130	930 2 000	12/ / 430	00 51509	50 154/280	1 2 34/ 13	7 000 77/	2 34/ 131
November	10.0	1.2194	687 9.990	034 35	78 305 2 2v	06 092 2 26	16 092 22	06 092 2 2	06 092 2:	948 433 2.	06 092 12	663 223 44	95 676 22	06 092 12	663 223 2 2	06 092 294	8433 121	63 223 2 206	092 9 680	288 3578	305 2206	092 9680.	288 2 206 0	92 12 663 22	23 1 880 504	5 745 118	12 663 223
December	11.5	1.2237	735 13592	5 706 2 34	68 542 20.	18 979 3 16	5547 20	18 979 31	65 547 3	841 801 21	18 979 14	296 210 13.	595 706 2 0	18 979 14	296 210 2 0	18 979 384.	1 801 142	96210 2018	979 7 503	518 4826	5 724 14 296	210 13 595	706 2 018 9	79 14 296 21	10 6 168 172	4 826 724	13 595 706
Annual	. 1.6	1.2222 8	579 8965	7 257 90 2	377 375 89:	783 574 89 8	46 976 89.	792 106 90	681 985 90	056 935 89	381 970 90	318 367 90.	339 663 89.	668 733 90	318 367 90.	163 301 90 11	13 636 89 8	37 428 89 66	733 90 22	9 267 90 26.	3 721 90 560	856 90 671	187 89 760 1	46 90 272 75	50 90 345 82.	89 615 940	89 153 675
Table N.3 Ener	gy product	ion map of th	e wind farm	for Cape	Saint James	(Canada)		witi	) sensitivit	/ analvsis	of E., (Ca.	ie , )															
	V <sub>WC</sub>	H	rod	•								17			$AEP_{aix}$	$u_{II}(k Wh)$											
Months	(m/s) (k	g/m <sup>3</sup> ) (l.	(1) yr	1 3	r2 y	r3 yı	r4 )	Urs )	or 6	yr 7	ors )	r9 y.	r 10 y	111 )	T 12 y.	r 13 yr.	14 yı	15 yr1	5 yr.	7 yr1.	8 yr 19	> yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
January	15.4	1.2561	738 32734	4 798 32 7	734 798 32 7	734 798 32 7.	34 798 32	734 798 32	734 798 32	734 798 32	734 798 32	734 798 32	734 798 32	734 798 86	13 494 32	734 798 32 73	34 798 32 7	34 798 32 73-	798 3273	4 798 32 734	4 798 32 734	798 40 754	809 32 734 7	98 32 734 79	98 28 019 99	1 8 013 494	7 100 933
February	14.7	1.2522	639 24248	\$ 099 I4 4	167 424 6 91	12 583 26 2.	28 520 14 -	467 424 14	467 424 26	228 520 26	228 520 6 9	12 583 14-	467 424 14	467 424 77	49 925 26.	28 520 6 912	2 583 173	77 262 6 912	583 6912	583 6912	583 6912.	583 22 462	574 26 228 5	20 26 228 52	20 28 959 58	1 749 925	17 351 256
March	12.7	1.2495	735 18226	5 532 18 2	226 532 8 89	96 263 278	34 779 12 :	376 594 18.	226 532 27	834 779 27	834 779 88	96 263 12.	376 594 18.	226 532 9 9	71 944 27	134 779 8890	6 263 301	08 137 8 896	263 8 890	263 8 896	263 8 896.	263 22 991	460 27 834 7	79 27 834 77	79 31 414 830	9 971 944	18 921 332
April	12.4	1.2490	711 16.057	7711 192	287 404 9 64	41 890 248	28 913 9 6	41 890 19.	287 404 24	828 913 24	828 913 96	41 890 96	41 890 19.	287 404 9 6	41 890 24	\$28 913 9641	1 890 265	13 496 9 641	890 2911	1609 9641	890 9 641	890 22 185	639 199719	09 24 828 91	13 24 919 93.	9 641 890	18 139 032
May	11.2	1.2425	735 12306	5 614 25 5	533 644 9 91	15 560 19 8.	34 848 99.	15 560 25.	533 644 19	834 848 19	834 848 99	15 560 99.	15 560 25.	533 644 12	306 614 19 2	34 848 9917	5 560 25 5	33 644 9915	560 27.67	7 395 9 915	516 6 915.	560 20989	216 198348	48 19 834 84	48 19 089 27	12 306 614	16 168 320
June	10.4	1.2351	687 9212	474 25 7	714 865 11 -	433 985 168.	38 388 82.	18 718 25	714 865 16	838 388 16	838 388 11	433 985 82.	18 718 25	714 865 15	342 558 16 4	11 438 388 11 43	33 985 16 8	38 388 11 43.	985 23 72	3 122 11 43.	3 985 11 433	985 16 955	390 16 838 3	88 16 838 35	88 16 760 68.	15 342 558	14 949 503
July	10.0	1.2275	735 8739	531 295	577 699 16 2	314 803 163	14 803 77	95 266 29.	577 699 16	314 803 16	314 803 16.	314 803 77.	95 266 29.	577 699 17	905 422 16.	314 803 1631	14 803 775	5 266 16 31-	803 1959	5 205 16 31.	4 803 16 314	803 15 530	715 16 046 4	66 1631480	03 16 760 18.	17 905 422	8 625 161
August	9.7	1.2216	735 7757	712 126	309 972 17 8	819 161 12 0	99 972 17 4	819 161 12.	099 972 12	099 972 12	099 972 17.	819 161 17.	819 161 12	099 972 19	501 798 12 0	199 972 1781	19 161 865	7 428 17 81	161 1781	9 161 17 815	9 161 17 819	161 12 903	119 15 377 8	61 12 099 97	72 12 588 98.	19 501 798	7 111 908
September	10.4	1.2234	711 9 444	238 751	15 148 182	892 028 9 44	14 238 26.	361 791 75	15 148 9.	144 238 94	44 238 18.	892 028 26.	361 791 75	15 148 24	319 940 94	44 238 1889	92 028 9 44	4 238 18 89.	028 15 72	\$ 541 18 89.	2 028 18 892	028 12 321	085 13 275 5	21 9 444 23	88 8842 059	24 319 940	19 029 793
October	13.1	1.2327	735 19679	9 010 877	76 461 29:	702 682 9 83	7 656 25.	333 032 87	76 461 9	837 656 92	37 656 29	702 682 25.	333 032 87	76 461 27	459 940 98.	37 656 25 35	33 032 9 85	7 656 25 33.	032 12 20	9 924 29 70.	2 682 25 333	032 12 242	414 88586	86 983765	56 8 122 639	27 459 940	21 596 003
November	14.3	1.2429	687 23874	4 256 9 2;	71 165 251	878 688 8 27	<sup>7</sup> I 078 27:	992 285 9 2	71 165 8.	1 078 8.2	71 078 25	878 688 27	992 285 9 2	71 165 27	992 285 8 2.	71 078 25 87	5 11 889 82	06 828 25 87	688 9271	165 25 87	8 688 25 878	688 7423 (	13 8 271 0	78 8 271 07	78 8 8 70 90	27 992 285	21 951 058
December	15.1	1.2528	735 30186	5350 995	97 848 25:	745 545 7 95	5 677 19:	999 456 9 9	97 848 71	155 677 71	55 677 25	745 545 19	999 456 9 9	97 848 32	498 621 79.	55 677 30 18	86350 164	50 529 30 180	350 9 997	848 2574.	5 545 30 186	350 6350.	393 79556.	77 795567	77 916364	1 32 498 621	42 475 115
Annual	12.5	1.2404 8	579 212 46	7 325 213 2	202 961 213 (	887 985 212 2	23 670 212	655 974 213	202 961 212	223 670 212	223 670 213	887 985 212.	655 974 213	202 961 212	704 429 212	223 670 213 95	59 139 213 4	37 670 213 95	139 213 67	8 613 213 88.	7 985 213 959	139 213100	827 213 228 5	30 212 223 67	70 213 512 71-	1 212 704 429	213 419 415

Table N.4 Wir	nd speed su	eries simulati	ions for AE.	P avail in An	acati (Brazi	0		wit	h sensitivit	y analysis	of $E_{pi}$ (Ca.	se 2)			1. J											1
Months	(m/s)	yr ,	yr 2	<i>yr</i> 3	Wr 4	yr 5	W6	yr 7	$yr_{\mathcal{S}}$	yr o	yr 10	Wr II	VF 12	VF13	VF14	yr 15	yr 16	VF 17	VF 18	VF 10	yr 20	VF 21	Vr 22	Vr 23	Vrad	Yr 25
January	5.8	5.8	101	7.6	9.6	4.0	101	4.0	4.0	7.9	101	101	4.0	7.6	9.6	7.9	101	1.01	4.0	7.6	9.6	4.0	7.6	9.6	7.9	2.0
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6	1.01	6.0	6.0	1.01	9.7	8.6	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7	10.1	7.6	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9 I	1.0.	4.9	4.0	4.7	9.2	7.9	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.9	10.1
Inte	86	86	2.6	1 01	5.8	7.0	2.6	7.0	7.0	4.0	4.0	2.6	86	1 01	60	7.6	2.6	4.0	90	4.0	4 0	7.0	7.0	5.8	4.7	4.0
(m. )	20	200			0.9	101	0.7	2 0	70			0.7	0.0		0.0	2 0				0.1		2 0		0.7		
August	9.0	9.0	0.0	0.0	0.0	1.01	0.0	8.0	Ø.0	4./	4./	0.0	6./	0.0	0.0	8.0	7.7	7.6	4./	<i>v.</i> /	7.6	8.0	0.0	0.0	4.0	4./
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9	10.1	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	9.7	6.0
December	2.6	2.6	4.0	4.0	4.9	8.6	4.0	10.1	10.1	2.6	7.6	4.0	9.6	4.0	4.0	10.1	2.9	2.9	2.6	9.7	8.6	10.1	4.0	4.0	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Table N.5 Wind	I speed ser	ies simulatio	ns for AEP	wait in Corv	vo Island (I	Portugal)		with	1 sensitivity	analysis o	t E <sub>pi</sub> (Cas	e 2) Wind spee	d data serie.	s for simula	tions (m/s)											
Months	( <i>m</i> /s)	vr ,	vr.,	Vr 2	Vr. 4	Vr «	VF K	VF 7	Vr s	$V L_{\alpha}$	VF 10	VL	VF 13	VF12	VF 14	Vris	VF 16 V	'L'17 V	T 18	11.10	VF 20	Vrai	Vr 22	Vraz	VF 24	Vras
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	10.6	211	9.01	1 0.0	1.7 1	0.6	0.6	10.6	10.6	10.6	10.6	0.6	10.6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5 1	11.5	9.5	1.7	8.2	8.9	7.6	1.7	11.5	6.4	9.5	1.5	11.7
March	10.5	10.5	1.7	11.5	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	1.5	7.6	9.5	8.2	11.5	11.7	6.1	10.5	1.7	7.1
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	1.7	11.5	8.2	8.2	1.5	7.1 1/	0.5	r I'L	11.7	11.5	7.1	1.7	1.5	7.6
May	8.2	8.2	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4 I	1.5	8.9	6.4	10.5	7.6	11.7	10.5	8.2
June	7.1	r 1.7	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1 1	1.5	9.5	6.1	9.5	8.2	11.5	9.5	8.9
July	6.1	6.1	11.5	8.2	8.9	10.5	11.5	9.5	7.1	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9 I	1.7 1	.0.5	7.6	8.9	8.9	11.5	7.6	9.5
August	6.4	6.4	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2 1	1.5	6.1 1.0	.1.5	8.2	8.2	9.5	8.2	1.7	10.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6 1	.1.5	6.4 1	.1.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	7.1	11.5	1.7	9.5	11.5	1.1 1	.0.6	7.1	6.1	9.5	7.1	11.5	6.4	6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	1.7	6.4	11.5	8.2	6.4	11.5	6.4	1.7	11.5	6.4 1	0.5	7.6	6.4	10.5	6.4	11.5	6.1	8.9	11.5
December	11.5	11.5	6.4	6.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2 1	1.7	11.5	6.1	11.7	8.9	8.2	11.5
Annual	9.1	9.1	9.1	1.6	9.1	1.6	9.1	9.1	1.6	9.1	1.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Table N.6 Win	od speed se	ries simu latio	ons for AE	P anait in Car	pe Saint Jar	res (Canad	a a	wit	h sensitivity	/ analysis o	of $E_{m}$ (Cas	že 2)														
	V ne											Wind spe	ed data seri	es for simula	ttions (m/s)											
SHIHOM	(m/s)	yr 1	$yr_2$	$yr_{\beta}$	yr 4	yr 5	yr 6	yr 7	$yr_8$	$yr_9$	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17 )	yr 18	yr 19	yr 20	yr 21	yr 22	yr23	yr24	yr25
January	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	15.4	15.4	15.4 1	15.4	15.4	16.6	15.4	15.4	14.7	9.7	9.3
February	14.7	14.7	12.4	9.7	15.1	12.4	12.4	15.1	15.1	9.7	12.4	12.4	10.0	15.1	9.7	13.1	9.7	9.7	9.7	9.7	14.3	15.1	15.1	15.6	0.01	13.1
March	12.7	12.7	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1	10.0	10.0	0.0	10.0	13.8	14.7	14.7	15.3	10.4	12.9
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	15.1 1	10.4	10.4	13.8	13.3	14.3	14.3	10.4	12.9
May	11.2	11.2	14.3	10.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3	10.4	14.7 1	10.4	10.4	13.4	13.1	13.1	13.0	11.2	12.3
June	10.4	10.4	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7	11.2	14.3 1	1.2	11.2	12.8	12.7	12.7	12.7	12.4	12.2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	12.4	13.1 1	12.4	12.4	12.2	12.3	12.4	12.5	12.7	10.0
August	9.7	9.7	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.0	12.7	12.7 1	12.7	12.7	11.4	12.1	11.2	11.4	13.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1	12.4 1	13.1	13.1	11.4	11.7	10.4	10.2	14.3	13.2
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2 1	1.5.1	14.3	11.2	10.1	10.4	9.8	14.7	13.5
November .	14.3	14.3	10.4	14.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	10.4	15.1	10.0	14.7	11.2	14.7	10.4 1	14.7	14.7	9.7	10.0 5 <u>7</u>	10.0 2 2	10.3	15.1	13.9
December	1.01	1.61	10.4	14.5	1.6	13.1	10.4	1.6	7.6	14.5	13.1	10.4	2.01	7.6	15.1	12.4	15.1	10.4 1	14.5	15.1	9.0	9.7	9.7	1.01	15.4	10.9
Annuai	C.21	C.21	C.21	C.21	C.21	C.21	C.21	12.5	C.21	C.21	C.21	C.21	C.21	12.5	C.21	12.5	12.5	1 (12.2)	2.5	12.5	C.21	C.21	C.21	C.21	C.2.1	C.21

Laure IN. / KW II pet reprod			1				~~ ****					KW/	'yr												
Sites	'r_I yr_	yr3	. yr 4	4 yr.	5 yr	.6 y.	r7 y	r8 yı	- 9 yr	10 yr	11 yr	- 12 y	r 13 )	1114 3	r15 3	Vr 16 3	r 17 3	W 18 3	119	yr20	yr 21	yr 22	yr 23	yr24	yr25
Aracari (Brazil) 5 6.	95 5647	5 674	5 629	5696	1 564	7 5.65	4 569	14 565	17 564	1 56	17 56	93 56	174 5.	537 5.	718 5.	737 54	90 5t	549 51	502 5	698 5	682	2 616	5 628	645	5 637
Corvo Island 10 4. (Portugal)	51 10 535	10 466	10 473	10 467	7 1057	0 1045	10 41	5 01 6.	8 1055	0 104:	52 105	28 105	10 10.	204 10-	172 10.	452 10:	17 10:	522 10.	556 10	569 10	1 463 1	9 523 1	9 531 II	1 946	392
Cape Saint James 24 7, (Canada) 24 7,	66 24 852	24 932	24 738	3 24 785	3 24 85	2 2475	8 247.	18 24 95	12 24 78	8 248	52 2479	94 247	738 24	940 24,	879 24	940 245	08 245	932 24 :	940 24	841 24	1 855 2.	4 738 2	4 888 2.	794 2	4 877
Table N.8 Cashflow for 25 years of	the wind fam	project	50000 k	W.	racati (Brazi	-			with	sensitivity a	nalvsis of E	(Case	-												
ltem	•	-	6		4	2	e v	-			11	12	Years 13	14	15	16	1	8	19	20	21	22	23	24	25
(-) LCCCM <sub>WF</sub>	60 225 901	, '		, ,		, ,										'				1					
$WT_{CM}$	27 686 278	'	,	,	,	,	,	,	,	,		,			'	'	,	,	,	,	,	,	,	,	,
$T_{CM}$	2421929		•	,				,	,	,						•	•	•	•	,	•			,	,
LWTG <sub>CM</sub>	1 959 78.			,					,	,	,						,	,	,			,			
CP CM	154534							,	,															,	,
TS <sub>CM</sub>	57283. 2136774																								
PO CM	1 796 870	'																							
$F_{CM}$	188 559		,	,					,	,	,				'	'	,	,	,		,	,		,	,
CCCCM	12021.	•	,	,							,					'	,	,	,		•	,		,	,
LCPM <sub>WF</sub> (kWh/yr)		48 856 319	48 444 328	48 676 026	48 290 403	48 895 032 4	8 444 328 48	(844.485 48)	344.485 48.3.	56354 4835	1173 4844	4 328 48 841	1866 48 67t	026 48362.	88 49 053 0	15 4921326	4817403	48 463 568	48 054 765	48 883 303	48 747 993	48 179 078 4	8 285 240 48	430 728 48	356 354
(+) AAK (\$M/yr) PPAR		4 29/170	4367456	4498053	4573979	4747030	4 820855 4	082 192 5	06747 515	12 C COL 23	-CFC 2483 5454 5483 5454	4 354 5 636	101 C 16C	889 58637	96 60962	33 626905.	6374.091	6486088 6486088	101 260 0	6873465	- 4918060	4 982 181	c 886/11 c	c ++/ 102	cm c8
EMP	'																				4918060	4982181	5 117 988 5	261 744 5	85 005
$(-) O \& M_{WFCM}$		3 949 353	4013810	4 133 691	4 203 326	4362211	4455205 4	603 526 4.	717835 47,	86.682 4.90	9110 5030	6591 5204	1091 5315	304 54122	99 56260.	56 5784761	5 880 906	5 983 464	6 080 550	6339242	5 846 637	5 922 095	6082752 6	252 834 6	98 541
O& M <sub>fixed</sub>		2 654 579	2 697 997	2 778 672	2 825 574	2 932 474	2 978 078	1077743 3.	154 685 32	01 236 328 55 447 1 60	3 628 3369 5 4 9 7 1 6 67	9414 3481	100 1756	919 3622. 205 17000	41 37659. 50 106010	27 387268-	1 3 9 3 7 5 7 0	1.076710	4072279	4 246 052	4 340 155	4396739	4516586 4	643 449 4 ano 205 1	152 224 546 216
(+) LRCM		863 268	884850	010 000 1	929 646	952 887	976709 1	001127 10	V26155 102	101 008 19	8104 1105	5057 1132	101 101	000 11900	25 12197.	76	-	-		-	-	-			-
(+) Depreciation		2 458 163	2519617	2582608	2 647 173	2713352	2 781 186 2	850716 25	121984 299	95 033 3 06	9909 3146	5 657 3 225	1323 3305	956 33886	05 34733	21 3560154	3 649 157	3 740 386	3 833 896	3 929 743	4 027 987	4128687	4 231 904 4	337 701 4	146 144
(=) Profit before tax	'	3 669 248	3 758 114	3 853 942	3 947 472	4 051 058	4123544 4	230 509 40	337 051 44-	12 265 455	4386 4665	9476 4790	507 4909	541 50301	28 51632.	73 404445	4 142 343	4243011	4345507	4 463 967	3099410	3 188 772	3 267 139 3	346 611 3	132 608
(-) Revenue tax	'	1289151	1310237	1 349 416	1 372 194	1424109	1446256	494.658 1.	532 024 15:	54 632 159	4 645 1 630	6306 1690	1727 1727	367 17591	39 18288.	70 1880710	1912227	1 945 827	1 977 648	2 062 040	1 475 418	1 494 654	1 535 396 1	578 523 1	515 502
(+) REPIM	270 696	3 746	3 639	3 584	3 485	3 460	3 362	3 325	3 262 3	169 3	14 3.0	61 3.00	31 2.9(	8 2896	457	469	477	486	494	515	526	533	548	563	576
RELCH	33 704																							,	,
KEP CH	- 000 966	5 424	2 312	5 24/	5 145	5 10H	2 001	. 7667	7 0897	7 19/	07 01/	07 70		2 43											
GHG.R CH	-	322	327	337	343	356	361	373	382	388	80 14	08	2	ų 439	457	469	477	486	494	515	526	533	548	563	576
(=) Profit after tax w/out interes.		2 383 843	2451517	2508110	2578764	2 630 409	2 680 650 2	739176 28	308 289 2 89	0803 296	2855 303t	5231 3102	560 3185	142 3 273 8	87 333480	50 2164195	2 230 593	2 297 670	2368353	2 402 442	1 624 518	1 694 651	1 732 291 1	768 651 1	817 683
(-) Debt payments			3 181 772	3 261 316	3 342 849	3 426 420 3	512 081 3.	199 883 3 68	19 880 3 782	127 3 876	680 3 973 5	597 4 072 5	87 4 174 7	61 4 279 13(	4 386 108	'								,	,
$(+) RCM_{WF}$		2 621 739	2 687 282	2754464	2823326	2 893 909	2966257	040413 3	116424 31	94334 325	4193 3350	6047 3435	3525	947 3614(	96 37044	48 379706	3 891 986	3 989 286	4089018	4 191 243	4 296 024	4 403 425	4513511 4	626 348 4	742 007
(+) Depreciation (=) Free net cashflow	-59 955 205	2458165	2519617 4476644	2 582 608 4 583 866	2 647 175 4 706 414	2713352 4811250	2781 186 1 4916012 5	850716 21 030422 51	921984 29 56816 529	95 033 3 UC 98 044 5 43	9909 3140 0276 5565	6657 3222 5338 5694	5323 3301 1895 5842	956 33884 285 59974	05 34733 58 612652	21 356015 <sup>4</sup> 21 9521412	9771736	3 740 386 10 027 342	3 833 896 10 291 266	3 929 745 10 523 428	4 027 987 9 948 529	4128687 10226763 1	4 231 904 4 0 477 705 10	337 701 4 732 701 11	146 144 105 834
$\Sigma$ freenet amual cashflon		-52 491 459	-48014815 -	-43 430 949 -2	38 724 536 -2	33 913 285 -2	8 997 273 -25	966852 -188	10 035 -135	11 992 -8 08	1715 -2516	5378 3178	1518 9020	803 150182	61 21 144 70	82 30 666 194	40437930	50465272	60756539	71 279 967	81 228 496	91455259	01 932 964 11	665 664 12	671 498
	LCOE ***	67.66	67.81	68.02	68.18	68.43	68.62	68.87 6	9.09 65	.26 69	49 69.	72 70.4	20 70.2	3 70.44	70.78	69.81	70.00	70.20	70.40	70.76	70.37	70.55	70.82	11.17	1.37

Table N.9 Cashflow for 25 years of th	e wind farm pr	oject	50 000 kW	Corv	o Island (Pc	ortugal)			with se	nsitivity and	dysis of $E_{ni}$	(Case 2)													1
Item	0	_	2	3	4	5	6	7 8	6	10	Π	12	13	14	15	16	17	18	19	20 2	2 2	23	24	25	
(-) LC CCM WF	60 225 901																								
$WT_{CM}$	27 686 278				,	,	,	,			•	•	•	•	•	,	,		,	,	,	,			,
T CM	24 219 295					,	,	,																	
CPC	1 545 346																								
$TS_{CM}$	572 832	,		,	,	,	,	,	,			'	'					,	,	,	,	,			
SICM	2 136 726										•	•	•	•	•				,						
PO CM	1 796 870		,																						
CCC	12021																								
LCPM wr (kWh/yr)		89 657 257 - 9	0377 375 89	783 574 89 8	46 976 89	792 106 90 6	81985 900	56 935 89 38	1 970 90 318.	367 903394	¥63 89 668 73.	3 90318367	7 90 163 301	90 113 636	89 837 428	89 668 733 9	0 220 267 90	1263 721 905	560.856 90 (	71 187 89 74	60 146 90 2	72.750 90.345	823 89 615 9	40 89 153 6	675
(+) AAR $(SM'yr)$		14 970 925 1	5 468 449 15	750 988 161.	56 163 165	549 954 17 1	31821 174	39 078 17 74	1 084 18 375	119 18838	339 19 166 50	12 19787994	4 20 247 871	20 742 636	21 196 034	21 685 138 2	2 363 982 22	2 934 122 23	584 858 24 2	03 932 17 19	91 828 17 72	22 258 18 18(	019 18483 9	75 18 848 3	346
PPAR		14 970 925	5 468 449 15	750 988 161	56 163 162	549 954 17 1	131 821 17 4	39 078 17 74	1 084 18 375	119 18 838	939 19 166 50	19 787 994	4 20 247 871	20 742 636	21 196 034	21 685 138 2	2 363 982 21	2 934 122 23:	584 858 24:	203 932	,	,			
EMP				-				-												- 171	91 828 17 7	22 258 18 18(	019 18 483 5	75 18 8483	346
(-) O&M WFCM		9 368 374	9679566 9	856225 101	09 621 10.	355.890 10.7	201 68361/	01 11 556 11 10	0.782 11 497	361 11787.	429 11 992 24	1 12380950	6 12 668 548	12 977 965	13 261 497	7 007 001	3 991 943 14	4 348 504 14	755 487 15	42.655 1313	54.746 13.50 ov.cc0 0.52	50473 13910 20424 0476	0.000 0.0000	24 14 421 6	619
O.&.M. Dired		4 6/1 4/4	. F COCCOCC	20 167 071	50 484 46	15 217 000	45.724 57	11 C COC #1	- 2021 - 2512-2	2001 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	100 0 0 20 0 0 100	20 04-20 09: 5	200,000,0 5	776 644 0	200 1690	102 000 /	6 71 4 853 6	1 402 001 11	014.049 14	21 201 CIG	20 000 17	00104 0400	7760 076	13 5 660.0	+0C
(+) IRCM		892 898	884.850	906971 9	20 646	6 28825t	01 00294	201 LCI K	6155 10513	10201 008	102011 10:05	7 1132 683	1161000	1 190.075	922.012.1	-	-			-		-			·
(+) Depreciation		2 451 726	2513019 2.	575 844 2.6	40 241 27	706247 27	73 903 28	43 250 2 91	4332 2987	190 3 061 5	770 3 138 41	6 3216877	7 3 297 299	3 379 731	3 464 224	3 550 830	3 639 601 3	3 7 30 591 38	823 856 3 9	19452 40	17 438 4 11	17 874 4 22(	821 43263	42 4 434 5	500
(=) Profit before tax	,	8 917 545	9 186 752 9	377.579 9.6	16 429 91	853 198 10 1	62 593 10 3	71 501 10 58	0.788 10.916	757 11 191 4	483 11 417 73	11 756 598	3 12 037 622	12 334 427	12 618 537	11 668 602 1	2 011 640 12	3316 208 12 6	553 227 12 9	80.729 8.0	54 520 8 2	79 659 8 490	248 8 667 2	93 8 861 1	166
(-) Revenue tax	,	4 491 277	4 640 535 4	725 296 48	46 849 45	964986 51	39546 52	31 723 5 32	2325 5512.	536 5651 t	582 574995	1 5 936 398	3 6074361	6 222 791	6358810	6 505 541	6 709 195 6	5880 237 71	075 458 7:	261179 51:	57 549 5 3	16677 5454	006 55451	93 5 6545	504
(+) REPIM	427 710	2.591	2 556	2486 2	435 2	2 383 2	357 2	293 2.2	30 2.20	8 2 165	5 2107	2.081	2 037	1 997	1954	1 914	1891	1 858	261	268	272	280 2	87 292	298	8
$REI_{CM}$	33 704				,				,			'	•	•	•			,	,		,				
$REP_{CM}$	,	2 425	2 385	2311 2	257	2 200 2	168 2	100 2.0	134 2.00.	5 1957	7 1 895	1862	1 813	1 768	1720	1 675	1 644	1 605	,		,	,			,
$OREP_{CM}$	394 006												•	•											
$GHG.R_{CM}$	•	166	1/1	174	179	183	189	193	96 20	6 20	8 212	219	224	229	234	240	247	254	261	268	272	280 2	87 292	298	8
(=) Profit after tax w/out interest		4 428 858	4 548 773 4	654768 47	72 015 41	890 595 5 (	25 404 51	42 070 5 26	0.693 5.406	430 55415	966 5 669 89	0 582228(	0 5965298	6 113 634	6 261 681	5 164 975	5 304 336 2	5 437 830 5:	578 031 57	719817 28	97 243 2 9	53 261 3 036	529 31223	93 3 2069	960
(-) Debt payments			5 173 439 3 2	52 775 3 33 77 4 4 7 4 9 00	4.095 3.4. 20.007 0.0	17.447 3.56	12 883 3 59	0.455 3.680	217 37722	22 3 866 52	8 3963 191	4 062 271	4 163 827	4 267 923	4 374 621										-
(+) RCM wF		2 621 739	2 687 282 2	754464 28	23 326 21	893.909 2.5	966.257 3.0 77.000 3.0	40.413 3.11	6424 3194	334 3274.	193 3 356 04	7 3439945	9 3525947	3 614 096	3 704 448	3 797 060	3 891 986	3 989 286 41	089.018 4	91243 42	96 024 4 4	03 425 4 513	511 46263	48 47420	200
(+) Deprectation	101 002 05	02/ 1050	2213019 2	02 the c/c	AU 241 2	100 241 21	1/3903 24	16.2 002.54	1.221 2.987	722 0.014	201 0 215841	2 0/16025	9121675 1	5 5/9 /5I	5 404 224 0 0 55 727	1 12 212 964	3 039 001	1157 200 12 10	12 008 228	20512 112	1/ 458 4 11	04 561 11 770	2 022 4 220 2	42 44545	000
(-) the net condition	y	202.95 868 -4	3720 233 -36	987.93230.0/	86 445 -23 (	13 142 -15 7	50.461 -83	15 183 -70	.111.2 156.5	780 151235	91 23 324 44	4 31741279	3 40365 995	40,205,532	58.261.265	8 0214170L	3 610.052 96	2100/0712	+20 2004 13 4	089174 135	299 880 1467	74 441 158 55	2301 170 630	84 183 013 8	852
- free net annaat cashilaw	1000		00-00-00-00-00-00-00-00-00-00-00-00-00-	200 200 200			-0- 00 P	- 10 M	10 20 20 20 20 20 20 20 20 20 20 20 20 20				00 000 00 0	10.00	-0.41	0.000		2022				01.0	-000	04.02	
	100								ł									0					2		
Table N.10 Cashflow for 25 years of t	he wind farm p	roject	50 000 kW	Cape	Saint Jame	s (Canada)			with se	nsitivity and	dysis of $E_{ni}$	(Case 2)													
Item	0	-	6	"	4	5	9	8	0	10	=	12 Ye	ars 13	14	15	16	17	81	10	w	6	2	24	56	1
																									1
(-) LC CCM wF	00 222 00																								
T	202 000 12																								
LWTG ~.	1 959 783																								
CPort	1 545 346		,	,							,	,						,							
TSCU	572 832		,	,							,	,						,	,		,				
SICH	2 136 726		,	,					,									,							
$PO_{CM}$	1 796 870	,	,																		,				
$F_{CM}$	188 559		,									'	•						,		,			'	
$CCC_{CM}$	120211		,	,	,	,	,	,	,		•	'	'	,	,	,	,	,		,	,	,			
LCPM WF (kWh/yr)		212 467 325	213 202 961 21:	3 887 985 212	223 670 212	2 655 974 213	202 961 212	223 670 212 2	23 670 213 885	985 212 655	974 213 202 96	51 212 704 429	9 212 223 670	213 959 139	213 437 670	213 959 139	213 678 613 2.	13 887 985 213	959 139 213	109 827 213 3	228 530 212 2	223 670 213 51	2714 212 704 4	29 213 419 4	415
(+) AAR $(SMVyr)$		30 129 143 2	0.989 297 31	866.088 32.4	08 583 331	286465 342	206386 349 06286 249	00 500 35 77	3012 36954	893 37 660 :	580 38 701 38 "00 26 701 38	6 39 576 165	3 40473 880	41 824 978	42.766.117	43 942 368 4	4 981 873 44	6 151 597 47.	321 124 48	311 614 34 6	82 891 35 3	82 431 36 487	277 37 257 8	77 38 317 6	694
FTAK		. CHI 671 00	10 167 686.04	57C 000 000	. 05 050 004	7 ±C C0± 027	245 000000		+06.00 710 c	. 100 / 6 668	20 10/ 00 000			41 974 9/9	42 /00 11 /	5 20C 756 CB	)+ C/Q 10/6 ++	. /+ /// ICIO	94 471 176	- 34.6	- 87 801 35 35	- 36.48		- 12 35 77	- 404
(-) O&M were		20.588.652 2	1176 288 21	775 288 22 1-	45 848 22 3	745 587 23 3	74.047 23.8	18 205 24 44	4263 25251	713 257337	770 26 444 81.	3 27 042 405	5 27 655 668	28 578 721	29 221 647	30.025.220_3	0 735 351 31	534 456 32 3	333 422 33 (	010 054 29 3	94 775 29 96	87.509 30.92	746 315767	00 32 4747	765
O&M	-	1 544 286 1	1 873 856 12	209801 124	17 656 12.7	754019 13 1	06489 133	72 438 13 70	6743 14159.	584 144295	¥68 14 828 75	5 15163927	7 15 507 888	16 025 565	16386164	16 836 847 1	7 235 134 17	7 683 316 18 1	131 422 18	10 929 18 9	84 265 19 30	57163 1997	913 20 393 7	07 20 973 8	808
O&M variable	,	9 044 366	9 302 432 9.	565 487 97.	28 192 95	391568 10.2	V67 558 104	75 767 10 73	7 520 11 092	129 11 303 5	302 11 616 05	8 11 878 478	3 12 147 781	12 553 156	12 835 484	13 188 373 1	3 500 217 13	3851 140 142	202 000 14 4	99125 104	10 511 10 60	20 346 10 951	834 11182 9	93 11 5009	957
(+) LRCM		863 268	884 850	906971 9.	5 949 5	952.887 9	76709 10	91 127 1 02	6155 1051.	809 1 078	104 1 105 05	77 1132 683	3 1161 000	1 190 025	1 219 776										
(+) Depreciation		2 425 624	2486265 2.	548 421 2 6	612 132 24	677 435 27	744371 28	12 980 2 88	3 305 2 955	387 3 029 2	272 3 105 00	M 3182625	9 3262195	3 343 749	3 427 343	3 513 027	3 600 852 2	3 690 874 37	783 146 3 1	877724 39'	74 667 4 07	74 034 4 175	885 42802	82 4 387 2	289
(=) Profit before tax		12 829 384	3 184 124 13	546193 138	04 513 14	171201 145	553419 148	66 402 15 23	8 209 15 710	376 16034	186 16 466 63	33 16849070	0 17 241 406	17 780 031	18 191 588	17 430 175 1	7 847 374 18	8 308 015 18	770 847 19	179 285 9 20	62 783 9 46	58 956 9 739	415 99614	60 10 230 2	218
(-) Revenue tax		9 038 743	9 296 789 9	559.826 97	22 575 9:	985 940 102	261916 104	70 150 10 75	1 904 11 086	468 11 298	174 11 610 41	6 11 872 845	9 12 142 164	12 547 493	12829835	13 182 710 1	3 494 562 1:	3 845 479 14	196 337 14	93484 104	04 867 10 6	14729 10940	183 11177 3	63 11 495 3	308
(+) KEPIM	1 004 339	8611	1 218	1 238 1	C47	1 200	1 /87	301 1.	521 1.55	7 1 30(	0 1392	1412	1 454	14/1	C87 I	1 320	1021	1 38/	775	1 104	489 I	c1 61c	66C T Q	1043	0
RFP	+0/ cc	- 203	- 287	- 180	- 11	- 2990	- 090			- 735	1.080	- 223	- 18	- 10											
OREPCH	1 030 635		'		1 ' 1	-			£ '	i '		-	1												
GHG.R CM		905	931	957	974 1	1 000 1	028 1	049 1.0	75 1110	0 1 131	1163	1189	1 216	1 257	1 285	1 320	1351	1 387 1	1 422	451 1	489 1	519 15	6 1 599	1 645	S
(=) Profit after tax w/out interest		3 791 839	3 888 553 3	987 605 40	83 183 4 1	186527 42	92.790 43	97 553 4 50	7 626 4 625.	260 4737 2	378 4 857 60	9 4977633	3 5100 676	5 234 008	5 363 038	4 248 785	4 354 164 4	1463 922 4:	575 932 4 (	87 252 -1 1-	40 596 -1 12	44 255 -1 205	202 -1 214 3	04 -1 2634	446
(-) Debt payments		1	1 139 654 3 2	18 145 3 29;	8599 338	81 064 3 46	6 591 3 55.	2.230 3.641	036 3732 0k	22 3 825 36	4 3 920 998	4 019 023	4 119 498	4 222 486	4 328 048			,	,	,	,				
$(+) RCM_{WF}$	•	2 621 739	2 687 282 2	754464 28	123 326 21	893 909 2 5	966257 30	40 413 3 11	6424 3194	334 3274.	193 3 356 04	17 3 4 39 9 45	9 3525947	3 614 096	3 704 448	3 797 060	3 891 986	3 989 286 4(	089 018 4	91243 42	96 024 4 4	03 425 4 513	511 46263	48 47420	600
(+) Depreciation	192101.02	2 425 624	2486205 2	548.421 2.6	612 132 24 mmn 63	677435 2.	744371 28	12 980 2 86	3305 2955	387 3029.	272 3 105 UL	7 7 201 100	9 3262 195	3 343 749	3 42/ 345	351302/	3 600 852 .	3 690 8/4 5	783 146 54	877724 39	74 667 4 0.	74034 41/2	885 42802	82 4 38/ 2	289
(=) Free net cashitow	100 101 66-	20222200	5922440 0	10 072.540 0.4	20 0HZ 0.	10 /080/5	237828 0C	98.710 000	5318 / 042 7.050 1.415	1027 026	70 / 67 / 6/ 5	102 009 22 0	<1C 60/ / 8	000 606 /	8 100 / 64	1 1/8 800 II	1 84/002 1.	2 144 082 121	21 CR0844	260.120 117	20.00 000 000 000 000 000 000 000 000 00	53.204 / 40-	7740 / 161	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	068

97.44

96.43

95.66

94.62

93.92

97.43

96.65

95.75

94.85

94.05

94.37

93.61

92.57

91.84

91.13

90.31

89.72

88.81

88.12

87.54

86.82

86.12

85.66

84.97

84.30

 $LCOE_{uno}$ 

## **APPENDIX O**

Г

LCOE wso Model Inputs

Legena				r			r		Revenues		wotes
Green cells indicate information and an	re updated		Of M warranty conditio		Notes	Depresiation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]
automatically based on user input into	yellow cells.		Oam warranty contaito			Deprectation					
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M on)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]
Wind Proiect Information		Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal Co	ost Model	Notes	Renewable Energy Public Inc	entive Model	Notes
Project Name	Firestar Wind Farm		ARCM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI CM	65.7637	[\$/kW_]
Project Location	Aracati (Brazil)		Deprwr.	76.9840	[\$/kW]	RM wT	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF	50 000	[kW]	LRCM	16.8443	[\$/kW]
Number of Wind Turbines (N <sub>WT</sub> )	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	N <sub>WT</sub>	25	[-]	ifr	2.50%	[%/yr]
Turbine Size	2 000	[kW]	N	25	[yr]	Mhrann	100	[m-h]	$\Psi_{total}$	15.00%	[%]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	C <sub>Mbr<sub>kMur</sub></sub>	85.00	[\$/m-h]	n <sub>y</sub>	3	[yr]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>mamar</sub>	3	[-]	REP CM	0.00000594	[\$/kW_h]
Swept Area per Turbine (A)	6 361.7	$[m^2]$	Y <sub>RC</sub>	15	[yr]	D <sub>m<sub>RMur</sub></sub>	2.0	[d]	AEP avail/H prod	5 695	[kW/yr]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	$C_{md_{kMyT}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]
Wind speed measured at $(H_0)$	10.0	[m]	TI	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ε	0.0339	[\$/kWeh]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.023377	[\$/kWeh]
Betz Limit's coefficient (C PBetz)	0.5926	[-]	$V_{0}$	6 100 000	[kW]	N <sub>WT</sub>	25	[-]	n <sub>c</sub>	15	[yr]
Lifetime of Wind Farm (N)	25	[yr]	C ()	1 457.72	[\$/kW]	Mirmur	3.0	[m-h]	OREP CM	21.6761	[\$/kWe]
Production Efficiency (WF PE)	11.2%	[%]	PR	0.70	[-]	C <sub>Mbr<sub>RCT</sub></sub>	85.00	[\$/m-h]	LCCCM WFOREGOM	4.5846	[\$/kW]
Availability	97.9%	[%]	b	-1.94	[-]	$N_{m_{pure}}$	3	[-]	LCCCM WF	1 204.5180	[\$/kW]
	357	[d/yr]	LRCM	16.8443	[\$/kW]	D <sub>m</sub> more	2.0	[d]	WACC proj	4.9000%	[%/yr]
						C <sub>ml</sub>	3 500.00	[\$/d]	$\Psi_{total}$	15.0%	[%]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M find	0.098275	[\$/kWh]	WF can	50 000	[kW]	n ,	15	[yr]
CM WT	265.32	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	NWT	25	[-]	CR	25.0%	[%]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	3 868.4070	[\$/tCO2]
$C_{kW}$	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>hr surv</sub>	3.0	[m-h]	$LCER_{co}$	56.2	[tCO2/MWeh]
IPT	10.00%	[%]	Ν	25	[yr]	CMhran	85.00	[\$/m-h]	$\sum AEP_{avail}$	48 856	[MWeh]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N	3	[-]	n <sub>w</sub>	25	[yr]
T <sub>mass</sub>	138 000	[kg]	O&M <sub>variable</sub>	0.025858	[\$/kWh]	$D_m^{m_{SARV}}$	3.0	[d]	GHG <sub>EM g</sub>	0.00123	[tCO2/MWeh]
RC <sub>T</sub>	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md</sub>	3 500.00	[\$/d]	GHG <sub>FM</sub>	0.00008	[tCO2/MWeh]
Csteel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	E	37.1056	[\$/tCO <sub>2</sub> ]
LWIG CM	39,1957	[\$/m/kW]	Rearry	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[%]
WF	50 000	[kW]	ifr	2.50%	[%/vr]	WTS var	1.4442	[\$/kW]	Č. RELOU	0.0%	[%]
La	13 950	[m]	N	25	[vr]	WF can	50 000	[kW]	Č. REP.cm	0.0%	[%]
CAB	2 000.00	[\$/m]	n <sub>mlh</sub>	72	[h]	ifr	2.50%	[%/yr]	$\xi_2 OREP_{CM}$	50.0%	[%]
CP CM	30.9069	[\$/kW]	n <sub>tlh</sub>	113	[h]	N	25	[yr]	$\xi_4$ GHG.R <sub>CM</sub>	50.0%	[%]
EF	400.00	[\$/kW]	AAR	4 192 361	[\$M]	WT	200 000	[kg]	REPIM	1 945.0415	[\$/proi]
ç	0.08%	[%]	AEP and	48 856 319	[kWh/yr]	C creed	0.1900	[\$/kg]			1+-121
TS and	11.4566	[\$/FW ]	0&M	0 124133	[\$/kWh/wr]	TS	0.9965	[\$/kW]	Exchange rates		Notes
TI	0.0400	[\$/m]	O CELIA WFCM	01121100	[0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.	WE	50,000	[(# K () ]		1 2252	[ ]
	1 200	[4/14]	04M	Г	Notar	wir cap	2 50%	[K ++ ]	CAN/JISD	0.0008	[-]
IL,	1 200	[1/KW]	OCM manag(STD)	0.000.105	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]
	3 000	[m]	SC O&M	0.000105	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]
SB <sub>c</sub>	113.00	[\$/kWh]	Work days	3.0	[d]	T <sub>mass</sub>	138 000	[kg]		1	
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE <sub>wso</sub>		Notes
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM		
WT inst	42.5238	[\$/kW]	USC O&M	0.000287	[\$/kWh]	Hours Distribution	$FLH_{wf}[h]$	H prod [h]	O&M ccm	1	[1/0]
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM		
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution		
FS	19.88	[\$/kW]	Hours required	112.5	[h]	April	720	711	$\zeta_1 REI_{CM}$	1	[1/0]
DT	87.22	[\$/kW]	SC O&M+USC O&M	184.5	[h/yr]	May	744	735	$\xi_2 REP_{CM}$	1	[1/0]
EG	404.52	[\$/kW]		0.000392	[\$/kWh/yr]	June (*)	720	687	$\xi_3 \text{ OREP }_{CM}$	1	[1/0]
F <sub>CM</sub>	3.7712	[\$/kW]				July	744	735	ξ <sub>4</sub> GHG.R <sub>CM</sub>	1	[1/0]
WACC proj	4.900%	[%/yr]				August	744	735	P&D <sub>LM</sub>		
n <sub>fin</sub>	1.0	[yr]				September	720	711	$\lambda_a$	1	[1/0]
W <sub>F<sub>CM</sub></sub>	0.30%	[%]				October	744	735	$\lambda_{ski}$	0	[1/0]
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]
К	0.20%	[%]				December	744	735	λ	1	[1/0]
LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 579		p.s.: 1 = yes at	nd 0=no
						(*)Period of less hours for produ-	ction				

**Figure O.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $E_{pi}(Case_3)$ . Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	us	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_cm)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[S/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
WE IN SALE OF			I malia d Baula anna d	Card Maded	N .	Wind From Brownel C	and Madel	N .	Bananahla Franse Bublis In		N	W-1 F	0		N .
Project Name	Firestar Wind Farm	otes	AR cu	16 8442	INOTES [S/kW]	DCM ws	1 339 9154	INOLES [S/kW]	RELCH	65 7637	INOIES [\$/kW_]	WE cu	-Cycle Frod	50.000	INOIES
Project Location	Corvo Island (Portugal)		Depr	76.9840	[\$/kW]	RM WF	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	WForm		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines $(N_{WT})$	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	$N_{WT}$	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	Mirmur	100	[m-h]	$\Psi_{solal}$	15.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	C Maranar	85.00	[S/m-h]	n ,,	3	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>Y<sub>RC</sub></sub>	60.1398	[S/KW]	D	3	[-] 60	KEP CM	0.0000831	[\$/KW_ch]	D L		90.0	[m]
Swept Area per Turbine (A) Hub height (H)	0.381.7	[m <sup>-</sup> ]	1 RC	0.000033	[yr] (\$//W)	C	2.0	[0] [\$/4]	AEP anail/ II prod	2 50%	[KW/yr] [%/yr]			2 430	[m]
Wind speed measured at (Ha)	10.0	[m]	71	1 798 743	[\$/kW]	RM cr	20.1954	[3/kW]	s, s	0.0869	[\$/kW_h]	$SD_{-}$		450	[m]
Terrain rugosity factor (a)	0.14	E	v	237 699 000	[kW]	WF car	50 000	[kW]	E <sub>0</sub>	0.060000	[\$/kW_ch]	SD <sub>scol</sub>		540	[m]
Betz Limit's coefficient (C PBerz)	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>e</sub>	15	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	C 0	1 457.72	[\$/kW]	Mhrance	3.0	[m-h]	OREP CM	39.7783	$[S/kW_e]$	PC PM			
Production Efficiency (WF PE)	20.5%	[%]	PR	0.70	[-]	$C_{Mhe_{h_{CT}}}$	85.00	[\$/m-h]	LCCCM <sub>WFCREGCM</sub>	4.5846	[\$/kW]	AEP avail		89 657 257	[kW <sub>e</sub> h/yr]
Aváilability	97.9%	[%]	b	-1.94	[-]	N <sub>mmcr</sub>	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wea}$		20.98%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/kW]		2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{\mathrm{harcs}_{\mathrm{(ref)}}}}$		25.00%	[%]
				F		C <sub>nd MCT</sub>	3 500.00	[\$/d]	$\psi_{solal}$	15.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capite	al Cost Model N	otes	Wind Farm O&M Cost 1	lodel	Notes	S&RV	1 297.3916	[S/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
WI CM	353.7250 [3	SKW J	LCCCM	1 204 5190	[5/KWI] [\$/KWI]	WF cap	30 000	[KW]	n, CP	25.0%	[yr] (95.)	AEB		428,000,000	[m <sup>*</sup> ]
RC ma	73 70% [%	/\$/VW1	TT TT	0.0000001%	[96]	Awa	43.00	[m <sup>2</sup> /mt]	GHG R ou	2 487 1430	ISUCON	P&D		450 000 000	[kn av j1]
CkW	400.00 [5	5/kW]	LLC	0.0530	[\$/kWh]	M <sub>M</sub>	3.0	[m-h]	LCER <sub>co.</sub>	103.2	[ICO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMman	85.00	[\$/m-h]	$\sum AEP_{aval}$	89 657	[MWeh]	2 . 41		0.00%	[%]
T <sub>CM</sub>	484.3859 [5	5/kW]	ifr	2.50%	[%/yr]	Nman	3	[-]	n ,,	25	[yr]	2.1		5.00%	[%]
Tmarr	138 000	[kg]	O&M <sub>variable cu</sub>	0.048935	[\$/kWh]	Dmsaav	3.0	[d]	GHG <sub>IM F con</sub>	0.00123	[tCO2/MWah]	λm		5.00%	[%]
RC <sub>T</sub>	26.30% [%	/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	$GHG_{EM_{unv},co_2}$	0.00008	[tCO2/MW2h]	LCPM WF		89 657 257	$[kW_eh/yr]$
Csteel	0.1900 [	\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	Ec	13.0000	[\$/tCO2]				
$LWTG_{CM}$	39.1957 [\$/	m/kW]	R <sub>MADES</sub>	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	ring		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[S/kW]	$\zeta_1 REI_{CM}$	0.0%	[%]	Debt ratio		50.0%	[%]
	2 000 00	[m] (\$/m]	N	25	[yr] [b]	WF cap	2 50%	[KW] [96/sr]	$\zeta_2 REP_{CM}$	50.0%	[%]	Debt an	ice neriod	14	[yr]
CP cu	30,9069 [5	5/kW1	n mite	113	[11] [15]	N	25	[vr]	$\xi_3$ GHGR $_{CM}$	50.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF.	400.00 [5	5/kW]	AAR	14 605 780	[SM]	WT	200 000	[kg]	REPIM	1 263,4606	[\$/proil	Debt value		29 615 722	[\$]
ç	0.08%	[%]	AEP anail	89 657 257	[kWh/yr]	C steel	0.1900	[\$/kg]	-			Debt pa	yments	2 991 898	[\$/yr]
TS CM	11.4566 [\$	/kW_]	O&M WFCM	0.147210	[\$/kWh/yr]	TS VM	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	,	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 615 722	[\$]
TL,	1 200 [1	1/kW]	O&M <sub>manag(STD)</sub>		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000057	[\$/kWh]	Ν	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00 [\$	/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE wso	Notes
SI <sub>CM</sub>	42.7345 [\$/1	m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE win		Notes	73.0793	$yr_1$	78.4116	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			73.4776	$yr_2$	77.5903	yr 15
WTinst	42.5238 [5	§/kW]	USC ORM	0.000156	[\$/kWh]	Hours Distribution	$FLH_{wf}[h]$	H prod [h]	O&M ccm	1	[1/0]	73.7436	$yr_3$	78.1098	yr 16
Bld cost	500.00 [	\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	74.0885	$yr_4$	78.5637	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February	672	639	REPIM			74.4286	$yr_S$	79.0704	yr 18
PO <sub>CM</sub>	35.9574 [5	S/KW J	Repair time	3.0	[h] (b)	March	744	735	KEPIM distribution		[1/0]	74.8887	yr 6	79.5598	yr 19
rs DT	87.22	2.2.W1	SC+USC	112.5	[II]	May	744	735	E REP ou		[1/0]	75.4602	37.7	78 1899	yr 20
FG	404.52 [3	5/kW1	SC O&M+0 SC O&M	0.000214	[S/kWh/wr]	June <sup>(*)</sup>	720	687	Č, OREP CH	1	[1/0]	75,9694	37.8 XL0	78.6500	yr 21 W 22
F <sub>CM</sub>	3.7712 [5	5/kW]		0.000214		July	744	735	$\xi_{4}$ GHG.R <sub>CM</sub>	1	[1/0]	76.3656	yr 10	78.9953	yr 23
WACC prei	4.900%	%/yr]		Г		August	744	735	P&D <sub>LM</sub>		(,	76.6792	yr 11	79.3896	yr 25
n <sub>fin</sub>	1.0	[yr]				September	720	711	λa	1	[1/0]	77.1795	yr 12	76.8138	Mean
WFCM	0.30%	[%]				October	744	735	$\lambda_{xdi}$	0	[1/0]	77.5814	yr 13	2.0085	SD
CCC <sub>CM</sub>	2.4042 [5	\$/kW]				November <sup>(*)</sup>	720	687	24	1	[1/0]	78.0080	yr 14	-0.4651	Υ (skewness)
K	0.20%	[%]				December	744	735	λ <sub>m</sub>	1	[1/0]	LCOE NO	76.8138	US\$/MWh	valid !
LUCCMWF	1 204.5180 [\$	/KWJ	L			Total [h/yr]	8 760	8 379		p.s.: I = yes at	ia U=no		0.076814	US\$/kWh	

**Figure O.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $E_{pi}$  (*Case* 3). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				-					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	on about the project.		Costs covered by manufacturer $(O \delta M_{\rm cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	ĺ	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	TORS	AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI <sub>CM</sub>	65.7637	[S/kWe]	WF CM		50 000	[kW_/yr]
Project Location	Cape Saint James (Canada)		Depr <sub>WTmi</sub>	76.9840	[\$/kW]	RM WT	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	C M Mar	100	[m-h]	$\varphi_{aotal}$	15.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tjr Denr.	60 1398	[%/yr] [\$/vW]	N Milwana ar	85.00	[5/m-n]	n <sub>T</sub>	0.00000053	[yr] [\$/FW b]	N col		90.0	[=]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Yac	15	[Urk()]	$D_{\mu}^{n_{HI}}$	2.0	[d]	AEP muit/Harod	24 766	[kW/yr]	L.		1 800	[m]
Hub height (H)	105.0	[m]	ТОсм	0.000033	[\$/kW]	$C_{nd_{max}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L. ~~		2 4 3 0	[m]
Wind speed measured at (H <sub>0</sub> )	10.0	[m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ŝ	0.0131	[\$/kW <sub>e</sub> h]	SD <sub>x</sub>		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.007998	$[kW_{o}h]$	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>e</sub>	20	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	C ()	1 457.72	[\$/kW]	M <sub>brance</sub>	3.0	[m-h]	OREP CM	83.3169	[\$/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	48.5%	[%]	PR	0.70	[-]	C <sub>Mbracr</sub>	85.00	[S/m-h]	LCCCM <sub>WF<sub>OBSIGM</sub></sub>	4.0521	[\$/kW]	AEP avail		212 467 325	[kWeh/yr]
Availability	97.9%	[%]	Ь	-1.94	[-]	D N M MCT	3	[-]	LCCCM <sub>WF</sub>	1 204.5180	[\$/KW]	$\eta_{wecs}$		20.35%	[%]
	357	[d/yr]	LRCM	16.8443	[\$/kW]	C <sup>m</sup> <sub>MCT</sub>	2.0		WACC proj	4.9000%	[%/yr]	n sectore		25.00%	[%]
Wind Farm Life-Cycle Canit	al Cost Model	Noter	Wind Farm O&M Cost	Model	Noter	S& PV	1 297 3916	[\$/d] [\$/JW]	Y antal	2.5%	[%] [%/97]	P&D <sub>LM</sub>	factor	0.814145	[-]
wr	553 7256	(S/FW)	O&M.	0.098275	(\$/FWP)	WE	50,000	[JAK11]	iji I	20.0	[10794]	4		6 361 7	6.25
CMwr	265.32	[\$/kW]	LCCCM we	1 204,5180	[\$/kW]	Nwr	25	[-]	CR (	25.0%	[%]	AEP		438 000 000	[m] [kW_h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	AWT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	10 881.1639	[\$/tCO2]	P&D <sub>IM</sub>			
CkW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Mbruny	3.0	[m-h]	LCER <sub>CO</sub>	244.5	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mbr_{sARY}}$	85.00	[\$/m-h]	$\sum AEP_{aud}$	212 467	[MW <sub>e</sub> h]	2,41		3.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub>	3	[-]	n ,,	25	[yr]	λd		5.00%	[%]
Tmass	138 000	[kg]	O&M variable cu	0.041531	[\$/kWh]	D <sub>m</sub> <sub>saky</sub>	3.0	[d]	$GHG_{IM_{TCO_2}}$	0.00123	[tCO2/MW2h]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md sarv</sub>	3 500.00	[\$/d]	$GHG_{EM_{unstable}}$	0.00008	[tCO2/MW,h]	LCPM <sub>WF</sub>		212 467 325	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	Ec	24.0000	[\$/tCO <sub>2</sub> ]			r	
LWTG CM	39.1957	[S/m/kW]	R tanes	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[KW]	ifr N	2.50%	[%/yr]	WIS VM	1.4442	[S/KW]	S <sub>1</sub> REI <sub>CM</sub>	0.0%	[%]	Debt ratio		50.0%	[%]
CAR	2 000 00	[m] [\$/m]	IV	25	[yr] [b]	WP cap	2 50%	[KW] [%/vr]	Č ORFP av	50.0%	[%]	Debt or	ace neriod	14	[yr]
CP cu	30.9069	[5/kW]	n atta	113	[h]	N	25	[vr]	Č, GHG R cu	50.0%	[%]	Deht in	erest rate	5.00%	[%/yr]
EF.	400.00	[\$/kW]	AAR	29 394 286	[\$M]	WT	200 000	[kg]	REPIM	5 482.2404	[\$/proil	Debt value		29 071 489	[\$]
ç	0.08%	[%]	AEP anail	212 467 325	[kWh/yr]	Csteel	0.1900	[S/kg]			1.1 11	Debt pa	yments	2 936 917	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139806	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates	1	Notes	Equity rati	o	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 071 489	[\$]
TL,	1 200	[1/kW]	O&M manag(STD)	Г	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	at rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000024	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	$[/m^2/kW]$	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	84.2996	$yr_1$	94.3718	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			84.9743	$yr_2$	94.0482	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000066	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M ccm	1	[1/0]	85.6626	yr 3	94.8532	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	86.1247	$yr_4$	95.7496	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.5	[per yr]	February <sup>(*)</sup>	672	639	REPIM			86.8183	$yr_{5}$	96.6483	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	3.0	[h]	March	744	735	REPIM distribution		F# 103	87.5429	yr <sub>6</sub>	97.4272	yr 19
F5	19.88	[\$/KW] [\$/14W]	SC USC	112.5	[n]	Apru	720	711	REICH	1	[1/0]	88.1136	yr 9	93.916/	yr 20
DI	404.52	[3%W] (\$/14W)	SC O&M+USC O&M	0 000000	(EAWh (we)	muy (*)	744	697	OPER	1	[1/0]	90 7729	<i>yr</i> 8	94.0108	37 21
EG F cu	3 7712	[\$/kW]		0.000090	[#KHN/yf]	June	744	735	GHG R cy	1	[1/0]	90.3120	97 9 VF 10	96.4289	37 22 VF 23
WACC mai	4,900%	[%/vr]		Г		August	744	735	P&D <sub>IM</sub>	1	[1/0]	91.1318	yr 11	97,4427	37 25 YT 25
n <sub>fin</sub>	1.0	[yr]				September	720	711	λa	1	[1/0]	91.8409	yr 12	91.7081	Mean
W <sub>F<sub>CM</sub></sub>	0.30%	[%]				October	744	735	$\lambda_{xdi}$	1	[1/0]	92.5685	yr 13	4.1890	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	687	$\lambda_d$	1	[1/0]	93.6087	yr 14	-0.3343	Y (skewness)
K	0.20%	[%]				December	744	735	λ,,	1	[1/0]	LCOE was	91.7081	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 579		p.s.: 1= yes ar	nd U=no		0.091708	US\$/kWh	

**Figure O.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $E_{pi}$  (*Case* 3). Source: Own elaboration

Table 0.2 Ener	gy producti	on map of th	e wind farm fe	or Corvo Is	s land (Port	ugal)		with sv	ensitivity a	nalysis of E	pi (Case 3)																
Months	V <sub>HC</sub>	, H	rod												AEP avail(k	(UN)											
	$(m/s)$ $(k_i)$	(m) (h)	() yr1	yr 2	yr	3 yr	4 yr	5 yr,	5 yr	7 yr	8 yrs	7 yr 16	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	$y_{r_{20}}$	yr 21	yr 22	yr 23	yr 24	yr 25
January	11.7	.2313	738 144512	298 14 451	298 1445	1 298 1445	1 298 14 45	1 298 14 45.	1 298 14 45	1 298 10 84	2 026 10 842	026 14 451	298 10 842 6	26 10 842 0	26 10 842 0	26 14 45 1 29	8 10 842 02	5 10 842 026	14 451 298	10 842 026	10 842 026	10 842 026	10 842 026	10 842 026 1	10 842 026 1	0 842 026 1	842 026
February	11.5 1	.2345	639 11 923 5	902 4233.	203 11 92	3 902 11 92.	3 902 11 92.	3 902 3 369	392 11 92	3 902 12 53	8 268 I 770	714 3369.	392 12 538 2	68 17707.	14 9 115 1.	21 11 923 90	2 658084.	3 12 538 268	4 233 203	5 409 699	3 369 392	2 776 293	11 923 902	2 077 293 6	580843 1	1 923 902 1	538 268
March	10.5 1	.2329	735 104715	380 3 189.	384 13 65	8 087 13 69.	8 087 13 69	8 087 6 214	620 13 69	8 087 13 65	8 087 2 386	378 3189.	84 13 698 6	87 23863	78 13 698 0	87 13 698 08	7 6214620	13 698 087	3 870 731	7 560 022	4 863 071	13 698 087	14 403 865	2 034 182 1	10 471 380 1	4 403 865 3	189 384
April	9.5 1	.2317	711 73058.	87 7305,	887 10 44	3 175 10 44.	3 175 10 44.	3 175 7 305	887 10 44.	3 175 4 695	596 3082	171 7305	187 13 237 6	J8 3 082 I	71 13 237 6	18 4 699 59	6 4 699 59	5 13 237 618	3 082 171	10 119 379	3 082 171	13 919 671	13 237 618	3 082 171 3	3 082 171 1	3 237 618 3	740 614
May	8.2 1	.2282	735 48448	207 10432	053 1043	2 053 10 43.	1013 6191	280 1043	053 1043	2 053 10 43	2 053 3 856	161 9 161	80 104320.	63 3 856 1	94 143497	68 10 432 05.	3 385619.	I 10 432 053	2 377 416	13 646 640	6 191 280	2 377 416	10 432 053	3 856 194 1	14 349 768 1	0 432 053 4	844 807
June	1 1.7	.2224	687 29555.	41 12 693	755 7 005	5 728 7 005	728 7 005	: 728 10.014	121 4506	515 12 69	3 755 4 506	515 10 014	121 7 005 72	28 45065.	15 7 005 7.	28 221141.	1 2 955 54.	1 7 005 728	1 885 038	12 693 755	7 005 728	1 885 038	7 005 728	4 506 515 1	12 693 755 7	005 728 5	758 970
July	6.1 1	2154	735 20052.	75 13 503	424 4 795	3 962 6126	305 10.32.	2 572 13 505	1424 7452	587 3144	060 6126	305 2 005 2	75 612630	05 61263	05 6 126 30	05 2 005 27	5 2 352 460	5 6126305	6 126 305	14 199 172	10 322 572	3 815 724	6 126 305 0	6 126 305 1	13 503 424 3	815 724 7	452 587
August	6.4 1	2075	735 2337 h	82 10 583	961 3 290	1935 3 790	935 3 790	135 13415	i 696 6 080	504 3 790	. 935 7 404	169 2 337	82 476281	17 7 404 1	59 4 762 8.	17 10 583 66	1 1 992 24	7 4 762 817	13 415 696	1 992 247	13 415 696	4 762 817	4 762 817	7 404 169 4	4 762 817 3	123 634 1	255 509
September	7.6 1	2064	711 3 663 8.	32 1 925 -	451 5 882	434 4603	129 4 603	129 4 603	129 1 925	. 451 5 882	434 9911	116 6 099	60 3 663 8:	32 99116	50 3 663 8.	32 588243	4 991166	3 663 832	12 965 892	2 258 821	12 965 892	5 882 434	3 663 832	6 0911660 3	3 663 832 2	258 821 1	925 451
October	8.0 1	2126	735 61124	2119 21.	412 3 130	5 030 2 000	727 3136	030 2 000	127 2347	131 7435	686 13 472	801 13 472	801 3 136 0	30 13 472 8	0 3 1 3 6 0	30 743568	6 13 472 80	1 3 136 030	10 628 711	3 1 36 030	2 000 727	7 435 686	3 136 030	13 472 801 2	2 131 2	2 222 2	181 278
November	10.6 1	2194	587 0 000 0	34 3 578	305 2 206	5 002 2 206	002 2 206	002 2 206	870 2 200	433 2.206	002 12 663	223 44054	76 2 206.00	92 12 663 2	23 2 206.0	22 2 948 43	3 12 663 22	3 2 206 002	9 680 288	3 578 305	2 206 002	9 680 288	2 206 002	12 663 223 1	880504 5	745 118 1	663 223
December	1 5 11	2227	735 135057	705 2 368	810 6 685	591 5 020	547 2018	591.5 020.	547 3.841	810 2 108	2011 020	210 13 505	706 2 018 02	2 14 206 2	0 2 018 0	70 3 841 80	12 302 21 1	2 018 070	7 503 518	PCL 908 P	012 902 71	13 505 706	2 018 070	9 010 900 FI	F 6218913	1 10 10	902 208
Annual	1 10	10 0000	C 20 00 02 3	257 00 277	02.00 326	1010 1220	ULU 7 110	102 00 2014	100 00 200.	000 7 00 30	010 00 001	000 00 220	1 0 7 0 0 0 0 0	C 01C UU CC	2 01 00 23	00 1100 10	UF 200 00 7	00 00 00 00	136 UKC UU	142 070 00	720 022 00	00 671 107	201 020 0	0 012 02 02 00	0 212 00 1 2	- 141 040 0	163 676
Annual	1 1.6	.8 2777	1/00 68 6/ 0	10 10 10	2/ 68 6/2	12/4 89.84	1 68 0/60	7 100 90 02		35.48 654.0	19/0 90.21	5 36/ 90 339	003 89 008 1	591506 55	0/ 901053	01 90113 03	0 89 85/ 42	8 89 608 /33	197 077 06	17/ 507 06	902 095 06	/01/0/06	0±1 00/ 62	6 00/ 7/7 06	8 578 C#5 M	2 046 CIQ	C/0 SCI /
Table O.1 Ener	ev producti	in (AEP and	) map of the	wind farm.	for Aracat	i (Brazil)		with se	snsitivity a	alvsis of E	(Case 3)																
:	V <sub>NC</sub>	H	po.												AEP avail(k	(hh)											
Months	(m/s) (fr	$r/m^{3}$ ) (h.	, vr.	. 1A	vr	, VF.	vr.	5 VF	in vr	- VF	2 VLO	VF 10	VF 11	Vr 17	VL	NF 14	VF 16	VF 16	VF 17	VF 10	VFID	VF10	VF	UP 11	VF 12	2011	VFac
Innum	1 85	1665	738 1603 13	1 008 8 62	CUS 5 801	16 7 507	10 557	198 8 800	108 557	361 557	191 132	117 8 800 1	01 00 8 80 10	21.12	21 22 20 1	5 7 507 410	01002010	8 800 108	8 800 108	557 261	3 802 165	7 507 410	5 192 13	2 371 003	507.410 4	222212 4	22 212
, January February	1 07	7 9991	7.20 847.04 530 847.04	10600 70	700 5 061	1001 001	.777 002	0600 100	100 061	777 215	2016 4713	110 67835	210600 06	00/00 00	95 2992 9	014/00/ 0	CFE C8F 0	487 347	3 200 403	100/00	COT 709 C	014/00/	C 10C/CC	y 0052092	4 014/00	+ 7177C	717 70
March	1 01	11291	735 555.00	00 7476.9	FUP 5 111	210 2223	070 075	820 7476	017 075	820 075	220 6542	10010 114 B	12 7776 21	075.87	12 10 1 2 10 1 2 10	20 2 2 2 2 0 2	804553	804 553	01 000 569	990 FLCF	895 000 1	1 696 327	1 626 333 7	2 906.620 9	952.070 2	9 129962	732 267
Anril		1/01	211 865.00	N 63770	705 6 377	9207 800	0891 921	708 6371	012 1630	0891 802	708 7 7 307	0105 100	18 637700	70 07 1 80 07 1 80	002029 8	921 920 0 8	2093.607	209 270	1 630 708	6 377 008	200 200 I	707 000 1	2 209 2P0	9 1090802	1 800 2 68	7 240 083 7	102.024
nuder Wax	1 09	1670	735 1800 50	1707 5 00	YEF L 00.	530 5424	0001 0/1	V7C0 00/	0081 004	000 1 000	2007 / 00/	1 000 5 000	UI FCF 5 00	91 989 1 0	04/700 0	0 4 543 124	1000000	1 60 1 789	075 702	8853641	00/ 000 1	106 100 0	2005 F08	P PCI 8P5 5	1 006/70	2 004 483	170.00
Inn	1 0.0	1 20101	004001 004	11 20440	0/1 7 30K	FC1 9 PPF	COD 1 COT	1776 130	001 5 2 4 V	100 T 000	4 90L 0 100	270 2 044 0	00 FEFE 10	01 000 1 00	CC0111 1	171 CLCO /	267 207 1 1	1 602 675	227 727	1 206 444	227737	727 727	0 040 TOD 12 0	2 872 2002	0 192 920	13 305 0	0129 900
anne «	1 98	1608	735 543707	2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	000 / 406	471 0 1444	##C C 071	444 C 1 CO	144C C 1406	##C C TCO	557 556 288	5##6 6/0	04 394490. 16 370558	10 140 C H	1 / 2005 1 1	40/0/06 4	085 202 8 2	C20 C60 L	902 955	### 00 C /	902 955	201 820	C 1C0 ##C C	1 088 700 1	8 001 009	2 2000 0. 2 22 29 20 20	26 306
Anoner	1 90	1677	735 7480.60	20121 10	018 1 802	0/01 100	508 8 505	-0181 195	705 5 AD7	T22 5 407	122 805.0	0308 21-	050181 2.	SILLEF M	0010181 1.	901 289 1 9	00000000	2810.678	873.018.7	205017	131 216 8	6710162	1 201 207 3	1 200 501 8 1	5 90506	55 378 B	21030
Sentember	1 101	1657	711 855438	1 0 2 9 1 75	1 620	176 3.658	243 7542	482 1 620	176 6321	175 6 321	972 8	8 2 76 01.	1 1 629 1 2	6 6 321 96	3 1 620 17	6 3.658.543	6 321 963	7 223 828	7 223 828	042.810	177 040 2	8 554 384	2 21 963	\$ 921.6291	658 543 6	221 963 9	12.810
October	9.7 1	.1645	735 778926	11 9736.	50 973	650 553 L	351 7460	125 9736	50 7460	125 7 460	125 1 682 4	467 1 682 4	57 973 65	0 883420	3 973 65	0 553 851	7 460 125	6 528 759	6 528 759	1 805 528	6 528 759	4 205 556	7 460 125	973 650 9	973 650 8	34 203 1	82 467
November	9.2 1	.1638 6	687 609893	39 8337	. 88 56.	795 833 ;	795 6 098	939 8337	195 7276	401 7 276	401 1 686 0	501 1 686 6	51 833 79.	5 727640	1 83379	5 833 795	7 276 401	5 055 889	5 055 889	1 571 703	6 968 989	6 098 939	7 276 401	833795 8	833 795 7.	276 401 1	86 661
December	7.6 1	1651	735 378036	55 554 Iv	66 554	166 974	204 5415	277 5541	66 8839	226 8 839	226 3780.	365 37803	55 554 16	6 746436	6 55416	6 974204	8 839 226	4 207 946	4 207 946	3 780 365	7 793 630	5 415 277	8 839 226	554166 5	554 166 7.	1643663	80 365
Annual	7.4 1	.1666 8.	579 48 856 3.	19 48 444	328 48.67	\$ 026 48 296	403 48 895	: 032 48 444	328 48 844	1485 48844	485 48 356	354 48 391 1	73 48 444 32	28 48 841 80	6 48 676 02	6 48 362 285	\$ 49 053 015	49 213 265	48 817 403	48 463 568	48 054 765	48 883 303	48 747 993 4	48 179 078 44	8 2 8 5 2 4 0 4 5	430 728 48	356 354
Table O.3 En	ergy produc	tion map of t	the wind farm	1 for Cape 5	Saint James	: (Canada)		with	sensitivity.	analysis of	E <sub>pi</sub> (Case 3)																
Months	$P_{HC}$	H	Prod												AEP avail(	( 4M4 )											
	(m/s) (	kg/m <sup>3</sup> ) (	(h) yr.	1 hi	12 3	Vr3 )	r4 )	15 y.	r6 )	r7 )	r <sub>8</sub> yı	9 yr	0 yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
Januar	o 15.4	1.2561	738 3273.	4 798 32 7.	34 798 32	734 798 32 :	34 798 32 :	734798 327	34 798 32 ;	734 798 32:	34 798 32 7.	14 798 32 73	1798 32734	798 80134	194 32734	798 32 734 7	98 32 734 79	8 32 734 798	32 734 798	32 734 798	32 734 798	40 754 809	32 734 798	32 734 798	28 019 994 8	013 494 7	100 933
Februar,	14.7	1.2522	639 2424	8 099 I4 4	67 424 6 9	12 583 261	28 520 14.	467 424 14 4	67 424 26 1	228 520 26.	28 520 6 91.	2 583 14 46	7 424 14 467	424 7749	25 26 228	520 691258	83 17 377 20	2 6912583	6 912 583	6 912 583	6 912 583	22 462 574	26 228 520	26 228 520	28 959 584 7	749 925 1	7 351 256
Marci	12.7	1.2495	735 1822	6 532 18 2.	26 532 8 8.	96 263 271	34 779 12 .	376 594 18 2	26 532 27 8	834 779 273	34 779 8 89,	5 263 12 37	5 594 18 226	532 99719	044 27834	779 8 896 26	33 30 108 1.	17 8 896 265	8 896 263	8 896 263	8 896 263	22 991 460	27 834 779	27 834 779	31 414 830 9	971 944 1	8 921 332
Apri	12.4	1.2490	711 16 05.	7711 1920	82 404 9 6	41 890 243	28 913 9 6.	41 890 192	87 404 24 5	328 913 241	28 913 9 64.	1890 9641	890 19287	1196 101	890 24828	913 9 641 86	0 26 913 41	N 9641890	29111 606	9 641 890	9 641 890	22 185 639	606 126 61	24 828 913	24 919 931 9	1 068 149	8 139 032
Ma	, 11.2	1.2425	735 1230	6 614 25 5.	33 644 9 9	15 560 191	34 848 991	15 560 25 5	33 644 19 1	834 848 191	34 848 991.	5 560 9 915	560 25 533	644 12 306	614 19834	848 991550	50 25 533 6 <sup>,</sup>	4 9915560	27 677 395	9 915 560	9 915 560	20 989 216	19 834 848	19 834 848	19 089 277 1	2 306 614 1	6 168 3 20
Jun	, 10.4	1.2351	687 9212	257.	14 865 11	433 985 161	<i>38 388 8</i> 2,	18 718 25 7	14 865 161	161	<b>38 388 11 4.</b>	3 985 8 218	718 25 714	865 15342	558 16 838	388 11 433 90	85 16 838 31	8 11 433 985	23 723 122	11 433 985	11 433 985	16 955 390	16 838 388	16 838 388	16 760 685 1	5 342 558 1	1 949 503
Jul	; 10.0	1.2275	735 8739	1 531 29 5:	77 699 16.	314 803 16 .	14 803 775	95 266 29 5	77 699 16 .	314 803 16.	14 803 16 31	1 803 7 795	266 29 577	699 17 905	422 16314	803 1631480	03 779526	6 1631480	19 596 205	16 314 803	16 314 803	15 530 715	16 046 466	16 314 803	16 760 185 1	7 905 422 8	625 161
Augus	9.7	1.2216	735 7757	7712 12 0	99 972 17	819 161 12 1	3 17 5	\$19 161 12 6	99 972 12 1	121 121	99 972 17 8 <sub>1</sub>	18 1 19 161	161 12 099	972 19 501	798 12 099	972 17819 h	61 8 697 42	8 17819161	17 819 161	17 819 161	17 819 161	12 903 119	15 377 861	12 099 972	12 588 985 1	9 501 798 7	806 111
Septembe	r 10.4	1.2234	711 9444	1 238 7 51.	5 148 18	892 028 9 4.	(4 238 26.	361 791 751	5148 94	44 238 9 4.	(4 238 18 8)	12 028 26 36	791 7515.	148 24319	940 9442	38 18 892 0	28 9 444 23	8 18 892 028	8 15 728 541	18 892 028	18 892 028	12 321 085	13 275 521	9 444 238 8	8 842 059 2	4 319 940 1	029 793
Octobe.	13.1	1.2327	735 1967.	778 010 6	6 461 29	702 682 9 8.	37 656 25.	333 0.32 8 77	6 461 98.	37 656 9 8.	87 656 29 7L	12 682 25 33.	3 032 8 776.	461 27 459	940 98370	56 25 333 0.	32 983765	6 25 333 032	12 209 924	29 702 682	25 333 032	12 242 414	8 858 686	9 837 656 8	8 122 639 2	7 459 940 2	596 003
Novembe	r 14.3	1.2429	687 2387	4 256 9 27.	7 165 25	878 688 82.	71 078 273	992 285 9 27	71165 82.	71 078 82.	71 078 25 8.	78 688 27 99.	2 285 9 271	165 27 992	285 8 271 (	78 25 878 6	88 11 506 8.	25 878 689	9 271 165	25 878 688	25 878 688	7 423 013	8 271 078	8 271 078 8	8 870 902 2	7 992 285 2	951 058
Annua	12.5	1.2404	8 579 212 46	7.325 213.20	92 961 213 0	987 985 212 2	23 670 212 6	(55 974 213 2)	92 961 212 2	23 670 212	23 670 213 86	7 985 212 65.	974 213 202	961 212 704	429 212 223	670 213 959 L	39 213 437 62	0 213 959 135	213 678 613	213 887 985	213 959 139	213 109 827	213 228 530 2	212 223 670 2.	0 100 044 0 13 512 714 21	2 704 429 21	217 617 1
DIMINITY	1410	10177												101 888 800								1 80 404 448					

Table O.4 Wir	nd speed s	eries simulati	ions for AE	P avail in Ar.	acati (Brazi	(1		wit	h sensitivity	analysis of	$E_{pi}$ (Case.	(E	The second for the second s	London Marine	attant and											
Months	(m/s)	yr 1	<i>yr</i> 2	<i>yr</i> 3	yr4	yr 5	$yr_{\delta}$	yr 7	yr <sub>8</sub>	yr 9	yr 10	yr II	yr 12	yr13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	Vr 24	yr 25
January	5.8	5.8	10.1	7.6	9.6	4.0	10.1	4.0	4.0	7.9	10.1	10.1	4.0	7.6	9.6	7.9	10.1	10.1	4.0	7.6	9.6	4.0	7.6	9.6	7.9	7.9
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6	10.1	6.0	6.0	10.1	9.7	8.6	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7	10.1	7.6	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	7.9	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.9	10.1
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	5.8	4.7	4.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	7.9	9.7	8.6	6.0	6.0	4.0	4.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9	1.01	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	9.7	6.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	1.01	10.1	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9	7.9	7.6	9.7	8.6	10.1	4.0	4.0	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Table O.5 Wind	speed seri	ies simulation	15 for AEP a	<sub>rvait</sub> in Corv.	o Island (P.	'ortu gal)		with	sensitivity a	nalysis of <i>l</i>	∑ <sub>pi</sub> (Case 3)															
	$V_{WC}$											Wind spee.	vd data serie	25 for simula	ttions (m/s)											
) (	(m/s)	yr1	yr 2	yr 3	yr 4	yr 5	$yr_6$	yr7	yr8	yr9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16 .	Vr17	Vr18	Vr19	yr 20	yr21	yr 22	yr23	1124	yr 25
January	11.7	11.7 1	11.7	11.7	11.7	11.7	11.7	11.7	10.6	0.01	11.7	10.6	10.6	10.6	11.7	9.01	10.6	1.7	10.6	10.6	10.6	10.6	10.6	10.6	0.6	10.6
Feb mary	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	11.7	8.2	8.9	7.6	1.7	11.5	6.4	9.5	1.5	11.7
March	10.5	10.5	7.1	11.5	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	11.5	11.7	6.1	10.5	1.7	7.1
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	1.7	11.5	8.2	8.2	11.5		10.5	1.7	11.7	11.5	1.7	1.7	1.5	7.6
May	8.2	8.2 1	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4	11.5	8.9	6.4	10.5	7.6	11.7	0.5	8.2
June	7.1	7.1 1	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	. 1.9	11.5	9.5	6.1	9.5	8.2	11.5	9.5	8.9
July	6.1	6.1 1	11.5	8.2	8.9	10.5	11.5	9.5	7.1	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9	11.7	10.5	7.6	8.9	8.9	11.5	7.6	9.5
August	6.4	6.4 1	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2	11.5	6.1	11.5	8.2	8.2	9.5	8.2	7.1	10.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	11.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	7.1	11.5	7.1	9.5	11.5	. 1.7	10.6	7.1	6.1	9.5	7.1	11.5	6.4	6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	7.1	6.4	11.5	8.2	6.4	11.5	6.4	7.1	11.5	6.4	10.5	7.6	6.4	10.5	6.4	11.5	6.1	8.9	11.5
December	11.5	11.5	6.4	6.1	7.1	6.1	1.7	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2	11.7	11.5	6.1	11.7	8.9	8.2	11.5
Amnal	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Table O.6 Wind	speed s eri	ies simulation	1s for AEP a	und in Cape	Saint Jame	ss (Canada)	_	with	sensitivity a	nalysis of <i>t</i>	$\mathbb{E}_{ni} \; (Case \; 3)$															
	Vwc											Wind spee	d data serie	s for simula	ttions (m/s)											
) ((	(m/s)	$yr_{I}$	yr 2	yr 3	$yr_4$	yr 5	$yr_{\delta}$	$yr_7$	$yr_8$	$yr_9$	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	Vr17	yr 18	yr 19	yr 20	yr21	yr 22	yr23	1124	yr 25
January	15.4	15.4 I	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	15.4	15.4	15.4	15.4	15.4	16.6	15.4	15.4	14.7	9.7	9.3
Feb mary	14.7	14.7 I	12.4	9.7	15.1	12.4	12.4	15.1	15.1	9.7	12.4	12.4	10.0	15.1	9.7	13.1	9.7	9.7	9.7	9.7	14.3	15.1	15.1	15.6	0.0	13.1
March	12.7	12.7 1	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1	10.0	10.0	10.0	10.0	13.8	14.7	14.7	15.3	0.4	12.9
April	12.4	12.4 1	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	15.1	10.4	10.4	13.8	13.3	14.3	14.3	0.4	12.9
May	11.2	11.2 1	14.3	10.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3	10.4	14.7	10.4	10.4	13.4	13.1	13.1	13.0	1.2	12.3
June	10.4	10.4 1	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7	11.2	14.3	11.2	11.2	12.8	12.7	12.7	12.7	2.4	12.2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	12.4	13.1	12.4	12.4	12.2	12.3	12.4	12.5	2.7	10.0
August	9.7	9.7 1	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.0	12.7	12.7	12.7	12.7	11.4	12.1	11.2	11.4	3.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1	12.4	13.1	13.1	11.4	11.7	10.4	10.2	4.3	13.2
October	13.1	13.1 1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2	15.1	14.3	11.2	10.1	10.4	9.8	4.7	13.5
November	14.5	14.3	10.4	14./	0.01	1.61	10.4	0.01	0.01	14./	1.61	10.4	1.61	0.01	14./	7.11	14.7	10.4	14./	14./	/ 60	0.01	10.0	10.2	1.0	15.9
December 4	201	1 3 61	+ 01	2.41	2.1	2 61	10.5	2.61	3.1	2 11 5	3 61	+:01	+:CI 2 CI	2.1	2.01	+:71 +:71	1.01	+.01	201	301	2.0	3.1	3.01	1.01	4.0 2 c	2.01
IDBININ	14.7	1 0.71		14.7	C.71	C.71	C:71	C.71	C:71	C:71	C.71	C-71	C.71	C-71	C.71	C.71				C.71				( C.7 )	<i>c.</i> 7	C.71

notice and the second												k W/yr												
y	1 yr2	yr 3	yr4	yr5	yr 6	s yr	7 yr	8 yr 5	yr1	9 yr 11	yr1.	2 yr 15	3 yr1.	t yr.	15 yr.	1 yr 1	7 yr12	8 yr 1	9 yr 2	9 yr2	1 yr.	22 yr	23 yr2	4 y
Aracari (Brazil) 5 69	5 5647	5 674	5 629	5 699	5 647	, 569-	4 569.	1 5 637	5 64.	5 647	5 69.	\$ 5.674	1 5637	7 571	8 573	7 569	1 5649	5 602	2 569	3 5682	2 561	16 56	8 564.	5 50
Corvo Island (Portugal) 10.45	1 10535	10 466	10 473	10467	10 576	) 10 49 <sub>6</sub>	8 1041:	10 528	10 53	10452	10 525	3 10 516	) IO 504	1 1047	2 10 45	2 10.51.	7 10522	10 554	5 10 56	) 1046	3 10 52	3 10 S.	1 1044	5 103
ape Saint James 2476 (Canada) 2476	6 24852	24 932	24 738	24788	24 852	24 73,	8 2473.	\$ 24 932	24 78,	8 24852	24 794	1 24 738	3 24 940	) 2487	9 24 94	0 2490	3 24932	24 94(	) 2484.	1 2485:	5 24 73	18 24 8,	8 2479	1 248
Table O.8 Cashflow for 25 years	s of the wind far	m project	50.000	) kw	Aracati (Bra	zil)			with	sensitivity an	alvsis of E	(Case 3)												
Item		-		6		ľ		r				1	Years	2	31	16	Ē	2	9	00			ĉ	sc
		-	7	0	t	n	0		0	<sup>4</sup>		7	c l	±	cr	0	-	10	6	70	7	7 77	5	3
(-) LC CCM WF	60 225 9	-																						
WT <sub>CM</sub>	27 6862	, 8, 8		•		•				,							•			,				
I CM	2 612 42	6																						
CPC	1 5453	97													• •									
TX	8.072	 																						
SICH	2 1367	26																						
POCH	1 7968	- 02:	•	,	•	,	,	,	,	,	,				,	•	,	,	,	,	,	,		
$F_{CM}$	1885	65	•	•	•	•									'	•								
$CCC_{CM}$	1202	- 11	•	•	•	•									•	•	•							
LCPM WF (kWh/yr)	'	48 856 31	9 48 444 328	8 48 676 026	48 290 403	48 895 032	48 444 328	18 844 485 48	844 485 48	356354 4839	91 173 48 44	4328 48841	866 48 6760	26 48 362 2	88 49 053 01.	5 49 213 265	48.817.403 4	48 463 568 41	8 054 765 48	883 303 487	147 993 48 1	79 078 48 28	5240 48430	28 48 356
(+) AAR $(SM/yr)$		4 297 17	0 4 367 456	5 4498 053	4 573 979	4747030	4820855	4 982 192 5	106 747 5	182 105 531	15 483 5 45	4354 5636	591 57578	89 58637	96 609623	3 6 269 053	6374091	6 486 088	65921616	873 465 45	18 060 49.	82 181 5 11	7988 5261	44 5385
PPAR		4 297 17	0 4 367 456	5 4498 053	4 573 979	4747030	4 820 855	4982192 5	106 747 5	182 105 531	15 483 5 45	4354 5636	591 57578	89 58637	96 609623	3 6 269 053	6374091	6 486 088	6592 161 6	873 465			-	
EMP		- 090 6	- 4 012 010	- 1122 601	-		- 146 706	1 and End 4	- 300 LIL			- 105				- 570,476	- 000 000	- 121 - 2	- 100 250 2	- 45 	18.000 49	1 C 181 78	107.0 986/	000 2 100 100 100 100 100 100 100 100 10
O&Mount		2.654 570	106109C 6	2778.672	2 825 574	2.932.474	870.879.5	3 077 743 3	154.685 3	X1 236 328	13 628 336	0414 3481	989 35569	19 36023	11 3765 97	3 872,684	025 226 5	4 006754	1072.279 4	246.052 43	40155 430	96 739 4 51	5586 4643	49 4752
O&M weights	,	1 294 774	4 1315813	3 1355 018	1 377 752	1 4 29 737	1477 127	1 525 784 1	563 150 1	585 447 1 62	5 482 1 66	7177 1722	102 17583	85 17899.	58 1 860 129	1 912 077	1 943 336	1 976 710 2	2 008 271 2	093 190 1 5	06483 15.	25 356 1 56	5166 1609	85 1 646
(+) LRCM		863 268	8 884 850	006 971	929 646	952 887	976709	1 001 127 1	026 155 1	021 809 1 07	78 104 1 10:	5 057 1 1 1 32	683 11610	00 1 190 0	25 1219 770									
(+) Depreciation		2 447 04-	4 2 508 220	) 2570926	2 635 199	2 701 079	2768606	2 837 821 2	908 766 2	981485 305	56 023 3 13.	2423 3210	734 32910	02 33732	77 3457 60:	3 544 049	3 632 650	3 723 467	3816553 3	911967 40	09766 41	10 011 4 21	2761 43181	80 4426
(=) Profit before tax	,	3 658 125	9 3 746 717	7 3842 260	3 935 498	4038784	4110964	4217613 4	323 833 4	428717 454	10 499 4 65.	5 243 4 775	917 48945	87 50147	99 514756.	2 4 028 341	4125836	4 226 091	4 328 165 4	446190 3.0	81189 31	70 096 3 24	7 996 3 326:	90 3412
(-) Revenue tax	'	1 289 15.	1 1 310 237	7 1349416	1 372 194	1 424 109	1446256	1 494 658 1	532 024 1	554 632 1 55	34 645 1 63	6306 1690	977 17273	61 17591	39 1828 87	9 1880716	1912 227	1 945 827	1977 648 2	062.040 14	175 418 14.	94 654 1 55	5396 1578.	23 1 615
(+) REPIM	541 902	1 069	1 087	1 119	1138	1181	1 200	1 240	1 271	1 290 1	323 15	57 140.	3 1433	1459	1 517	1560	1 586	1614	1640	1 710 1	748 1	771 15	19 1 87.	191
$REI_{CM}$				•	•																			
$REP_{CM}$			•													•								
$OREP_{CM}$	541902		,	•	,	,	,		,		,	,			'	•		,	,	,	,	,		
$GHG.R_{CM}$		1 069	1 087	1 119	1138	1181	1200	1240	1 271	1 290 1	323 15	57 140.	3 1433	1459	1 517	1560	1 586	1614	1640	1710 1	748 1	71 12	181 61	191
(=) Profit after tax w/out inte	- 18a	2370.04	7 2 437 567	7 2 493 963	2 564 442	2 615 857	2 665 907	2724195 2	793 080 2	875375 294	47 177 3 02	0294 3086	343 31686	63 32571	20 332020	9 2 149 185	2215 195	2 281 879	2 352 157 2	385 861 1 6	807.520 16	77 213 1 71	4420 1750.	37 1 798
(-) Debt payments		- 109 0	3 16/ 5/9	5 240 504	327 128 5	3 410 921 7 902 000	3 496 194	2 040 412 3	116 404 2	00 019 5 80 00 00 00 00 00 00 00 00 00 00 00 00	74 102 2 254	625 4-0545. 5047 2-420-6	1/8 ccl 4 2 2 2 2 2 0 10	311 962 5 Th	4 300 20/ DE 2 704 444	- 2 707 0.60	2 001 006	2 000 205					- 2027 1122	CFL F OF
(+) Denreciation		C1 170.7	1 2 508230	90500256 (	2 635 100	6/0 10L C	2768.606	2 1087880	0.08766 2	381 485 3.05	16.023 3.132	0125 1000	734 32910	01 33737	77 3457.604	3 544 049	3.632.650	3 773 467	3816553 3.	011 967 40	14 99766 41	10.011 4.21	7761 43181	907 7 7 7 90
(=) Free net cashflow	-59 683 9	98 7438 830	0 4465 690	4572789	4 695 239	4 799 923	4 904 575	5 018 831 5	145 081 5	286176 541	8 248 5 55.	3 141 5 682	511 58297	26 59847.	20 6115 999	9 490 294	9 7 39 831	9 994 631 10	0 257 728 10	489 072 99	13311 1015	90 649 10 44	1691 10 694	65 10 966
$\Sigma$ free net amual cash	low -	-52 245 16	8 -47 779 478	3 -43 206 689	-38 511 450	-33 711 527	-28 806 951 -	3 788 121 -18	643 040 -13	356863 -793	38 615 -2 38.	5 474 3 297	038 91267	64 15 111 4	34 21 227 48.	3 30 717 777	40 457 608 5	90 452 239 60	17 799 967 71	199 039 81 1	12349 9130	02 998 1017	13 689 112 438	154 123 405
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2082/05         3108         5104         5131         3246         5571         566         5501         4101         416         470         438         4401         468         472         4491         506         534         5314         546         5301         566         5301         4101         4176         420         4491         468         4724         4427         5497         5466         5304         5314         5314         5316         5361         5366         5304         5314         5466         13345         5316         5366         5304         4314         4638         4724         4432         4431         5466         13356         1334         5314         5466         13346         5314         5466         13346         5314         5466         13346         53014         4101         4168         4724         4434         5466         13346         13356         13346         13346         1																										
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2082 93       3094       3181       3236       3233       3445       3571       3690       3564       3054       4041       4176       420       4387       4491       4665       5294       5314       5314       5465       5244       5314       5314       5467       5466       5204       5314       5315       500       3864       3955       4001       4176       420       4868       4724       480.05       4947       5066       5204       5314       5466         www.minerer       -       375188       3870.05       3055       5001118       5179.144       519136       4505       1405       120570       120570       120570       127346       120570       120570       127346       120570       120570       127346       120570       1205752       120569       120559		,	,	,	,	,	,	,	,	,				'	'	,	,	,	,	,	,	,	,	,	,	,
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		LCOE uro	84.30	84.97	85.66	86.12	86.82	87.54 2	8.12 80	(81 89.7	2 90.5	c1.16 1	1.84	92.57	93.61	15 #6	94.05	94.85	95.75	96.65	97.43	93.92	94.62	95.66	96.43	97.44

# **APPENDIX P**

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				_					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar	ve updated vellow colle		O& M warranty condition		Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		MCA	50	[\$/kW]
Yellow cells are for use input informatio	m about the project.		Contractment for manufactures (0.6M	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC	4 9000%	[%/vr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information		Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal Co	ost Model	Notes	Renewable Energy Public In-	centive Model	Notes	Wind Farm Life	Cycle Prod	uction Model	Notes
Project Name	Aracati (Brazil)		Denr	76 9840	[\$/KW] [\$/W]	DCM WF RM	22 3284	[S/KW] [S/FW]	KEICM	1 204 5180	[5/KWe] [5/WV]	WF CM		50.000	[KW@/yr]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF cm	50 000	[kW]	LRCM	16.8443	[\$/kW]	N <sub>WT</sub>		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	[yr]	Mirmy	100	[m-h]	$\Psi_{total}$	25.00%	[%]	N <sub>raw</sub>		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	$C_{Mhr_{HF_{HF}}}$	85.00	[S/m-h]	n ,,	5	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>T<sub>BC</sub></sub>	60.1398	[\$/kW]	N <sub>menur</sub>	3	[-]	REP CM	0.00002485	[S/kWeh]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	D <sub>mmm</sub>	2.0	[d]	AEP avail/Hprod	5 693	[kW/yr]			1 800	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	[\$/kW]	C ad <sub>awar</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Termin magazity factor $(a)$	10.0	[m]	Π	1 798 743	[\$/kW]	RM CT	20.1954	[S/KW]	E C	0.1415	[S/kWeh]	SD		450	[m]
Retz Limit's coefficient (Cana)	0.5976	[-]	V V	5 100 000	[KW]	WF cap Num	25	[_]	n	12	[JrKwell]	EIH (		8 760	[III] [h/sr]
Lifetime of Wind Farm (N)	25	[vr]	V 0	1 457.72	[\$/kW]	Mw	3.0	[m-h]	OREP CM	20.7438	[\$/kW_]	РСрм		0 100	[10,91]
Production Efficiency (WF PE)	11.2%	[%]	PR	0.70	[-]	C <sub>Mbra</sub>	85.00	[\$/m-h]	LCCCM	4.3886	[\$/kW]	AEP avail		49 057 055	[kWeh/yr]
Availability	98.4%	[%]	ь	-1.94	[-]	N	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{mea}$		20.98%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]	D,	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{\rm MED_{rat}}}$		25.00%	[%]
						C <sub>nd m</sub>	3 500.00	[\$/d]	$\Psi_{total}$	25.0%	[%]	P&D <sub>Lb</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capite	al Cost Model	Notes	Wind Farm O&M Cost M	Model	Notes	S&RV	1 297.3916	[S/kW]	ifr	2.5%	[%/yr]	N <sub>WT</sub>		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>ful ci</sub>	0.098275	[\$/kWh]	WF cap	50 000	[kW]	Π	12	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM <sub>WT</sub>	265.32	[\$/kW]	$LCCCM_{WF}$	1 204.5180	[\$/kW]	$N_{WT}$	25	[-]	$CR_f$	60.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	2 427.4170	[\$/tCO2]	$P\&D_{LM}$			
$C_{kW}$	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>kr xanv</sub>	3.0	[m-h]	$LCER_{CO_2}$	31.4	[tCO2/MWah]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	C <sub>Mbr<sub>Saaty</sub></sub>	85.00	[S/m-h]	ALF and your yo	48 856	[MW <sub>c</sub> h]	2.41		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ijr O&M	2.50%	[%/yr] (\$/58/b)	D N N N N N N N N N N N N N N N N N N N	3	[-] 60	n , GHG	25	[yr]	1		5.00%	[%]
I mass	138 000	[Kg]	MIC	71 5608	[5/KWI]	C .	3.0	[a]	GHG	0.00069	[ICO <sub>2</sub> /MW <sub>4</sub> h]			40.057.055	[%]
C .	20.50%	[70/3/KW]	TIC	124 5699	(\$/h)	DI/M	61 0184	(\$442)	CHICEM www.co2	41 7428	[ICO2/MW28]	LCI M WF		47 037 033	[K W en yr ]
I WTG au	39 1957	[3/kg] [\$/m/kW]	P.	30,00%	[3/1]	Nwa	01.0184	[3/K/Y]	6 <sub>c</sub> PFPIM distribution	41.7438	[96]	Project Finan	cina	ſ	Notes
WF	50,000	[Jean Kiri ]	ifr	2.50%	[%/vr]	WTS und	1 4442	[\$/kW]	Č. RFL au	50.0%	[%]	Deht ratio	cing	50.0%	[%]
L.	13 950	[m]	N	25	[vr]	WF	50 000	[kW]	č. REP cu	25.0%	[%]	Debt term	1	14	[vr]
CAB	2 000.00	[S/m]	n wih	48	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 OREP_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tik</sub>	100	[h]	N	25	[yr]	$\xi_4 GHG.R_{CM}$	0.0%	[%]	Debt in	terest rate	5.00%	[%/yr]
EFc	400.00	[\$/kW]	AAR	4 209 586	[\$M]	WTweight	200 000	[kg]	REPIM	39.7324	[\$/proj]	Debt value		29 551 470	[\$]
ς	0.08%	[%]	AEP anail	49 057 055	[kWh/yr]	Csteel	0.1900	[\$/kg]		-		Debt pa	yments	2 985 407	[\$/yr]
TS <sub>CM</sub>	11.4566	$[S/kW_e]$	O&M <sub>WFCM</sub>	0.124115	[\$/kWh/yr]	TS VM	0.9965	[S/kW]	Exchange rates		Notes	Equity rati	0	50.0%	[%]
TLc	0.0400	[S/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 551 470	[\$]
TL,	1 200	[1/kW]	O&M <sub>O&amp;Mmanag(A)</sub>		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	at rate	9.00%	[%/yr]
$L_i$	3 000	[m]	SC OBM	0.000070	[\$/kWh]	Ν	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB c	113.00	[\$/kWh]	Work days	2.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE win		Notes	67.6756	yr 1	70.7929	yr 15
WF cap	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			67.8295	yr 2	69.8226	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000254	[\$/kWh]	Hours Distribution	$FLH_{wf}[h]$	H prod [h]	O&M ccm	1	[1/0]	68.0385	$yr_3$	70.0172	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	N <sub>WT</sub>	25	[-]	January	744	740	(%) ccm	80.0%	[%]	68.2028	yr 4	70.2229	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.0	[per yr]	February <sup>(*)</sup>	672	648	REPIM			68.4513	yr s	70.4241	yr 18
POCM	35.95/4	[\$/kW]	Repair time	4.0	[h]	March	744	736	KEPIM distribution		(1.00)	68.6399	yr 6	70.7751	yr 19
PS DT	19.88	[3/KW]	SC USC	148.0	[n]	April	720	712	E PEP	1	[1/0]	60.1010	yr 7	70.5899	yr <sub>20</sub>
EC	87.22	[3/KW] [5/VW]	SC O&M+USC O&M	148.0	[Nyr]	stay	744	696	Č OPEP	1	[1/0]	69.1016	yrs yr	70.5764	yr <sub>21</sub>
EG F	404.52	[3/KW] [\$/6W]		0.000324	[a/KWR/yr]	June' '	720	726	CHCP CM	1	[1/0]	60.5002	yr <sub>9</sub>	70.8470	yr <sub>22</sub>
* CM WACC	3.7/12	[3/KW] [9/./vr]		г		August	744	736	P&D	1	[1/0]	69.2063	yr 10 NF 11	71.1502	yr 23 Yr 24
R fin	4.500%	[yr]				September	720	712	λ.	1	[1/0]	70.0200	WD	69.6991	Mean 37 23
W <sub>Em</sub>	0.30%	[%]				October	744	736	λ	0	[1/0]	70.2471	yr 13	1.0849	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	696	λd	1	[1/0]	70.4639	yr 14	-0.4478	Y (skewness)
ĸ	0.20%	[%]				December	744	736	λm	1	[1/0]	LCOF	69.6991	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	L			Total [h/yr]	8 760	8 616		p.s.: I = yes ar	nd 0=no	LCOL NIS	0.069699	US\$/kWh	

**Figure P.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 1). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend		ĺ		_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
				а Г											
Wind Project Information	F	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public Inc	centive Model	Notes	Wind Farm Life	<ul> <li>Cycle Prod.</li> </ul>	ction Model	Notes
Project Name	Corvo Island (Portural)		Depr	76 9840	[\$/KW] [\$/VW]	DC.M WF PM ww	22 3284	[5/KW] [5/FW]	ICCCM we	1 204 5180	[5/KWc] [5/VW]	WF CM		50.000	[KW@yr]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF com	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	[yr]	Mhran	100	[m-h]	$\psi_{actal}$	25.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMbreakyr	85.00	[\$/m-h]	n ,,	5	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>mawar</sub>	3	[-]	REP CM	0.00000982	[\$/kW <sub>e</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>m sweet</sub>	2.0	[d]	AEP anait/H prod	10 458	[kW/yr]	L <sub>x</sub>		1 800	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	[\$/kW]	C <sub>mfmyr</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$	10.0	[m]	11	1 /98 /43	[\$/kW]	RM cr	20.1954	[S/KW]	E	0.1027	[S/KW <sub>e</sub> h]	SD <sub>x</sub>		450	[m]
Betz Limit's coefficient (Cas. )	0.5926	[-]	V V	£ 100,000	[KW] [FW]	WP cap N mm	25	[_]	n	0.007.500	[3/KW ell]	ELH (		8 760	[hij]
Lifetime of Wind Farm(N)	25	[vr]	v 0 C 0	1 457.72	[k/r]	Mw	3.0	[m-h]	OREP CH	33.6767	[\$/kW_]	PC BM		0.100	[17]
Production Efficiency (WF PF)	20.6%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[\$/m-h]	LCCCM	3.8789	[\$/kW]	AEP annil		90 107 610	[kW_h/yr]
Aváilability	98.4%	[%]	Ь	-1.94	[-]	N	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{uncl}$		20.98%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]	$D_{m_{BUCC}}^{m_{CT}}$	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{out}}$		25.00%	[%]
				_		C <sub>md mer</sub>	3 500.00	[\$/d]	$\Psi_{astal}$	25.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost 1	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>faul</sub>	0.098275	[\$/kWh]	$WF_{cap}$	50 000	[kW]	n ,.	17	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	NWT	25	[-]	CRf	60.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	1 248.5415	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>br un</sub>	3.0	[m-h]	$\sum_{AED} AED$	57.6	[tCO2/MW,h]	2		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMbrsanv	85.00	[S/m-h]	null_mull_p_1===p_n	89.657	[MW <sub>e</sub> h]	A. 141		0.00%	[%]
T CM	484.3839	[5/KW]	ogen	0.048925	[%/yr] [\$//Wb]	D N <sub>m</sub> <sub>un</sub>	30	[-]	n, GHG	0.00059	[yr]	24		5.00%	[%]
P marr	26 206	(*5)	MIC	71 5609	(\$%)	C .	2 500.00	(C)	GHG	0.00005	peoparticat	ICPM		90 107 610	(IvW b/cm)
C	0.1900	[%/3/KW]	TIC	124 5688	[3/1] [5/b]	PVM wer	61.0184	[3/4] [\$/JW]	C C C C C C C C C C C C C C C C C C C	11 7000	[8/(CO <sub>2</sub> )	LCI M WF		30 107 010	[K W du yi ]
I WIG out	39 1957	[3/Kg] [S/m/kW]	R.	30.00%	[96]	N wa	25	[3%"]	Berein REPIM distribution	100.0%	[%]	Project Finan	rina	ſ	Notes
WF	50 000	[kW]	ifr	2.50%	[%/vr]	WTS vie	1.4442	[\$/kW]	ξ, RELOV	50.0%	[%]	Debt ratio		50.0%	[%]
L,	13 950	[m]	N	25	[yr]	WF	50 000	[kW]	ζ, REP CH	25.0%	[%]	Debt term		14	[yr]
CAB cont	2 000.00	[\$/m]	n mih	48	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 OREP_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	100	[h]	Ν	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	0.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	14 679 146	[\$M]	$WT_{weight}$	200 000	[kg]	REPIM	42.9657	[\$/proj]	Debt value		29 470 640	[\$]
ç	0.08%	[%]	AEP anail	90 107 610	[kWh/yr]	C steel	0.1900	[S/kg]				Debt pa	yments	2 977 241	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.147200	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	2	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 470 640	[\$]
TLr	1 200	[1/kW]	O&M O&Mmanag(A)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000038	[\$/kWh]	Ν	25	[yr]	BRL/USD dec2010	0.5986	[-]			r	
SB <sub>c</sub>	113.00	[\$/kWh]	Work days	2.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	73.1255	$yr_1$	78.4712	yr 15
WF cap	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			73.5187	$yr_2$	77.6515	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000138	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	73.7873	yr 3	78.1612	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	Nwr	25	[-]	January	744	740	(%) ccm	80.0%	[%]	74.1334	$yr_4$	78.6268	yr 17
Bld area	300.0	[m <sup>4</sup> ]	Frequency	1.0	[per yr]	February	672	648	KEPIM			74.4746	yr <sub>5</sub>	79.1175	yr 18
FS FS	35.95/4	[5/KW] [5/FW]	Hours required	4.0	(n) (b)	Anril	744	730	EFIM distribution	1	[1/0]	75 2252	yr <sub>6</sub>	79.0115	yr 19
r3 DT	19.88	[3'KW] [\$/FW]	SC+USC	148.0	(h/vr)	May	744	736	E REP	1	[1/0]	75 5275	37.7 NT.	78 2446	yr 20
FG	404 57	[\$/kW]	DEM COC DEM	0.000176	(\$/kWh/yr?	Jung <sup>(*)</sup>	720	696	Č. OREP.CH		[1/0]	76.0152	77 8 NT 0	78 7103	37 21 NT 22
EG	3 7712	[\$/kW]		0.0001/0 [		July	744	736	ŠA GHG R CH		[1/0]	76.4118	VT 10	79.0644	37 22 VE 23
WACC arei	4.900%	[%/yr]		Г		August	744	736	P&D <sub>LM</sub>		[170]	76.7332	yr 11	79.4723	yr 25
n <sub>fin</sub>	1.0	[yr]				September	720	712	λa	1	[1/0]	77.2289	yr 12	76.8666	Mean
W <sub>FOV</sub>	0.30%	[%]				October	744	736	λ <sub>sdi</sub>	0	[1/0]	77.6321	yr 13	2.0151	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	696	$\lambda_d$	1	[1/0]	78.0589	yr 14	-0.4631	Y (skewness)
ĸ	0.20%	[%]				December	744	736	λ,,,	1	[1/0]	LCOF	76.8666	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 616		p.s.: 1= yes at	nd 0=no		0.076867	US\$/kWh	

**Figure P.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 1). Source: Own elaboration
LCOE wso Mode	l Inputs											Financial Ind	exes	ĺ	Notes
Legend				-					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatic	on about the project.		Costs covered by manufacturer $(O {\rm A} M_{\rm cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	ĺ	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	TORS	AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI <sub>CM</sub>	69.0930	[S/kW <sub>e</sub> ]	WF CM		50 000	[kW_/yr]
Project Location	Cape Saint James (Canada)		Depr <sub>WTmi</sub>	76.9840	[\$/kW]	$RM_{WT}$	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	C M Mar	100	[m-h]	$\psi_{aoaal}$	25.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tjr Denr.	2.50%	[%/yr] [\$/vW]	N N	85.00	[S/m-n]	PFP out	0.000000.0	[yr] (\$/FW-b)	N col		90.0	[-] [m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Yac	15	[Urk()]	$D_{\mu}^{n_{m_{yr}}}$	2.0	[d]	AEP muit/Harod	24 780	[kW/yr]	L.		1 800	[m]
Hub height (H)	105.0	[m]	ТОсм	0.000033	[\$/kW]	C <sub>nd max</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L		2 430	[m]
Wind speed measured at (H <sub>0</sub> )	10.0	[m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ŝ	0.0121	[\$/kW_eh]	SD <sub>x</sub>		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.008998	[\$/kW_eh]	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>e</sub>	12	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	c 0	1 457.72	[\$/kW]	M <sub>brance</sub>	3.0	[m-h]	OREP CM	90.2828	[\$/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	48.7%	[%]	PR	0.70	[-]	C <sub>Mbracr</sub>	85.00	[S/m-h]	LCCCM <sub>WFORSIGCM</sub>	4.3886	[\$/kW]	AEP avail		213 509 813	[kWeh/yr]
Availability	98.4%	[%]	Ь	-1.94	[-]	D N m mcr	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wecs}$		20.35%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]		2.0		WACC proj	4.9000%	[%/yr]	n sectore		25.00%	[%]
Wind Farm Life-Cycle Canit	al Cost Model	Noter	Wind Farm O&M Cost	Model	Noter	SA PV	1 297 3916	[\$/d] [\$/FW]	9° antal i Gu	25.0%	[%] [%/vr]	P&D <sub>LM</sub>	factor	0.814145	[-]
wr	553 7256	(S/FW)	O&M.	0.098275	(\$/FWP)	WE	50,000	(JAW)	iji i	12	[/0/ 91] [ve]	4		6 361 7	- C-25
CMwr	265.32	[\$/kW]	LCCCM we	1 204,5180	[\$/kW]	N wr	25	[-]	CR	60.0%	[%]	AEP		438 000 000	[m] [kW_h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	A WT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	6 827.9067	[\$/tCO2]	P&D <sub>IM</sub>			
CkW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Mbr sam	3.0	[m-h]	LCER <sub>co</sub> ,	136.4	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mir_{sanv}}$	85.00	[\$/m-h]	$\sum AEP_{aud} = \sum_{r_1, r_2, r_3}$	212 467	[MW <sub>e</sub> h]	2,41		3.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub> <sub>MP</sub>	3	[-]	n <sub>v</sub>	25	[yr]	λd		5.00%	[%]
Tmass	138 000	[kg]	O&M variable cu	0.041527	[\$/kWh]	D <sub>m saks</sub>	3.0	[d]	$GHG_{IM_{FCO_2}}$	0.00069	[tCO2/MW2h]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md sav</sub>	3 500.00	[\$/d]	$GHG_{EM_{unit}CO_2}$	0.00005	[tCO2/MWah]	LCPM <sub>WF</sub>		213 509 813	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[S/kW]	Ec	27.0000	[\$/tCO2]			r	
LWTG CM	39.1957	[S/m/kW]	R tanes	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[S/kW]	$\zeta_1 REI_{CM}$	50.0%	[%]	Debt ratio		50.0%	[%]
CAR	2 000 00	[m] [\$/m]	N	25	[yr] [b]	WP cap	2 50%	[KW] [% /vr]	Č ORFP ou	25.0%	[%]	Debt or	ace neriod	14	[yr]
CP cu	30.9069	[5/kW]	n atta	100	[h]	N	25	[vr]	ζ <sub>3</sub> GHG R <sub>CV</sub>	0.0%	[%]	Deht in	erest rate	5.00%	[%/yr]
EF.	400.00	[\$/kW]	AAR	29 538 512	[\$M]	WT	200 000	[kg]	REPIM	57.1172	[\$/proil	Debt value		29 116 852	[\$]
ç	0.08%	[%]	AEP anail	213 509 813	[kWh/yr]	C steel	0.1900	[S/kg]			1.1 11	Debt pa	yments	2 941 500	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139802	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	o	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 116 852	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanag(A)	Г	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	at rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000016	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	2.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	$[/m^2/kW]$	Feb/Jun/Nov	6	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	84.3997	$yr_1$	94.4943	yr 15
WF cap	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			85.0669	$yr_2$	94.1699	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000058	[\$/kWh]	Hours Distribution	FLH wf [h]	H prod [h]	O&M ccm	1	[1/0]	85.7507	yr 3	94.9708	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	86.2255	$yr_4$	95.8775	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.0	[per yr]	February <sup>(*)</sup>	672	648	REPIM			86.9196	$yr_{5}$	96.7795	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	4.0	[h]	March	744	736	REPIM distribution		64.003	87.6452	yr <sub>6</sub>	97.5702	yr 19
P3	19.88	[5/KW]	nours requirea	100.0	[n]	April	720	712	REICH	1	[1/0]	88.2242	yr 🤊	94.0503	yr 20
DI	404.52	[\$/KW] [\$/FW]	SC O&M+USC O&M	148.0	[H/yr]	May	744	696	OREP CM	1	[1/0]	89,8260	yr <sub>8</sub>	94.7536	yr <sub>21</sub>
EG	3 7712	[3/KW] [5/J/W]		0.000074	[\$KHUJI]	June	744	736	GHG P au		[1/0]	90.4267	yr 9 NF 10	95.8087	37 22 NT 33
WACC mai	4,900%	[%/vr]		Г		August	744	736	P&DIM	•	[1,0]	91.2477	yr II	97,5891	VT 25
n <sub>fin</sub>	1.0	[yr]				September	720	712	λa	1	[1/0]	91.9572	yr 12	91.8264	Mean
WFCH	0.30%	[%]	1			October	744	736	λ <sub>sdi</sub>	1	[1/0]	92.6946	yr 13	4.2043	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	696	$\lambda_d$	1	[1/0]	93.7245	yr 14	-0.3333	Y (skewness)
K	0.20%	[%]				December	744	736	λ.,,	1	[1/0]	LCOE was	91.8264	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 616		p.s.: 1= yes as	nd U=no		0.091826	US\$/kWh	

**Figure P.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 1). Source: Own elaboration

Months <sup>Wwe</sup> , January 5 , January 4 April 4 April 4 April 6 , July 8	; <u>s) (kg/m<sup>3</sup></u> 5.8 1.16t 1.9 1.16t	$H_{proc}$ (3) $(h)(55$ $7$ , (566 $6$	10 1697720 48 859.945	yr2 10 89142	yr 91 3812	469 7 527	yrs 55 558 5	; yr <sub>6</sub> 372 89142	yr 7 291 5588	yr <sub>8</sub> 72 5588: 21 7883	yr9 72 4 243 68	yr <sub>10</sub> XI 891429 X2 687956	yr 11 1 891429	yr 12 1 558 87	ALF avail (K) yr 13 2 812 461	WR) 97 14	yr 15 5 4 7 4 2 68	yr 16	)r17	yr 18 1 558 872	yr <sub>19</sub> 3 812 469 7 802 526	yr 20 7 527 755	yr 21 558 877	yr 22	yr 23 7 527 755	yr 24 243 681	yr 25
January 5 February 4 March 4 April 4 May 6 June 7 Julv 8	, (xg/m 1.8 1.16( 1.9 1.16	) (11) 165 7. 166 6	40 1 697 720 48 859 945	0 89142	91 3812	469 7527:	75 5588	372 89142	291 5588	72 5588: 71 7883	72 4 243 6	yr 10 1 891429 2 687956	yr 11 1 891429	1 558.87.	7 2 817 46	y1 14	yr 15 E 4 3 4 2 6 8	yr 16	71.17	yr 18 1 558 872	yr 19 3 812 469 7 802 526	yr 20 7 527 755	yr 21 558 877	yr 22 460	yr 23 7 527 755 -	yr 24 243 681	yr 25
, January 5. February 4 April 4 May 6 June 7 July 8	8 1.160 1.9 1.161	00 / 20 900 / 20	10 1697720 48 859 945 	0 891425	91 3812	469 7 527 7	55 5588	72 89142	8866 16	12 7883 11 7883	2 4 2 4 3 6 8	1 891429 2 687956	1 891429	18866 1	1 4X17 460		XY 286 8 3		. DC FID X .	2/8866	3 812 469 7 802 526	7 527 755	N N N 1		7 527 755	243 681	
rebruary 4. March 4 April 4 May 6 June 7 July 8	1.100	00 00	CFU UCS 81	in the second seco	844.6					11 7XX3		2 687956			014100	· (//7C/		1 8 914 291	0 214 27.		7 802 526		7/0 0/0	5 812 409			245 081
March 4 April 4 May 6 June 7 Julv 8			しむご ししり しい	5 68795.	+1/ C 10	421 6879.	61 788.5	21 68795	561 7883.		21 47801:		1 687956	1 78832.	371442	1 687956.	1 489 17.	489 171	3 336 98	8 4 780 152		I 594 674	I 594 674	7 802 526	6 879 561	780 152	1780 152
April 4. May 6 June 7 July 8	1.0 1.16.	1 1/2	1/8 CCC 05	7 74874.	19 5432	002 8866.	25 9772	12 74874	19 9772	12 9772.	12 6 552 6.	15 748741	9 748741	9 97721.	2 543200	2 8 806 52.	5 895 82.	228 268 3	1 812 13-	4 220 942	1 812 134	1 688 623	1 688 623	7 817 699	8 866 525	792 040	552 645
May 6 June 7 July 8	4.7 1.16	67 7.	12 866360	6 6337 I.	84 6337	184 4082.	51 1 633 (	998 63371	184 1633 (	98 1 633 0	98 72412.	0 633718	4 633718	4 175254	8 633718-	4 408215.	I 945 08t	945 080	1 633 092	8 6337184	1 633 098	3 667 352	945 080	7 241 220	6 337 184	752 548	241 220
, June 7 July 8	5.0 1.16;	670 7.	36 1812060	6 54318	00 7487	140 5431	800 1812 (	966 54318	800 1812 (	66 18120	56 781740	9 543186	0 543180	0 168856	9 7 487 140	9 655240.	1 1 688 560	9 1688560	977176 0	8866195	977 176	555 856	895 788	6 552 401	4 220 785	688 560	817409
July 8	7.9 1.16z	86 6:	36 3 996 85.	2 39968.	82 7402.	657 6204;	64 3 590;	720 3 996 8	152 3 590 ;	20 3 590 7.	20 8 395 80	0 3 996 85.	2 3 996 85.	2 3 590 72.	) 740265;	7 5 143 610	5 1715 92;	7 1715925	7 848 262	7 402 657	848 262	848 262	3 590 720	5 143 616	5 143 616	925 332	395 800
· · · · ·	3.6 1.165	.68 7.	36 5 444 782	2 38009	62 8887.	385 1 692 5	96 4 230 8	873 38005	V62 4 230 8	73 4 230 8	73 55718	5 55718.	5 3 800 96.	2 5 444 78.	2 8887385	5 1816393	7 3 800 962	3 800 962	\$557185	7 505 034	557 185	979 511	4 230 873	4 230 873	1 692 596	897 929	557 185
August 9.	1.16	77 77	16 7 491 301	1 1813.02	73 1813	773 18136	123 8 871	123 18136	73 54348	19 5 434 8	19 89628	6 896280	5 1813 07.	3 4 223 13	1 813 075	\$ 1 689 496	9 5 434 815	7 821 753	7 821 753	896 286	4 223 131	7 821 753	5 434 819	1 813 073	1 813 073	556 165	896 286
Cantambar 10	11 116	57 7	CO 995 8 C.	3 1 621 5	1891 19.	264 2 662 0	9 2 2 2 2 2 2 2 2	2 1 621 5	6 122 9 19.	20 6 221 3	01 01 10	01 100 0	1 1 621 56	1 6 221 721	1 1 621 560	1 2 662 004	× 6 221 726	1 7 7 3 4 4 1 7	CIF F26 2 .	COL VVO .	121 216 2	8 566 072	6 221 720	1 621 564	3 663 006	221 220	201 100
or induction	10111 - 110		760000 71					-1001 000	1000 to	7 ICC 0 0C						102 000 0 4	107 ICC 0 0	114407/	14 407 /	767 446	1010170	C74 000 0	007 100 0	+00 TC0 T	006 000 0	007 100	767 116
October 5	0.7 1.16	i45 7.	36 780024	6 9750.	31 975 (	31 5546	36 7470.	703 975 0	31 7470	03 74707	03 16848:	3 168485	3 975 03.	1 884673.	9 75 031	554 631	5 747070.	3 6538010	5 6538010	1 808 085	6 538 016	4 211 519	7 470 703	975 031	975 031	846 730	684 853
November 9	9.2 1.16.	i38 6:	96 617925	2 84477	75 844.	75 8447	75 61792	252 8447	75 7372 2	18 73722	18 1 708 87	2 1708.87	2 844 77.	5 737221	8 844 775	84477:	5 737221k	8 5122467	7 5 122 46;	7 1 592 395	7 060 758	6179252	7 372 218	844 775	844 775	372 218	708 872
December 7	7.6 1.162	51 7.	36 378572:	5 55495	51 5545	151 9755	85 54225	956 5549.	51 88515	59 8 851 7.	59 3 785 72	5 378572.	5 55495.	1 7 474 95	9 554951	975 582	5 8 851 755	4 213 915	\$ 4213915	3 785 725	7 804 681	5 422 956	8 851 759	554 951	554 951	474 950	\$ 785 725
Annual 7.	7.4 1.160	66 86.	16 49 057 05	5 48 667 4	162 48 892	652 48 537	127 49 088	734 48 667 -	462 49 051 c	93 49 051 5	93 48 608 02	1 48 624 21	9 48 667 46.	2 49 049 27.	5 48 892 652	2 48 596 80;	7 49 239 93	2 49 380 375	1 49 009 701	48 697 726	48 317 889	49 064 437	48 965 360	48 420 199	48 519 758	18 661 536	48 608 021
ole P.2 Energy pr	oduction n	map of the	wind farm for	r Corvo Isl	land (Portu	gal)		with se	nsitivity an	ilysis of Od	M manag(A)	$+ E_{pi} (Case$	(1		11/ 024	101											
Months Var	с 	3 . (L)													AEF avail (K	(UM)		:									
( <i>m</i> /s	s) (kg/m	(u) (u)	$yr_I$	$yr_2$	yr.	s yr.,	yr5	5 yr6	yr 7	yr 8	$yr_9$	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
January 11	1.7 1.23.	13 7.	40 14 490 40	62 14 490	462 14 49	) 462 14 490	462 14 490	9462 14490	462 14 490	462 10 871	408 10 8714	06 14 490 4	62 10 871 4	08 10 871 4	8 10 871 40	14 490 40	52 10 871 4t	8 10 871 40	14 490 46	2 10 871 40	8 10 871 402	10 871 408	10 871 408	10 871 408	10 871 408	10 871 408	10 871 408
February 11	-57-1 C1	-0 -	48 12 092 74	21 4 295 1	137 12 09.	: 721 12 092	721 12 092	121 3417	090 12 092	<li>21 12 12/</li>	/ (6/ 1 / 02/	84 341/0	1 01 21 06	7 C6/ I 08	4 9 244 17	3 12 092 7.	21 0 0/4 01	5 12/12/5	0 4 295 13	/ 5 480 29	3417090	000 CI 8 Z	12 092 721	2 100 / 03	CIU 7/0 0	12 092 721	08/ 01/ ZI
March 16	0.5 1.23.	129 7.	36 10 486 21	28 3 193 5	907 1371.	510 13715	510 13717	510 6223	433 13717	510 13717	510 23897.	62 3 193 9(	<b>J7</b> 13 717 5.	10 238970	2 13 717 51	0 13 717 51	10 6 223 45	3 1371751	0 387622	0 757074.	. 486996	13 717 510	14 424 289	2 037 067	10 486 228	14 424 289	3 193 907
April 5	.5 1.23.	17 7.	12 731659	97 73165	597 10.45.	8 483 10 458	483 10 458	8 483 7 316.	597 10458	483 4706.	85 30866	89 73165	97 13 257 0.	22 3 086 68	9 13 257 02	2 470648	5 470648	5 13 257 02	2 3 086 68	9 1013421	2 3 086 685	13 940 075	13 257 022	3 086 689	3 086 689	13 257 022	3 746 098
May 8	8.2 1.22,	82 7.	36 4851 67	76 10 446.	845 10 44	845 10 440	845 6200	059 10 446	845 10 446	845 10 446	845 38616	62 6 200 0.	59 10 446 8	45 3 861 60	2 1437011	5 10 446 84	15 3 861 60	2 10 446 84	6 238078	7 13 665 99	0 6 200 055	2 380 787	10 446 845	3 861 662	14 370 115	10 446 845	4 851 676
June 7	7.1 1.22.	24 6.	96 2 994 46	61 12 860	010 7 016	981 7 097	981 7097	981 10 145	990 4565.	858 12860	910 45658.	58 10 145 9.	90 709792	81 4 565 82	8 709798	1 2 2 40 55	2 2 994 46	1 7 097 98	1 1 909 86	1 12 860 91.	1 7 097 981	1 909 861	7 097 981	4 565 858	12 860 910	186 260 2	5 834 806
July 6	5.1 1.21.	54 7.	36 2 008 11	18 13 522.	571 4806	760 6134	992 10337	209 13 522	571 7463	154 3 148:	18 61349	92 2 008 1.	18 613499	92 613499	2 6134 99	2 2 008 11	8 235586	1 613499.	2 613499	2 14 219 30.	\$ 10.337.209	3 821 135	6 134 992	6 134 992	13 522 571	3 821 135	7 463 154
August 6	5.4 1.20.	175 7.	36 234049	96 10 598 (	668 3796	310 3796	310 3796	310 13 434	719 6 095	134 3 796 :	10 74146	68 23404	96 47695;	71 741460	8 476957	T 10 598 6t	88 1 995 07	2 476957.	1 13 434 71	9 1 995 07.	13 434 715	4 769 571	4 769 571	7414668	4 769 571	3 128 063	10 270 051
September 7	7.6 1.20	064 7.	12 3 669 26	02 19282	273 5891	057 4 609	876 4609	876 4 609.	876 1928.	273 5891(	157 99261	89 9926 li	89 3 669 21	12 9926 h	9 3 669 20	2 5 891 05	7 9 926 18	9 3 669 20.	2 12 984 89	8 2 262 13.	12 984 895	5 891 057	3 669 202	9 926 1 89	3 669 202	2 262 132	1 928 273
October 5	8.9 1.21.	26 7.	50 6 121 07	79 6121(	079 3141	378 2 003	564 3 141	378 2 003.	564 2350	459 7 446	29 13 491 5	05 13 491 5	05 3 141 3,	78 13 491 9	5 3 141 37	8 7 446 22	9 13 491 <del>9</del> 7	5 3 141 37.	8 10 643 78	2 3 141 37.	\$ 2 003 564	7 446 229	3 141 378	13 491 905	2 350 459	2 003 564	2 350 459
November 10	0.6 1.21	.6 6.	96 10 121 52	86 3 625 4	425 2235	143 2 235	143 2235	143 2 235	143 2 987.	258 2235	43 12 829 5	76 45548.	76 2 235 14	43 12 829 9.	6 2 2 3 5 14	3 2 987 25	8 12 829 9;	6 2 235 14.	3 980776	1 3 625 42.	5 2235145	9 807 761	2 235 143	12 829 976	1 905 267	5 820 771	12 829 976
December 11	1.5 1.22.	37 7.	36 1361492	84 23715	901 2 021	842 3170	035 2 021	842 3170	035 3847.	349 2 021 2	42 143164	81 13 61 4 9.	84 2 021 84	42 143164	81 2 021 84.	2 384724	14 316 42	u 2 021 84.	2 751415	8 4 833 56	8 14316481	13 614 984	2 021 842	14 316 481	6 176 918	4 833 568	13 614 984
Annual 9	1.1 1.22.	22 86.	16 90 107 61	10 90 769	774 90.190	491 90 253	921 90 198	910 16 226	328 90 443	405 89 858	742 90 685 3	74 90 700 6.	78 90 078 6.	77 90 685 3.	24 90 530 33	6 90 473 15	34 90 246 85	8 90 078 67	7 90 557 46	4 90 666 43	1 90 855 215	90 985 978	90 162 393	90 643 598	90 743 354	90 059 500	89 670 577
ble P.3 Energy pro	oduction ir	nap of the v	vind farm for	r Cape Sain	nt James (C	ânada)		with se	nsitivity and	lysis of O&	+ (F)	· E <sub>ni</sub> (Case	3														
a		Н									11190000				AFP(k)	(4/4)											
Months (m/s	<ol> <li>(k e/m<sup>2</sup></li> </ol>	3) (h)	VLI	VF 2	VL	VI 4	VFS	VF6	VF 7	VFR	VFQ	VF 10	VF 11	VF 12	VF 13	VF 14	VF 15	VF 16	VF 17	VF 18	VF 1.0	VF 20	VF 21	Vro	VF 22	FC JA	Vras
January 15.	1.4 1.25t	. 19.	10 32 823 51	10 32 823 :	510 32.82:	510 32 823	510 32 823	510 32 823	510 32 823	510 32 823.	510 32 823 5	10 32 823 5.	10 32 823 51	10 8 035 21	0 32 823 51	0 32 823 51	0 32 823 51	0 32 823 51	0 32 823 51	9 32 823 51c	32 823 516	40 865 255	32 823 510	32 823 510	28 095 929	8 035 210	7 120 177
February 14	(.7 1.252	.22 6-	18 24 591 46	04 14 672 2	254 7010	451 26 599	864 14 672	254 14 672	254 26 599	864 26 599.	864 7 010 4.	51 14 672 2.	54 14 672 2:	54 785964	9 26 399 86	4 701045	1 17 623 29	9 701045.	1 701045.	1 701045	7 010 451	22 780 600	26 599 864	26 599 864	29 369 594	7 859 649	17 596 916
March 12.	7 1.245	.62 7.	16 18 252 37	76 18 252 :	376 8 908	878 27 874	248 12 394	144 18 252	376 27 874	248 27 874	348 8 908 8.	78 12 394 1-	H 18 252 35	76 9 986 08	4 27 874 24	8 8 908 87.	8 30 150 82	9 8 908 87	8 8 908 87.	\$ 8 908 872	8 908 878	23 024 061	27 874 248	27 874 248	31 459 374	9 986 084	18 948 162
April 12	2.4 1.245	'2 06.	12 16 081 24	49 193151	677 9 656	023 24 865	308 9 656	023 19315	677 24 865	308 24 865.	108 9 656 0.	23 9 656 02	3 193156	77 9 656 02	3 24 865 30	8 965602	3 26 952 94	7 9 656 02.	3 29 154 28	2 9 656 02:	9 656 023	22 218 160	20 001 184	24 865 308	24 956 459	9 656 023	18 165 621
May II.	.2 1.242	25 7:	36 12 324 06	54 25 569 5	850 9929	620 19 862	973 9.929	620 25 569	850 19862	973 19 862	73 9 929 6.	20 9 929 62	10 25 569 8:	50 12 324 0t	4 19 862 97.	3 9 929 62	0 25 569 85	0 9 929 620	0 2771664	1 9 929 620	9 929 620	21 018 978	19 862 973	19 862 973	19 116 345	12 324 064	16 191 245
June 10.	0.4 1.23:	51 65	16 933378	87 26 053 4	485 11 58,	: 551 17 060	120 8 326	944 26 053	485 17 060	120 17 060	20 11 584 5	51 832694	t4 26 053 4:	95 15 544 51	3 17 060 12	0 11 584 55	1 17 060 12	0 11 584 55	1 24 035 51	4 11 584 55.	11 584 551	17 178 664	17 060 120	17 060 120	16 981 395	15 544 593	15 146 363
July 10.	0.0 1.225	75 7.	36 8751 92.	23 29 619 0	639 16337	936 16337	936 7806.	320 29619	639 16337	936 16337	36 16 337 9	36 7 806 32	30 296196	39 17 930 81	1 16 337 93	6 16 337 95	16 7 806 32	0 16 337 93	6 19 623 99	1 16 337 93	16 337 936	15 552 737	16 069 219	16 337 936	16 783 950	17 930 811	8 637 391
August 9.	1.7 1.22	16 7.	36 7 768 71.	12 12 117 -	129 17 84.	: 428 12 117	129 17 844	428 12 117	129 12 117	129 12 117	29 17 844 4	28 17 844 4.	28 12 117 12	29 19 529 4:	1 12 117 12	9 17 844 42	8 209 76	0 17 844 42.	8 17 844 42	8 17 844 424	: 17 844 428	12 921 415	15 399 666	12 117 129	12 606 836	19 529 451	7 121 992
September 10.	1.22	34 7.	12 9 458 08.	92 7 526 1	16.2 18.91	721 9 458	782 26 400	433 7 526	165 94580	182 94580	82 18 919 7	21 26 400 4.	33 752616	15 24 355 55	9 9 458 08.	2 18 919 72	1 9 458 08.	2 18 919 72.	1 15 751 59	5 18 919 72.	18 919 721	12 339 146	13 294 981	9 458 082	8 855 020	24 355 589	19 057 685
October 13.	1.1 1.232	27 7:	16 10 202 61	14 8 788 9	305 2974	158 6 662 :	505 25 368	828 8 288	905 9821 c	105 98510	05 29 744 7	99 25 368 9.	53 8 788 96	15 27 498 8	7 985160.	5 25 368 95	3 985160	5 25 368 95.	3 12 227 23	7 29 744 79.	25 368 953	12 259 773	8 871 247	9 851 605	8 134 157	27 498 877	21 626 625
November 14.	1.3 1.242	.29 65	16 24 188 63	39 93932	250 26 2B	466 8 379	093 28 360	. 862 6 363.	250 8379	93 83795	.63 262194	66 28 360 8:	95 939325	0 283608	5 837999.	3 26 219 46	6 11 658 35	3 2621946	6 939325	J 26 219 46	26 219 466	7 520 762	8 379 993	8 379 993	8 987 716	28 360 895	22 240 116
December 15.	5.1 1.252	.28 7.	36 30 229 15	53 10 012 1	025 25 782	021 7 966	958 20 027	814 10 012	025 7 966 :	158 79665	58 25 782 6	51 20 0278.	14 10 012 02	25 32 544 70	12 7 966 95	8 30 229 15	3 16 674 13	9 30 229 15.	3 10 012 02	5 25 782 05.	30 229 153	6 359 397	7 966 958	7 966 958	9 176 637	32 544 702	42 535 343
Annual 12	5 1.240	98 FU	16 213 509 81	13 214 144 2	266 214 761	434 213 197	728 213 611	337 214 144	266 213 197	728 213 197	728 214 761 4	34 213 611 3.	37 214 144 20	SK 213 625 94	8 213 197 72	8 214 832 68	214 338 80	5 214 832 68	9 214 501 80	3 214 761 43.	214 832 685	214 038 947	214 203 964	213 197 728	214 523 412	13 625 948	14 387 639

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Table P.4 Winc	d speed se	ries simulatio	ons for AE.	Pavait in An	acati (Brazi	(]		wit	h sensitivit	/ analysis o	f O&M manas	$Q(A) + E_{pi}$ (	Case 1)	in trucing	ations (m/a)											
Months	(m/s)	yr 1	$yr_2$	<i>yr</i> 3	yr 4	<i>yr</i> 5	$yr_6$	<i>yr</i> 7	$yr_8$	yr 9	yr 10	yr11	yr 12	yr 13	yr 14	yr15	yr 16	yr 17	yr 18	yr 19	yr 20	yr21	yr 22	yr 23	YF 24	yr 25
January	5.8	5.8	10.1	7.6	9.6	4.0	10.1	4.0	4.0	7.9	10.1	10.1	4.0	7.6	9.6	7.9	10.1	10.1	4.0	7.6	9.6	4.0	7.6	9.6	7.9	7.9
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6	1.01	6.0	6.0	10.1	9.7	8.6	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7	10.1	7.6	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	7.9	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.9	10.1
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	5.8	4.7	4.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	7.9	9.7	8.6	6.0	6.0	4.0	4.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9	1.0.1	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	9.7	6.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	1.01	1.01	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9	7.9	7.6	9.7	8.6	10.1	4.0	4.0	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Table P.5 Winc	d speed se:	ries simulatio	ons for AE.	Pavait in Col	rvo Island	(Portugal)		wit	h sensitivit	/ analysis o	f O&M mana	$\frac{1}{2(A)} + E_{pi}$ ( Wind spe	Case 1) red data seri	ies for simula	ations (m/s)											
Months	(m/s)	vr ,	25.2	vr.,	vr ,	ur c	VFe	vr-	vro	Vr.o	VF 10	VEL	VF 15	Vr	VF	vrie	VLIC	VF 17	VF 10	VF 10	VENO		UL	VF 13	Ur 11	VLIE
lanuary	11 7	117	117	211	117	211	117	117	901	10.6	2117	901	10.6	10.6	7117	106	901	7.11	9.01	10.6	10.6	10.6	10.6	9.01	106	10.6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	11.7	8.2	8.9	7.6	7.1	11.5	6.4	9.5	1.5	11.7
March	10.5	10.5	1.7	11.5	11.5	11.5	8.9	11.5	11.5	6.4	1.7	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	11.5	11.7	6.1	10.5	1.7	7.1
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	7.1	11.5	8.2	8.2	11.5	7.1	10.5	1.7	11.7	11.5	7.1	1.7	1.5	7.6
May	8.2	8.2	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4	11.5	8.9	6.4	10.5	7.6	11.7	0.5	8.2
June	1.7	7.1	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1	11.5	9.5	6.1	9.5	8.2	11.5	9.5	8.9
July	I.9	6.1	11.5	8.2	8.9	10.5	11.5	9.5	1.7	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9	11.7	10.5	7.6	8.9	8.9	11.5	7.6	9.5
August	6.4	6.4	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2	11.5	6.1	11.5	8.2	8.2	9.5	8.2	7.1	10.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	11.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	1.7	11.5	7.1	9.5	11.5	1.7	10.6	7.1	6.1	9.5	1.7	11.5	6.4	6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	7.1	6.4	11.5	8.2	6.4	11.5	6.4	7.1	11.5	6.4	10.5	7.6	6.4	10.5	6.4	11.5	6.1	8.9	11.5
December	11.5	11.5	6.4	0.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2	11.7	11.5	6.1	11.7	8.9	8.2	11.5
Annual	9.1	9.1	9.1	9.1	9.1	9.1	1.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Table P.6 Wind	t sneed ser	ries simulatio	us for <i>AE</i>	P	se Saint Iar	thes (Canady	2	lin	i sensitivita	analveis o	W 30.	- - 	, are													
	Vwc						,		The second	o ere fmm	mana	Wind spe	red data seri	ies for simul.	ations (m/s,											ĺ
MONINS	(m/s)	$yr_I$	$yr_2$	yr3	yr 4	yr 5	$yr_{\delta}$	yr7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr20	yr21	yr 22	yr 23	yr 24	yr 25
January	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	15.4	15.4	15.4	15.4	15.4	16.6	15.4	15.4	14.7	9.7	9.3
February	14.7	14.7	12.4	9.7	1.61	12.4	12.4	1.61	1.61	7.6	12.4	12.4	10.0	1.61	9.7	13.1	9.7	9.7	9.7	9.7	14.5	1.61	1.61	0.01	0.0	13.1
March	12.7	12.7	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1	10.0	10.0	10.0	10.0	13.8	14.7	14.7	15.3	0.4	12.9
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	15.1	10.4	10.4	13.8	13.3	14.3	14.3	0.4	12.9
May	11.2	11.2	14.3	10.4	13.1	10.4	14.5	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3	10.4	14.7	10.4	10.4	13.4	13.1	13.1	13.0	7.7	12.3
aunt	10.4	10.4	14./	7.11	1.2.1	0.01	14./	/77	1.21	7.11	0.01	14./	4.71	/.71	7.11	1.2.1	7.11		7.11	7.11	0.71	1.2.1	12.1	12.1	4.7	7.71
<i>yul</i>	0.01	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	7.6	15.1	12.7	12.4	12.4	9.7	12.4	13.1	12.4	12.4	12.2	12.3	12.4	12.5	2.7	10.0
August	1.6	1.61	2.11	1.21	7.11	1.21	2.11	7.11	7.11	1.2.1	1.21	2.11	13.1	7.11	1.21	10.0	1.2.1	12.7	12.7	1.21	11.4	1.21	7.11		5.1	7.27
September	10.4	10.4	1.60	13.1	10.4	14./	1.6	10.4	10.4	13.1	14./	1.6	14.5	10.4	1.5.1	10.4	13.1	4.71	13.1	1.5.1	4.11	11./	10.4	7.01	5.4 1	13.2
October November	1.61	1.61	10.01	1.61	10.0	151	10.01	10.0	10.0	1.61	151	10.0	14./	10.0	14.7	11.2	C.41	711	1.61	14.7	97	1.01	10.0	0.6	1.4./	0.61
December	15.1	15.1	10.4	14.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	10.4	15.4	9.7	15.1	12.4	15.1	10.4	14.3	15.1	0.0	9.7	9.7	1.01	5.4	16.9
Annual	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
1																										

0.14													yr											
y y	r1 yr2	yr3	yr 4	yr 5	yre	yr yr	7 yı	'8 yi	'9 yr	1ý 0'	п у.	r12 y	<i>T</i> 13	yr 14	yr 15	yr 16 3	W 17	yr 18	yr 19	yr 20	yr 21	yr22	yr 23	yr 24
Aracari (Brazil) 5 69	13 5648	5 674	5 633	5 697	5 648	5 69.	3 569	3 564	1 564	3 564	18 56	93 56	574 5	640 5	715 5	731 5.	588 5	652 5	5 809	2 694	5 683	5 620	5 631	648
Corvo Island 10 45 (Portugal)	8 10 535	10 467	10 475	10 468	10 563	10 49:	7 1042	9 10.52	5 10.52	7 104:	54 105	25 105	507 10	500 10	474 10	454 10.	510 10	523 10	545 IL	1560 II	) 464	9520 h	) 532	452
Cape Saint James 24 78 (Canada) 24 78	0 24 853	24 925	24 743	24 791	24 853	2474.	3 2474	3 24 92	5 24 79	1 248.	53 247	.63 24	743 24	933 24	876 24	933 24.	895 24	925 24	. 933 24	4 841 Z.	4 860 2.	4743 2.	1 897 2.	793
(mmm)																								
					8 1				:				1											
the P.8 Cashflow for 25 years off	he wind farm	project	50 000 K	W N	acatı (Brazıl)				with £	ensitivity ai	alysis of Oc	KM manag(A)	+ E <sub>pi</sub> (Case Years	()										
Item	0	-	2	3	4	5	6	7	8	E	11 0	1 12	13	14	15	16	17	18	19	20	21	22	23	24
-) LCCCM WF	60 225 901																	•						
WT CH	27 686 278		,					,	,											•				,
$T_{CM}$	24 219 295																	•	•	•				
LWTG CM	1 959 783						,			,	,	,					'	•	•					,
TX OI	1 242 CHC 1 577 837																							
SI CM	2 136 726		,							,							'					,		,
PO CM	1 796 870															•	•	•	•	•	•			
$F_{CM}$	188 559	,	,	,				,	,	,		,					'	•	•	•	•			,
CCC <sub>CM</sub>	120211	-											-	-			-	-	-	-	-	- 001 001 01		
CPM wF (KWh/yr) ++ AAD (SAK)		CCU /CU 64	48 00/ 402 4	4 20026884	8 55/ 12/ 49	765 926 A	600/402 49	002249 51	06 42 45 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40 45 40	18 UZI 48 64	4.219 48.00	1 407 5 660	102 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	2 052 48 590	231 61104	152 49 380 3/ 62 6 200 3/)	10/60069 .	121 169 84	6831/889	49 064 45/	48 905 500 4	484.20199 4	2 200 C/1 2	9 0CC 100
PPAR		4314826	4 387 573	4518071 4	1 597 349 4	1765 836 4	843 059 5	003 348 51	28432 520	9075 534	1081 547	9477 5660	527 578	513 5892	231 61194	68 629034.	1 6399200	6 5 17 427	6 628 256	6 898 935	-	-		
EMP	,		,	,	,	,	,	,	,	,	,	,					'	,	,	'	4 939 990	5 007 115	5 142 845 5	286820 5
-) O&M WFCM		3 964 703	4 031 427	4151213 4	4 223 934 2	1378615 4	1471 031 4	618343 41	733137 48	16 905 4 92 7 805 7 3 26	8061 505	5 095 5 221	1459 533	1243 5433	856 56421	74 579964	1 5899344	1 6 007 676	6109183	6 357 999	5 867 984	5 947 062	5 107 615 6	277 939 6
O& M veriable		1 299 217	1 321 003	1 360 175	1 383 923 1	434.523 1	479 236 1	527531 15	65 056 1 58	9 009 162	8620 167	9 162 1724	1683 176	494 1793	950 18624	67 1913 800	1946264	1 981 563	2014606	2 096 214	1 508 477	1528319	+ 220.022 +	512361 1
+) LRCM		863 268	884 850	906971	929 646	952 887	976 709 1	001127 1(	V26155 1 05	1 809 1 07	8 104 1 10	5 067 1132	2 683 1 16	000 1 190	025 1219 7	92-	'		•	•				
+) Depreciation		2 423 221	2 483 801	2 545 896	2 609 544 2	674782 2	741 652 2	810 193 21	180 448 2 95	2 459 3 02	6270 310	1 927 3 175	9475 325	1962 3340	436 34235	147 3 509 54.	5 3 5 9 7 2 8 5	3 687 217	3 779 397	3 873 882	3 970 729	4069 997	4 171 747 4	276041 4
=) Profit before tax	•	3 636 612	3 724 797	3819726	3 912 604	1014890 4	1090 389 4	196325 4.	301 898 4 44 20 200 - 5 20	06438 451 3 200 1 50	7395 465	1 365 475	1227 486	9 233 4 988	836 51204	H2 4 000 24. 20 1 007 107	5 4097140	1 4 196 967	4 298 471	4 414 818	3 042 735	3 130 050	3 206 977 3	284 921 3
(-) Kevenue Iax (+) REPIM	1122 040	1 294 446	7/7 016 1	124 000 1	. CUA 47 C I	1 10/6741	1 513	1 400 100	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	101 07/70	101 1707	37 131	C/ T 0CT0	/0/ T +CN 0	1 000 1 600	11/001 666	- 1919/00.	277 006 1	1/1004/1	080 600 7	166 195 1	+CT 70C T	1 +00 7+0 1	040.000
REICH	863.662	1	-	-	-			- 			;	-	· ·											
REPCM		1 725	1 670	1 637	1585	1564	1 513	1 488 1	451 1.	103 15	13 13	37 13.	15				'							
$OREP_{CM}$	259 298	•														•	•	•	•	•	•			
$GHGR_{CM}$	•	,	,	,	,	,	,	,	,	,	,	,		,		•	•	'	,	•	,	,	,	,
=) Profit after tax w/out interest	•	2 343 889	2 410 195	2 465 941	2 534 985	2586703 2	638 984 2	696808 2.	764.820 2.8	5 118 291	6440 298	8 859 3 054	4383 313	4179 3221	167 32840	903 2 113 14	3 2177380	1 2 241 739	2 309 994	2 345 137	1 560 738	1 627 915	1 664 124 1	598 875 1
(-) Debt payments		- 1090	3 136 543	3 214 957 3 7 75 4 46 4 5	295331 3	377 714 3-	462.157 3.: 0.66.757 2	548.711 3.6. 040.412 2.1	16424 3728	364 3821 4 224 2 77	573 3917 4102 2254	112 4 015 t 5 047 2 4 20	040 4115 1040 2574	16 42183 047 2.614	02 432375 006 27044	9 2 707 061	- 2 001 006	2 000 706	- 4 000 010	- 101 1/2	- 206.004	- 2014		
(+) ACM WF (+) Depression		LCC 1707	2 483 801	2 245 896	2 600 544 7	C C8LTL9.	C (77 0) C	810193 25	80448 2.05	7 450 300	4120 330	1 977 3176	200 2440	10 C 14C	436 34739	100 121 C 011	3 507 285	3 687 217	3 779 307	3 873 887	3 970729	4060 997	+ IICCIC+	7 040 070
=) Free net cashflow	-59 102 941	7 388 849	4 444 735	4551345 4	4 672 524 4	1777 681 4	884 735 4	998704 51	24263 524	3 547 5 39	5329 552	9 722 5 658	3767 580	672 5 957	397 60892	39 941974	9 9666651	9 918 241	10178409	10 410 263	9 827 491	10 101 337	0 349 381 10	501.265 10
$\Sigma$ free net annual cashflow		-51714092 -	47 269 357 -4	12718012 -3	3 045 489 -35	1267 808 -28	383 073 -23	384 369 -182	0.106 -12 95	6 559 -7 60	1 229 -2 07	1508 3587	7259 939	V 931 15 348	378 21 427 5	18 LS8 06 19.	5 40 523 967	50 442 208	60 620 617	71 030 879	on 958 371	002.020.00	11 000.000.10	1 101010

Table P.9 Cashflow for 25 years of th	te wind farm p	oject	50 000 k	W C	ervo Island	(Portugal)			with	sensitivity a	nalysis of O	& M manag(A)	$+ E_{pi} (Case$	(1											
Item	0	-	6	e	4	ŝ	9	7	~	6	0	-	Years 2 1:	14	15	16	17	8	61	30	21	22	23	24	25
	,															2		2	-	1	1	1	à		
(-) LCCCM wr wr	60 225 901 27 686 278															• •			•						
Tot	24 2 19 295																								
LWTG CM	1 959 783									,															
CP CM	1 545 346		,					,		,	,		,											,	,
TS CH	572 832	•	•		,				,		,	,	,					•	•	•			,	,	
SICM	2 136 726		,		,			,		,	,		,											,	,
For	1 /30 5 /0																								
CCC St	120211																								
LCPM WF (k Wh/yr)		90 107 610	90 7 69 7 74	90 190 491 9	0 253 921	0 198 973 5	016328 9	0 443 405 85	858 042 90 6	85 374 90 7	0 678 90 0	78 677 90 68	5 374 90 53	0 336 90 473	134 90 246	388 90.078.67	7 90 557 46	4 90 666 43	90 855 213	90 985 978	90 162 393 5	0 643 598 9	0.743.354 90(	59 500 89 6	570.577
(+) AAR $(SM/yr)$	,	15 046 124	15 535 609	15 822 374 1	6 229 340	16 624 945 1	7 194 985 T	7513916 17	835 578 18 4	49 787 18 9	14 223 19 2	54 127 19 86	8 402 20 33	0 295 20 825	386 21 292	541 21 784 27	7 22 447 56	7 23 036 44	23 661 518	24 287 963	17 268 871	1 795 063 1	8 260 013 18 5	75 463 18 9	957 626
PPAR	•	15 046 124	15 535 609	15 822 374 1	6 229 340	16 624 945 1	7 194 985 T	7 513 916 17	835 578 18 4	49 787 18 9	14 223 19 2	54127 1986	8 402 20 33	0 295 20 825	386 21 292	541 21 784 27	7 22 447 56	7 23 036 44	23 661 518	24 287 963					
EMP					•																17 268 871	1 202 063	8 260 013 18 5	75 463 18 9	957 626
(-) O&M wrcar		9414550	9 720 704	9 900 012 1	0 154 527	0 401 931 1	0 758 472 10	0.057 897 11	159 028 11 5	43 192 11 8	33 646 12 0	46185 1243	0378 1271	9 232 13 028	853 13 321	257 13 628 51	1 14 043 35	1441163	14 802 558	15 194 336	13 212 815	3 615 294 1	3970912 142	12 144 14	504 416
O&M fixed	,	4 895 943	5 055 217	5 148 526	5 280 948	5 409 674	5 595 159	0.098 935	803 599 60	03 456 6 1	54.579 6.2	65 179 6 46 01 007 5 04	5057 661	5 352 6 776	1449 6.928	488 7 088 46 200 7 7 1088 46	0 730428	2 7 495 901	7 100 204	7 201 207	8 02/ 381	8 271 977	5 4 8 8 1 0 5 8 6 8 6 8 6 8 6 8 6 8 6 8 6 8 6 8 6 8	54 738 85	512 382
O & M variable		4518607	4 665 487	4 751 486	4 873 579	4 992 258	5 163 313	2258 962 5	355 430 5 5	39736 56	79 068 57	81 006 5 96	5 321 6 10	3880 6252	405 6392	569 6540.05	1 6739.06	3 691573	7 103 264	7 291 205	5 185 434	5 343 317	5 482 807 5 5	77 406 54	592 034
(+) TKC M		802 208	884 830	1/6 906	929.040	188756	60/ 9/6	1 171 100 1	0.1 0.21 0.20	01 608 10	12 104 11	511 / 90 90	2 083 1 10	NULL 0001	617 1 2704	- 000 0 000					- 020 020	- 0-60 0 4			-
(+) Depreciation		760147	100/147	706 900 7	0047007	2004/007	·	7 000 709 7	57 600 7/9		DC 066/1	10 00000	C C C 6// 0	100 C 940 C	4140 040	H664-C 790	H-/900 0	CT //OC 0	000.60/ 0	007 000 0	000 666 6	009 900 5	10,000 10 10 10	14 04040	±060/0
(=) Projit before tax	,	8 9 11 4 35	4 660 603	4 7 46 7 10	1 0.60 0.00	9 845 56/ 1	2014/302	11 200 605 1	201 5/7 C/C	1 11 98/70	74.767 57	00441 11/4	1 480 12 02	1621 1112	20071 /02	1/ CC0 11 756 00 202 202 700	2 672427	1 12 501 94	7 000 4 66	21696621	476 CI 0 8	8 238 634 ¢ 230 ¢ 10	5 4 49 4 5/ 8 ( 5 4 70 0 0 4 5 6	28 400/7	524 105
(-) KEVENUE TAX	- 109 Pac 1	100 01 0 4	1 2 21	1 102	1 165	1 126	064-901.0	2 0/1 +07 0	1 1301	1 200 200	10 107 110	KC 9070/	ADO 1700	26 0.24	/000 010	376 07 666 0 761	012 40 0 0	260160 0	CC+ 960 /	600 007 /	100 091 0	610 900 0	20 100 0/ 10	6607/	007 /00
ML-1 XC+ )	170 407 1	0071	1071	661.1	001 1	0011	0111	1 004	1 1001	1	010	0/6	10	8	00 71	000	040								
KEI CH	700 002							- 00 -			' 010					1 10	' 9° 0								
REP CM		1 253	1 231	1 193	1 165	1 136	1 118	1 084	1001	035 1	010	8/6	19	30	88	865	848						,		
OKEP CH	420.929		,	,		,	,				,	,	,	,				'	,		,			,	,
GHG.R CM			•					•									1								
(=) Profit after tax w/out interest		4 398 850	4517311	4 622 747	4 7 39 2 27	4857019	4 989 997	5 106 562 5	225 651 5 3	68 885 5 5	33416 56	31 182 578	1 926 5 92	3 958 6 07	154 6219	JB7 5 12 1 29	4 5 258 23	9 5391008	5 529 564	5 670 523	2 835 263	2 900 115	2971434 30	55 025 3	36 875
(-) Debt payments		•	3 127 964	3 206 163 3	286 317	3 368 475	3 452 687 3	539 004 3	27 479 371	8166 381	120 3906	5 398 4 004	058 4104	160 4 206	64 431193		1			•					
$(+) RCM_{WF}$	1	2 621 739	2 687 282	2754464	2 823 326	2 893 909	2 966 257	3 040 413 3	116 424 3 1	94 334 3 2	74 193 33	56047 342	9 949 3 52	5 947 3 614	1096 3704	448 3 797 06	361682 0	5 3989280	4089018	4 191 243	4 296 024	4 403 425	4513511 46	26348 47	742 007
(+) Depreciation		2416592	2477007	2 538 932	2 602 406	2 667 466	2 7 34 1 53 3	2 802 506 2	872 569 2 5	44 383 3 0	17 993 3 0	93 443 3 17	0779 325	0.048 3.331	299 3414	582 3 499 94	6 358744	5 3 677 131	3 769 060	3 863 286	3 959 868	4 058 865	4160336 42	64 345 4 3	370 954
(=) Free net cashiftow	-58 941 280	9 437 182	6 553 636	6 709 981	6878642	7 049 919	7 237 720	7 410 477 7	587 164 77	89 436 7 9	84.481 8.17	74 273 8 38	8 595 8 59	5 794 8 809	785 9 026	135 1241830	0 12 737 67	0 13 057 425	13 387 641	13 725 053	11 091 155	11 362 405 1	1 645 281 11 9	45718 122	249 836
$\Sigma$ free not assured on these		-49 504 098	42 950 462 -	36 240 481 -2	9 361 839 -:	22 311 920 -1	5 074 200 -	1 663 723	-76 559 77	12 878 15 6	97 359 23 8	71 632 32 26	0 227 40 85	5 021 49 665	807 58 691	241 71 110 24	1 83 847 91	1 96905330	110 292 978	124 018 031	135 109 186	146 471 591 1	58 116 872 170	062 590 182	312 426
	1001	1 2 1 2	13 67	02.62	24.12	44.44	24.02	6 L 3L	L (3 3L	2 00 2	12 I.F.	22 CE 3	<i>LL</i> 61	20 70	1 02 30	39 22 6	20.16	20 63	20.12	20.62	62 22	10 24	. 12.02		27.02
Table P.10 Cashflow for 25 years of t	the wind farm	noject	50 000 k	0 M	ipe Saint Ja	mes (Canada			with	sensitivity a	nalysis of O	& M manag(A)	+ $E_{pi}$ (Case	(1											
liem													Years												
IIIOI	0	-	2	6	4	5	9	7	8	6	0	-	2	14	15	16	17	18	19	20	21	13	23	24	25
(-) TCCCM we	60 225 901																								
WTer	27 686 278	,		,	,	,	,		,			,			,	,			,	,	,	,	,		
	21200012																								
I CH	267 617 47																								
LWICCN 25	20/ 606 1																								
CFON	1 545 540											,	,												,
TS CH	572 832																'	'	•						
SICM	2 136 726	,		,		,	,		,			,			,			•	'	,	,	,	,		
POGN	1 796 870	,	,	,		,	,	,	,	,	,	,	,	,			'	'	,	,	,			,	,
$F_{CM}$	188 559	,		,			,					,							'	•	,				
CCCar	120211	,	,	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,
ICPM (k Wh/wr)		213 509 813	214 144 266	214 761 434 2	13 197 728	213 611 337	214 144 266 2	13 197 728 2	3 197 728 214	761 434 213	511 337 214	144 266 213 6	25 948 213 1	ri 728 214 83	2 689 214 338	805 214 832 69	9 214 501 80	3 214 761 43-	214 832 689	214 038 947	214 203 964	213 197 728 2	14 523 412 213	625 948 214	1387 639
		1092006	21120112	21006210 2	100 233 0	2 126 006	001251	000 000 36	1 22 000 220	05 001 27 0	0 00 00000	102 33CCL	2010 1002	1646 41 00	1004	2210117 923	2 46 166 16	46 240 06	9CC 113 LF	10 577 744	24 041 551	2 000 113 30	22 200 02 32	00 200 01	101 6.21
DAAD		VL0 YLC UC	21130112	31 006 210 3	0 557 331	23.436.006 3	2 001 100 L	2040,685,38	1 12 000 120	0.5 000 37.8	385 644.00	ND 05 30 77	2907 40.65	0011 9190	040 CV 1VL	121	1 221 24 2	9000000	070 LT 0 11 20K	NA 522 244					100 101
E ME						-															133 110 10	0 000 11 2 20	200.000	00 000 01	101 631
100 PM		002 009 UC	000 090 10	0 002 200 10	. 019.940.0	000 970 00	2 176 261 2	10 102 330 2	5 SC 113 333	52.046 25.0	296 007 01	51 26 20 10	0226 1020	09 00 102 1	1515 20244	127 20 146 01	20 05 02 0	2 21 660 244	22 464 546	22 152 000	00500240	C 070 440 0	10 000 000 000	-00 007.01	100 103
D.E.M.		000 009 11	086 900 11	1 19905001	13974.651	1 212 113 01	3164355 1	1 318 812	C FI FS 09L	17 401 14 4	07 102 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17 80 17	04.775 15.77	0.623 15.57	002 1400	55791 7004	246 16905 58	8 17 201 53	XCS SSL LL 6	010 2015 4440	18 501 624	01112061	C 1209210	00 22 200	82 041 21 0	0.61
Datif was		000 000	0124240	0 603 663	001220	0.025 572	1 200 01 2 0	01 000 000 0	705 072 11 1	36 630 11 2	511 CUL 23	011 097 99	00001 0300	0001 000	000 01 103	201 12 241 22	1 12 651 2	1200601	200.02011	14 561 454	03623201	1 110 099 0	11 102 000	11 12 12 12	01000
O CC M variable		700/00/6	610 240 6	CDD CDD 6	706 111 6		00071C0	VI 006 770	11 576 501			74 TT 00+00	1771 6006	0071 0007	00071 170	CC 1+7 C1 160	HC TOC CT   1	1000661 1	160 607 41	+C+ IOC +I	007/0401	1 117 000 01	11 16/ 700 1	11 00000	047700
(+) LRCM		863 268	884 850	906971	929 646	952 887	976709	001 127 1	026 155 1 0	51 809 1 0	78 104 1 10	05 057 1 13	2 683 116	000 1 19(	025 1 219										
(+) Depreciation		2 387 582	2 447 271	2 508 453	2 571 165	2 635 444	2 701 330	2768 863 2	838 085 2 5	09 037 2 9	81763 30	56307 313	2714 321	1 032 3 291	308 3373	591 345793	0 354437	3 632 988	3 723 813	3 816 908	3 9 12 331	4 010 139	4110393 42	13152 43	318 481
(=) Profit before tax		12 839 034	13 189 340	13 548 319 1	3 811 529	14 177 446 1	4 559 087 1	1 873 892 15	245 865 15 7	12 704 16 0	41 140 164	72 933 16 85	4338 1724	9 956 17 782	558 18 195	905 1743278	6 17 846 67	0 18310700	18 773 593	19 186 064	9 225 522	9 430 702	9 701 144 99	19 825 10 1	188 803
(-) Revenue tax		9 083 092	9 337 835	9 598 866	661 192 6	10 030 802 1	0 307 223 10	518 205 10	781 161 11 1	31 741 11 3	48 931 11 6	61 677 11 92	4 287 12 19	7 894 12 598	1722 12 884	03 13 236 53	3 13 546 54	9 13 902 019	14 254 298	14 556 673	10 452 465	0 663 448 1	0667690	25 788 11 5	547 459
(+) REPIM	1 992 197	148	144	141	137	134	131	127	124	122	118	116	113		,			'	'	,	,	,	,		,
REICH	863 662	,	,	,		,	,	,	,	,	,	,	,	,	,		'	'	,	,	,	,	,	,	,
REP CH		148	144	141	137	134	131	127	124	122	118	116	13		,		'	'	,	,	,			,	,
CBED	1 1 78 535																			,	,	,	,		
AND AND	000 071 1																								
OHO.K CM						-								-	-						-				
(=) Profit after tax w/out interest		060.967.5	3 851 649	3 949 500	4 044 400	4 146 7 78	7 C66 IC2 F	1 3 3 5 8 1 4	464 828 4 5	81 084 4 6	92.527 48	11 3/2 4 95	0.164 5.05	2003 218	836 5.311	03 419625	4 430012	4 408 688	4 5 19 292	4 629 391	-1 226 944	-1 232 740	1- 1- 1- 1	- 1- 206 QD	000 809
(-) Debt payments		•	3 090 413	3 167 674 3	246 866	3 328 037	3 411 238 3	496519 3	83 932 3 67	3530 376	369 3856	9 503 3 955	990 4 054	890 4156	62 4 2 60 16		1	•	•						
$(+) RCM_{WF}$	•	2 621 739	2 687 282	2 754 464	2 823 326	2 893 909	2 966 257	3 040 413 3	116 424 3 1	94 334 3 2	74 193 33	56047 343	9 949 3 52	2 3 617	096 3704	448 3 797 06	0 389198	5 398928	4089018	4 191 243	4 296 024	4 403 425	4513511 46	26348 47	742 007
(+) Depreciation		2 387 582	2 447 271	2 508 453	2 571 165	2 635 444	2 701 330	2768 863 2	838 085 2 5	09 037 2 9	81763 30	56.307 3.13	2714 321	1 032 3 291	308 3373	591 345793	0 354437	3 632 98	3 723 813	3 816 908	3 9 12 331	4 010 139	411039342	13 152 43	318 481
(=) Free net cashflow	-58 233 703	8 765 410	5 895 790	6 044 838	6 192 091	6348094	6 5 08 3 43	5 668 571 6	835 404 7 0	10 925 71	82.913 7.3	64 223 7 54	6836 773	4 152 7 932	977 8 129	773 11 451 24	4 11 736 48	5 12 030 96	12 332 126	12 637 542	6981412	7 180 818	7 327 049 75	33 538 7	701 832
2. free net annual cathflow	•	- 668.295	43 57/2 504 -	37 52/ 665 -5	1 335 574	24 98/ 480 -1	84/913/ -1	810 500 4	975 162 24	G5 /03 y z	18 6/0 10 20	82 900 24 12	9730 3180	3 888 39 14	865 47 920	538 59 51 7 89	1 71 114 50	8514552	95 47/1 4 24	108 114 996	115 096 408	122 277 226 1	29 604 275 157	137 813 144	839 645
	$LCOE_{wro}$	84.40	85.07	85.75	86.23	86.92	87.65	88.22	88.92 8	9.83 9.	143 91	1.25 91	.96 92.	59 93.	72 94.4	94.17	94.97	95.88	96.78	97.57	94.05	94.75	95.81 5	6.56 5	97.59

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## APPENDIX Q

LCOE wso Mode	l Inputs											Financial Ind	exes	ĺ	Notes
Legend				-					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	e updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	n about the project.		Costs covered by manufacturer $(O \Delta M_{\rm cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	ĺ	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI CM	69.0930	[S/kW <sub>e</sub> ]	WF CM	-	50 000	[kW_/yr]
Project Location	Aracati (Brazil)		Depr <sub>WTmi</sub>	76.9840	[\$/kW]	$RM_{WT}$	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	M <sub>hrmar</sub>	100	[m-h]	$\varphi_{\rm astal}$	25.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tjr Denr.	60 1398	[%/yr] [\$/vW]	N N	85.00	[5/m-n]	PFP out	0.00002485	[yr] (\$/FW-b)	N col		90.0	[-]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	YBC	15	[Urk()]	$D_{\mu}^{n_{m_{yr}}}$	2.0	[d]	AEP and/Harod	5 693	[kW/yr]	L.		1 800	[m]
Hub height (H)	105.0	[m]	TOCM	0.000033	[\$/kW]	C <sub>nd max</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L		2 430	[m]
Wind speed measured at (H <sub>0</sub> )	10.0	[m]	Π	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ŝ	0.1415	[\$/kW_eh]	SD <sub>x</sub>		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.105194	[\$/kW_eh]	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>x</sub>	12	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	c 0	1 457.72	[\$/kW]	M <sub>brance</sub>	3.0	[m-h]	OREP CM	20.7438	[S/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	11.2%	[%]	PR	0.70	[-]	C <sub>Mbracr</sub>	85.00	[S/m-h]	LCCCM <sub>WFORSIGCM</sub>	4.3886	[\$/kW]	AEP avail		49 057 055	[kWeh/yr]
Availability	98.4%	[%]	Ь	-1.94	[-]	D N m mcr	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wecs}$		20.98%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]	C <sup>m<sub>IMCT</sub></sup>	2.0		WACC proj	4.9000%	[%/yr]	n sectore		25.00%	[%]
Wind Farm Life-Cycle Canit	al Cost Model	Noter	Wind Farm O&M Cost	Model	Noter	SA PV	1 297 3916	[\$/d] [\$/JW]	Y total	25.0%	[%] [%/vr]	P&D <sub>LM</sub>	factor	0.839325	[-]
wr	553 7256	(\$/JW)	O&M.	0.098275	(\$/FWP)	WE	50,000	[JAK11]	ip "	12	[/0/ 91] [ve]	4		6 361 7	6.25
CMwr	265.32	[\$/kW]	LCCCM we	1 204,5180	[\$/kW]	N wr	25	[-]	CR /	60.0%	[%]	AEP		438 000 000	[m] [kW_h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	A WT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	2 427.4170	[\$/tCO2]	P&D <sub>IM</sub>			
CkW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Mbr sam	3.0	[m-h]	LCER <sub>co</sub> ,	31.4	[tCO2/MW,h]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mir_{sanv}}$	85.00	[\$/m-h]	$\sum AEP_{aut}$	48 856	[MW <sub>e</sub> h]	2,41		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub> <sub>MP</sub>	3	[-]	n ,,	25	[yr]	λd		5.00%	[%]
Tmass	138 000	[kg]	O&M variable cu	0.025840	[\$/kWh]	D <sub>m saks</sub>	3.0	[d]	$GHG_{IM_{FCO_2}}$	0.00069	[tCO2/MW2h]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md sav</sub>	3 500.00	[\$/d]	$GHG_{EM_{unreform}}$	0.00005	[tCO2/MWah]	LCPM <sub>WF</sub>		49 057 055	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	Ec	41.7438	[\$/tCO <sub>2</sub> ]			r	
LWTG CM	39.1957	[S/m/kW]	R <sub>tanes</sub>	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	ifr N	2.50%	[%/yr]	WIS VM	1.4442	[S/KW]	ζ <sub>1</sub> KEI <sub>CM</sub> č nrn	50.0%	[%]	Debt ratio		50.0%	[%]
CAR	2 000 00	[m] [\$/m]	JV	25	[yr] [b]	WP cap	2 50%	[KW] [%/vr]	ζ <sub>2</sub> REP <sub>CM</sub> ζ ORFP at	25.0%	[%]	Debt or	ice neriod	14	[yr]
CP cu	30.9069	[\$/kW]	n atta	100	[h]	N	25	[vr]	Č, GHG R cu	0.0%	[%]	Deht in	erest rate	5.00%	[%/yr]
EF.	400.00	[\$/kW]	AAR	4 209 586	[\$M]	WT	200 000	[kg]	REPIM	39,7324	[\$/proil	Debt value		29 551 470	[\$]
ç	0.08%	[%]	AEP anail	49 057 055	[kWh/yr]	C steel	0.1900	[S/kg]			1.1 11	Debt pa	yments	2 985 407	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.124115	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	,	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 551 470	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanag(A)	Г	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000070	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				-
SB <sub>c</sub>	113.00	[S/kWh]	Work days	2.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	$[/m^2/kW]$	Feb/Jun/Nov	6	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	67.6756	yr i	70.7929	yr 15
WF cap	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			67.8295	$yr_2$	69.8226	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000254	[\$/kWh]	Hours Distribution	FLH wf [h]	H prod [h]	O&M con	1	[1/0]	68.0385	yr 3	70.0172	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	68.2028	$yr_4$	70.2229	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.0	[per yr]	February <sup>(*)</sup>	672	648	REPIM			68.4513	$yr_5$	70.4241	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	4.0	[h]	March	744	736	REPIM distribution		64.003	68.6399	yr <sub>6</sub>	70.7751	yr 19
P3	19.88	[\$/KW]	nours requirea	100.0	[n]	Apru	720	712	ζ <sub>1</sub> κει <sub>CM</sub> ξ nrn	1	[1/0]	08.8838	yr 7	70.5899	yr 20
DI	404.52	[\$/KW] [\$/FW]	SC O&M+USC O&M	148.0	[H/yr]	May	744	696	Č. ORFP av	1	[1/0]	69.1016	yr <sub>8</sub>	70.5764	yr <sub>21</sub>
EG	3 7712	[3/kW] [\$/FW]		0.000324	[\$KHUJI]	June	744	736	Č, CHG P ou		[1/0]	69 50 53	y7 9	71 1302	yr 22 VF 22
WACC mai	4,900%	[%/vr]		Г		August	744	736	P&D <sub>IM</sub>		[1,0]	69.7421	yr II	71.3951	VF 25
n <sub>fin</sub>	1.0	[yr]				September	720	712	λe	1	[1/0]	70.0200	yr 12	69.6991	Mean
W <sub>F<sub>CM</sub></sub>	0.30%	[%]				October	744	736	$\lambda_{sdi}$	0	[1/0]	70.2471	yr 13	1.0849	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	696	$\lambda_d$	1	[1/0]	70.4639	yr 14	-0.4478	Y (skewness)
K	0.20%	[%]				December	744	736	λ,,,	1	[1/0]	LCOE was	69.6991	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 616		p.s.: 1 = yes as	nd U=no		0.069699	US\$/kWh	

**Figure Q.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 2). Source: Own elaboration

LCOE wso Mode	l Inputs										Financial Ind	exes		Notes
Legend								Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and as	re updated	Of Managements and Hits		Notes	Demociation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		MC A	50	[\$/kW]
automatically based on user input into Yellow cells are for use input informatic	yettow cetts. on about the project.	O&M warranty conauto	80.00%	[96]	Depreciation rate per year	4.00%	[%/vr]	Emacted Market Price	0.11403	(SAWE)		WACC .	4 9000%	[%/vr]
Gray cells are not used.		Period of warranty $(n_y)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
				07			0.7							
Wind Project Information	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	AR CM	16.8442	[\$/kW]	$DCM_{WF}$	1 339.9154	[\$/kW]	REI <sub>CM</sub>	69.0930	[\$/kW e]	WF CM		50 000	[kW <sub>e</sub> /yr]
Project Location	Corvo Island (Portugal)	Depr <sub>WTmr</sub>	76.9840	[\$/kW]	RM WT	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW	WT CM	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[S/kW]	N <sub>WT</sub>		25	[-]
Number of wind Turbines (IV WT)	2000 000	I CM	484.3839	[5/KW]	M	23	[-] (m.h.)	ijr W	2.50%	[%/yr]	WI rated		2000	[KW]
Wind Farm Canacity (WF)	50.000 [kW]	ifr	2.50%	[91] [%/yr]	C <sub>Mbree</sub>	85.00	[S/m-h]	T total	20.00%	[70] [vr]	N row		5	[-]
Rotor Diamenter (D)	90.0 [m]	Depr	60.1398	[\$/kW]	Nmen	3	[-]	REP CM	0.00000982	[\$/kW_h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7 [m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	Dmm	2.0	[d]	AEP anail/H prod	10 458	[kW/yr]	L <sub>x</sub>		1 800	[m]
Hub height (H)	105.0 [m]	TO CM	0.000033	[\$/kW]	C <sub>ndmur</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	$L_{x_{col}}$		2 430	[m]
Wind speed measured at $(H_0)$	10.0 [m]	77	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	3	0.1027	[\$/kW <sub>e</sub> h]	$SD_{x_{norm}}$		450	[m]
Terrain rugosity factor (a)	0.14 [-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.067500	[\$/kWch]	SD <sub>xcol</sub>		540	[m]
Betz Limit's coefficient (C PBetz)	0.5926 [-]	Vo	6 100 000	[kW]	NWT	25	[-]	n <sub>z</sub>	17	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N) Deschool of Wind Farm (WF )	25 [yr]	<i>c</i> <sub>0</sub>	1 457.72	[5/kW]	M <sub>W Mar</sub>	3.0	[m-h]	ICCCM	33.5/6/	[\$/KW e]	PC PM		00 107 610	(DAV b/cm)
Aváilability	98.4% (%)	PK	-194	[-]	N N	3	[.]	LCCCM wFOREGOM	1 204 5180	[3/KW] [S/kW]	n		20.98%	[%]
	359 [d/yr]	IRCM	16.8443	[\$/kW]	$D_{\pi}^{m_{exc}}$	2.0	[d]	WACC	4.9000%	[%/vr]	$\eta_{uucr}$		25.00%	[%]
				[4.0.1.]	$C_{nl}^{n_{Bd}}$	3 500.00	[\$/d]	$\Psi_{total}$	25.0%	[%]	P&DIM	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT	,	25	[-]
WT <sub>CM</sub>	553.7256 [\$/kW]	O&M <sub>ful ct</sub>	0.098275	[\$/kWh]	WF cap	50 000	[kW]	n ,,	17	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM WT	265.32 [\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	NWT	25	[-]	$CR_f$	60.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70% [%/\$/kW	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	1 248.5415	[S/tCO <sub>2</sub> ]	$P\&D_{LM}$			
$C_{RW}$	400.00 [\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>bran</sub>	3.0	[m-h]	$LCER_{co_2}$	57.6	$[t\mathrm{CO}_2/\mathrm{MW}_0\mathrm{h}]$	λ.,		7.00%	[%]
IPT	10.00% [%]	N	25	[yr]	$C_{Mbr_{SARV}}$	85.00	[\$/m-h]	$\sum AEP_{avail} = \sum_{r_1, \dots, r_n}$	89 657	[MW <sub>e</sub> h]	λ,,,,		0.00%	[%]
T <sub>CM</sub>	484.3859 [\$/kW]	ifr O&M	2.50%	[%/yr]	D N <sub>M MAY</sub>	3	[-]	n , GHG	25	[yr]	24		5.00%	[%]
I man	138 000 [kg]	MC	0.048925	[S/KWh]	C	3.0	[d]	CHC	0.00069	[tCO2/MWah]			5.00% 00.107.610	[%]
C .	0.1900 [5/ke]	TIC	124 5688	[3/1] [\$/b]	BVM	61.0184	[3/U] [\$/VW]	CHO <sub>EM</sub> <sub>www.co<sub>2</sub></sub>	11 7000	[ICO2/MW28]	Let M <sub>WF</sub>		30 107 010	[K Well yi ]
LWIG car	39 1957 [\$/m/kW	R	30.00%	[%]	Nww	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	ina	1	Notes
WF our	50 000 [kW]	ifr	2.50%	[%/vr]	WTS VM	1.4442	[\$/kW]	ζ <sub>1</sub> RELCM	50.0%	[%]	Debt ratio		50.0%	[%]
L	13 950 [m]	N	25	[yr]	WF car	50 000	[kW]	$\xi_2 REP_{CM}$	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00 [S/m]	n <sub>mlh</sub>	48	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM	25.0%	[%]	Debt gri	ice period	1	[yr]
CP CM	30.9069 [\$/kW]	n <sub>tih</sub>	100	[h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	0.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00 [\$/kW]	AAR	14 679 146	[\$M]	WTweight	200 000	[kg]	REPIM	42.9657	[\$/proj]	Debt value		29 470 640	[\$]
ç	0.08% [%]	AEP avail	90 107 610	[kWh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	2 977 241	[\$/yr]
TS CM	11.4566 [S/kWe	O&M WFCM	0.147200	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	2	50.0%	[%]
TL <sub>c</sub>	0.0400 [S/m]		r		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 470 640	[\$]
TL,	1 200 [1/kW]	O&M <sub>O&amp;Mmanag(A)</sub>		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discoun	t rate	9.00%	[%/yr]
L	3 000 [m]	SC ORM	0.000038	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB c	113.00 [\$/kWh	Work days	2.0	[d]	T <sub>mass</sub>	138 000	[kg]	a re con	1	N (	Initial Results	summary	of LCOE <sub>wso</sub>	Notes
SI <sub>CM</sub>	42.7345 [\$/m²/kW	] Feb/Jun/Nov	6	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE win		Notes	73.1255	yr i	78.4712	yr 15
WF cap	50 000 [KW]	Hours required	48.0	[h]	II Distribution	FIH (h)	n (h)	O&M WFCM		(1/0)	/3.518/	yr <sub>2</sub>	77.6515	yr 15
WI inst	42.3238 [S/KW]	USC ORM	0.000138	[\$/kwnj	Hours Distribution	744	740	(%) arm	80.0%	[1/0]	74.1224	yr <sub>3</sub>	78.1012	yr 16
Bld cost	300.0 [5/m]	Frequency	10	[=]	February <sup>(*)</sup>	672	648	REPIM	30.0%	[/0]	74.1334	yr4	79.1175	yr 17
POcu	35.9374 [\$/kW]	Repair time	4.0	[h]	March	744	736	REPIM distribution			74.9273	Vr.	79.6115	VF 10
FS	19.88 [\$/kW]	Hours required	100.0	[h]	April	720	712	$\xi_1 REI_{CM}$	1	[1/0]	75.2253	yr 7	77.7347	yr 20
DT	87.22 [\$/kW]	SC O&M+USC O&M	148.0	[h/yr]	May	744	736	$\xi_2 REP_{CM}$	1	[1/0]	75.5275	yr <sub>8</sub>	78.2446	yr <sub>21</sub>
EG	404.52 [\$/kW]		0.000176	[\$/kWh/yr]	June <sup>(*)</sup>	720	696	$\xi_3 \text{ OREP }_{CM}$	1	[1/0]	76.0152	yr <sub>9</sub>	78.7103	yr 22
F <sub>CM</sub>	3.7712 [\$/kW]	1			July	744	736	$\xi_{4}$ GHG.R <sub>CM</sub>	1	[1/0]	76.4118	yr 10	79.0644	yr 23
WACC proj	4.900% [%/yr]				August	744	736	P&D <sub>IM</sub>			76.7332	yr 11	79.4723	yr 25
n <sub>fin</sub>	1.0 [yr]	11			September	720	712	λa	1	[1/0]	77.2289	yr 12	76.8666	Mean
W <sub>F<sub>CM</sub></sub>	0.30% [%]	11			October	744	736	λ <sub>261</sub>	0	[1/0]	77.6321	yr 13	2.0151	SD X (down)
K	2.4042 [S/KW]	11			November <sup>(1)</sup>	720	736	2	1	[1/0]	78.0589	yr 14 76 8664	-0.4631	1 (skewness) valid !
LCCCM <sub>wr</sub>	1 204.5180 (\$/ĿW	11			Total [h/wr]	8 760	8 616	× m	n s · l = yer er	10=no	LCOE NTO	0.076867	IS\$/kWh	vana :
Locom WF	1 204.5100 [\$/KW]				zonai [n/yr]	0700	5 010		p.s 1 – yes a	na J-RU	L	0.0/000/	0.70/K 111	

**Figure Q.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* <sub>2</sub>). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_cm)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	Г	Notes	Levelized Replacement	Cost Model	Noter	Wind Farm Removal C	ost Model	Noter	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	Cycle Prod	uction Model	Notar
Project Name	Firestar Wind Farm	ivotes	AR cu	16 8442	Ivotes [\$/kW]	DCM we	1 339 9154	[S/kW]	RELCH	69,0930	[S/kW_]	WE cu	-cjele 1764	50.000	[kW_/yr]
Project Location	Cape Saint James (Canada)		Depr	76.9840	[\$/kW]	RM WT	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	WF our		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	$T_{CM}$	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	Mhrman	100	[m-h]	$\Psi_{astal}$	25.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMBranger	85.00	[\$/m-h]	n <sub>v</sub>	5	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>Tac</sub>	60.1398	[\$/kW]	N <sub>11,117</sub>	3	[-]	REP CM	0.0000049	[\$/kWeh]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]		2.0	[d]	AEP avail/Hprod	24 780	[kW/yr]			1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	C <sub>mlmyr</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 4 30	[m]
Tampin massifu faster (n)	0.14	[m]	"	1 /98 /43	[\$/KW] [1/30/]	KM CT	20.1954	[5/KW]	5	0.0121	[\$/KW_0]]	SD		430	[m]
Betz Limit's coefficient (Cas. )	0.5926		V V	6 100 000	[KW] [FW]	WP cap N mm	25	[_]	е <sub>0</sub>	0.008998	[3/K// ell]	EIH (		8 760	[h]
Lifetime of Wind Farm(N)	25	[vr]	v 0 5 0	1 457 72	[\$/kW]	M <sub>w</sub>	3.0	[m-h]	OREP	90.2828	[S/kW ]	PC nu		0 100	[10] [1]
Production Efficiency (WF nr)	48.7%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[S/m-h]	LCCCM	4,3886	[\$/kW]	AEP		213 509 813	[kW_h/yr]
Aváilability	98.4%	[%]	h	-1.94	[-]	N_	3	[-]	LCCCM we	1 204,5180	[\$/kW]	η		20.35%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]	$D_m^{m_{er}}$	2.0	rdi	WACC anal	4,9000%	[%/vr]	$\eta_{max}$		25.00%	[%]
		( 77			[4,4,]	$C_{ml}$	3 500.00	[\$/d]	Wand	25.0%	[%]	P&D	lantes.	0.814145	(-)
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost 1	Model	Notes	S&RV MCT	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT	Jacon	25	E E
WICH	553.7256	[\$/kW]	O&M fund	0.098275	[\$/kWh]	WF com	50 000	[kW]	, n.,	12	[yr]	Α		6 361.7	(m <sup>2</sup> )
CMWT	265.32	[\$/kW]	LCCCM	1 204.5180	[\$/kW]	NWT	25	[-]	CR	60.0%	[%]	AEP rated		438 000 000	[kW_h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	6 827.9067	[\$/tCO2]	P&D <sub>IM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>br sur</sub>	3.0	[m-h]	$LCER_{CO_2}$	136.4	[tCO2/MWah]	λ <sub>a</sub>		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	$C_{Mir_{sanv}}$	85.00	[\$/m-h]	$\sum AEP_{aud} = \sum_{r_1, \dots, r_n}$	212 467	[MW <sub>e</sub> h]	2,41		3.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub> <sub>MR</sub>	3	[-]	n ,	25	[yr]	λd		5.00%	[%]
Tmaxr	138 000	[kg]	O&M variable ou	0.041527	[\$/kWh]	D <sub>m<sub>saky</sub></sub>	3.0	[d]	$GHG_{IM_{TM_{2}}}$	0.00069	[tCO2/MWah]	λ <sub>m</sub>		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	GHG <sub>EM</sub> <sub>unit CD</sub> ,	0.00005	[tCO2/MWah]	LCPM WF		213 509 813	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	E <sub>c</sub>	27.0000	[\$/tCO <sub>2</sub> ]				
LWTG CM	39.1957	[\$/m/kW]	Rtanes	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\tilde{\zeta}_1 REI_{CM}$	50.0%	[%]	Debt ratio		50.0%	[%]
Lg	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\xi_2 \operatorname{REP}_{CM}$	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mih</sub>	48	[h]	ifr	2.50%	[%/yr]	$\zeta_3 OREP_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	100	[h]	N	25	[yr]	$\zeta_4 GHG.R_{CM}$	0.0%	[%]	Debt in	terest rate	5.00%	[%/yr]
EF,	400.00	[\$/kW]	AAR	29 538 512	[\$M]	WIweight	200 000	[kg]	REPIM	57.1172	[\$/proj]	Debt value		29 116 852	[5]
5	0.08%	[%]	AEP anail	213 509 813	[kWh/yr]	C steel	0.1900	[5/kg]		1		Debt pa	yments	2 941 500	[5/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139802	\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[S/kW]	Exchange rates		Notes	Equity rati	<i>.</i>	50.0%	[%]
IL <sub>c</sub>	0.0400	[\$/m]		F		WF cap	50 000	[KW]	EUR/USD dec2010	1.3252	[-]	Equity	ralue	29 116 852	[8]
TL,	1 200	[1/kW]	O&M O&Mmanag(A)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	if rafe	9.00%	[%/yr]
L <sub>1</sub>	3 000	[m]	SC ORM	0.000016	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	2.0	[d]	Tmass	138 000	[kg]		1		Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	84.3997	yr1	94.4943	yr 15
WF cap	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			85.0669	$yr_2$	94.1699	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000058	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	85.7507	yr 3	94.9708	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	86.2255	$yr_4$	95.8775	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.0	[per yr]	February'	672	648	REPIM			86.9196	yr <sub>5</sub>	96.7795	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	4.0	[h] (h.)	March	744	736	REPIM distribution		(1/0)	87.6452	yr <sub>6</sub>	97.5702	yr 19
F 5	19.88	[3/KW] [\$/MW]	SC USC	148.0	[n]	Aprii	720	712	REICM	1	[1/0]	88.2242	yr 9	94.0503	yr 20
DI	67.22	[3/KW] [\$/MW]	SC O&M+USC O&M	148.0	[avyr]	May (*)	744	130	OPER	1	[1/0]	88.9241	yr <sub>8</sub>	94.7536	yr 21
EG	404.52	[3/KW] [\$/MW]		0.000074	orkwn/yr]	June"	720	726	CHC P	1	[1/0]	89.8200	yr 9	95.8087	yr 22
WACC	3.7/12	[3/KW] [96/97]		Г	1	August	744	736	P&DIM	1	[1/0]	90.4267	yr 10 NF 11	90.3049	37 23 NT 26
nac c proj	4.500%	[90/91]	-			Sentember	720	712	1.	1	[1/0]	91.0477	27.12	91 8264	Mean
We We	0.30%	[%]				October	744	736	λ	1	[1/0]	92.6946	yr 12 VF 12	4.2043	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	696	λd	1	[1/0]	93.7245	yr 14	-0.3333	Y (skewness)
ĸ	0.20%	[%]				December	744	736	λ	1	[1/0]	1005	91.8264	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 616		p.s.: 1= yes ar	nd 0=no	LCOE wzo	0.091826	US\$/kWh	
-						Charles de March anna fan mar de									

**Figure Q.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 2). Source: Own elaboration

Table Q.1 Energy	productior.	(AEP avail)	map of th	te wind farm	for Aracati (	(Brazil)		with sens	itivity analy	sis of O&M	manag(A) + E	vi (Case 2)															1
Months	лис	Hprod	-											$AEP_{c}$	nail(kWh)												I
	n/s) (kg/i	m <sup>5</sup> ) (h)	yr.	1 yr2	yr 3	yr 4	yr 5	$yr_6$	yr 7	$yr_8$	$yr_{g}$	yr 10	yr 11	yr 12	yr 13 y	r14 y	15 y	r 16 y	17 yr	18 yr	19 yr.	0 yr 21	1 yr 22	2 yr 23	yr 24	yr 25	I
, January	5.8 1.1	665 74	40 1697	720 89142	291 38124	69 752775.	5 558 872	8 914 291	558 872	558872	4 243 681	8 914 291	8 914 291	558 872 34	812 469 7 52	27 755 4 24	3 681 891	4291 891	4 291 558	872 3812	469 7 527	755 5588	72 38124	469 7 527 7:	55 4 243 68	1 4 2 4 3 6 8.	18
February	4.9 1.1	666 64	48 8593	945 68795	561 37144.	21 687956	- 788 321	6 879 561	788 321	788321	4 780 152	6 879 561 (	5 879 561	788.321 37	714 421 6 83	79 561 489	171 489	- 222 - 233	6 988 4 780 	152 7802	526 1 594	674 15946	574 7 802 5	526 6 879 50	1 478015	2 478015	22 :
Marcn	4.0 1.1	c/ 1/0	> CCC 00	5// /45/4	419 24520	70 00 2 70	717 116 0	148/419	717 116	717 / 16	CH0 7CC 0	/ 48/ 419	48/419	C 717/14	127 007 2 20	60 070 00	60 770	191 7790	2 1 24 4 22(	1947 1917	154 1 0 0 0	0 2 2 0 1 0 2 2 0	0/19/ 670	7C 002 2 660	14076/2 03	1070C0 1	£
April	4.7 1.1	667 71	12 866.	366 63371	184 63371¢	84 408215	1 1 633 098	6 337 184	1 633 098	I 633 098	7 241 220	6 337 184	5 337 184 1	752 548 6	337 184 4 00	82 151 94	080 94	5 080 1 65	3 098 6 33;	184 1635	098 3 667	352 9450	80 7 241 2	220 6 337 IX	84 175254	8 724122	50
May	6.0 1.1	670 75	36 1812.	066 54318	800 748714	40 543180	0 1812 066	5 431 800	1 812 066	1 812 066	7 817 409	5 431 800	5 431 800 1	688 560 74	487 140 65:	52 401 1 68	8 560 168	8560 97.	176 886	195 977	176 555	856 8957	88 65524	401 4 220 72	35 1 688 56	9 781740	60
, June	7.9 1.1	686 65	96 3 996.	852 3 996 8.	852 740262	57 620476	4 3 590 720	3 996 852	3 590 720	3 590 720	8 395 800	3 996 852	3 996 852 3	590 720 74	402 657 514	13 616 171	5 927 171	5927 84	262 740	657 848	262 848.	262 35907	720 5 143 6	516 5 143 6	16 925332	2 8 395 80	8
July	8.6 1.1.	698 73	36 5 444.	782 38009	962 88873t	85 1 692 59	5 4 230 873	3 800 962	4 230 875	4 2 30 873	557185	557 185	3 800 962 5	444 782 8 8	887 385 181	16397 380	0.962 3.80	0.962 55	185 750	034 557	185 979.	511 42308	873 4 230 8	873 1 692 59	6 897929	9 55718:	35
August	9.6 1.1	677 73	36 7491.	301 1813 0	73 1813 0	73 181307.	3 8 871 123	1 813 073	5 434 815	5 434 819	896286	896 286	1813073 4	223 131 14	813 073 1 68	89 499 5 43	4819 782	1 753 782	1 753 896	286 4223	131 7821	753 54348	819 1 813 (	073 1 813 03	73 55616	5 896280	36
September	10.1 1.1	657 71.	12 8 566	923 1 631 5	564 1 631 50	64 3 663 90	5 7 553 538	1 631 564	6 331 230	6331230	944 192	944 192	1 631 564 6	331 230 1 0	531 564 3 60	3 906 633	1 230 7 23	4417 723	4 417 944	192 5 248	454 8566	923 63312	230 1 631 5	564 3 663 9(	06 633123	944 192	2
October	9.7 1.1	645 73	36 7800	246 975 0.	31 975 03	31 554 630	5 7470 703	975 031	7 470 703	7 470 703	1 684 853	1 684 853	975 031 8	846 730 9	75 031 55	4 636 7 47	0 703 653	8016 653	8 016 1 80	088 6535	016 4211	519 74707	703 975 0	031 975 03	1 884673	0 1 684 85.	53
Manamhar	11 60	638 60	.021.9 90	757 8447	LL VV8 3L.	75 844 77	2 6 1 70 252	844 775	210 072 7	816 62 8 7	CT9 907 1	CT9 907 1	844 775 3	277 719 8	14 775 84	A 775 7 37	212 8166	1 2 234 6	051 297 0	300 7.067	758 6170	7277 737	7 8 8 4 7	75 84477	10 022 2 31	1 709 97	1
December	76 11	651 73	16 3 785	1 1 2 2 2 2 0 -	50755 15	51 07558	950 667 5 5	130 735 3	8 851 750	8 851 750	3 785 775	3 785 775	2 150 755	5 050 727	20 150 75	5585 885	1750 421	3013 471	3 013 3 78	2021 2021	CCP 5 189	056 8851	0 755 052	50755 150	150 FLF L L	3 285 72	: 5
Annual	74 1.1	666 8.61	16 49 057	055 48 667 4	462 48 892 6.	52 48 537 12	7 49 088 734	48 667 462	49 051 89	49 051 893	48 608 021	48 624 219	48 667 462	9 049 275 48	892 652 48	96 807 49 2	39 93 2 49 3	80.379 49.0	09 701 48 69	7 726 48 31	7 889 49 06	437 48 965	360 48 420	199 48 519 7	58 48 661 53	6 48 608 02	12
Annual	1.1 4.1	10 0 000	100.64 01	100.94 CCD	407 42 27 0	71 /22 27 17	49,000 /34	1 48 00/ 407	69 ICO 64	568 ICO 6#	4 0 000 071	48 024 219	9 706 / 00 86	94 C/7 640 6	2.94 200.269	7 64 / 102 060	C 64 7 76 60	80.379 496	10 / 10 48 0A	1 / 20 40	00 47 49 00	. COK 24 / 54	300 48420	7 61C 84 661	SC 100 SF SC	70 909 94 0	7
Table Q.2 E	tergy produ	iction map of	f the wind	farm for Corv	vo Island (Pc	ortugal)		with s	ensitivity a	alysis of Od	M manag(A) +	E <sub>pi</sub> (Case	(2		1.000												I
Months	Vuc	- ,	Hprod											AE	$P_{avail}(kWh)$												Í
	(m/s) .	$(kg/m^3)$	(4)	yr 1	yr 2 .	yr3 y.	r4 yr	·5 yr	6 yr	7 yr8	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17 )	11 IS Y	19 yı	20 yr 2	21 yr2	2 yr 23	yr 24	yr 25	1
Januar	v 11.7	1.2313	740	14 490 462 1,	14 490 462 14	1 490 462 14 4	90 462 14 49	0 462 14 49	0 462 14 49	162 10 871	408 10 871 40	14 490 46	10 871 408	10 871 408	10 871 408	14 490 462 1	0 871 408 1	0 871 408 1	1 490 462 10	871 408 10	271 408 10 8	71 408 10 87.	1 408 10 871	1 408 10 871	408 10 871 4	08 10 871 40	408
Februar	y 11.5	1.2345	648	12 092 721 4.	293 137 12	092 721 12 6	92 721 12 09	2 721 3 417	096 12 09	21 12 715	785 1 795 78	4 3417090	12 715 785	1 795 784	9 244 173	12 092 721 6	674 015 1	2 715 785 4	293 137 54	86 290 34	17 096 2 81	5 600 12 09.	2 721 2 106	703 66740	15 12 092 7	21 12 715 74	785
Marc	h 10.5	1.2329	736	10 486 228 3	193 907 13	217 510 13 7	17 510 13 71	7510 6223	1 433 13 71	510 13717	510 2 389 76	2 3 193 907	13 717 510	2389762	13 717 510	13 717 510 6	223 433 1	3717510 3	876 220 75	70 742 48	59 967 13 7	17 510 14 42	4 289 2 037	067 10 486.	228 14 424 2	89 3 193 90	07
Apr.	1 9.5	1.2317	712 ;	7 316 597 7.	. 316 597 10	1458483 104	58 483 10 45	8 483 7 316	597 10 45	3 4 706	82 3 086 68	9 7316597	13 257 022	3 0 86 689	13 257 022 4	1 706 485 4	706 485 1	3 257 022 3	086 689 10	134 212 3 0	86 689 13 9	40 075 13 25	7 022 3 086	689 3 086 6	89 13 257 0	22 3 746 05	86
Ma	v 8.2	1.2282	736 4	4 851 676 16	0 446 845 10	1 446 845 10 4	46 845 6 200	0 059 10 44	6 845 10 44	845 10 446	842 3 861 60	2 6 200 055	10 446 845	3861662	14 370 115	10 446 845 3	861 662 1	0 446 845 2	380 787 13	665 991 6 2	0 059 2 38	0 787 10 44	6 845 3 861	662 14 370	115 10 446 8	45 4 851 67	929
Int	12 .	PCCC 1	6 909	ci 197 700 c	2 860 010 7 0	107 081 7 00	7 081 7 00	7 081 10 14	5 000 V 5V	858 12 860	1 1 565 8	8 10145 00	7 007 081	1 565 858	7 007 081	240.522 2	2 197 700	107 081	ci 198 000	010 010 20	1 1 00	0 861 7 007	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	858 12 860	010 7 002 01	21 5 824 81	206
int.	. 61	12154	736 3		3 622 571 4 8	0 / 10 / /00	120 / 100 / 100 /	12 200 13 52	59FL 1257	154 3.148	00 151 9 81.	511 800 6 6	00 134 000	000 707 4	C00 781 9	2 200 012 -	y 108 558	1 100 /20 V	134 000 14	210306 10	07 1 107 1	1135 6134	100 K134	225 13 200	11682 125	1 897 2 38	75
Auouk	. 64	1 2075	736 3	7 340 40K	0 508 668 2 7	706.310 2.76	K 210 270	5 210 13 43	4710 K.004	13.4 2 706	10 2414 C	8 2 240 404	125 092 8	2414668	1 760 571	1 899 805 01	005.077 A	1 125 092	1 21 21 21 2	05.070 IS	124 710 4 76	0 571 4 760	NUV 123	9 1 760	0861 8 12	0 0 2 0 0 2 0 0	150
Sentembe	r 7.6	1.2064	712 5	3 669 202 1	928.273 5.8	891.057 4.66	9876 460	9876 4609	876 1 928	273 5 891 (	67 9 926 18	9 9 9 2 6 180	3 669 202	9926189	3 669 202	2 891 057 9	926 189 3	669 202 1	984 898 2.2	62 132 12	084 898 5 80	1 057 3 669	202 9 926	189 3 669	02 2 262 1	32 1 928 23	23
Octobe	r 8.9	1.2126	736 6	5 121 079 6	121 079 31	141 378 2 06	3 564 3 14	1378 2.005	564 2350	459 7 446	29 13 491 9	13 491 90	3 141 378	13 491 905	3 141 378	7 446 229 1	3 491 905 3	141 378 1	0 643 782 31	41 378 2 0	3 564 7 44	6 2 2 9 3 141	378 13 491	1 905 2 350 4	(59 2 003 50	4 235045	(59
Novembe	r 10.6	1 2194	969	10 121 586 3	625425 22	235 143 223	5 143 2 23	5 143 2 234	143 2 985	258 2235	43 12 829 9	12 4 5 5 4 871	2 2 3 5 143	12 829 976	2 235 143	087.258	2 829 976 2	235 143 0	807.761 3.6	25 425 22	35 143 9 80	7 761 2 235	143 12 829	2 200 1 926 6	67 58207	71 12 829 9	926
Decembe	211 4	1 2227	736	13 614 084 2	371 001 2 6	21 8 678 1 66	0 0 2 2 00	1812 CF81	1035 3 847	6160 6 086	79 17 18 T	13 614 08	CF8 1 CD C 1	14 316 481	CF8 1 CU C	1 076 278 8	4 316 481 2	2 018100	814158 48	73 568 14	16 481 13 6	1 CU C 780 FI	112 11 618	9421 9 128 9	18 482351	0 13 614 0	780
Annual	10 1	100001	8616	00 107 610 00	00 FLL 09L 0.	C 00 10F 001.	23 07 1 00 10	10 10 210 101	FF 00 868 9	1405 80.858	2 289 00 670	24 00 700 675	00.078.677	FLE 589 00	00 530 336	00 473 134 0	0 246 888 0	0.078.677_0	00 PMP 235	6666.424 000	255 213 00.0	55 078 00 1K	2 203 00 64	3 508 00 743	5 050 00 /52	2 02 7 08 00	577
AMI	76 1	7777.1	070 0	s 00 00 00 00 00 00 00 00 00 00 00 00 00	04 +// 60/ 02	· 06 160 061 0	41 MA		## 0% 07 0	000 K0	10 CO0 04 74	×0 00/ 00/	//0 0/0	#/c C00 06		< +c1 c/+ 04	6 000 0 <del>1</del> 7 /		06 +0+ / CC /	04 +C+ 000	6 05 CC	07.04	240 AX	. c+/ 04 04C c	r x ro nx	10000 A0	
Table Q.3 E	tergy produ	tction map of	f the wind	farm for Cap.	e Saint Jame.	s (Canada)		with s	ensitivity a	alysis of Od	M manag(A) +	Epi (Case	(3														I
Mandha	$V_{HC}$	4	$H_{prod}$											AE	$P_{avail}(kWh)$												ĺ
MONINS	( <i>m</i> / <i>s</i> )	$(kg/m^3)$	(4)	yr 1	yr 2	yr3 y.	r4 yr	-5 yr	6 yr	7 yr 8	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17 3	T 18 Y	19 yr	20 yr 2	21 yr2	12 yr 23	yr 24	yr 25	1
Januar	y 15.4	1.2561	740 .	32 823 510 32	12 823 510 32	823 510 32 8	23 510 32 82	23 510 32 82	3 510 32 82	1 510 32 823	510 32 823 5.	0 32 823 510	32 823 510	8035210	32 823 510	32 823 510 3	2 823 510 3	2 823 510 3	\$ 823 510 32	823 510 32	23 510 40 8	5 255 32 82.	3 510 32 82:	3 510 28 095	929 8 035 21	10 7 120 17	22
Februar	v 14.7	1.2522	648 .	24 591 404 Iv	4 672 254 76	910 451 26 5	99 864 14 67	2 254 14 67	2 254 26 59	864 26 599	864 7 010 45	1 14 672 254	14 672 254	7859649	26 599 864	7 010 451 1	7 623 290 7	010 451 7	010451 70	10 451 70	10 451 22 7	80 600 26 59	9 864 26 599	9 864 29 369.	594 78596	19 17 596 9.	916
Marc	h 12.7	1.2495	736	18 252 376 11	18 252 376 8 5	908 878 27 8	74 248 12 39	14 144 18 25	2 376 27 87	1 248 27 874	248 890887	8 12 394 144	18 252 376	9986084	27 874 248 8	8 908 878 3	0 150 829 8	908 878 8	908 878 89	08 878 89	08 878 23 0	24 061 27 87-	4 248 27 874	4 248 31 459.	374 998602	34 18 948 10	162
Apr	1 12.4	1.2490	712	16 081 249 IS	9 315 677 9 6	656 023 24 8	65 308 9 650	5 023 19 31	5 677 24 86	308 24 865	308 9 656 02	3 9 656 023	19 315 677	9656023	24 865 308 9	0 656 023 2	6 952 947 9	656 023 2	154 282 96	56 023 9 6	56 023 22 2	18 160 20 00.	1 184 24 862	5 308 24 956.	459 965602	23 18 165 6.	621
Ma	v 11.2	1.2425	736	12 324 064 2:	5 569 850 9 5	929 620 19 8	62 973 9 929	9 620 25 56	9 850 19 86	973 19 862	73 992962	0 9 929 620	25 569 850	12 324 064	19 862 973 9	929 620 2	5 569 850 9	929 620 2	716 641 95	29 620 9 9	29 620 21 0	18 978 19 86	2 973 19 862	2 973 19 116.	345 12 324 0	64 16 191 2-	245
Jun	e 10.4	1.2351	5 969	9 333 787 21	11 587 550 92	584 551 176	60 120 8 320	5 944 26 05	3 485 17 06	0 120 17 060	120 11 584 5.	1 8 326 944	1 26 053 485	15 544 593	17 060 120	11 584 551 1	7 060 120 1	1 584 551 2	1 035 514 11	584 551 11.	84 551 171	78 664 17 06	0 120 17 060	0 120 16 981.	395 15 544 5	93 15 146 30	363
Ju	v 10.0	1.2275	736 2	8 751 923 23	19 619 639 16	337 936 16 3	37 936 7 800	5 320 29 61	9 639 16 33	936 16337	936 163379.	16 7 806 320	29 619 639	17 930 811	16 337 936	16 337 936 7	806 320 1	6 337 936 1	0 623 991 16	337 936 16.	137 936 15 5	52 737 16 06	9 219 16 337	7 936 16 783	950 17 930 8	11 8 637 35	16
Augu.	1 9.7	1.2216	736	7 768 712 1.	11 129 17	7 844 428 12 1	17 129 17 84	14 428 12 11	7 129 12 11	7 129 12 117	129 17 844 4.	8 17 844 428	8 12 117 129	19 529 451	12 117 129	17 844 428 8	1 092 602	7 844 428 1	844 428 17	844 428 17.	44 428 12 9	21 415 15 39	9 666 12 113	7 129 12 606	836 19 529 4	51 7 121 95	92
Septembe	r 10.4	1.2234	712 \$	9 458 082 7.	526165 18	8 919 721 9 42	8 082 26 40	0 433 7 526	165 9458	082 9458(	82 189197.	26 400 433	7 526 165	24 355 589	9 458 082	18 919 721 9	458 082 1	8 919 721 1	6 751 596 18	919 721 18	19721 123	39 146 13 29.	4 981 9 458	082 8855 (	20 24 355 5	89 19 057 6	888
Octobe	r 13.1	1.2327	736	19 706 914 8	3 788 905 29	744 799 98.	1 605 25 36	8 953 8 788	1 905 9851	605 98510	05 29 744 7	9 25 368 95:	8 788 905	27 498 877	9 851 605	25 368 953 9	851 605 2	5 368 953 1	227 237 29	744 799 25.	168 953 12 2	59 773 8 871	247 9851	605 81341	57 27 498 8	77 21 626 6	625
Novembr	r 14.3	1.2429	. 969	24 188 639 9	393 250 26	5219466 83;	95 87 566 6.	0 895 9 395	250 8379	993 83799	93 26 219 4	6 28 360 895	9 393 250	28 360 895	8 379 993	26 219 466 1	1 658 353 2	6 219 466 9	393 250 26	219 466 26.	219 466 7 52	0 762 8 379	993 8379	993 89877	16 28 360 8	95 22 240 1.	116
Annue	r 15.1 1 12.5	1.2528 1.2404	736 8 616 2.	30 229 153 h 13 509 813 214	10 012 025 25 4 144 266 214	5 782 051 7 9( : 761 434 213 1	6 958 20 02 97 728 213 61	1 337 214 14	2 025 7 966 4 266 213 19	958 79669 728 213 197	158 25 782 0. 728 214 761 4.	11 20 027 814 14 213 611 337	10 012 025 214 144 266	32 544 702 213 625 948	7 966 958 .	30 229 153 1 14 832 689 21	5 674 139 3 4 338 805 21	0 229 153 1 4 832 689 21	012 025 25 501 803 214	782 051 30. 761 434 214.	29 153 6 35 32 689 214 0	9 397 7 966 38 947 214 20.	3 964 213 197	958 91766	637 32 544 7 412 213 625 9	02 42 535 3. 48 214 387 6.	539
																											1

Table Q.4 Win	l speed sen	ies simulatic	ons for AEF	<sup>2</sup> avail in Ara	cati (Brazil)			wit	h sensitivity	/ analysis o	f O&M <sub>mana,</sub>	$g(A) + E_{pi}$ (0	Case 2)													
Months	P <sub>WC</sub>										1	Wind spe	ed data ser	ies for simu	ations (m/s	-										
January	5.8	5.8	1.01	7.6	9.6	4.0	10.1	4.0	4.0	7.9	10.1	10.1	4.0	7.6	9.6	7.9	10.1	10.1	4.0	7.6	9.6	4.0	7.6	9.6	7.9	7.9
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6	10.1	6.0	6.0	10.1	9.7	8.6	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7	10.1	7.6	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	7.9	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.9	0.1
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	5.8	4.7	4.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	7.9	9.7	8.6	6.0	6.0	4.0	4.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9 I	0.1	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	9.7	6.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	10.1	10.1	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9	7.9	7.6	9.7	8.6	10.1	4.0	4.0	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
	-	-				-			2			1														
II AD A CO AIDE I	v we	les simulatio	ODS TOF ALL	avail III COI	VO ISIAND	Fortugal)		IIM	n sensurvury	/ analysis o	I U&M mana,	$g(A) + E_{pi}$ (1) Wind spe	case 2) ed data ser	ies for simu	ations (m/s											I
Months	( <i>m</i> /s)	vr ,	vr.,	vr ,	vr.,	VF c	Vre	VF -	vro	Nr.o	VF10	VF	vr.v	Vr 13	vri	Vr ie	VF 16	VF 17	VF 10	VF 10	VF 20	<i>ur1</i>	VF 11	V V	1.71	or ne
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	0.01	11.7	9.01	). IO	11.7	10.6	10.6	10.6	10.6	10.6	10.6 1	0.6	0.6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	11.7	8.2	8.9	7.6	1.7	11.5	6.4	9.5 1	1.5	1.7
March	10.5	10.5	1.7	11.5	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	11.5	11.7	6.1	10.5 1	1.7	7.1
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	7.1	9.5	11.5	7.1	11.5	8.2	8.2	11.5	7.1	10.5	7.1	11.7	11.5	7.1	1.1 1.7	1.5	7.6
May	8.2	8.2	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4	11.5	8.9	6.4	10.5	7.6	11.7 1	0.5	8.2
June	1.7	7.1	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1	11.5	9.5	6.1	9.5	8.2	11.5	9.5	8.9
July	6.1	6.1	11.5	8.2	8.9	10.5	11.5	9.5	1.7	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9	11.7	10.5	7.6	8.9	8.9	11.5	7.6	9.5
August	6.4	6.4	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2	11.5	6.1	11.5	8.2	8.2	9.5	8.2	1.7	0.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	11.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	1.7	11.5	1.7	9.5	11.5	7.1	10.6	7.1	6.1	9.5	1.7	11.5	6.4	6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	1.7	6.4	11.5	8.2	6.4	11.5	6.4	7.1	11.5	6.4	10.5	7.6	6.4	10.5	6.4	11.5	6.1	8.9	1.5
December	11.5	11.5	6.4	6.1	1.7	6.1	1.7	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2	11.7	11.5	6.1	11.7	8.9	8.2	1.5
Annual	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	1.6	9.1	9.1	9.1	9.1	9.1	9.1	<i>I.6</i>	9.1	9.1	<i>I.6</i>	9.1	<i>I.6</i>	9.1	9.1	9.1	1.6	9.1
		-				ç	,		3			1	ć													
Table Q.6 Win	1 speed ser	les simulatio	ons for AEI	avait m Cal	e Sant Jan	nes (Canad	(F	WIL	n sensitivity	/ analysis o	t O&M mana,	$g(A) + E_{pi}$ (0	(ase 2)		ما منا مسام السارم											I
Months	ан,											adennuu	lac ninn na:	muie rofeat	can cuom											1
	(m/s)	711	yr2	yr 3 15 1	yr4	yr 5 1 - 1	yr6 15 4	yr 7 1 C 4	yr8 15 4	yr 9	yr 10	yr 11	yr 12 07	yr 13 15 4	yr 14	yr 15 15 4	yr 16 15 4	yr 17 15 4	yr 18 15 4	yr 19	yr 20	yr 21	yr 22 15 4	yr23 )	124	1 25
January Fehruary	12.4	14.7	12.4	9.7	15.1	12.4	12.4	15.1	15.1	4.CI	12.4	4.CI 4.21	10.0	15.1	9.7	13.1	9.7	9.7	4.CI	9.7	10.0	15.1	15.1	15.6 1	0.0	9.5 3.1
March	12.7	12.7	12.7	10.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2	12.7	10.4	14.7	10.0	15.1	10.0	10.0	10.0	10.0	13.8	14.7	14.7	15.3 1	0.4	2.9
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	15.1	10.4	10.4	13.8	13.3	14.3	14.3 1	0.4	2.9
May	11.2	11.2	14.3	10.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1	10.4	14.3	10.4	14.7	10.4	10.4	13.4	13.1	13.1	13.0 1	1.2	2.3
June	10.4	10.4	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7	11.2	14.3	11.2	11.2	12.8	12.7	12.7	12.7 1	2.4	2.2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	12.4	13.1	12.4	12.4	12.2	12.3	12.4	12.5 1	2.7	0.0
August	9.7	9.7	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.0	12.7	12.7	12.7	12.7	11.4	12.1	11.2	11.4 1	3.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1	12.4	13.1	13.1	11.4	11.7	10.4	10.2 1	4.3	3.2
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2	15.1	14.3	11.2	10.1	10.4	9.8 1	4.7	3.5
November	14.3	14.3	10.4	14.7	0.01	15.1	10.4	10.0	0.01	14.7	15.1	10.4	15.1	10.0	14.7	11.2	14.7	10.4	14.7	14.7	9.7 2.0	10.0	10.0 2 2	10.3 1	5.1	3.9
December	15.1	15.1	10.4	14.3	9.7	13.1	10.4	7.6	7.6	14.5	13.1	10.4	15.4	9.7	15.1	12.4	15.1	10.4	14.3	15.1	9.0	9.7	9.7	10.1 1	5.4	6.9 2 5
Annual	12.5	12.5	12.5	12.5	2.21	12.5	5.21	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5 1	2.5	2.5

lable Q. / Kwh per Hprod							with sen	sitivity anal	ysis of O&1	M manag(A)	$+ E_{pi}$ (Case	e 2)													
Citae												kW/5	yr												
(	r1 yr2	yr 3	yr 4	$yr_5$	yr 6	s yr	. х. Ул	r.8 yı	'9 yr	10 yr	16 11.	r 12 yı	r 13 )	114 3	W 15 >	T16 y.	r17 y	r 18 )	r 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 25
Aracari (Brazil) 5 6:	13 5648	5 674	5 633	5 697	5 648	5 69.	3 565	3 564	1 5.64.	3 564	48 56	93 56	74 50	540 5;	715 5;	731 56	88 56	52 51	5 08 5.	694 5	683 5	620 5	631 5	648	5 641
Corvo Island 10 4. (Portugal)	8 10535	10 467	10475	10 468	10 563	1049	7 10 42	9 1052	5 10 52.	7 10.45	54 105.	25 10 5	.01 10.	200 10 4	10 -	105 105	10 105	23 10:	545 10.	560 10	464 10	1520 10	532 10	1452 I	0 407
Cape Saint James 24 7, (Canada)	0 24853	24 925	24743	24 791	24 853	2474	3 2474	(3 2492	5 2479	1 24 85	53 247.	93 247.	43 249	333 24 0	876 245	133 248	95 249	25 245	133 24	841 24	860 24	1743 24	897 24	793 2	4 882
Takla O 2 Cashilourén 25 yaaan of	the mind form of	roiact	V1 000 02	TT Area	Conti (Bendl)				, a differen		alonia of OP	-	с. (С.												
1able Q.8 Cashllow for 25 years of	the wind larmp	roject	50 000 K	W An	acati (Brazil)				with s	ensitivity an	alysis of Ock	k M manag(A) +	- Epi (Case	5)											
ltem	0	-	2		4	5	9	7	8	10	=	12	Years 13	14	15	16	11	18	19	W	21	27	23	24	25
(1) ICCCM	60.225.901																								
WT	20102200																								
T	202 010 12																								
I CM	C67 617 47																								
LWIG CH	CO1 4C4 1																								
CP CM	1 545 540							,																	
TS CM	572 832						,													,				,	
$SI_{CM}$	2 136 726								,	,		,				•	•						,	,	
POCH	1 796 870															•									
F CM	900 180 1																								
CCC CM	117 071									- -	-		-						-						-
LCPM WF (KWn/yr)		2001/00/64	48.00/ 402 4	45 200268 8F	46 /71 /2CS	0088 / 34 48 48 48	5 00/ 407 42	165 668100	-00.54 5.68 IC	8 UZI 48 6240	4.219 48.00.	(407 5 600 40 40 40 40 40 40 40 40 40 40 40 40 4	768.85 (17)	2062.84 700	26 667 64 /08	2 6200241	10/ 600 65	07/ //0.94	48.51/889 6.670 76.6	49 U04 45/ 4	4 0.00 000 4	84 661 0248	2 389 CF 1 2	36 000 300	170 809
(+) AAK (\$MU)F) DDAD		9070 710 7	CIC 10C +	4 1/0010 +	4 640 160 + 4 042 105 - 4 042 105 -	+ 000000/+	- 040 000 5 0	15 940 000	10 427 5 00 06 427 5 00	10075 5240	02/5 1001- 02/5 1001	0000 11+6	201 2 172	7760 5 615	21 6110 46	140.062.0 00	0.02 440.0	174/10.0	017 070 0	0 000 0.25 6 000 0.25	066 606 +	c c11/mc	C CH0741	C 079 097	100 01 +
EMP		070 +1C +	C/C /0C+	* T/00TC +		1 0C0 C0/ 4	·	1 n 0+n nm	77 7 77 07		2/+C 100 I	000 C 11+C	0010 170	1760 C CTC	¥ 6110 103	1+0.067 0 01	NN7 660 0	174 / 10 0	0.07 070.0	CC 0 00 0	1 030 000	5 007 115 5		2 002 200	413.031
(-) O&M		3 964 703	4.031 427	4 151 213 4	223 034 4	378.615 4	471.031 4	618343 47	33 137 4 80	6905 4925	8.061 5.055	2005 5001	450 5334	243 5 433 8	PL CP 95 95.	1 5 700 641	5 800 344	9191009	6 100 183	6 357 000	2867.084	2 011 000 S 017 062	9 2192013	020000	100.014
O& M		2 665 486	PCF 012 C	2 701038 2	6 010 078.	C 100700	901 705 3	000812 31	68.081 3.21	7896 3794	0.441 3384	1934 3496	775 3577	748 3.639	7 2780 C 104	7 3,885,835	3 953 081	4 00 6 113	4004 576	4 261 785	4359 507	4418743 4	1538573 41	-F 822 595	176.957
O& Municipality	,	1 299 217	1 321 003	1 360 175 1	. 383 923 1	434.523 1	479 236 1	527 531 1 5	.02 020 158	9 009 1 62	8 620 1 670	3162 1724	683 1761	494 1 793 9	50 1862 46	7 1 913 806	1 946 264	1 981 563	2 0 14 606	2 096 214	1508477	1 528 319 1	569 092 1 0	512.361 1	650196
(+) LRCM		863 268	884 850	1/6 906	929 646	952 887	976 709 1	001127 10	26 155 1 05	1 809 1 07	8 104 1 105	5 057 1 132	683 1161	000 1 1900	121 22	- 9									
(+) Depreciation		2 423 221	2 483 801	2 545 896 2	3 609 544 2	674782 2	741 652 2	810193 28	80 448 2 95.	2459 302t	6270 3101	1 927 3 179	475 3258	962 3 340 4	136 3 4 23 94	7 3 509 546	3 597 285	3 687 217	3 779 397	3 873 882	3 970 729	4 069 997 4	171747 4:	276 041 4	382 942
(=) Profit before tax	,	3 636 612	3 7 24 797	3 819 726 3	3912 604 4	014 890 4	090 389 4	196325 45	01 898 440	6438 451	7 395 4 631	1365 4751	227 4869	233 4 988 8	36 512044	2 4 000 245	4 097 140	4 196 967	4298471	4 414 818	3 042 735	3 130 050 3	206977 3:	284 921 3	368 820
(-) Revenue tax	,	1 294 448	1 316 272	1 355 421 1	379 205 1	429 751 1	452 918 1	501 004 15	38 530 1 56	2723 160.	2 324 1 645	3 843 1 698	158 1735	054 1 767 6	69 1835 85	9 1 887 102	1 919 760	1 955 228	1 988 477	2 069 680	1 481 997	1 502 134 1	542 854 1:	586 046 1	623 909
(+) REPIM	1 122 960	1725	1 670	1 637	1 585	1564	1 513	1488 1	451 14	103 13	69 13.	37 131	5				,								
$REI_{CM}$	863 662																,	•							
$REP_{CM}$		1725	1 670	1 637	1 585	1564	1 513	1 488 1	451 14	103 13	69 13:	37 131	5							,				,	,
$OREP_{CM}$	259 298															•									
GHG.R CN	•			,																					
( =) Profit after tax w/out interes		2 343 889	2410 195	2 465 941 2	3534 985 2	586703 2	638 984 2	696808 27	164 820 2 84.	5118 291	6440 2988	8859 3054	383 3134	179 3 221 1	67 3284.60	3 2113143	2177380	2 241 739	2 309 994	2 345 137	1 560 738	1 627 915 1	664124 10	598 875 1	744911
(-) Debt payments	,	,	3 136 543	3 2 14 957 3 2	295331 33	377 714 3 4	462.157 3:	548 711 3 63	7 428 3 728	364 3.821:	573 39171	112 4 015 0	40 41154	16 4 2 18 302	2 4323759	•	,	,	,	,	,	,	,	,	,
$(+) RCM_{WF}$		2 621 739	2 687 282	2 754 464 2	323 326 2	.893909 2	966 257 3	040413 31	16 424 3 19.	4334 327.	4 193 3 3 3 6	5047 3439	949 3525	947 36146	96 370444	8 3 797 060	3 891 986	3 989 286	4 089 018	4 191 243	4 296 024	4403425 4	513511 40	526348 4	742 007
(+) Depreciation		2 423 221	2483801	2 545 896 2	3 609 544 2	.674782 2	741 652 2	810 193 2 8	80 448 2 95.	2459 3024	6270 3101	1 927 3 179	475 3258	962 3 340 4	136 3423 94	7 3 509 546	3 597 285	3 687 217	3 779 397	3 873 882	3 970 729	4 069 997 4	171747 43	276 041 4	382 942
(=) Free net cashiftow	-59 102 941	7 388 849	4 444 735	4 551 345 4	1672 524 4	1777 681 4	(884 735 4	998704 51	24 263 5 26	3547 539.	5 329 5 525	9722 5658	:767 5803	672 5 957 3	197 6089 25	9 9419749	9 666 651	9 918 241	10178409	10 410 263	9 827 491 1	0 101 337 10	349381 100	501 265 10	869 860
$\Sigma$ free net annual cathflon		-51 714 092 -	47 269 357 -4	42 718 012 -38	3 045 489 -33	267 808 -28	383 073 -23	384 369 -18 2	60 106 -12 99	6559 -760	1 229 -2 071	1508 3587	259 9390	931 15 348 3	328 21 437 56	57 30 857 316	40 523 967	50 442 208	60 620 617	71 030 879 8	80 858 371 9	0 959 708 10	11 309 090 111	910 354 12:	2 780 214
	$LCOE_{win}$	67.68	67.83	68.04	68.20	68.45	68.64	68.89 6	69 01.6	.28 69.	51 69.	74 70.0	2 70.2	5 70.46	70.79	69.82	70.02	70.22	70.42	70.78	70.39	70.58	70.85	1.13	71.40

Table Q.9 Cashflow for 25 years of th	ne wind farm p	roject	50.000 kV	V Coi	wo Island (	Portugal)			with se	nsitivity ana	ysis of O&M	$mana_{N}(A) + E$	pi (Case 2)											
- Item	0	-	2	e	4	5	9	7	8	10	Ξ	12	arrs 13	14	15	16	17	18	19	20 2	1 22	23	24	25
	100 200 02																							
(-) LCCCMWF	8176 2422 00																							
Tew	24 219 295			,	,	,		,									,		,		,	,		,
LWTGCH	1 959 783	,	,	,	,	,	,	,	,	,				,		,	,	,	,	,		,		,
CP or	1 545 346	,	,	,			,		,		,	'		'	,	,		,	,		,			,
TS CM	572 832	,			,	1			,				1	1	1	,	1							1
$SI_{CM}$	2 136 726		,				,							•	'	,		,	,		,			•
$PO_{CM}$	1 796 870	,		,					,						•	•								1
$F_{CM}$	188 559							,						'	•					,		,		
CCCar	120211		,				,							•				,	,					'
$LCPM_{WF}$ (k Wh/yr)		90 107 610	0 769 774 9.	0 190 491 90	1253 921 9.	0 198 973 91	1 016 328 90	443 405 89 8	58 042 90 685	374 90700	578 90 078 6	77 90 685 37	4 9053033	6 90 473 134	90 246 888	90 078 677	90 557 464 5	0 666 434 90	855213 909	85 978 90 16	2 393 90 643	3 598 90 743	354 90 059 5	0 89 670 577
(+) AAR (SM/yr)		15 046 124	15 535 609 1.	5 822 374 16	229 340 1	6 624 945 1	7 194 985 17	513916 178	35 578 18 449	787 18914	223 19 254 1	27 19 868 40	2 20 330 29	5 20 825 386	21 292 641	21 784 277	22 447 567 2	3 036 443 23	661 518 24 2	87 963 17 26	8 871 17 795	5 063 18 260	013 18 575 4	3 18 957 626
PPAR		15 046 124	15 535 609 1.	5 822 374 16	5229 340 1	6 624 945 17	7 194 985 17	513916 178	35 578 18 449	787 18914	223 19 254 1	27 19 868 40	2 2033029	5 20 825 386	21 292 641	21 784 277	22 447 567 2	3 036 443 23	661 518 24 2	87 963				
EMP																				- 17.26	8871 17795	5 063 18 260	013 18 575 4	3 18 957 626
(-) O&M WFCM		9414550	9 720 704	9 900 012 10	0154 527 10	0 401 931 10	0758 472 10	957 897 111	59 028 11 543	192 11 833	546 12 046 1	85 12 430 37	8 1271923	2 13 028 855	13 321 057	13 628 511	14 043 351 1	4411633 14	802 558 15 1	94 336 13 21	2815 13615	5 294 13 970	912 14 212 1	4 14 504 416
$O\&M_{\beta,xed}$	,	4 895 943	5 055 217	5 148 526 5	280 948	5 409 674	5 595 159 5	698 935 58	03 599 6 003	456 6154	579 62651	79 646505	7 661535	2 6776445	6 928 488	7 088 460	7 304 288	7 495 901 7	699 294 79	03 132 8 02	7381 8271	1 977 8 488	105 8 634 7.	8 8812382
$O\& M_{variable}$	,	4518607	4 665 487	4751486 4	1873 579	4 992 258	5 163 313 5	258962 53	55 430 5 539	736 5679	068 57810	06 596532	1 6103 88	0 6 252 405	6392569	6 540 051	6739 063	6915732 7	103 264 72	91 205 5 18	5434 5343	3 317 5 482	807 55774	6 5 692 034
(+) LRCM		863 268	884850	906971	929 646	952 887	976 709 1	001127 10	26 155 1 051	809 1 078	104 11050	67 1 1 1 3 2 6 8	3 1161 00	0 1 190 025	1219776									
(+) Depreciation		2416592	2 477 007	2 538 932 2	602 406	2 667 466	2734 153 2	802 506 2 5	72 569 2 942	383 3 017	993 30934	43 317077	9 3250.04	8 3 331 296	3414582	3 499 946	3 587 445	3 677 131 3	769 060 3 8	63 286 3 95	9868 4058	8 865 4 160	336 42643	5 4 370 954
(=) Profit before tax		8911435	9 176 763	9 368 266 9	606 864	9 843 367 10	0 147 375 10	359 653 10 5	75 273 10 902	786 11176	573 114064	41 11 741 48	6 12 022 11	1 12 317 857	12 605 942	11 655 712	11 991 661 1	2 301 941 12	628 019 12 9	56 912 8 01	5 924 8 238	8 634 8 449	437 8 627 6	4 8 824 163
(-) Revenue tax		4513837	4 660 683	4746712 4	1868 802	4 987 484	5 158 496 5	254175 53	50 673 5 534	.936 5 674	267 57762	38 596052	1 6099 08	9 6 247 616	6387792	6 535 283	6734270	6910933 7	098455 72	86 389 5 18	0 661 5 338	8 519 5 478	004 55726	9 5 687 288
(+) REPIM	1 284 621	1 253	1 231	1 193	1 165	1136	1 118	1 084 1	051 1.0	35 1.01	978	961	936	912	888	865	848	,	,	,	,	,		•
$REI_{CM}$	863 662	,	,	,		,	,	,	,			'	'	'	'	,	,	,	,	,	,	,		,
$REP_{CM}$	'	1 253	1 231	1 193	1 165	1136	1 118	1 084 1	051 1.0	35 101	978	961	936	912	888	865	848	,	,	,	,	,		'
$OREP_{CM}$	420 959	,		,	,		,		,			'		1	'	,		,	,	,	,	,		,
$GHGR_{CM}$		,	,	,	,	,	,	,	,					'	•	,	,	,	,	,	,	,		
(=) Profit after tax w/out interest		4398850	4517311 .	4 622 747 4	139 227	4 857 019 4	4 989 997 5	106562 52	25 651 5 368	885 5503	416 5 6311	82 578192	6 592395	8 6 071 154	6219 037	5 121 294	5 258 239	5 391 008 5	529564 56	70 523 2 83	5263 2900	0.115 2.971	434 3 0 5 5 0	5 3 136 875
(-) Debt payments	,	-	3 127 964 3	. 206 163 3 2	286.317 3	368 475 3	452 687 3 5	39 004 3 62	7 479 3 718	66 381113	0 3 906 398	4 004 058	4 104 160	4 206 764	4 311 933	,	,	,	,	,	,	,		,
$(+) RCM_{WE}$	,	0571730	2 687 282	2 754 464 2	973 326	000 208 2	0,066,257 3	040.413 3.1	16 424 3 194	334 3.274	193 33560	47 3 439 94	9 3525 94	7 3.614.096	3 704 448	3 797 060	3 891 986	3 989 286 4	089.018 4.1	91 243 4 26	6.024 4.403	3 42.5 4 513	511 46263	8 4 742 007
(+) Damagintion		2 416 502	- 200 LDF C	2 539.037 2	000 000	000000	0 734 153 0	5 C 905 CU8	10 0 095 02	202 3017	003 30034	72 0212 14	000000	331200	3 414 502	3 400 046	3 597 445	3 677 131 3	760.060 3.9	20 5 205 205	0.011 970.0	301 2 2 1 160	336 47643	5 4 370.054
(+) Deprecianon	000 011 000	760 01+7	1001117	2 20000022	0.010 2000	001/007	2 000 000 0	07 005700	-H6 7 600 71	100 2000	#C6DC C64	0/0/16 64	+0 0 2 7 0 1 0 1	5671000 0 V	201414-002	0+6 66+ 0	. 010 LOD C	C 101/100		06 C 007 C0		001 + COO 0	6 407 th 000	1000/01 0
(=) Free net cash flow	087.156.85-	943/182	0505550	0 186.60.0	8/8 042	616.640 /	1 23/ 720 7	410477 72	8/ 104 / /8/	430 7984	181 81/42	7.5 8.388.59 50 50 50 50	6, 6668 0	8/6/8/6/8/	9.020 135	12 418 500	12/3/6/0	3 05 / 425 13	38/041 13/	60 II 600 67	202 11 201 1	2 401 I 042	/ 566 11 187	8 12 249 8:50
2. free net annual cashflow		-49 504 098	12 950 462 -3	6 240 481 -29	361 839 -2	2 311 920 -13	5 074 200 -7	663 723	76 559 7 713	878 15 697	359 23 871 6	32 32 260 22	7 40 856 02	1 49 665 807	58 691 941	71 110 241	83 847 911 9	6 905 336 11	0 292 978 124	018 031 135 1	09 186 146 47.	1 261 1651	872 170 062 5	0 182 312 426
	LCOE uno	73.13	73.52	73.79	74.13	74.47	74.93	75.23 7	5.53 76.	22 76.4	1 76.73	77.23	77.63	78.06	78.47	77.65	78.16	78.63	79.12 7	1970	-73 - 78.2	24 78.	1 79.06	79.47
79			11 000 02	,		(-F0)				1			ç											
THUR ALL CASHIDA IN STAND AL		indian.	11 000.00	1					SC IIIIM	מווא ווא מוופוו		V.	pi (Luse 2)											
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(-) LCCCM <sub>WF</sub>	60 225 901												'	'	'	•				,				
WT <sub>CM</sub>	27 686 278								,				'		•	•								
$T_{CM}$	24 219 295	•	,			,	,	,	,	,		'	'	'	'	,	,	,	,	,	,	,		•
$LWTG_{CM}$	1 959 783													•	'	,			,		,			'
CP CM	1 545 346	,					,		,						•	,		,			,			1
TS car	572 832		,			,	,	,						'	,	,	,	,	,	,	,	,		,
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r cw													•								,			
CCC CM	117 071	,				,		,	,			'	'	'	'	'	,		,	,	,	,		'
$LCPM_{WF}$ (k WhAr)		213 509 813	214144266 2	21476143421	3 197 728 2	13611337 2	14 144 266 21	3 197 728 213	197 728 214 76	434 213 611	337 214 144 2	213 625 94	8 213 197 72	8 21483268	214 338 805	214 832 689	214 501 803	21476143421	4832689 214	038 947 2142	03 964 213 19	7728 21452	1412 213 625 9	18 214 387 639
(+) AAR (SM/yr)		30 276 974	31 126 117 3	1 996 219 32	557 331 3.	3 436 006 34	4357 409 35	060.685 35.5	37 202 37 105	804 37829	772 38 872 2	55 39 747 62	2 40 659 64	6 41 995 741	42 946 676	44 121 775	45 155 164 4	6340.065 47	514326 485	22 244 34 84	1551 35544	4 828 36 659	995 37419 2	3 38 491 531
PPAR		30 276 974	31 126 117 3	1 996 219 32	557 331 3.	3 436 006 34	1357 409 35	060 685 35 5	37 202 37 10	804 37 829	772 388722	55 39 747 62	2 40 659 64	6 41 995 741	42 946 676	44 121 775	45 155 164 4	6340.065 47	514326 485	22 244				'
EMP	'	,	,	,		,	,	,	,			'	'	'	'	,	,	,	,	- 34.84	1551 35544	4 828 36 655	995 374192	3 38 491 531
$(-) O\&M_{WFCM}$	'	20 688 790 2	21 268 898 2	1863324 22	246 612 2	2 846 890 23	3 476 361 23	956782 245	55 577 25 35	946 25 848	498 265606	85 27 158 68	1 2778172	1 28 694515	29 344 137	30 146 9 19	30 852 873 3	11 662 346 32	464546 331	53 088 29 52	8360 30124	4 265 31 065	244 31712.6	1 32 621 209
$O\&M_{fixed}$	,	11 600 929	11 926 280 1.	2 259 661 12	474 651 1.	2 811 317 13	3 164 355 13	433 815 137	69 654 14 217	407 14494	795 148942	25 15 229 62	3 1557906	5 16 090 994	16 455 346	16 905 588	17 301 532 1	7755529 18	205 449 18 5	91 634 19 07	1110 19456	5 054 20 066	453 20482 0	1 21 068 961
$O\&M_{minhh}$		9 087 862	9342619	9 603 663 9	771 962 10	0 035 573 10	0312 006 10	522 968 10 7	85 923 11 136	539 11 353	703 11 6664	60 11 929 05	9 12 202 65	6 12 603 521	12 888 791	13 241 331	13 551 341 1	3 906 817 14	259 097 145	61 454 10 45	7250 10668	8 211 11 002	791 11 230 5	0 11 552 248
(+) I BCM	,	896 578	884.850	006.071	212 6/6	067 887	1 002 920	01122 10	06155 1.061	800 1 078	11050	67 1137.68	0011111	1 100.02	710101	,	,	,	,	,	,	,		
(+) Danwoidtion		7 387 587	126 244 6	C 2508.05 C	5 391 125	WE SEA	701 330 7	2 C 298 89L	38.085 2.000	180 6 220	2021 30563	12 2132 70	4 3211.03	301306	3 3 73 501	3 457 030	3 5/11 370	3 637 088	773813 38	16 008 3 01	2 331 4 010	0 130 4 110	1 212 4 213 1	7 4318481
		1 10000001	-1 OFCODIC	C1 010072	-1 002 110	1 244 111 4	FL L00 101 -	121 000 cL0	012 at 200 00	1002 1002	0022731 071		30 00 01 0	333 COL L1 9	10105 005	SOLUCY LI	0000000		101 000000	0000	0000 0000		00100 111	2010101 01 2
(=) Leola before tax		+cn 6co 71	1 040 691 01	CT 6109400	1 670 119	-I 0++//I+	+I / 90 600+	7 01 760 010	T/ CT CO0 CH	1001 10/1	67/+01 0+1	CC +CO 01 CC	06 647 11 0	00070//1 0	CUR 061 01	00/704/1	0/0.0+0 / 1	01 /0/ 010 0	161 060 011	7 6 100 00	0646 7700	IN 6 7N 0	0 6166 ++1	
(-) Revenue tax		9 083 092	9 337 835	9 598 866 9	1 661 196	0 030 802 10	0307 223 10	518 205 107	81 161 11 131	741 11 348	931 11 661 6	77 11 924 28	7 12 197 89	4 12 598 722	12884 003	13 236 533	13 546 549 1	3 902 019 14	254 298 14 5	56 673 10 45	2465 10663	3 448 10 997	999 11 225 7	8 II 547 459
(+) REPIM	1 992 197	148	144	141	137	134	131	127	124 1	=	8 116	113	'	•	,	,		,	,	,	,	,		,
$REI_{CM}$	863 662	,	,	,		,	,	,	,			'	'	'	'	,	,		,	,		,		,
$REP_{CM}$	,	148	144	141	137	134	131	127	124 1	11	8 116	113	'	'	,	,	,	,	,		,	,		'
OREP CM	1 128 535	,	,	,	,	,	,	,	,			'	'	'	,	,	,	,	,	,	,	,		,
GHGR CV	,	,	,	,			,		,			,			,	,		,	,		,			,
(=) Profit after tax w/out interest	,	3 756 090	3 851 649	3 949 595 4	044 466 4	4 146 778 - z	1251 995 4	355.814 44	64.828 4.581	084 4692	327 48113	72 4 930 16	4 5.052.06	3 5 183 836	5311 903	4 196 254	4300121	4 408 688 4	519295 46	20 1- 105 60	6944 -1 232	2.746 -1 296	854 -13059	3 -1 358.656
(-) Date moments			1000413 3	167.674 3.7	2004.000	278.027 2	2 226 114	06.510 2.50	1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	20 2768.20	0 3 959 503	3 955 990	4 064 800	4 156 262	4 260 169									
		062 109 0		C 22642010			C LSC 2200	040.412 2.1	16 404 2 10	224 2774	00 33550	242004	10 3636 0	2014000	2 TON 440	02020020	2 001 00 5	200000	11 010000	01.042 4.00	2011 1 100	1212 4 512	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	LUO UFL F O
(+) Domestation		CO3 LOC C	7 112 207 /00 7	4 LOLLOV	231 122	000000 T		0 00000	00 C 200 0C	1000 1000	69906 691			2001000	2 2 7 2 601	2 467 020	000 100 0	007/0/0	14 010 000	10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0101 1000	1120 4110	10704 110	1010101010101
(+) pebiedanon	000000000000000000000000000000000000000	200 /002	2 006 200 v	2 0001002	- 100 UC1	**********	7 000 10/ 7	07 00000/	00.007 F00.00	1067 100		1/7010 10	20 117 C +	10000167.0 7	14C C/C C	006 (Ch C	6/0 ##CC	C 0067000	0.6 61062/		010+1 0111	111 + 6010	10124 060	10
$(=)$ Free net custing $V_{-}$	m/ CC7 0C-	0 /10 468 293 -4	2 2 2 272 504 -37	v 000##00	335 574 -24	31- 087 480 h	v C+C 00C0 11- 751 0FA 8	00 1/C 000	05 162 - 2 03 <sup>4</sup>	769 0218	7	CO 04C / CZ	0 //34/0	11/70/1 0 8	0 127 127 128	188122-05	5 295 711 12	20 302 308 571 E	V21 U21200	0.211 300 111	1412 / 100 06.408 122.27	1.201 0101 1.201 01010	ALUCCI 4440	3 144839 645
4 JIEC NET GRI BRING COANGLOW	1000	10.10	10 / K 000 -	1 0k1 000		1 201.200		010.000	1.0 Mile # 1.	100 000			0 01 00 00		TI /m	01 01 100	11.117.001	0.170.000	11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	114 AVA 111			1410 No. 10	
	LCOE was	84.40	85.07	85.75	86.23	86.92	87.65	88.22 8	8.92 89.	3 90.4	3 91.25	91.96	92.69	93.72	94.49	94.17	94.97	95.88	96.78 9	7.57 94	.05 94.7	7.5 95.8	1 96.56	97.59

## **APPENDIX R**

LCOE wso Mode	l Inputs									_		Financial Ind	exes		Notes
Legend				_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	ve updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \Delta M_{em})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information		Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public Inc	entive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[S/kW]	REI CM	65.7637	[\$/kW <sub>e</sub> ]	WF CM		50 000	[kW <sub>e</sub> /yr]
Project Location	Aracati (Brazil)		Depr <sub>WTmr</sub>	76.9840	[\$/kW]	$RM_{WT}$	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	$N_{WT}$		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	N <sub>WT</sub>	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	C Margar	100	[m-h]	$\Psi_{solal}$	15.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tjr Denr.	60.1398	[%/yr] [\$/W]	N Morener	85.00	[5/m-n]	n v PFP out	0.00000595	[yr] [\$/FW b]	n col		90.0	[=]
Swept Area per Turbine (A)	6 361 7	[m]	V NO	00.1398	[3'K'']	$D_{-}$	20	[-]	AEPt/Hd	5.693	[3 KW ell]	L		1800	[m]
Hub height (H)	105.0	[m]	TO CH	0.000033	[\$/kW]	$C_{md}$	2 500.00	[G] [\$/d]	ifr	2.50%	[%/yr]	L		2 430	[m]
Wind speed measured at (Ho)	10.0	[m]	TI	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	ε	0.0339	[\$/kWeh]	SD.		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.023377	[\$/kWeh]	SD <sub>scol</sub>		540	[m]
Betz Limit's coefficient (CPBetz)	0.5926	[-]	$V_0$	6 100 000	[kW]	N <sub>WT</sub>	25	[-]	n <sub>e</sub>	15	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	C ()	1 457.72	[\$/kW]	M <sub>brance</sub>	3.0	[m-h]	OREP CM	21.6705	$[S/kW_{e}]$	$PC_{PM}$			
Production Efficiency (WF PE)	11.2%	[%]	PR	0.70	[-]	CMuscr	85.00	[\$/m-h]	LCCCM <sub>WFORSIGCM</sub>	4.5846	[\$/kW]	AEP avail		49 057 055	[kW <sub>e</sub> h/yr]
Availability	98.4%	[%]	b	-1.94	[-]	N <sub>mmcr</sub>	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wecs}$		20.98%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]		2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{wechow}}$		25.00%	[%]
				г		C <sub>ml avcr</sub>	3 500.00	[\$/d]	$\Psi_{sotal}$	15.0%	[%]	P&D <sub>IM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capite	al Cost Model	Notes	Wind Farm O&M Cost 1	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	Nwr		25	[-]
WI CM	553.7256	[\$/kW]	langud cu	0.098275	[\$/kWh]	WF cap	50 000	[kW]	n ,	15	[yr]	A		6 361.7	[m*]
PC ma	73 70%	[3/KW] [96/S/VW]	D D	0.000001%	[3/ 6/1	Awa	43.00	[-] [m <sup>2</sup> /mt]	GHG R au	3 868 4070	[%] [%(CD_4)	P&D		438 000 000	[Kw at/yr]
C int	400.00	[5/kW]	LLC	0.0530	[%] [\$/kWh]	Mwi	3.0	[m-h]	LCER	56.2	ICO/MW.bl	Â.		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMbr	85.00	[\$/m-h]	$\sum AEP_{areal}$	48 856	[MW <sub>e</sub> h]	2,41		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	Nmmm	3	[-]	n <sub>v</sub>	25	[yr]	λd		5.00%	[%]
Tmass	138 000	[kg]	O&M variable cu	0.025840	[\$/kWh]	D <sub>m SARY</sub>	3.0	[d]	GHG <sub>IM g an</sub>	0.00123	[tCO2/MWah]	λ <sub>m</sub>		5.00%	[%]
RCT	26.30%	[%/\$/kW]	MLC	71.5608	[\$/h]	C <sub>nd</sub> <sub>surv</sub>	3 500.00	[\$/d]	GHG <sub>EM</sub>	0.00008	[tCO2/MWah]	LCPM WF		49 057 055	[kWeh/yr]
Canad	0.1900	[S/kg]	TLC	124.5688	[S/h]	$RVM_{WF}$	61.0184	[\$/kW]	E <sub>c</sub>	37.1056	[\$/tCO <sub>2</sub> ]				
LWTG CM	39.1957	[S/m/kW]	R tasses	30.00%	[%]	$N_{WT}$	25	[-]	REPIM distribution	105.0%	[%]	Project Finan	ring		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\tilde{\zeta}_1 REI_{CM}$	0.0%	[%]	Debt ratio		50.0%	[%]
Lg	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\zeta_2 REP_{CM}$	0.0%	[%]	Debt term		14	[yr]
CAB cont	2 000.00	[S/m]	n mik	48	[h]	ifr	2.50%	[%/yr]	$\zeta_3 OREP_{CM}$	50.0%	[%]	Debt gn	ice period	1	[yr]
CP CM FF	30.9089	[5/KW] (\$/5W)	n <sub>sth</sub>	4 200 586	[n]	N WT	200,000	[yr]	S4 GHG.R CM	2 128 4501	[76]	Debt mi	erest rate	20,842,060	[%/yr]
C C	400.00	[3/KW]	AFR	4 209 380	[.5IVI]	W 1 weight	0.1000	[84]	REFIM	2 138.4391	[\$/proj]	Debt value		29 842 009	[3] [\$/ue]
75	11.4566	[70] (\$1497.1	O.E.M.	43037033	[KWIFy1]	TS	0.1900	[3/Kg]	Exchange rates	1	Notes	Equity ratio	ymenis	50.00	[3/ y1] 10/ 1
13 CM	0.0400	[3/KWc]	OCCM WFCM	0.124115	(ak maji)	1.5 VM WF	50,000	[3/KW]	EUR/USD + ante	1 3252	[_]	Equity in	alua	20 842 060	[70]
71	1 200	[1///W]	0&M	Г	Notes	ini cap	2 50%	[% (vr]	CAN/USD 1 2010	0.9998		Discour	t mte	9,00%	[0] [9]/97]
12,	3 000	[1/k11]	SC own	0.000070	(\$/kWh]	N	25	[vr]	RRI/USD 4=2010	0.5986	[-]			73074	[/// ]1]
SB -	113.00	[S/kWh]	Work days	2.0	[d]	Tmerr	138 000	[kg]	000 2010	0.000		Initial Results	Summarv	of LCOE	Notes
SLow	42,7345	[S/m <sup>2</sup> /FW]	Feb/Jun/Nov	6	ra	RCMwr	1 278,8970	[\$/kW]	Conditions for LCOE		Notes	67.6756	Vr.	70,7929	NT 16
WF can	50 000	[Juli / Kur]	Hours reauired	48.0	[h]				O&M weem			67.8295	Vr 2	69.8226	NT 15
WT int	42.5238	[\$/kW]	USC ORM	0.000254	[\$/kWh]	Hours Distribution	$FLH_{vf}[h]$	H aread [h]	O&M .cm	1	[1/0]	68.0385	yr a	70.0172	yr 16
Bld cart	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	68.2028	Vr.4	70.2229	NT 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.0	[per yr]	February <sup>(*)</sup>	672	648	REPIM			68.4513	yr <sub>5</sub>	70.4241	yr 18
PO CM	35.9374	[\$/kW]	Repair time	4.0	[h]	March	744	736	REPIM distribution			68.6399	$yr_6$	70.7751	yr 19
FS	19.88	[\$/kW]	Hours required	100.0	[h]	April	720	712	$\xi_1 REI_{CM}$	1	[1/0]	68.8858	yr 7	70.3899	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	148.0	[h/yr]	May	744	736	$\xi_2 REP_{CM}$	1	[1/0]	69.1016	$yr_8$	70.5764	yr21
EG	404.52	[\$/kW]		0.000324	[\$/kWh/yr]	June <sup>(*)</sup>	720	696	$\xi_3 OREP_{CM}$	1	[1/0]	69.2789	yr 9	70.8470	yr 22
F <sub>CM</sub>	3.7712	[\$/kW]				July	744	736	$\xi_{4}$ GHG.R <sub>CM</sub>	1	[1/0]	69.5063	yr 10	71.1302	yr23
WACC proj	4.900%	[%/yr]	·			August	744	736	P&D <sub>IM</sub>			69.7421	yr 11	71.3951	yr25
n <sub>fin</sub>	1.0	[yr]				September	720	712	λ.,	1	[1/0]	70.0200	yr 12	69.6991	Mean
W <sub>FCH</sub>	2,4042	[76] [5/FW]				Neuroper (*)	744	696	2 141	1	[1/0]	70.2471	yr 13	.0.4479	SU Y (chamer)
K	0 2004	[%]				December	744	736	2	1	[1/0]	70.4039	69.6991	18\$/MWb	valid !
LCCCM <sub>wr</sub>	1 204 5180	[\$/kW]				Total [h/vr]	8 760	8 616	^	p.s.: 1 = yes at	ad 0=no	LCOE was	0.069699	ISS/kWh	
			L						L			L			

**Figure R.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 3). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Inde	exes		Notes
Legend		ĺ		_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_m)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
				а Г											
Wind Project Information	F	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public Inc	centive Model	Notes	Wind Farm Life	Cycle Prod	uction Model	Notes
Project Name	Corvo Island (Portural)		Denr	76 9840	[\$/KW] [\$/VW]	DCM WF PM ww	22 3284	[5/KW] [5/FW]	ICCCM we	1 204 5180	[5/KWc] [5/VW]	WF CM		50.000	[KW@yr]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF com	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	M	100	[m-h]	$\psi_{actal}$	15.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMINEMAT	85.00	[\$/m-h]	n ,,	3	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>Yac</sub>	60.1398	[\$/kW]	N <sub>marar</sub>	3	[-]	REP CM	0.00000831	[\$/kW <sub>e</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	D <sub>m smar</sub>	2.0	[d]	AEP anait/H prod	10 458	[kW/yr]	L <sub>x</sub>		1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	C <sub>mf<sub>Myr</sub></sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Termin measured to faster $(\pi)$	10.0	[m]	<i>TI</i>	1 798 743	[\$/kW]	RM cr	20.1954	[S/KW]	E E	0.0869	[\$/KW_h]	SD		450	[m]
Betz Limit's coefficient (C as . )	0.14	[-]	V.	237 699 000	[KW] [FW]	WF cap N mm	30 000	[KW]	e0 1	0.080000	[3/KWon]	FIH (		540 8 760	[m] [b/sr]
Lifetime of Wind Farm(N)	25	[vr]	v 0 C 0	1 457.72	[k/r]	Mw	3.0	[m-h]	OREP CH	39,8043	[\$/kW_]	PC and		0700	[17]
Production Efficiency (WF PF)	20.6%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[\$/m-h]	LCCCM	4.5846	[\$/kW]	AEP avail		90 107 610	[kW_h/yr]
Aváilability	98.4%	[%]	Ь	-1.94	[-]	N	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{max}$		20.98%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]	D <sub>m</sub> <sub>max</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{int}}$		25.00%	[%]
				_		C <sub>md mer</sub>	3 500.00	[\$/d]	$\Psi_{astal}$	15.0%	[%]	$P\&D_{LM}$	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost M	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>ful cu</sub>	0.098275	[\$/kWh]	WF cap	50 000	[kW]	n ,.	15	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	$N_{WT}$	25	[-]	CRf	25.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	2 487.1430	[\$/tCO <sub>2</sub> ]	P&D <sub>IM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>br sur</sub>	3.0	[m-h]	$\sum_{AED} AED$	103.2	[tCO2/MW,h]	2 a		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMinsanv	85.00	[S/m-h]	null_mull_p_1===p_n	89.657	[MW <sub>e</sub> h]	× 141		0.00%	[%]
T CM	484.3839	[5/KW]	ogen	0.048925	[%/yr] [\$//Wb]	D N <sub>mun</sub>	30	[-]	n, GHG	0.00123	[yr]	2.3		5.00%	[%]
P marr	26 206	(*5)	MIC	71 5609	(\$%)	C .	2 500.00	(C)	GHG	0.00008	peoparticat	LCPM		90 107 610	() W b/m
C	0.1900	[%/3/KW]	TIC	124 5688	[3/1] [5/b]	PVM w r	61.0184	[3/4] [\$/JW]	C C C C C C C C C C C C C C C C C C C	13,0000	[8/(CO <sub>2</sub> )	LCI M WF		30 107 010	[K W du yi ]
I WIG out	39 1957	[3/ kg] [S/m/kW]	R.	30.00%	[96]	Nwa	25	[3%"]	Berein REPIM distribution	100.0%	[%]	Project Finan	ina	ſ	Notes
WF	50 000	[kW]	ifr	2.50%	[%/vr]	WTS vu	1.4442	[\$/kW]	ξ, RELOV	0.0%	[%]	Debt ratio		50.0%	[%]
L,	13 950	[m]	Ň	25	[yr]	WF can	50 000	[kW]	ζ, REP CH	0.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mlh</sub>	48	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM	50.0%	[%]	Debt gro	ice period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	100	[h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	50.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	14 679 146	[\$M]	$WT_{weight}$	200 000	[kg]	REPIM	1 263.4736	[\$/proj]	Debt value		29 615 397	[\$]
ç	0.08%	[%]	AEP anail	90 107 610	[kWh/yr]	C steel	0.1900	[S/kg]				Debt pa	yments	2 991 865	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.147200 [	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	,	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 615 397	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanag(A)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discoun	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000038	[\$/kWh]	Ν	25	[yr]	BRL/USD dec2010	0.5986	[-]			r	
SB <sub>c</sub>	113.00	[S/kWh]	Work days	2.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	73.1255	$yr_1$	78.4712	yr 15
WF cap	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			73.5187	$yr_2$	77.6515	yr 15
WT inst	42.5238	[\$/kW]	USC OBM	0.000138	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	73.7873	yr 3	78.1612	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	74.1334	$yr_4$	78.6268	yr 17
Bld area	300.0	[m <sup>4</sup> ]	Frequency	1.0	[per yr]	February''	672	648	KEPIM			74.4746	yr 5	79.1175	yr 18
FC CM	35.9374	[\$/KW] (\$/14W)	Kepair time	4.0	[n] (h)	March	744	730	EFIM distribution	1	[1/0]	74.9275	yr <sub>6</sub>	79.0113	yr 19
r3 DT	19.88	[3'KW] [\$/FW]	SC USC	148.0	(h/vr)	May	744	736	E REP	1	[1/0]	75 5275	37.7 NT.	78 2446	yr 20
FG	404 52	[5/kW]	SC OEM TO SC OEM	0 000176	(S&Wh/wr)	Jung <sup>(*)</sup>	720	696	Č, OREP.CH	1	[1/0]	76.0152	37.8 VT 0	78 7103	37 21 NT 22
EG Fcw	3 7712	[3/kW]		0.0001/6	(In the second s	June	744	736	Š. GHG R cy	1	[1/0]	76.4118	97.9 VF 10	79.0644	37 22 VF 23
WACC mai	4,900%	[%/vr]		Г		August	744	736	P&D <sub>IM</sub>	1	[1/0]	76,7332	yr 11	79.4723	37 25 YT 25
n fin	1.0	[yr]				September	720	712	λ.,	1	[1/0]	77.2289	VF 12	76.8666	Mean
WFree	0.30%	[%]	1			October	744	736	$\lambda_{sdi}$	0	[1/0]	77.6321	yr 13	2.0151	SD
CCC CM	2.4042	[\$/kW]	1			November <sup>(*)</sup>	720	696	$\lambda_d$	1	[1/0]	78.0589	yr 14	-0.4631	Y (skewness)
ĸ	0.20%	[%]				December	744	736	λ,,,	1	[1/0]	LCOF	76.8666	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 616		p.s.: 1= yes at	nd 0=no		0.076867	US\$/kWh	

**Figure R.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 3). Source: Own elaboration

LCOE wso Mode	l Inputs									Financial Ind	lexes		Notes
Legend				_			Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and a automatically based on user input into	re updated yellow cells.	O&M warranty condition	s Note	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.	Costs covered by manufacturer (O&M_om)	80.00% [%]	Depreciation rate per year	r 4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.		Period of warranty (nw)	5 [yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind During Information	Notes	I eveliged Penlagement C	ort Model Net	Wind Farm Pamoval	Cost Model	Natas	Panawahla Enaray Public In	cantive Model	Natar	Wind Farm Life	e-Cycle Prod	luction Model	Natas
Project Name	Firestar Wind Farm	AR CH	16.8442 [S/kV	DCM ws	1 339 9154	[S/kW]	RELCH	65 7637	INDIES	WE cu	cjen 170a	50.000	fkW_/yr]
Project Location	Cape Saint James (Canada)	Depr	76.9840 [S/kV	RM wr	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WFam		50 000	[kW]
Turbine Model	Vestas V90-2MW	WT <sub>CM</sub>	553.7256 [S/kW	WF cm	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	-
Number of Wind Turbines (NWT)	25 [-]	T <sub>CM</sub>	484.3859 [S/kW	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000 [kW]	N	25 [yr]	$M_{i\nu_{m_{HT}}}$	100	[m-h]	$\Psi_{sotal}$	15.00%	[%]	N raw		5	[-]
Wind Farm Capacity (WF cap)	50 000 [kW]	ifr	2.50% [%/y	CMMMAN	85.00	[\$/m-h]	n ,	3	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0 [m]	Depry	60.1398 [S/kV	N <sub>mener</sub>	3	[-]	REP CM	0.00000053	[\$/kW_ch]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7 [m <sup>2</sup> ]	$Y_{RC}$	15 [yr]	D <sub>m smer</sub>	2.0	[d]	AEP anail/H prod	24 780	[kW/yr]	L.,		1 800	[m]
Hub height (H)	105.0 [m]	TO CM	0.000033 [S/kW	$C_{md_{MNT}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	$L_{x_{col}}$		2 430	[m]
Wind speed measured at $(H_0)$	10.0 [m]	TI	1 798 743 [S/kV	RM CT	20.1954	[\$/kW]	£	0.0131	[\$/kWch]	SD <sub>x</sub>		450	[m]
Terrain rugosity factor (a)	0.14 [-]	V	237 699 000 [kW	WF cap	50 000	[kW]	$\varepsilon_0$	0.007998	[\$/kW_ch]	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C PBerz)	0.5926 [-]	Vo	6 100 000 [kW	Nwr	25	[-]	n <sub>e</sub>	20	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25 [yr]	C ()	1 457.72 [\$/kW	] M <sub>M</sub> <sub>M</sub>	3.0	[m-h]	OREP CM	83.3617	[\$/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	48.7% [%]	PR	0.70 [-]	CMBrace	85.00	[\$/m-h]	LCCCM <sub>WFORIOCM</sub>	4.0521	[\$/kW]	AEP avail		213 509 813	[kWeh/yr]
Aváilability	98.4% [%]	b	-1.94 [-]	N <sub>mmcr</sub>	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{sees}$		20.35%	[%]
	359 [d/yr]	LRCM	16.8443 [\$/kV		2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{wecz_{(rel)}}}$		25.00%	[%]
				C <sub>nd MC</sub>	3 500.00	[\$/d]	$\psi_{total}$	15.0%	[%]	$P\&D_{LM}$	factor	0.814145	[-]
Wind Farm Life-Cycle Capit	al Cost Model Notes	Wind Farm O&M Cost M	odel Note	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
WT <sub>CM</sub>	553.7256 [S/kW]	O&M fand cu	0.098275 [S/kW	1] WF <sub>cap</sub>	50 000	[kW]	n ,,	20	[yr]	Α		6 361.7	[m <sup>2</sup> ]
CM WT	265.32 [S/kW]	LCCCM <sub>WF</sub>	1 204.5180 [S/kV	] N <sub>WT</sub>	25	[-]	CRf	25.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70% [%/\$/kW]	ω	0.000001% [%]	A <sub>WT</sub>	43.00	[m²/wt]	GHG.R CM	10 881.1639	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
C kW	400.00 [S/kW]	LLC	0.0530 [S/kW	1 M <sub>kr saw</sub>	3.0	[m-h]	$\sum_{AEP} AEP$	244.5	[tCO2/MWah]	λ		7.00%	[%]
IPI	10.00% [%]	N	25 [yr]	C <sub>Mbr<sub>saRv</sub></sub>	85.00	[\$/m-h]	∠ <sup>ML1</sup> and <sub>F11-116</sub>	212.467	[MW <sub>e</sub> h]	141		3.00%	[%]
T <sub>CM</sub>	484.3859 [5/kW]	ifr O&M	2.50% [%/y	N <sub>m<sub>xan</sub></sub>	3	[-]	n, CHC	25	[yr]	×		5.00%	[%]
I marr	158 000 [kg]	O'della variable Cu	0.041527 [5/kw	C	3.0	[0]	GHC GHC	0.00123	[8CO <sub>2</sub> /MW <sub>2</sub> h]	A m		3.00%	[%]
RC T	26.30% [%/\$/kW]	MLC	/1.5608 [S/h	C nd saw	3 500.00	[\$/d]	GHG <sub>EM</sub> <sub>www.co2</sub>	0.00008	[tCO2/MW,h]	LCPM <sub>WF</sub>		213 509 813	[k W <sub>e</sub> h/yr]
C sted	0.1900 [S/kg]	TLC	124.5688 [S/h	RVM WF	61.0184	[\$/kW]	E <sub>c</sub>	24.0000	[\$/tCO <sub>2</sub> ]			r	
LWIG <sub>CM</sub>	39.1957 [S/m/kW]	R taxes	30.00% [%]	N <sub>WT</sub>	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF <sub>cap</sub>	50 000 [kW]	ifr	2.50% [%/y	WTS <sub>VM</sub>	1.4442	[\$/kW]	$\zeta_1 REI_{CM}$	0.0%	[%]	Debt ratio		50.0%	[%]
Ls	13 950 [m]	N	25 [yr	WF cap	50 000	[kW]	ζ <sub>2</sub> REP <sub>CM</sub>	0.0%	[%]	Debiterm		14	[yr]
CAB cont	2 000.00 [S/m]	n mih	48 [n]	tfr N	2.50%	[%/yr]	$\zeta_3 OREP_{CM}$	50.0%	[%]	Debt gr	ace perioa	1	[yr]
CP CH	30.9009 [S'KW]	n th	20 520 510	IN NUT	200,000	[yr]	54 GHG.RCM	5 402 2620	[%]	Debi in	terest rate	3.00%	[%/yr]
EF c	400.00 [SKW]	AAR	29 558 512 [SM	WIweight	200 000	[Kg]	REPIM	5 482.2028	[\$/proj]	Debivalue		29 070 929	[5]
5	0.08% [%]	ALF anail	213 509 813 KWh	r] C ned	0.1900	[5/kg]				Debi pa	yments	2 936 861	[\$/yr]
TS CM	11.4566 [\$/kW <sub>c</sub> ]	O&M WFCM	0.139802 [\$/kWh	r/ IS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	0	50.0%	[%]
IL <sub>c</sub>	0.0400 [5/m]			WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	salue	29 070 929	[\$]
TL,	1 200 [1/kW]	O&M <sub>O&amp;Mmanag(A)</sub>	Note	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	it rate	9.00%	[%/yr]
$L_t$	3 000 [m]	SC OLM	0.000016 [\$/kW	y N	25	[yr]	BRL/USD dec2010	0.5986	[-]			r	
SB c	113.00 [\$/kWh]	Work days	2.0 [d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE wso	Notes
SI <sub>CM</sub>	42.7345 [\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6 [d]	RCM WF	1 278.8970	[\$/k W]	Conditions for LCOE was		Notes	84.3997	yr i	94.4943	yr 15
WF cap	50 000 [kW]	Hours required	48.0 [h]		-		O&M WFCM			85.0669	$yr_2$	94.1699	yr 15
WTinst	42.5238 [S/kW]	USC ORM	0.000058 [\$/kW	Hours Distribution	$FLH_{wf}[h]$	H prod [h]	O&M ccm	1	[1/0]	85.7507	yr3	94.9708	yr 16
Bld cost	500.00 [\$/m <sup>2</sup> ]	NWT	25 [-]	January	744	740	(%) ccm	80.0%	[%]	86.2255	$yr_4$	95.8775	yr 17
Bld area	300.0 [m <sup>2</sup> ]	Frequency	1.0 [per y	] February <sup>(*)</sup>	672	648	REPIM			86.9196	$yr_{3}$	96.7795	yr 18
PO <sub>CM</sub>	35.9374 [S/kW]	Repair time	4.0 [h]	March	744	736	REPIM distribution			87.6452	$yr_6$	97.5702	yr 19
FS	19.88 [\$/kW]	Hours required	100.0 [h]	April	720	712	REI <sub>CM</sub>	1	[1/0]	88.2242	yr 7	94.0503	yr 20
DT	87.22 [\$/kW]	SC O&M+USC O&M	148.0 [h/yı	May	744	736	REP CM	1	[1/0]	88.9241	$yr_8$	94.7536	yr 21
EG	404.52 [\$/kW]		0.000074 [\$&Wh	r] June <sup>(*)</sup>	720	696	OREP CM	1	[1/0]	89.8260	yr 9	95.8087	yr 22
F <sub>CM</sub>	3.7712 [\$/kW]			July	744	736	GHG.R CM	1	[1/0]	90.4267	yr 10	96.5649	yr 23
WACC proj	4.900% [%/yr]			August	744	736	P&D <sub>LM</sub>			91.2477	yr 11	97.5891	yr 25
n <sub>fin</sub>	1.0 [yr]			September	720	712	λ.,	1	[1/0]	91.9572	yr 12	91.8264	Mean
W <sub>F<sub>CM</sub></sub>	0.30% [%]			October	744	736	$\lambda_{xki}$	1	[1/0]	92.6946	yr 13	4.2043	SD
CCC CM	2.4042 [S/kW]			November <sup>(*)</sup>	720	696	24	1	[1/0]	93.7245	yr 14	-0.3333	I (skewness)
K	0.20% [%]			December	744	736	λ <sub>m</sub>	1	[1/0]	LCOE NZO	91.8264	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 204.5180 [\$/kW]			Total [h/yr]	8 760	8 616		p.s.: 1 = yes ar	nd 0=no		0.091826	US\$/kWh	

**Figure R.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(A)}$  and  $E_{pi}$  (*Case* 3). Source: Own elaboration

Lable K.1 Ener	gy produc	TION (ALL ava	· dura (10			()	l								4 7.0	11.11.1.1											
Months	V WC	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	prod L.												AEF .	vail ( K WH)								1	1	1	
	(m/s) (1	kg/m <sup>2</sup> ) (.	(1)	yr 1	yr 2	yr 3	yr 4	yr 5	$yr_6$	yr 7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13 )	JF 14	yr 15 )	JF 16	r 17	r 18 y	19 yi	20 yr 2	1 yr 2	2 yr 23	yr 24	yr 25
, January	5.8	1.1665	740 1	697 720 8	8 914 291	3 812 469 7.	527 755	558872 v	8 914 291	558 872	558 872 4	243 681 8	914291 8	914 291	58872 31	12 469 752	27 755 42	243 681 89	14 291 89	14 291 55	8 872 381	2 469 7 52	755 558	872 3812.	469 75277	55 424368	4 243 6
February	4.9	1.1666	648 8.	59 945 6	879 561	3714421 6.	879 561	788 321 ¢	\$ 879 561	788 321	788 321 4	780152 6	879 561 6	879 561	88 321 3:	14421 68	79 561 4	89 171 48	9171 35	36 988 47	80 152 780	2 526 1 59	t 674 1594	674 7802	526 68795	51 478015	4 780 1.
March	4.0	1.1671	736 5.	55 877 7	487 419 5	5 432 002 8.	866 525	977212 3	7 487 419	977 212	9772126	552 645 7	487 419 7	487 419	77212 54	32 002 8 80	66 525 81	95 822 89	5 822 1 8	12 134 42	20 942 181	2 134 168	8 623 1 688	623 78170	699 88665	25 3 792 04	65526
April	4.7	1.1667	712 80	66366 6	337 184 6	1337184 4	982 151 1	, 633 098 6	337 184 1	1 860 833 098	633 098 7	241 220 6	337 184 6	337 184 1	752 548 6	37184 4 00	82 151 9.	45 080 94	5 080 1 6	33 098 63	37 184 1 63	3 098 3 66	7 352 945 (	080 7241	220 63371	84 1 752 54	8 72412
Mav	60	1 1670	736 13	5 990 618	231 800 5	7 487 140 5	131 800 1	\$ 990 CT8	1 1008 187 :	1 990 618	812 066 7	5 007 218	431 800 5	131 800 1	688.560 7.4	87 140 65	1 107 65	88 560 1.6	38 560 03	7 176 88	56 105 073	176 55	856 805	788 6552	20222 108	45 1 688 56	78174
, introduction of the second sec		0.01.1				C 041 /04			000 TOL .		/ 000 710			- 000 FC			101 10								10771 101		
June	6./	1.1080	090 3.	c 202 066	202 066 1	1 402 657 6	204 764	\$ 290.720	2020 066 5	\$ 290 720	590720 8	595 800 3	996 852 3	5 202 066	20/720 74	02 057 5 14	43 616 1	12 67 17	12 927 82	8 202 74	12 657 840	207 849	202 3590	720 5 143 0	010 21430	65 626 01	N C65 8
July	8.6	1.1698	736 5.	444 782 3	\$00.962 8	887385 I.	692 596 4	1 230 873 3	800 962 4	1 230 873 4	230 873	57 185 5	57185 3	800 962 5	444 782 88	87385 181	16397 32	800 962 38	00 962 5:	7185 75	05 034 55	185 979	511 4230	873 42308	873 16925	96 89792	55718
August	9.6	1.1677	736 74	1 102 161	813 073 1	1 813 073 1.	813 073 8	3 871 123 1	813 073 5	5 434 819 5	434819 8	96 286 8	896 286 1	813 073 4	223 131 1 8	13 073 1 68	89 499 54	434 819 78	21 753 78	21 753 89	6 286 4 22	8 131 782	1 753 5 434	819 1 813 0	073 18130	73 55616	89628
Sentember	101	1 1657	112 8.	1 800 995	1 293 189	2 12 2 2 2 3	2 900 295	1 223 538 1	1 293 564 6	5 331 230 6	331230 6	44 102 0	1 201 77	9 795 189	331 230 11	31 564 3 64	9 900 89	31 230 72	34 417 73	54 417 04	4 102 524	8 454 8 56	122 6331	230 1631	564 36639	16 633123	07710
Uctober	7.6	1.1045	/20 /.	800 240	150 C/6	c 150 c/6	24 050	/ 4/0 /05	150 C/6	4/0/03	4/0/03 1	1 508 480	508480	8 150 C/6	840 / 30 9.	CC 150 C	4 030 /4	C 0 50/ 0/1	58 UI0 03	58 010 18	FC 0 880.80	8 010 4 21	0/4/ 610	1076 50/	0 0 1 6 1 5 0	1 8840/3	1 084 8
November	9.2	1.1638	696 6.	179 252 8	844 775	844775 8	44 775 6	\$ 179 252	844 775 ;	7 372 218 ;	372 218 1	708 872 1	708 872 8	844 775 7	372 218 8.	14 775 84	4 775 7	872 218 51.	22 467 51	22 467 15	92 399 7 06	0758 617	9 252 7 372	218 8447	75 8447	75 737221	1 708 8.
December	7.6	1.1651	736 3	785 725 5	554 951	554 951 9	75 585 5	1422 956	554 951 8	1 851 759 8	851759 3	785 725 3	785 725	554 951 7	474 950 5.	54 951 97.	5 585 81	851 759 42	13 913 42	13 913 37	85 725 780	1 681 5 42	2 956 8851	759 554 5	151 5549	1 7 474 95	3 785 7.
Annual	7.4	1.1666 8	\$ 616 49	057 055 4	18 667 462	48 892 652 48	\$ 537 127 4	19 088 734 4	48 667 462	19 051 893 4	0 051 893 4	8 608 021 4	8 624 219 4	18 667 462 4	9 049 275 48	892 652 48 3	596 807 49	239 932 49.	380 379 49	00 701 48	597 726 48 3	7 889 49 0	4 437 48 963	360 48 420	199 48 519	58 48 661 53	48 608 0
le R.2 Energ	gy produci	tion map of th	he wind fi	arm for Cor	rvo Island (	Portugal)		M	ith sensitiv	ity analysis	of O&Mman	$a_{g(A)} + E_{pi}$	(Case 3)														
	V <sub>NC</sub>	$H_{\mu}$	prod												AEP.	$v_{ail}(kWh)$											
donths	( <i>m</i> /s) (Y	(1) (1) (1)	(4)	yr 1	YF 2	yr 3	Vr 4	VF 5	yr 6	YF 7	yr s	yr o	VF ID	Vr 11	Vr 12	Vria V	JF 14	Vr 15 1	JT 16	T 17	T 18 V	10 M	20 VF 3	1 VF 2	2 VF 23	VF 24	Vr 25
Innum	117	1 2313	740 12	1 400 467	CYP 00P FI	1 CYF 00F FI	CYP 00F F	CYP 00P PI	CYF 00F FI	CYP 007 FI	10 871 408	0 871 408	CYP 007 FI	10.871.408	0.871.408 1	FI 80F 12	1 697 007	01 807 108	871 408 12	400 462 10	871.408 10.1	21 408 103	71 408 10.87	1408 10.871	108 10 821	10.871.4	8 10.871
T-L	211	37661	0+/	704 064 4	201 000 1	1 102 000 01	704.044.4	704 064 41	704 064 41	704 064 41	004 1/0 01	004 1/0 0	701 001 1	202 212 41	0 102302	41 004 1/0	7 TVL 000	01 0041/07	F 202 212	01 704.004	F C 000 70	0 C 200 L	10 01 004 1/	701 C 142 C	10.01 004	2 100 VI 31	
repruary	C-11	C+C7-1	0+0	. 17/ 760 7	101 067 #	1 17/ 760 71	17/ 760 7	17/ 760 71	060 / 1+ 0	17/ 760 71	. CO/ CI / 71	6 #0/ 06/	060 /1+	C0/ C1/ 71	6 #0/ 06/	71 0/1 ##7	0 17/ 760	71 CIO #/0	+ CO/ CT/	6 / CT CK	+ C 067 00	107 060 /	60 71 000 C	0017 17/7	#/0 0 CO/	/ 760 71 Ch	0171
March	10.5	1.2329	736 1	0 486 228	3 193 907	13 717 510 1	3 717 510	13 717 510	6 223 433	13 717 510	13 717 510 2	389 762	193 907	13 717 510	389 762 1.	717510 13	717 510 6	223 433 13	717 510 3.	76 220 75	70 742 48	9 967 13 2	17 510 14 42	4 289 2 037	067 10 486	228 14 424 2	9 3 193 9
April	9.5	1.2317	712 7	316 597	7 316 597	10 458 483 1	0 458 483	10 458 483	7 316 597	10 458 483	4 706 485	086 689 7	316 597	13 257 022	086 689 1.	257 022 47	06 485 4	706 485 13	257 022 3	86 689 10	134 212 3 0	6 689 13 9	40 075 13 25	7 022 3 086	689 3 086 (	89 13 257 0	2 37460
May	8.2	1.2282	736 4	851 676	10 446 845	10 446 845 1	0 446 845	6 200 059	10 446 845	10 446 845	10 446 845 3	861 662 6	200 059	10 446 845	861 662 1-	370 115 10	446 845 3	861 662 10	446 845 2.	£1 28 08.	665 991 6 20	0 059 2 38	0 787 10 44	5 845 3 861	662 14370	115 10 446 8	5 48516
June	1.7	1.2224	696 2	994 461	12 860 910	7 097 981 7	186 260	7 097 981	10 145 990	4 565 858	12 860 910 4	565 858	10 145 990	186 260 7	565 858 7	<i>397 981</i> 2 2	40 532 2	994 461 7 (	1 186 260	09 861 12	860 910 7 0	7 981 1 90	9 861 7 097	981 4565	858 12 860	96 7 097 90	1 58348
July	6.1	1.2154	736 2	. 811800	13 522 571	4 800 760 6	134 992	10 337 209	13 522 571	7 463 154 .	3 148 518 6	134 992 2	008118 0	5 134 992 (	134 992 6	134 992 20	08118 2	355 801 61	34 992 6	34 992 14	219 306 10.	37 209 3 82	1135 6134	992 6134	992 13 522	571 3 821 1.	5 74631
August	6.4	1.2075	736 2	340 496	10 598 668	3 796 310 3	796 310	3 796 310	13 434 719	6 095 134	3 796 310 7	414 668 2	340 496	4 769 571	414 668 4	01 125 69 2	598 668 I	995 072 47	69 571 13	434 719 1 5	95 072 13-	34719 470	9 571 4 769	571 7414	668 4 769	71 3 128 0	3 10 270 (
eptember	7.6	1.2064	712 3	669 202 1	1 928 273	5 891 057 4	, 978 00	4 609 876	4 609 876	1 928 273	5 891 057 5	926189 9	926 189	3 669 202 9	926189 3	569 202 58	01 057 9	926189 36	69 202 12	984 898 2 2	62 132 12	84 898 5 89	1 057 3 669	202 9 926	189 3 669	02 2 262 1.	2 1 928 2
October	8.9	1.2126	736 6	121 079 €	5 121 079	3 141 378 2	003 564	3 141 378	2 003 564	2 350 459	7 446 229 1	3 491 905	13 491 905	3 141 378	3 491 905 3	141 378 74	146 229 1.	3 491 905 31	41 378 10	643 782 31	41 378 2 0	3 564 7 44	6 229 3 141	378 13.491	905 2 350	59 2 003 5	4 23504
Vovember	10.6	1.2194	696 h	9 121 586 3	3 625 425	2 235 143 2	235 143	2 235 143	2 235 143	2 987 258	235143	2 829 976 4	( 554 876 2	2 235 143	2 829 976 2	235 143 29	87 258 1.	2 829 976 2 2	35 143 9.	02 761 3 6	25 425 22.	5 143 9 80	7 761 2 235	143 12 829	976 1 905	67 5 820 7	1 12 829
December	11.5	1.2237	736 1.	3 614 984 2	371 901	2 021 842 3	170 035	2 021 842	3 170 035	3 847 249	3 021 842	4 316 481	13 614 984	2 021 842	4 316 481 2	021 842 38	47 249 1-	4316481 20	021 842 7.	14 158 48	33 568 14.	16 481 13 0	14 984 2 021	842 14316	121 6 176	18 4 833 50	8 13614
Annual	1.6	1.2222 8	3616 9	0 107 610	90 769 774	6 16# 061 06	0 253 921	60 198 973	91 016 328	90 443 405	89 858 042 5	0 685 374	90 700 678	90 078 677	0 685 374 9	530 336 90	473 134 9	0 246 888 90	078 677 90	557 464 90	666 434 90 8	55 213 90 9	85 978 90 16	2 393 90 643	1 598 90 743	354 90 059 5	0 89 670
le R.3 Energ	zv product	tion map of th	he wind fa	am for Car	se Saint Jan	nes (Canada)		×	ith sensitiv	ity analysis	of <i>0&amp;M</i>	$+E_{ni}$	(Case 1)														
TAIPT CALM	ej pronuc	a to dam mon-		and to the	Inc limber of	inna (canaa)				are fimine fu	or occur ma	ag(A) pi	1 0 000 3/		111	1 111 1											
Months	V <sub>NC</sub>	μ,	prod												AEP	vail(KWh)											
	(m/s) (j.	kg/m <sup>3</sup> ) (1	(4)	yr 1	yr 2	yr 3	yr 4	yr 5	yr 6	yr 7	yr8	yr 9	yr 10	yr 11	yr 12	yr 13 y	11 14	yr 15 )	JT 16	r 17	r 18 y	19 yi	20 yr 2	1 yr2.	2 yr 23	yr 24	yr 25
January	15.4	1.2561	740 3.	2 823 510	32 823 510	32 823 510 3	2 823 510	32 823 510	32 823 510	32 823 510	32 823 510	2 823 510	32 823 510	32 823 510 2	035 210 3.	823 510 32	823 510 3.	2 823 510 32	823 510 32	823 510 32	823 510 32 8	23 510 40 8	<b>55 255 32 82</b>	3 510 32 823	1 510 28 095	229 8 035 2.	0 71201
February	14.7	1.2522	648 2-	4 591 404	14 672 254	7 010 451 2	6 599 864	14 672 254	14 672 254	26 599 864	26 599 864 7	010 451	14 672 254	14 672 254	859 649 20	599 864 7 0	10 451 1:	7 623 290 7 (	10 451 7	10 451 70	10 451 70	0 451 22 3	80 600 26 59	9 864 26 599	864 29369	594 7 859 6	9 17 596
March	12.7	1.2495	736 4	8 252 376	18 252 376	8 908 878 2	7 874 248	12 394 144	18 252 376	27 874 248	27 874 248 8	908 878	12 394 144	18 252 376	986 084 2:	874 248 89	08 878 30	0 150 829 8 9	08 878 8	08 878 89	08 878 89	8 878 23 (	24 061 27 87	4 248 27 874	1 248 31 459	374 9 986 0	4 18 948.
April	12.4	1.2490	712 11	6 081 249	19 315 677	9 656 023 2	4 865 308	9 656 023	19 315 677	24 865 308	24 865 308 9	656 023 5	056 023	19 315 677	656 023 2	865 308 9 6	56 023 20	5 952 947 96	56 023 29	154 282 96	56 023 9 6	6 023 22 2	18 160 20 00	1 184 24 865	308 24 956	459 9 656 0	3 18 165 0
Mav	611	36861	736 1	PSU FCE C	05 560 850	1 009 000 0	0 862 073 0	009 000 6	05 560 850	270 238 01	9 870 68.01	0 009 000	009 000	25 560 850	1 F90 FC2 C	0 0 223 0 0	< 000000	2 0 0 5 8 0 9 5	2 009 000	216 641 0.0	00 06906	110 0090	18 078 10 86	0 073 10 862	911 01 110	0 FCE CI 5FE	101 91 17
(mu		13001			200 000 00	1 122 702 11	1000 000	0.000 0.000	207 020 70	17 060 110		0 122 102 1	040 /4/	200 000 00	1 000 100 2	11 041 050	1 122 702				11 132103	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	20 61 0100	200 ET 041 0	100 21 041	2 7 7 2 7 2 0 2 0 2 0 2 0 2 0 2 0 2 0 2	
aunr	10.4	1007-1	6 060	10/ 000	CO+ CCD 07	1 ICC #0C II	071.000 /	0 2 C 0 444	CO+ CCD 07	071 000 /1	071 000 /1	2 ICC +0C I	##6 07C	CO+ CC0 07	T C6C ##C C	11 071 000	T ICC #0C	11 071 000	57 TCC +0C	11 +IC CC0	. II ICC #0C	1 /1 100 40	00 /1 +00 0/	000 /1 0710	196 01 071	C ##C CT C60	0+1 C1 C
July	10.0	1.2275	730 8	751 923	29 619 639	16 337 936	6 337 936	7 806 320	29 619 639	16 337 936	16 337 936	6 337 936 7	806 320	29 619 639	7 930 811 14	337 936 16	337 936 7	806320 16	337 936 15	623 991 16	337 936 16.	37 936 15 3	52 737 16 06	9 219 16 337	936 16783	950 17 930 8	1 8 637 3
August	9.7	1.2216	736 7	768 712	12 117 129	17 844 428 1	2 117 129	17 844 428	12 117 129	12 117 129	12 117 129	7 844 428	17 844 428	12 117 129	9 529 451 1.	117 129 17	844 428 8	209 760 17	844 428 15	844 428 17	844 428 17 8	44 428 12 9	21 415 15 39	9 666 12 117	129 12 606	836 19 529 4	1 7 121 9
September	10.4	1.2234	712 9	458 082 3	7 526 165	18 919 721 9	458 082	26 400 433	7 526 165	9 458 082	9458082 .	8 919 721	26 400 433	7 526 165	4 355 589 9	458 082 18	919721 9	458 082 18	919 721 15	751 596 18	919 721 18	19 721 12 3	39 146 13 29	4 981 9 458	082 8 855 (	20 24 355 5	9 19 057 0
October	13.1	1.2327	736 h	9 706 914 8	\$ 788 905	29 744 799 9	851 605	25 368 953	8 788 905	9 851 605	3 851 605	6 744 799	25 368 953 2	8 788 905	7 498 877 9	851 605 25	368 953 9	851 605 25	368 953 12	227 237 29	744 799 25	68 953 12 2	59 773 8 871	247 9851	605 8 134.	57 27 498 8	7 21 626 0
November	14.3	1.2429	696 2-	4 188 639 5	9 393 250	26 219 466 8	379 993	28 360 895	9 393 250	8 379 993	\$ 379 993	6 219 466	28 360 895 9	9 393 250	8 360 895 8	379 993 26	219 466 1.	1 658 353 26	219 466 9.	93 250 26	219 466 26	19 466 7 52	0 762 8 379	993 8379	993 8 987	16 28 360 8	5 22 240
December	15.1	1.2528	736 A	9 229 153	10 012 025	25 782 051 7	966 958	20 027 814	10 012 025	7 966 958	7 966 958 2	5 782 051	20 027 814	10 012 025	2 544 702 7	966 958 30	229 153 h	5 674 139 30	229 153 10	012 025 25	782 051 30	29 153 635	9 397 7 966	928 7966	928 9176	37 32 544 7	2 42 535 .
Annual	12.5	1.2404 8	3 616 21.	3 509 813 2.	14 144 266 2	14 761 434 21	3 197 728 2	13 611 337 2	14 144 266 2	13 197 728 2	13 197 728 2.	4 761 434 2.	13 611 337 2	14 144 266 2	3 625 948 21.	197 728 214	832 689 21-	4 338 805 214	832 689 214	501 803 214	761 434 214 8	32 689 214 0	38 947 214 20	3 964 213 197	728 214 523	412 213 625 9	8 214 387 0
			I																								

Table R.4 Wind	d speed sei	ies simulation	is for $AEP_a$	wail in Arac	ati (Brazil)			with	sensitivity :	malysis of	O& M manag(A	$(A) + E_{pi} (C_{i})$ Wind snee	ase 3) d data serie	s for simula	tions (m/s)										
Months	(m/s)	yr 1	yr 2	yr 3	yr4	yr 5	yr6	yr7	yr 8	yrg	yr 10	yr 11	yr 12	yr 13	yr 14	Vr 15 )	r16 yr	17 yr	18 yr	19 yr.	20 Jr2	1 yr	22 yr 2	3 yr24	yr 25
January	5.8	5.8 1	1.0	7.6	9.6	4.0	10.1	4.0	4.0	7.9	10.1	10.1	4.0	7.6	9.6	1 6.7	0.1 10	.1 4.	0 7	6 9.	6 4.1	9 7.	6 9.	5 7.9	7.9
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0 7	.6 8.	6 10	I 6.	0 6.	0 10	I 9.	7 8.6	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7 6	.0 7.	9 6	0 5.	8 5.	8	7 IO.	7.6	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9 5	.8	2 5	8 7.	6 4.	9.	6 9.	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8 4	.9 10.	I 4	9 4.	0 4.	7 9.	2 7.	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0 4	.7 9.	7 4	7 4.	7 7.	5 8.	6 8.1	5 4.9	10.1
July	8.6	8.6	7.6 1	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6 4	.0 9.	6 4	0 4.	9 7.	9 7.	9 5.	8 4.7	4.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7 9	.7 4.	7 7	9.9.	7 8.1	5 6.	0 6.1	0.4.0	4.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6 9.6	.6 4.	8	6 10.	I 9.	2 5.	8 7.1	5 9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2 9	.2 6.	0 0	2 7.	9.9	5 4.	9 4.	10.1	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6 8	.6 5.	8	6 9.	2	7 4.	7 4.	7 9.7	6.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	10.1	10.1	7.6	7.6	4.0	9.6	4.0	4.9	1.01	7.9 7	.9 7.	6 9	7 8.	6 10.	I 4.	0 4.1	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4 7	4 7.	4 7	4 7.	4 7.	4 7.	4 7.	1 7.4	7.4
Table R.5 Wind	d speed ser	ies simulation	is for AEP <sub>a</sub>	wait in Corv	o Island (P	ortugal)		with	sens itivity a	analysis of	O& M manag(1.	$\frac{A_{j} + E_{pi}(C_{l})}{Wind snee}$	ase 3) data serie	s for simular	tions (m/s)										
Months	( <i>m/s</i> )	vr.,	vr.	vr ,	vr.,	Vr c	Vre	VF-7	vr.«	Vro	VLIO	Vr.1	VF 15	VF 13	VF 14	UL 16 1	1. VI	17 VF	vr Vr	IO VL	00 NL	u vr	, VL ,	vr3	VF 25
January	11.7	11.7 1	1.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	7.11	10.6	10.6	10.6	11.7	0.6 1	0.6 11	7 10.	6 10	6 10.	6 107	5 10.	6 10 <sup>1</sup>	5 10.6	10.6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5 1	1.7 8	2	6 6	6 7.	11 11	6.0	4 9	11.5	11.7
March	10.5	10.5	1 12	11.5	11.5	11.5	8.9	11.5	11.5	6.4	172	11.5	6.4	11.5	11.5	1 6.8	15 7	9	, s	2 11.	5 11	0.0	1 10	11.7	1.7
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	1.7	9.5	11.5	1.7	11.5	8.2	8.2 1	1.5 7	1 IO	5	1 11.	7 11.	5	I 7.	11.5	7.6
May	8.2	8.2 1	0.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6 1	0.5 6	.4 11.	· ~	9 6.	4 10.	5	6 11.	7 10.5	8.2
June	1.7	1 1.7	51.	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	1.7	9.5 6	.H L.	5 9	5 6.	I 9	5 8.	2 11	5 9.5	8.9
July	6.1	6.1 1	51.	8.2	8.9	10.5	11.5	9.5	7.1	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9 8	.11 6.	7 10	5 7.	6 8.	9 8.	9 11.	7.6	9.5
August	6.4	6.4 1	0.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2 11	.5 6.	11 1	5 8.	2 8.	2	5 8.	1.7	10.5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6 11	.5 6.	4 11	5 8.	9 7.	5 10.	5 7.1	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	7.1	6.1	6.4	9.5	11.5	11.5	7.1	11.5	7.1	9.5	1.5	7.1 10	.6 7.	1 6	I 9.	5 7.	I 11.	5 6.	t 6.1	6.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	1.7	6.4	11.5	8.2	6.4	11.5	6.4	1.7	1.5	6.4 10	.5 	0 ; 0	4 10. -	2 0.	4 11.	5 6.	8.9	11.5
December	11.5	11.5	6.4	6.1	1.7	6.1	1.7	7.0	6.1	11.7	11.5	6.1	11.7	6.1	7.0	1.7	0.1 9	.5 8.	2 11	7 II.	5 6.	11.	7 8.	8.2	11.5
Annual	1.6	9.1	1.6	9.1	9.1	9.1	9.1	1.6	9.1	1.6	9.1	9.1	9.1	9.1	1.6	1.6	9.I 9	.I 9.	1 9	I 9.	I 9.	1 9.	I 9.	1.6	9.1
Table R.6 Wind	l speed ser	ies simulation:	s for <i>AEP</i> a	wait in Cape	Saint Jame	s (Canada)		with	sensitivity 8	nalysis of e	A managed	$(1) + E_{mi}(Ca)$	18e_3)												
Mandha	V wc										0	Wind spee	ed data serie	rs for simula.	tions (m/s)										
	(m/s)	yr 1	yr 2	yr 3	$yr_4$	yr 5	$yr_6$	$yr_7$	$yr_8$	$yr_{g}$	yr 10	yr 11	yr 12	yr13 .	yr 14	Vr 15 )	r16 yr	17 yr	18 yr	19 yr.	20 yr2	1 yr.	22 yr 2	3 yr24	yr 25
January	15.4	15.4 1	5.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	5.4 1	5.4 15	.4 I5. 	4 15	4 16.	6 15.	4 15.	4 14.	9.7	9.3
rebruary	14.1	1 14./	4.7	7.6	1.61	4.71	4.71	1.61	1.61	7.6	4.71	12.4	10.0	1.61	1.6	3.1	6 / 6 / 6 / 6 / 6 / 6 / 6 / 6 / 6 / 6 /		~ ~ ~	/ 14. 0	5 . []		1.cl 1	10.0	13.1
March	1.21	1 /71	1.7	10.0	14./	7.11	12.1	14./	14./	0.01	7.11	12.1	10.4	14./	10.0	1 2.81	01 0.0	.0. 10. 10.		.ci b	o 14. o	. 14.		101	6.71
nide.	£:71	1 611		10.4	13.1	+01	1.61	13.1	1.51	10.4	+10.4	1.61	+:01	131	10.4		CT FO	- 10 - 10	+ +	4 F	4 13. 13		1 13.	+'01 U	12.2
Inne	10.4	10.4	4.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	1 2.7	1.2 14	3 11	2 11	2 12.	8 12	7 12.	7 12.	7 12.4	12.2
July	10.0	10.0	5.1 1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7 1	2.4 13	.1 12.	4 12	4 12.	2 12.	3 12.	4 12.	12.7	10.0
August	9.7	9.7 1	1.2 1	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	1 0.0	2.7 12	.7 12.	7 12	7 11.	4 12.	1 11.	2 11.	13.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4 1	3.1 12	.4 13.	1 13	I II.	4 11.	7 10.	4 10.	14.3	13.2
October	13.1	13.1 1	0.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	1 4.0	4.3 11	.2 15.	1 14	3 II.	2 10.	1 10.	4 9.	8 14.7	13.5
November	14.3	14.3 I	1 0.4	14.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	10.4	15.1	10.0	14.7	1.2 1	4.7 10	.4 14.	7 14	7 9.	7 10.	9 10.	0 10.	3 15.1	13.9
December	15.1	15.1 1	0.4	14.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	10.4	15.4	9.7	15.1	12.4 1	5.1 10	.4 14.	3 15	I 9.	0 9.	7 9.	7 10.	15.4	16.9
Annual	12.5	12.5 1	2.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5 1	2.5 12	.5 12.	5 12	5 12.	5 12	5 12.	5 12	5 12.5	12.5

Mids         yr			yr2	yr <sub>3</sub> 5674 10467	yr.4 5 633 10 475	yrs 5 697	yr 6		yr8	yr9 5641	yr 10	yr 11 5 648	569.	2 yr1							01.10	yr 20					
	Sites	$yr_{I}$		5674 10467	5 633 10 475	5 697		yr 7		5 641		5 648	5 69.	593 6	3 yr.	14 yı	15 yı	r 16 yi	. 17 y.	r 18	61.1		yr 21	yr 22	yr 23	yr 24	yr25
Corron Mature (Perronga)         10.458         10.353         10.467         10.475         10.463         10.353         10.473         10.425	Aracari (Brazil)	693 5	648	0467	10.475		5 648	5 693	5 693		5 643			201	4 564	0 57.	15 57	31 56	88 56	52 51	508 5	694 5	. 683	5 620	5 631	5 648	5 641
	Corvo Island (Portugal)	1458 10	1 235 1		C1+01	10 468	10563	10 497	10 429	10525	10 527	10 454	1052.	5 1050	7 1050	0 104	74 104	54 105	10 105	23 10.	545 10	560 16	1 464 II	0 520 I	0 532 1	0452	10 407
bit RS Cability for 25 years of the wind fram projet       9000 kW       Amound (fbrain)       with start $1 - LCCCM w_T$ $0 - 1$ $2$ $3$ $4$ $5$ $6$ $7$ $8$ $WCaccW w_T$ $0 - 3$ $0 - 1$ $2$ $3$ $4$ $5$ $6$ $7$ $8$ $9$ $9$ $WCac       0 - 3 0 - 3 0 - 3 0 - 3 3 6 7 8 9 $	Cape Saint James (Canada) 2,	4 780 24	1 853 2	24925	24 743	24 791	24853	24 743	24 743	24925	24 791	24 853	2479.	3 2474.	3 2493	3 248	76 249	33 248	95 249	25 24.	933 24	841 24	1 860 2.	4 743 2	4 897 2	4 793	24 882
Table R.8. Cavifyther for 25 years of the wind familytic $S(100 \text{ kW})$ $Amont (Rhad)$ $a(10 \text{ km})$ $a(10 \text{ km})$ $a(11 \text{ km})$ Item         0         1         2         3         4         5         6         7         8         9           VW Cr         0         1         2         3         4         5         6         7         8         9           VW Cr         2109/258         -         -         2         3         4         5         6         7         8         9           Col         100         0         1         2         3         4         5         6         7         8         9           Col         1303/58         -         -         2         3         4         5         6         7         8         9           Col         1303/58         -																											
The R3 Catalfore for 25 cars of the wind farm project         9000 NW         Amont (Rand)         Amont (Rand)         with some           Ibm         0         0         1         2         3         4         5         0         2         9         0           Ibm         0         1         2         3         4         5         6         7         8         9           Ibm         0         1         2         3         4         5         6         7         8         9           Ibm         0         1         2         3         4         5         6         7         8         9           Ibm         1000         1         2         3         4         5         6         7         8         9         9           Ibm         0         1         2         3         4         5         4         5         6         7         8         9																											
Table R3 Califfux for 25 years of the wind fram project         9100 kW         Ament (Brad)         with sect           Item         0         1         2         3         4         5         6         7         8         9           Item         0         1         2         3         4         5         6         7         8         9           Item         0         1         2         3         4         5         6         7         8         9           Col         7         3         4         5         6         7         8         9           Col         1         2         3         4         5         6         7         8         9           Col         1905         5         5         5         5         6         7         8         9           Col         1905         5         5         5         5         6         7         8         6         7         8         6         7         8         9         9         9         9         9         9         9         9         9         9         9         10         10 <th< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>																											
The RA Califbre for 25 years of the wind finm project         9000 kW         Anceri (Buzi)         with scale           Iom         0         0         1         2         3         4         5         6         7         8         9           Iom         0         1         2         3         4         5         6         7         8         9           Virt Cal         199978         2         2         5         6         7         8         9           Cal         55 cm         15 cm         2195678         2         2         5         6         7         8         9           Cal         15 cm         15 cm         2         4         5         6         7         8         9           Cal         199678         48 cm/d 48 cm/d 4901874         4901763         49         47564         49018748         48         47564         49018748         49         47564         49018748         49         475664         480193         46018348         460183         460183         460183         460183         460183         460183         460183         460183         460183         460183         460183         460183         4601																											
Table R.8. Cashflow for 25 yours of the wind farm project         9000 MW         Arrorat (Baraf)         with stars           Item         0         1         3         3         4         5         6         7         84         9           Item         0         1         2         3         4         5         6         7         84         9           Item         0         1         2         3         4         5         6         7         84         9           Item         0         1         2         3         4         5         6         7         84         9         9           Item         0         1         2         3         4         5         6         7         8         9           Item         1         2         3																											
Inble R8 Gabihow for 25 years of the wind fam project         50.00 kW         Ancari (Brail)         with sense           Item         0         1         2         3         4         5         6         7         8         9           Term         0         1         2         3         4         5         6         7         8         9           Term         0         1         2         3																											
Intern         Solution         Solution         Annoti (Bradi)         Annoti (Bradi)         with state           Intern         0																											
The R3 Gathbov for 25 years of the wind farm project         50.00 kW         Ancasi (Ben2)         Ancasi (Ben2)         with same           Item         0         1         2         3         4         5         6         7         8         9 <i>WT cu</i> 2768.738         1         2         3         4         5         6         7         8         9 <i>WT cu</i> 2768.738         2         2         5         7         8         9         9 <i>WT cu</i> 2766.0378         2         2         6         7         8         9																											
Item         0         1         2         3         4         5         6         7         8         9 $T_{Cac}$ 2130255         -	Table R.8 Cashflow for 25 y	ears of the w	vind famn pro	oject	50 000 k	W A	racati (Brazil	6			with s	ensitivity an	alysis of O&	$M_{mang(A)} +$	E <sub>pi</sub> (Case 3	~											
(J LLCCM wr equal (M1 carried for the form of the f	Item			-	,		V	v	y	-				2	Years 13	14	ž	14	17		10	00	2	<i>"</i>	23	74	×
$V_{T,cut}$ $Z766223$ $Z$ $Z_{cut}$ $Z131253$ $Z_{cut}$ $Z1312345$ $Z_{cut}$ $Z1312345$ $Z_{cut}$ $Z1312345$ $Z_{cut}$ $Z1312345$ $Z_{cut}$ $Z1312345$ $Z_{cut}$	(-) ICCCM are		0.225 901		4	,	,	,	,						-		a '	-		, 1		,	1	-	, ,	5	3
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	WTCM	- 61	7 686 278																1	,		,					1
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$T_{CM}$	6	4219295																								1
CP cut         1543.86         .         <	$LWTG_{CM}$		1 959 783										,						'	'							1
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	CP <sub>CM</sub>		1 545 346																								'
$PO_{CA}$ Total	ID CM		2136726																								
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	POCM		1 796 870																		•						
$ \begin{array}{rcrc} CCc, C, C,$	$F_{CM}$		188 559																•	•	•	•					'
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	CCC CM		120211	•	•	•	•		•										•		•	•	•	•			1
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	LCPM WF (KWh/yr)			49 05/ 055 -	48 06/ 462	48.892.652 -	4 507 240	P 088 734 4	48.667.462.45 4.842.050 5	101 895 491	0.81 893 48 6 70 427 5 2	J8 U21 48 62	4219 48 66	0.462 49.045 0.477 5.660	268 84 2/2	652 48596 512 5 900'	2 6 5 7 6 7 7 8 7 7 9 7 7 9 7 1 9 7 1 9 7 1 9 7 1 9 1 9	52 4938034 52 630034	10/.600.95 1	48 697 726	48.317.889	49 064 43/ 6 909 035	48 965 360	48 420 199 - 5 007 115	4 80/91084	5061 536 4	2008.02
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	PPAR			4 314 826	4 387 573	4518071	4 597 349	4 765 836	4843059 5	003 348 51	128 432 5 20	19075 534	1081 5475	9477 5660	527 5783.	513 5892.2	231 61194	63 629034	1 6399200	6 5 17 427	6 628 256	6 898 935		-			
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	EMP																		•				4 939 990	5 007 115	5 142 845	5 286 820	5 413 0
$\begin{array}{rclcrc} O(kM_{final} & - 2.66-46 & 2120, 210, 210, 230, 280, 010 & 244, 001 2795 & 500, 011 271 035 136, 861 321/38 \\ O(kM_{mask} & - 129217 ) 321, 013, 015 138, 023 244, 012 925 646 2 827531 156, 666 1 880, 0117 1026 155 1618 \\ (+) LRCM & - 862, 088 84, 860 960, 971 392, 056, 052 201 085 2 52631 2567 051 263733 2 84, 473 2 84, 476 0 2 38, 252 2 653, 253 2 149, 252 6 4 223 04 4 23 2 2 44, 451 2 103, 113, 012 1 23 1 44, 013 2 1 492 26 6 1 280, 0117 1 026 155 1618 \\ (-) Revenue tax & - 24446 1 3792 2 453, 263 2 401 193 4 17394 4 223 04 4 392 3 44, 44 2 2 34, 44 2 2 1 45 2 31 4 4 2 2 34 1 3 9 2 2 6 2 38, 26 4 1 193 4 17394 6 4 2 200 4 3 2 2 2 33 3 4 4 4 2 2 30 4 3 2 3 2 4 4 4 2 2 3 4 4 4 2 2 3 4 4 4 2 2 3 4 1 2 3 4 1 2 3 1 4 2 3 4 2 3 4 4 2 2 3 4 2 1 2 3 4 2 1 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 3 2 4 2 2 2 2$	(-) $O \& M_{WFCM}$			3 964 703	4 031 427	4 151 213	4 223 934	4 378 615	4471031 4	618 343 4	733 137 48	06905 492	8061 505.	5 095 5 221	459 5334	243 5433	856 5 642 7	44 579964	1 5899344	6 007 676	6 109 183	6357999	5 867 984	5 947 062	6 107 615	5277 939	5 427 1
$ (+) Rem_{malek} = - \frac{1.29441}{1.000} + \frac{1.29441}{1.000} + \frac{1.29441}{1.000} + \frac{1.29446}{1.000} + \frac{1.20420}{1.000} + \frac{1.2040}{1.000} $	$O\& M_{fixel}$			2 665 486	2 710 424	2 791 038	2 840 010	2 944 091	2 991 795	6000812 3.	168 081 32 .ce oec 1 er	17.896 3.29	9441 338	4934 3494	m 3572	748 3639	907 37802	77 388585 77 101260	5 3953081	4 026 113	4 094 576	4 261 785	4 359 507	4 418 743	4 538 523	1 665 578	1 776 9.
(*) Depreciation = 247060 - 288 26 - 557093 - 265 25 0 - 2701068 - 27857 - 287857 - 29877 - 29877 - 29847 + 29751 - 59614 + 29751 - 596257 - 298720 - 298720 - 59872 - 59872 - 598761 - 596257 - 298720 - 2987500 - 298720 - 298720 - 298720 - 298720 - 298720 - 298720 - 298720 -	(+) LRCM			863 268	884 850	126906	929 646	952 887	1 602.014	01 122 100	26 155 1 0	201 60815	8 104 1 102	5 057 1 132	683 1161V	000 1190(	725 1 219 7		-	-	-	-	-	-			
$ (=) Profile bertarx = - 3600 + 41 - 3749 \geq 21 - 344761 - 398.36 - 4011 + 93 - 423960 - 4330 \geq 4339 \geq 44534 + 6349 + 63$	(+) Depreciation			2 447 050	2 508 226	2570932	2 635 205	2 701 085	2768612 2	837 827 25	908 773 2 9	31 492 3 054	6030 313.	2 430 3 210	741 3 291	010 3373:	285 34576	17 354405	7 3 632 659	3 723 475	3 816 562	3 911 976	4 009 776	4 110 020	4212771	1318 090	426 0×
(A Revaine (ax - 1.294.48   316.27   1535.421   1579.265   429.551   425.98   500 (004   538.550   567.7   542.84   425.84   426.84   4	(=) Profit beföre tax			3 660 441	3 749 221	3 844 761	3 938 265	4 041 193	4117349 4	223 960 4	330 223 44	35471 454	7154 466	1869 4782	493 4901	280 5 021	684 51541	11 403475	7 4132514	4 233 226	4 335 636	4452912	3 081 782	3 170 072	3 248 001	326970	3 411 92
$ \begin{array}{cccccc} (+) REG (m) & (+)$	(-) Revenue tax	i	-	1 294 448	1 316 272	1 355 421	1 379 205	1 429 751	1452918 1	501 004 1.	538 530 15	52.723 160	2324 164	3 843 1 698	158 1735	054 1767	669 18358	01 1887 10	2 1919760	1 955 228	1 988 477	2 069 680	1 481 997	1 502 134	1542854	1586046	623.9
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	(+) KEPIM	,	241 /05	1 181	1071	1 25/	807 1	1502	1 3.20	1 3/0	1 404	4.20 I.4	. I 704	.00	9C T 00	0 I 0I	c/01 c	7/1	70/1	1 /84	1814	1 889	796 1	8661	110.7	/00/7	/117
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	DEP																										
GHGR_cut         -         1181         1201         127         128         1305         1326         1370         1404         1425           (=) Print/indertau wout interest         -         2.36(71         2.494.151         2490.577         2560.377         2353.275         2754.32         2560.77         2561.377         2563.375         2583.275         2754.35         2580.07         2581.17         2661.377         2561.37         2583.27         2969.37         2581.07         2661.77         2561.37         2581.07         2764.04         2873.17         2581.07         2661.77         2581.07         2661.77         2581.07         2661.77         2581.07         2661.77         2581.07         2661.73         2581.07         2661.74         2581.07         2661.74         2581.07         2661.74         2581.07         2661.74         2581.07         2661.74         2581.07         2661.74         2581.07         2661.74         2581.77         2581.07         2581.74         2581.74         2581.74         2581.74         2581.72         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74         2581.74 <td>OREP CU</td> <td>5</td> <td>541 763</td> <td></td> <td>,</td> <td></td>	OREP CU	5	541 763													,											
(=) Profit after tax wourd interest - 2367 174 2454 151 2400577 2560.319 2612 747 2665757 2734 325 2793 097 25874 (-) Dehtpoputatis	$GHGR_{CM}$			1 181	1201	1 237	1 258	1 305	1 326	1 370 1	404 1	426 1.4	62 1.5	00 155	1 58	3 1 615	3 1675	1 722	1 752	1784	1814	1 889	1 932	1 958	2 011	2 067	2117
(c) Debr payments	(=) Profit after tax w/out	interest		2 367 174	2 434 151	2 490 577	2 560 319	2 612 747	2 665 757 2	724 325 21	793 097 2 8	74174 294	6292 3019	9 526 3 085	884 3167.	810 3255	628 33199	48 214937	7 2214506	2 279 782	2 348 973	2385120	1 601 716	1 669 896	1 707 158	142 992	1 790 12
(+) fCM wr (+) Depreciation - 2 647 367 268 282 2734444 283 238 2983 999 2566 257 3040 433 3116 424 31943 (+) Depreciation - 2 447 660 288 226 2550 992 2 653 D0 C88 10 685 2 588 652 2887 827 298 73 2 884 (=) Free net configure - 99684137 7 438 963 4462 273 4580 41 460 115 4 796 812 4 904 424 5018 958 5145 075 5384 Externationations2.8415 47785 903 42216 (600 1385 258 73 728 552 288 451 42 - 8018 998 115 400 74 357 51 Externationations2.8415 47785 903 42216 (600 1385 258 73 728 552 288 451 42 - 8018 91 74 357 15 Externationations	(-) Debt payments				3 167 387	3 246 571	3 327 736	3 410 929 5	3 496 202 3.	583 607 3 62	73.197 3.76	. 027 3 859	153 3955	632 4 054 5	23 4 155 86	16 4 259 78	13 4 366 275		•	•	•	•	•				1
(+) Pupreciation 2487 060 2388 26 2501932 2653 26 2701 065 2769512 2637 2248 773 2584 4 (=) 584 17 2584 (=) 584 17 2584 (=) 45272 45804 (=) 4601	$(+) RCM_{WF}$			2 621 739	2 687 282	2754464	2 823 326	2 893 909	2 966 257	: 040 413 3	116 424 31	94334 327.	4193 335	6 047 3 435	949 3525	947 3614	096 3 704 4	48 379706	0 3891986	3 989 286	4 089 018	4 191 243	4 296 024	4 403 425	4513511	1 626 348	1 742 00
$\Sigma_{International contract} = -52.248 175 + 47.85 903 + 33.216501 + 38.525 387 - 32.824 152 - 23.806 194 - 18.660 (97 - 13.375 - 52.824 153 - 52.824 175 - 52.844 175 - 52.824 175 - 52.84$	(+) Depreciation	Ŷ	0.684.137	2 447 050 7 435 063	2 508 226 4 463 773	2.570.932	2 635 205	2 701 085 4 706 812	2 768 612 2	018 058 51	908 773 29. .45 007 5 35	81492 305 305 305	6030 313 7361 555	2 430 3 21( 3 371 5 687	051 58281	010 3373 881 5.0837	285 34576 226 61157	36 9.40040 36 9.40040	7 3 632 659	0 000 543	3 816 562	3911976	4 009 776 9 907 517	4 110 020	4212771	1318 090	1 426 04 0 058 17
	$\Sigma free net annum$	cashflow	1	52 248 175 -4	47 785 903	43 216 501 -5	8 525 387 -3	3 728 575 -2	8 824 152 -23	805 194 -18 (	560 097 -13 3	15 124 -7 95	7763 -2400	5 392 3 276	659 9105	540 15 088	766 21 204 5	02 30 694 99	5 40434147	50 426 690	60 681 243	71 169 583	81 077 099	91 260 440	101 693 880 1	12 381 310 1	23 339 4
LCOE 67.68 67.83 68.04 68.20 68.45 68.64 68.89 69.10 69.28			LCOE **	67.68	67.83	68.04	68.20	68.45	68.64	68.89 6	9.10 68	.28 69.	51 69.	74 70.6	12 70.2:	5 70.41	5 70.79	69.82	70.02	70.22	70.42	70.78	70.39	70.58	70.85	71.13	71.40

Table R.9 Cashflow for 25 years of th	re wind farm p	roject	50 000 K	w C	orvo Island	(Portugal)			wit	ı sensitivity	malysis of C	& M manag(A)	$+E_{pi}$ (Cas	(8 2											
Item	0	-	2	e	4	5	9	7	∞	6	10	11	Years	3 1	4 15	16	17	18	19	20	21	22	23	24	25
1000117	100 200 001																								
(-) LCCCM WF	106 622 00																								
$T_{CM}$	24 2 19 295		,	,	,			,	,		,		,	,	,	,				,	,		,		
LWTG CM	1 959 783																			•	•	•			
CP CM	1 545 346	,		,		,	,		,		,		,		,										
TS CM	572 832																								
SI CH	2 136 726																		• •						
For	188 559										,														
CCC CN	120211			,	,		,	,	,	,	,	,	,	,	,	,					'	,	,	,	,
LCPM WF (KWh/yr)	1	90 107 610	90 7 69 7 74	90 190 491	0 253 921	90 198 973	91 016 328 9	0 443 405 8	9858.042 90	685 374 90	00 678 90(	718 677 90 6	85 374 90 5	30 336 90 47	3 134 90 24	5 888 90 078	677 90 557	464 90 666	434 90 855 21	3 90 985 971	8 90 162 393	90 643 598	90 743 354 9	3 005 650 0	9 670 577
(+) AAR (SM/yr)	•	15 046 124	15 535 609	15 822 374	6 229 340	16 624 945	17 194 985	7 513 916 1	7 835 578 18	449 787 18	014 223 19 2	254 127 19 8	58 402 20 3	30 295 20 82	5 386 21 29	2 641 21 784	277 22 447	567 23 036	443 23 661 51	8 2428796	3 17 268 871	17 795 063	18 260 013 1	8 575 463 1	8 957 626
PPAR	,	15 046 124	15 535 609	15 822 374	6 229 340	16 624 945	17 194 985	7 513 916 1	7 835 578 18	449 787 18	014 223 19 2	254 127 19 8	58 402 203	30 295 20 82	5386 2129	2 641 21 784	277 22 447	567 23 036	443 23 661 51	8 24 287 96					
EMP	'	-	-	- 000 0	-	-	-			-		-		-		-	-	-		-	17 268 871	17 795 063	18 260 013 1	8 575 463 1	8 957 626
(-) U&M WFCM		9414550	to/ 07/ 6	710 006 6	0 154 527	0 401 931	01/2/2020	1 /68/660	11 820 661 1	243 192 11	555 040 12(	12 1 2 1 2 4	50.5/8 127	19 252 13 02	28 80 3 13 52	00/ 13 628	511 14 045	551 14411 200 2 100	233 14 802 50 201 7 200 20	22 200 200 200 200 200 200 200 200 200	CIS 212 81 0	PR2 CI0 CI	1 216 0/6 51	1 212 144 1	4 504 416
O&M pred		4 518 607	4 665 487	4 751 486	0160070	4/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0/0	2 163 313	CC6 040 C	2 060 000 0	0 009-000 0 239-736 5	10 6/C+C	+0 6/100 81008	19 102.55	110 700 CT	0.402 V 207 C	0 400 / 100 0 269 6 540	400 / 204	2667 290	76607 106	061667 15	100/200 2	116 117 0	5 482 807	907 100 0	2012 202
(+) LRCM	,	863 268	884850	176 906	929 646	952 887	976709	1 001 127	1 026 155 1	051 809 1	78 104 11	05 057 11	32 683 11	61 000 1 15	0 025 1 21	0.776									
(+) Depreciation		2 428 463	2 489 174	2 551 403	2 615 189	2 680 568	2 747 582	2 816 272	2 886 679 2	958.846 31	32.817 31	08 637 3 1	36353 32	66012 334	17 662 3 43	354 3517	138 3 605	066 3 695	193 37875	73 3 882 26	2 3 979 319	4 078 802	4 180 772	4 285 291	4 392 423
(=) Profit before tax		8 923 305	9188929	9 380 737	9 619 647	9 856 469	10 160 805 1	0 373 418 1	0.589.383 10	917 249 11	91497 112	11 636 117	57 060 12 0	38 075 12 33	14 220 12 62	2714 11 672	904 12 009	282 12 320	03 12 646 5	33 12 975 88	8 8 035 375	8 258 571	8 469 873	8 648 610	8 845 633
(-) Revenue tax	,	4513837	4660683	4746712	4868802	4 987 484	5 158 496	5 254 175	5 350 673 5	534 936 5	574 267 57	776238 59	50 521 60	99.089 6.24	17 61 6 6 38	792 6535	283 6734	270 6910	933 7 098 45	55 7 286 38	9 5180661	5 338 519	5 478 004	5 572 639	5 687 288
(+) REPIM	995 107	169	713	727	745	764	790	804	819	847	869	884	912	934	956 9	78 100	0 1 03	1 105	3 1 087	1115	1 133	1 167	1 198	1 219	1 244
$REI_{CM}$	•	,				,			,	,		,		,	,	,				'	•	'	,		,
$REP_{CM}$	,	,	,	,	,	,	,	,	,	,	,	,	,	,	,	,		,		'	'	,	,	,	,
$OREP_{CM}$	995 107			,	•				,		,				,						'	•	,		
$GHGR_{CM}$		691	713	727	745	764	790	804	819	847	869	884	912	934	956 9	78 100	0 1 03	1 105	8 1087	1115	1 133	1 167	1 198	1 219	1 244
(=) Profit after tax w/out interest	,	4410159	4528960	4 634 751	4751590	4869749	5 003 099	5 120 048	5 239 529 5	383 160 5	5 6 2 1 8 0 9 9 6 0	946 282 57	97 452 59	39 920 6 06	17 561 623	5 899 5 138	621 5276	043 5410	128 554910	54 5 690 61:	5 2855846	2 921 219	2 993 067	3 077 190	3 159 589
(-) Debt payments	'	,	3 143 328	3 221 911	3 302 459	3 385 021	3 469 646	556387 3	645 297 3	36 429 3 8	9 840 3 92	5 586 4 02	1726 412	4 319 4 227	427 4333	113				'	'	'	•		,
$(+) RCM_{WF}$	•	2 621 739	2 687 282	2 754 464	2 823 326	2 893 909	2 966 257	3 040 413	3 116 424 3	194334 3	274 193 33	356047 34	39.949 3.5	25 947 3 61	4 096 3 70	1448 3797	060 3 891	986 3989	286 4 089 0	8 419124	3 4 296 024	4 403 425	4 513 511	4 626 348	4 742 007
(+) Depreciation		2 428 463	2 489 174	2 551 403	2 615 189	2 680 568	2747582	2816272	2 886 679 2	958.846 31	32.817 31	08 637 31	86353 3.2	66012 334	17 662 3 43	354 3517	138 3 605	066 3.695	193 37875	13 3 882 26	2 3979319	4 078 802	4 180 772	1 285 291	4 392 423
(=) Free net cashflow	-59 230 794	9 460 360	6 562 088	6718708	6 887 646	7 059 206	7 247 292	7 420 346	7 597 334 7	2 116 662	95 269 81	85 381 84	0 0 2 8 6	07 561 8 82	1 892 9 03	8 589 12 452	818 12 773	095 13 094	906 13 425 75	55 13 764 120	0 11 131 189	11 403 446	11 687 349 1	628 886 1	2 294 019
$\Sigma$ from a model or difference		49 770 434 -	43 208 345 -	36 489 638 -	29 601 992 -	22 542 786 -	15 295 494	7 875 149	-277 814 7	522 096 15	17 365 23	02 746 32 1	02 774 40 7	10 335 49 53	2 227 58 57	816 71 023	635 83796	730 96 891	337 110 317 0	91 124 081 21	2 135 212 401	146 615 847	158 303 196	70 292 025	182 586 044
Precence annual cashipa n	LCOE	73.13	73.52	73.79	74.13	74.47	74.93	75.23	75.53	76.02	6.41 7	6.73 7.	.23 7.	7.63 78	.06 78.	17 77.6	5 78.1	5 78.6	79.12	19.67	77.73	78.24	78.71	79.06	79.47
Table R.10 Cashflow for 25 years of	the wind farm,	project	50 000 K	M N	ape Saint Ja	ames (Canad	(1		wit	n sensitivity	malysis of C	& M manag(A)	$+E_{pi}$ (Cas	(8)											
Item	0	-	2		4	5	9	7		6	10	1	Years	3	4	16	17	18	19	20	21	22	23	24	25
	100 999 00																								
(-) LCCCM WF WT	106 022 00																								
Tour	24.2.19.2.95		,	, ,	,			,														,			
LWTGOL	1 959 783													,											
CP.cv	1 545 346	,				,			,	,		,		,	,	,				,	,	,	,		,
TSCM	572 832						,				,														
SIGU	2 136 726																				,		,		,
$PO_{CM}$	1 796 870				,								,								'	•	,		,
$F_{CM}$	188 559	,			•	,			,	,		,		,	,	,			·	'	'	'	,		,
CCC CM	120211	,				,			,	,		,		,	,	,				'	,	•	,		,
LCPM <sub>WF</sub> (kWh/yr)	,	213 509 813	214 144 266	214 761 434	213 197 728	213 611 337	214 144 266	13 197 728 2	13 197 728 21	4761434213	611 337 214	144 266 213	525 948 213	197 728 214 8	32 689 214 3	8 805 214 832	689 214 501	803 214761	434 214 832 6	89 214 038 94	214 203 964	213 197 728	214 523 412	13 625 948	214 387 639
(+)AAR(SM'yr)		30 276 974	31 126 117	31 996 219	32 557 331	33 436 006	34 357 409	5 060 685 3	5 937 202 37	105 804 37	388 29 772 388	872.255 39.7	47 622 40 6	59 646 41 99	5 741 42 94	676 44 121	775 45 155	164 46 340	065 47 514 32	26 48 522 24	4 34 841 551	35 544 828	36 659 995 3	7 419 293 3	8 491 531
PPAK		30 2 76 9 74	31 126 117	31 996 219	52 557 351	33 4 36 006	34 357 409	5 060 685 3	5 957 202 37	105 804 37	29.772 388	12255 397	17 622 40 6	59 646 41 95	5 741 42 94	0.6/6 44 121	775 45 155	164 46 340	05 47 514 5	26 48 522 24		-			
(-) O& M mean		00688.700	808 897 10	21 863 324	2 246 612	22 846 890	198.9478.0	3 956 782 2.	- 225 525 1	353 946 25	- 96 367	20.685 271	58.681 277	- 28.60	- 2034	-	919 30.852	- 31 662	- 32 464 5	- 33 153 083	100 140 40 8	396 746 06	5 106 200 05	5 109 CIL I	50K 129 C
O&M Breed	,	11 600 929	11 926 280	12 259 661	12 474 651	12 811 317	13 164 355 1	3 433 815 1	3 769 654 14	217 407 14.	94 795 148	94 225 15 2	29 623 15 5	79 065 16 06	0 994 16 45	346 16905	588 17 301	532 17755	529 18 205 4	18 591 63	1 19 071 110	19 456 054	20 066 453 2	0 482 061 2	1 068 961
$O\&M_{whable}$	'	9 087 862	9342619	9 603 663	9 771 962	10 035 573	10312006	0 522 968 1	0.785 923 11	136 539 11	353 703 11 6	66 460 119	29 059 12 2	02 65 6 12 60	3 521 12 88	8 791 13 241	331 13 551	341 13 906	817 14 259 05	7 14 561 45	4 10457250	10 668 211	1 102 791 1	1 230 560 1	1 552 248
(+) LRCM		863 268	884850	176 906	929 646	952 887	976 709	1 001 127	026155 1	021 809 1	78 104 1	05 057 11	32 683 11	61 000 1 15	0 025 1 21	0.776						•			
(+) Depreciation		2 383 816	2443412	2 504 497	2567109	2 631 287	2 697 069	2 764 496	2 833 608 2	904 449 2	77 060 3(	51486 31	27773 32	05 968 3 28	6117 336	8 270 3 452	477 3 538	788 3 627	258 371792	10 3 810 88	3 3 906 160	4 003 814	4 103 910	4 206 507	4 311 670
(=) Profit before tax		12 835 269	13 185 480	13 544 363	3 807 474	14 173 290	4 554 827	4 869 525 1	5 241 389 15	708 116 16	16437 164 164	68 113 168	17.2 TT 17.2	44 892 17 7	7 367 18 19	584 17 427	332 17 841	080 18 304	11 18 767 72	10 19 180 04	1 9219351	9 424 378	9 694 662	913 180 1	0 181 992
(-) Revenue tax	- 0.04.042	9 083 092 2 072	9 337 835	9 598 866 2 104	976/199	3 3 3 9	3.420	3 500	2.500 2.500	37.04	948 931 11 0	611 0/1 119 1 881 3	24 287 12 1	97.894 12.55 050 A	102 1288	1003 13 236	553 13 546 5 A 50	549 13 902 s 463	019 14 254 25 5 4 744	14 14 556 67. 4 944	5 10 452 465 4 060	10 663 448 5 060	10.997.999 1 5 220	5 227 788	5.400
(+) MELIN	CH0 +00 7	C70 C	101 0	<u>t</u> , '	007.0	0000	00+c	0000	00000	•		C 100	* '	*	7 +	06 1	R+ 	* *	****	1 011	4 202	600 C	677 0	1000	- D6+ C
BED																									
ORFP	2 084 043																								
GHGR CM		3 023	3 107	3 194	3 250	3 338	3 4 30	3 500	3 588	3 704	1777 3	881 3	968 4	059 4	193 42	88 440	5 450	8 462	4 744	4844	4 969	5 069	5 229	5 337	5 490
(=) Profit after tax w/out interest	,	3 755 199	3 850 753	3 948 691	4 043 525	4 145 826	4 251 034	4 354 820	4 463 816 4	580 079 4	91 282 48	810.317 4.9	29 079 5 0	51 057 5 18	12 838 5 31	869 4195	205 4 299	039 4407	584 451810	6 4 628 21	5 -1 228 145	-1 234 001	-1 298 109 -	1 307 271	1 359 978
(-) Debt payments	,		3 085 539	3 162 678	3 241 745	3 322 788	3 405 858	491 004 3	578 279 34	67 736 37.	9 430 3 85	3 416 3 9 46	751 4.048	3 495 4 1 49	707 4 253	150						,			
$(+) RCM_{WF}$		2 621 739	2 687 282	2754464	2 823 326	2 893 909	2 966 257	3 040 413	3 116 424 3	194 334 3	274 193 33	856047 34	39.949 3.5	25 947 3 61	4 096 3 70	1448 3797	060 3891	986 3989	286 40890	8 419124	3 4 296 024	4 403 425	4 513 511	4 626 348	4 742 007
(+) Depreciation		2 383 816	2 443 412	2 504 497	2567109	2 631 287	2 697 069	2 764 496	2 833 608 2	904 449 2	77 060 3 (	51486 31	27773 32	05 968 3 28	16117 336	\$ 270 3 452	477 3 538	788 3 627	258 371794	10 3 810 881	3 3 906 160	4 003 814	4 103 910	1 206 507	4 311 670
$(=)$ Free net cashflow $\Sigma_{c}$	-58 141 858	8 760 754	5 895 907 42 485 196	6 044 975	6 192 215 21 748 006 -	6 348 234 24 809 777 -	6 508 502	6 668 725	5 835 568 7 • • • 6 978 2	011125 7	105 73 105 73	864435 75 51687 747	47 050 77 • • 737 31 9	34478 795	(3.343 8.13) 16.558 48.01	0 138 11 444	741 11729	813 12 024	128 12 325 12 277 95 540 54	23 12 630 34' W 108 130 84	0 6974.040	7 173 238	7 319 312	7 525 585	7 693 699
🗠 preena annual casnyarn	ICOF	-07 10C 40-	20.29	01 775 V	01 272 000	4 02 02	97.65	04.22	* 000 210	00.62	0.12 0.0	0 30 10	0 101 01	0.00 03 02 03 0	77 00	1.00 01	- 010 - 210	242 0.141	011 20070	07.67	or of	04.75	05.87	00 5K	07.50
	LCOE	84.40	85.07	85.75	86.23	86.92	87.65	88.22	88.92	89.83	0.43	4.25 9.	-96 -	2.69 9.5	.72 94.	F 16 61	7 94.9	8.09 7	87.96.78	97.57	94.05	94.75	95.81	96.56	97.59

## **APPENDIX S**

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend		ĺ		_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{cos})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
				а Г										<b>r</b>	
Wind Project Information	F	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public Inc	centive Model	Notes	Wind Farm Life	<ul> <li>Cycle Prod.</li> </ul>	ction Model	Notes
Project Name	Aracati (Brazil)		Depr	76 9840	[\$/KW] [\$/VW]	DC.M WF PM ww	22 3284	[5/KW] [5/FW]	ICCCM we	1 204 5180	[5/KWc] [5/VW]	WF CM		50.000	[KW / yr]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF com	50 000	[kW]	LRCM	16.8443	[\$/kW]	N <sub>WT</sub>		25	[_]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	Ν	25	[yr]	Mhran	100	[m-h]	$\psi_{actal}$	25.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMBreakyr	85.00	[\$/m-h]	n ,,	5	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>mawar</sub>	3	[-]	REP CM	0.00002484	[\$/kW <sub>e</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>m sweet</sub>	2.0	[d]	AEP anait/H prod	5 696	[kW/yr]	L <sub>x</sub>		1 800	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033	[\$/kW]	C <sub>mfmyr</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Tampin monoity factor $(\pi)$	10.0	[m]	Π	1 798 743	[\$/kW]	RM cr	20.1954	[S/KW]	E	0.1415	[\$/KW_h]	SD		450	[m]
Betz Limit's coefficient (Cas . )	0.5926	[-]	V V	£ 100,000	[KW] [FW]	WP cap N mm	25	[_]	n	0.100194	[3/KW dl]	FIH (		8 760	[11] [h/vr]
Lifetime of Wind Farm (N)	25	[vr]	v 0 C 0	1 457.72	[k/r]	Mw	3.0	[m-h]	OREP CH	20,7516	[\$/kW_]	PC RM		0 100	[10]1]
Production Efficiency (WF PF)	11.2%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[\$/m-h]	LCCCM	4.3886	[\$/kW]	AEP avail		48 979 624	[kW_h/yr]
Availability	98.2%	[%]	Ь	-1.94	[-]	N	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{max}$		20.98%	[%]
	358	[d/yr]	LRCM	16.8443	[\$/kW]	$D_{m_{BUCC}}^{m_{CT}}$	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{out}}$		25.00%	[%]
				_		C <sub>md mer</sub>	3 500.00	[\$/d]	$\Psi_{astal}$	25.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capite	al Cost Model	Notes	Wind Farm O&M Cost 1	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>faul</sub>	0.098275	[\$/kWh]	$WF_{cap}$	50 000	[kW]	n ,.	12	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	NWT	25	[-]	CRf	60.0%	[%]	AEP rated		438 000 000	[kW <sub>c</sub> h/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	2 427.4170	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>br sur</sub>	3.0	[m-h]	$\sum_{AEP} AEP$	31.4	[tCO2/MW2h]	λ <sub>a</sub>		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMbrsanv	85.00	[S/m-h]	null_mull_p_1===p_n	48 856	[MW <sub>e</sub> h]	A		0.00%	[%]
T CM	484.3839	[5/KW]	ogen	0.025839	[%/yr] [\$//Wb]	D N <sub>m</sub> <sub>un</sub>	30	[-]	n, GHG	0.00059	[yr]	2		5.00%	[%]
P marr	26 206	(*5)	MIC	71 5609	(\$%)	C .	2 500.00	(C)	GHG	0.00005	peoparticat	I CPM		48 979 624	D/W b/ml
C	0.1900	[%/3/KW]	TIC	124 5688	[3/1] [5/b]	PVM wer	61.0184	[3/4] [\$/JW]	C C C C C C C C C C C C C C C C C C C	41 7438	[8/(CO <sub>2</sub> )	LCI M WF		40 777 024	[KWellyi]
I WIG out	39 1957	[3/Kg] [S/m/kW]	R.	30.00%	[96]	N wa	25	[3%]	Berein REPIM distribution	100.0%	[%]	Project Finan	rina	Г	Notes
WF	50 000	[kW]	ifr	2.50%	[%/vr]	WTS vie	1.4442	[\$/kW]	ξ, RELOV	50.0%	[%]	Debt ratio		50.0%	[%]
L,	13 950	[m]	N	25	[yr]	WF	50 000	[kW]	ζ, REP CH	25.0%	[%]	Debt term		14	[yr]
CAB cont	2 000.00	[\$/m]	n mih	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 OREP_{CM}$	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	90	[h]	Ν	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	0.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	4 202 942	[\$M]	WTweight	200 000	[kg]	REPIM	39.7344	[\$/proj]	Debt value		29 551 422	[\$]
ç	0.08%	[%]	AEP anail	48 979 624	[kWh/yr]	C steel	0.1900	[S/kg]				Debt pa	yments	2 985 402	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.124114	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	2	50.0%	[%]
TLc	0.0400	[\$/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 551 422	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanag(B)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
L <sub>1</sub>	3 000	[m]	SC ORM	0.000105	[\$/kWh]	Ν	25	[yr]	BRL/USD dec2010	0.5986	[-]			,	
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	67.6693	yr 1	70.7843	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			67.8196	$yr_2$	69.8148	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000229	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	68.0301	yr 3	70.0062	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	Nwr	25	[-]	January	744	738	(%) ccm	80.0%	[%]	68.1907	$yr_4$	70.2090	yr 17
Bld area	300.0	[m <sup>4</sup> ]	Frequency	1.8	[per yr]	February	672	641	KEPIM			68.4452	yr <sub>5</sub>	70.4052	yr 18
FC CM	35.9374	[\$/KW] (\$/14W)	Repair time	2.0	[n] (h)	March	744	757	EFIM distribution	1	[1/0]	68.0285	yr 6	70.7652	yr 19
PJ DT	19.88	[3'KW] [\$/FW]	SC+USC	162.0	(h/vr)	May	744	737	E REP	1	[1/0]	69.0922	977 NT.	70,5607	37 20 VF
FG	404 52	[5/kW]	SC O&MTOSC O&M	0 000324	(S&Wh/wr)	Jung <sup>(*)</sup>	720	689	Č, OREP.CH	1	[1/0]	69 2651	37.8 NT 0	70.8306	37 21
Fou	3 7712	[\$/kW]		0.000334 [		July	744	737	ŠA GHG R CH		[1/0]	69.4927	VT 10	71 1149	37 22 VT 23
WACC mpi	4.900%	[%/yr]		Г		August	744	737	P&D <sub>LM</sub>		[170]	69.7293	yr 11	71.3767	yr 25
n fin	1.0	[yr]				September	720	713	λa	1	[1/0]	70.0108	yr 12	69.6873	Mean
W <sub>FOV</sub>	0.30%	[%]				October	744	737	$\lambda_{xdi}$	0	[1/0]	70.2358	yr 13	1.0827	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	689	$\lambda_d$	1	[1/0]	70.4493	yr 14	-0.4490	Y (skewness)
ĸ	0.20%	[%]				December	744	737	λ,,,	1	[1/0]	LCOF	69.6873	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 600		p.s.: 1= yes as	nd 0=no		0.069687	US\$/kWh	

**Figure S.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* 1). Source: Own elaboration

Lept         Name         Description         Name	LCOE wso Mode	l Inputs									Financial Ind	exes		Notes
$ \begin{array}{        \\                              $	Legend				_			Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Green cells indicate information and an	re updated	0& M warranty conditi	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[S/kWh]		$MC_A$	50	[\$/kW]
$ \begin{array}{                                    $	Yellow cells are for use input informatio	on about the project.	Concerned to manufactures (0.6M	80.00% [%]	Depreciation rate per year	4.00%	[%/vr]	Expected Market Price	0 11403	[S/kWh]		WACC	4 9000%	[%/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Grav calle are not used		Daried of moments (m. )	5 (m)	Daried of despeciation	25	(rec) (rec)	DRAR and EMP entire	70.00%	(0.1.1.1)		UCPE	0.070242	1.1
Num         Num <td>Only can be not and.</td> <td></td> <td>rende of warranty (nw)</td> <td>5 [yī]</td> <td>Period of depreciation</td> <td>23</td> <td>[y1]</td> <td>FFAR and EMF fatto</td> <td>70.00%</td> <td>[70]</td> <td></td> <td>CCM</td> <td>0.070245</td> <td>[-]</td>	Only can be not and.		rende of warranty (nw)	5 [yī]	Period of depreciation	23	[y1]	FFAR and EMF fatto	70.00%	[70]		CCM	0.070245	[-]
$ \begin{split} & mem mem mem mem mem mem mem mem mem mem$	Wind Project Information	Note	Levelized Replacement	Cost Model Notes	Wind Farm Removal	Cost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Project Name	Firestar Wind Farm	AR CM	16.8442 [S/kW]	DCM WF	1 339.9154	[\$/kW]	REI CM	69.0930	[\$/kWe]	WF CM		50 000	[kW <sub>o</sub> /yr]
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Project Location	Corvo Island (Portugal)	Depr <sub>WT<sub>int</sub></sub>	76.9840 [S/kW]	RM WT	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
$ \begin{array}{c ccccc} \begin{tabular}{ cccccccccccccccccccccccccccccccccccc$	Turbine Model Number of Wind Turbines (N )	vestas v90-2M W	WT <sub>CM</sub>	553.7256 [S/KW] 494.2950 [S/KW]	WF cap	50 000	[kw]	LRCM	16.8443	[\$/KW]	N <sub>WT</sub>		25	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Turbine Size	2.000 R/W	I CM	404.30.39 [3'KW] 25 [yr]	M wr M.	100	[-] [m-h]	lfr W	25.00%	[%]	N N		2 000	[-]
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Wind Farm Capacity (WF can)	50 000 [kW	ifr	2.50% [%/yr]	C <sub>Mbran</sub>	85.00	[\$/m-h]	n	5	[vr]	N cal		5	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Rotor Diamenter (D)	90.0 [m]	Depry	60.1398 [\$/kW]	N <sub>mather</sub>	3	[-]	REP CM	0.00000982	[\$/kW_ch]	D		90.0	[m]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Swept Area per Turbine (A)	6 361.7 [m <sup>2</sup> ]	Y <sub>RC</sub>	15 [yr]	D <sub>m may</sub>	2.0	[d]	AEP avail/Hprod	10 458	[kW/yr]	L		1 800	[m]
$ \begin{split} &                                    $	Hub height (H)	105.0 [m]	TO CM	0.000033 [S/kW]	$C_{md_{MNT}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	$L_{x_{col}}$		2 430	[m]
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Wind speed measured at $(H_0)$	10.0 [m]	П	1 798 743 [\$/kW]	RM CT	20.1954	[\$/kW]	8	0.1027	[\$/kWeh]	SD <sub>xm</sub>		450	[m]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Terrain rugosity factor (a)	0.14 [-]	V	237 699 000 [kW]	WF cap	50 000	[kW]	£0	0.067500	[\$/kW_eh]	SD <sub>scal</sub>		540	[m]
$ \begin{array}{c} r_{\alpha} & r_{\alpha} & r_{\alpha} & r_{\alpha} \\ r_{\alpha} & r_{\alpha} $	Betz Limit's coefficient (C pBetz)	0.5926 [-]	Vo	6 100 000 [kW]	N WT M	25	[-] [m.h]	OPER	22 6767	[yr]	FLH <sub>wf</sub>		8 /60	[h/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Production Efficiency (WF as)	20.6% [%]	C 0 PP	0.70 [-]	$C_{10}$	85.00	[S/m-h]	LCCCM	3.8789	[3/kW]	AEP .		90 107 610	[kW h/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Aváilability	98.4% [%]	h	-1.94 [-]	N_	3	[-]	LCCCM <sub>W.E</sub>	1 204.5180	[\$/kW]	η		20.98%	[%]
$ \begin{array}{c ccccc} \hline War are Higher ar$		359 [d/yr	LRCM	16.8443 [\$/kW]	D <sub>m</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{mer}$		25.00%	[%]
New Life-Cycle Capitel Can Madel         New Mark Life-Cycle Capitel Capi					C <sub>nd ma</sub>	3 500.00	[\$/d]	$\psi'_{solal}$	25.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Wind Farm Life-Cycle Capito	al Cost Model Note:	Wind Farm O&M Cost	Model Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	NWT		25	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WT <sub>CM</sub>	553.7256 [S/kW	O&M find co	0.098275 [\$/kWh]	WF cap	50 000	[kW]	n "	17	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	CM WT	265.32 [S/kW	LCCCM WF	1 204.5180 [S/kW]	$N_{WT}$	25	[-]	$CR_f$	60.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
$ \begin{array}{cccccc} C_{ac} & 400.0 & [5.W] \\ \mu T & 000.0 & [5.W] \\ T_{cu} & 484.88 & [5.W] \\ T_{cu} & 186.00 & [b] \\ \mu $	RC WT	73.70% [%/\$/k	n <i>a</i>	0.000001% [%]	Awr	43.00	[m <sup>2</sup> /wt]	GHG.R CM	1 248.5415	[S/tCO <sub>2</sub> ]	$P\&D_{LM}$			
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	C <sub>kW</sub>	400.00 [\$'kW	LLC	0.0530 [\$/kWh]	MARTIN	3.0	[m-h]	$\sum_{AEB}$	57.6	[tCO2/MW,h]	2		7.00%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	IPI T	10.00% [%]	N	25 [yr]	C Marsany	85.00	[5/m-h]	rata and v_1+_+v_a	89.657	[MW <sub>e</sub> h]	A 141		0.00%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	T CM	484.3839 [3'KW 138.000 [kg]	197 O&M	0.048925 [%/yt]	D N M MARY	30	[-]	n , GHG	0.00069	lyrj ICO-MW N	2		5.00%	[%]
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	RC =	26 30% [%/\$/k]	0 MIC	71 5608 [S/h]	$C_{md}$	3 500 00	[8/d]	GHG	0.00005	ICO./MW.bl	LCPM		90 107 610	[kW b/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Curre	0.1900 [S/kg	TLC	124.5688 [\$/h]	RVM w.c	61.0184	[\$/kW]	E	11.7000	[\$/tCO <sub>1</sub> ]	WF			(,,)
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	LWTGCM	39.1957 [\$/m/k	Runa	30.00% [%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Proiect Finan	cing	1	Notes
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WF cap	50 000 [kW	ifr	2.50% [%/yr]	WTS VM	1.4442	[\$/kW]	$\xi_1 REI_{CM}$	50.0%	[%]	Debt ratio		50.0%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$L_g$	13 950 [m]	N	25 [yr]	WF cap	50 000	[kW]	$\xi_2 REP_{CM}$	25.0%	[%]	Debt term		14	[yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	CAB cost	2 000.00 [\$/m]	n <sub>mlb</sub>	48 [h]	ifr	2.50%	[%/yr]	$\xi_3 \text{ OREP}_{CM}$	25.0%	[%]	Debt gri	ace period	1	[yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	CP CM	30.9069 [S'kW	n <sub>tih</sub>	100 [h]	N	25	[yr]	$\hat{\zeta}_4 GHG.R_{CM}$	0.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	EF c	400.00 [\$/kW	AAR	14 679 146 [\$M]	WTweight	200 000	[kg]	REPIM	42.9657	[\$/proj]	Debt value		29 470 640	[\$]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	5	0.08% [%]	AEP anail	90 107 610 [kWh/yr	C steel	0.1900	[\$/kg]	<b>n</b> 1	i i	N. c	Debt pa	yments	2 977 241	[\$/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	IS <sub>CM</sub>	11.4566 [S/kW	O&M WFCM	0.14/200 [\$/kWh/yr	IS VM	0.9965	[\$/kW]	Exchange rates	1 2252	Notes	Equity ratio	,	20,470,640	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1L <sub>c</sub>	0.0400 [5/m]	OFM	Natas	WF cap	30'000	[KW]	EOR/OSD dec2010	1.3232	[-]	Discourse	aiue	29470640	[3] (0( (m))
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	11.	1 200 [1/kW 3 000 [m]	SC on V	0 000038 (\$/1.WL)	ifr N	2.50%	[%/yr]	CAIN/USD dec2010	0.9998	[-] [_]	Discour	. ,C	9.00%	[%/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	SR	113.00 [\$/kW	Work days	2.0 [d]	T	138.000	[y+] [ke]	DALL 03D 202010	0.3980	[-]	Initial Results	Summary	of LCOE	Notes
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	SICU	42 7345 (8/2/2/2	Feh/Jun/Nov	6 (4)	RCM wr	1 278.8970	(\$/kW]	Conditions for LCOF	j	Notes	73 1255	xr.	78 4712	NT 16
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WF cm	50 000 [kW	Hours required	48.0 [h]			[4.4.1.]	O&M WECH			73.5187	yr.,	77.6515	yr 15
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	WTinst	42.5238 [S/kW	USC ORM	0.000138 (\$/kWh)	Hours Distribution	$FLH_{vc}[h]$	H mad [h]	O&M com	1	[1/0]	73.7873	YT 3	78.1612	VF 16
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	Bld cont	500.00 [\$/m <sup>2</sup>	NWT	25 [-]	January	744	740	(%) ccm	80.0%	[%]	74.1334	YF 4	78.6268	VF 17
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Bld area	300.0 [m <sup>2</sup> ]	Frequency	1.0 [per yr]	February (*)	672	648	REPIM			74.4746	yr s	79.1175	yr 18
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	PO <sub>CM</sub>	35.9374 [\$'kW	Repair time	4.0 [h]	March	744	736	REPIM distribution			74.9273	yr 6	79.6115	yr 19
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	FS	19.88 [\$/kW	Hours required	100.0 [h]	April	720	712	$\zeta_1 REI_{CM}$	1	[1/0]	75.2253	yr 7	77.7347	yr 20
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	DT	87.22 [\$/kW	SC O&M+USC O&M	148.0 [h/yr]	May	744	736	$\xi_2 REP_{CM}$	1	[1/0]	75.5275	yr 8	78.2446	$yr_{2I}$
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	EG	404.52 [\$/kW		0.000176 [\$/kWh/yr]	June <sup>(*)</sup>	720	696	$\xi_3 OREP_{CM}$	1	[1/0]	76.0152	$yr_9$	78.7103	yr 22
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	F CM	3.7712 [S/kW			July	744	736	S₄ GHG.R <sub>CM</sub>	1	[1/0]	76.4118	yr 10	79.0644	yr 23
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WACC proj	4.900% [%/y			August	744	736	r&D <sub>IM</sub>	1	(1/0)	76.7332	yr 11	79.4723	yr 25 Mawr
$ \begin{array}{c ccccc} c_{ca} & c_{ca} $	n fin Wr	0.30% [%]			October	744	736	2.41	0	[1/0]	77.6321	yr 12 yr 12	2.0151	SD
K         0.20%         [%]           LCCCM_wr         1 204.5180         [\$k\$w]             Total         [hbyr]         8 760         8 616             LCOE         \$	CCC CM	2.4042 [S/kW			November <sup>(*)</sup>	720	696	λd	1	[1/0]	78.0589	yr 14	-0.4631	Y (skewness)
LCCCM <sub>WF</sub> 1 204.5180 [\$kW] Total [hlyr] 8 760 8 616 p.s. 1= yes and 0=no 0.05667 US\$kWh	К	0.20% [%]	_11		December	744	736	λ	1	[1/0]	LCOF	76.8666	US\$/MWh	valid !
	LCCCM <sub>WF</sub>	1 204.5180 [\$/kW	1		Total [h/yr]	8 760	8 616		p.s.: 1= yes ar	nd 0=no	LCOE NED	0.076867	US\$/kWh	

**Figure S.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* 1). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend		ĺ		_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated vellow cells.		O&M warranty condition	15	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer $(O \& M_{out})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind During Information		Notor	Levelized Penlagement (	Cost Model	Natas	Wind Farm Removal C	ort Model	Natas	Panawahla Enargy Public In	cantina Madal	Notes	Wind Farm Life	Cycle Prod	uction Model	Natas
Project Name	Firestar Wind Farm	ivotes	AR cu	16 8442	(\$/kW)	DCM we	1 339 9154	INDIES [S/kW]	Relew	69,0930	[S/kW_]	WE cu	-c,ete 170a	50.000	[kW_/yr]
Project Location	Cape Saint James (Canada)		Depr	76,9840	[\$/kW]	RM wr	22.3284	[5/kW]	LCCCM WF	1 204,5180	[\$/kW]	WFam		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF car	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	(-)
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	$M_{hr_{max}}$	100	[m-h]	$\psi_{aobal}$	25.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	$C_{Mbr_{EM_{HT}}}$	85.00	[S/m-h]	n ,	5	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>manyo</sub>	3	[-]	REP CM	0.00000049	[\$/kW_eh]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]	D <sub>m store</sub>	2.0	[d]	AEP anail/H prod	24 762	[kW/yr]	L.,		1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	$C_{ml_{ml_{WT}}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L		2 4 3 0	[m]
Wind speed measured at $(H_0)$	10.0	[m]	TI	1 798 743	[\$/kW]	RM cr	20.1954	[\$/kW]	£	0.0121	[\$/kW_eh]	SD <sub>3</sub>		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.008998	[\$/kW <sub>e</sub> h]	$SD_{x_{col}}$		540	[m]
Betz Limit's coefficient (C <sub>PBetz</sub> )	0.5926		$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>z</sub>	12	[yr]	FLH <sub>wf</sub>		8 /60	[h/yr]
Lifetime of Wind Farm(N)	25	[yr]	C 0	1 457.72	[\$/kW]	M <sub>krmc</sub>	3.0	[m-h]	UREP CM	90.2196	[S/KW <sub>e</sub> ]	PC PM		212.042.465	11.317 h (m.)
Production Efficiency (WP PE)	48.0%	[%]	PR	0.70	[-]	N MURCT	85.00	[5/m-n]	LCCCM WFORMCM	4.3880	[3/KW]	ALP anall		212 943 465	[KW en/yr]
Availability	98.2%	[%]	b	-1.94	[-]	D	3	[-]	LCCCM <sub>WF</sub>	1 204,5180	[5/KW]	n n		20.33%	[%]
	338	[d/yr]	LRUM	10.8443	[\$/KW]	C "MCT	2.0	[d]	WACC proj	4.9000%	[%/yr]	Twees and		25.00%	[%]
Wind From Life Cools Cools	-I Cont Model	N. 1	Wend From ORM Cost	4-4-1	N /	C a DU	3 300.00	[5/0]	9° aodal	25.0%	[%]	PaD <sub>IM</sub>	factor	0.814145	
wina Farm Lije-Cycle Capia	ai Cosi Model	notes	ound Farm Own Cost N	0 000275	Notes	Sarv	1 297.3916	[5/KW]	ıjr	2.5%	[%/yr]	IV WT		(2017	[-]
WI CM	355.7250	[\$/KW] (\$/14W)	LCCCM	1 204 5190	[\$/KWI] (\$/4W)	WF cap	30 000	[KW]	n ,	FD (06)	[yr] (95)	AFR		428 000 000	[m <sup>-</sup> ]
RC	73 70%	[3/KW] [96/S/FW]	m	0.0000001%	[3/6/1]	A	43.00	[=] (-2/)	CHG R	6 827 9057	[20] [S/(CD,1	R&D		438 000 000	[Kw cu/yr]
C	400.00	(%//W)		0.0530	(S/Wh)	M <sub>WT</sub>	3.0	[m/wt]	LCFR	136.4	ICO AWE	1 acD IM		7.00%	[96]
IPT	10.00%	[%]	N	25	[ork() II]	C	85.00	[S/m-h]	$\sum AEP$	212.467	(MW h)	2		3.00%	[%]
Tau	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N N	3	[-]	<i>R</i> =	25	[vr]	Â		5.00%	[%]
T marr	138 000	[kg]	O&M variable	0.041526	[\$/kWh]	$D_m^{MN}$	3.0	[d]	GHG <sub>pu</sub>	0.00069	[ICO./MW.h]	λ		5.00%	[%]
RCT	26.30%	[%/\$/kW]	MLC	71,5608	[\$/h]	C <sub>md</sub>	3 500.00	[\$/d]	GHG	0.00005	ItCO-/MW.hl	LCPM <sub>WE</sub>		212 943 465	[kW.h/yr]
Cuted	0.1900	[\$/kg]	TLC	124,5688	[S/h]	RVM w.e	61.0184	[\$/kW]	E EN west CO2	27.0000	[\$/tCO <sub>2</sub> ]				
LWTG CM	39.1957	[\$/m/kW]	Riser	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Proiect Finan	cing	Г	Notes
WF.com	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\xi_1 REI_{CM}$	50.0%	[%]	Debt ratio	0	50.0%	[%]
L,	13 950	[m]	N	25	[yr]	WF car	50 000	[kW]	ζ, REP CM	25.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mih</sub>	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_{3}$ OREP CM	25.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tlh</sub>	90	[h]	N	25	[yr]	$\xi_4 GHG.R_{CM}$	0.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	29 460 159	[\$M]	WTweight	200 000	[kg]	REPIM	57.1014	[\$/proj]	Debt value		29 117 247	[\$]
5	0.08%	[%]	AEP avail	212 943 465	[kWh/yr]	C steel	0.1900	[S/kg]				Debt pa	yments	2 941 540	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.139801	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	,	50.0%	[%]
TLc	0.0400	[\$/m]				WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 117 247	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanag(B)	Γ	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC OBM	0.000024	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE was	]	Notes	84.3448	yr i	94.4360	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			85.0205	$yr_2$	94.1138	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000053	[\$/kWh]	Hours Distribution	$FLH_{yf}[h]$	H prod [h]	O&M com	1	[1/0]	85.7100	yr 3	94.9205	yr 16
Bld cont	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	86.1734	yr4	95.8186	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.8	[per yr]	February <sup>(*)</sup>	672	641	REPIM			86.8681	$yr_5$	96.7191	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	2.0	[h]	March	744	737	REPIM distribution			87.5940	yr <sub>6</sub>	97.4969	yr 19
FS	19.88	[\$/kW]	Hours required	90.0	[h]	April	720	713	REI CM	1	[1/0]	88.1682	yr 7	93.9817	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	162.0	[h/yr]	May	744	737	REP CM	1	[1/0]	88.8666	yr <sub>8</sub>	94.6831	yr 21
EG	404.52	[\$/kW]		0.000077	[\$/kWh/yr]	June <sup>(*)</sup>	720	689	OREP CM	1	[1/0]	89.7788	$yr_9$	95.7335	yr 22
F <sub>CM</sub>	3.7712	[\$/kW]		_		July	744	737	GHG.R CM	1	[1/0]	90.3684	yr 10	96.5076	yr 23
WACC proj	4.900%	[%/yr]				August	744	737	$P\&D_{IM}$			91.1898	yr 11	97.5244	yr 25
n fin	1.0	[yr]				September	720	713	λa	1	[1/0]	91.9082	yr 12	91.7691	Mean
W <sub>F<sub>CM</sub></sub>	0.30%	[%]				October	744	737	$\lambda_{xdi}$	1	[1/0]	92.6296	yr 13	4.1987	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	689	24	1	[1/0]	93.6712	yr 14	-0.3338	Y (skewness)
K	0.20%	[%]				December	744	737	λ	1	[1/0]	LCOE was	91.7691	US\$/MWh	valid !
LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 600		p.s.: 1= yes as	nd U=no		0.091769	US\$/kWh	

**Figure S.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* 1). Source: Own elaboration

Months	P HC	1 (kg/m <sup>3</sup> )	Hprod Vr.						. er. ,	VF -	yr s	yr 9	yr 10	VF 11	VF 12	vr12	VF	40			VP 10	WF 10	WF 20	Vrai	UF 11	WF	
		(kg/m <sup>3</sup> )	(h) Vr	.0					, 40	21-7	$yr_8$	yr 9	yr 10	VF 11	VT 12	$V T_{I3}$	27.11			-	100 100	WF 40	27.00	UP 11	VF 11	27.00	
	(m/s) (.		1 21	5	r2 .	ر <i>د</i> ا	r4 .	yr s	<i>71</i> 0								P1 14	CI 16	yr 16	yr 17	Jr 18	21.12	07 .6	17.0	77.0	27 52	. 24
January	5.8	1.1665	738 1 693 1.	.32 8896	0 198 3 80	12 165 7 50	7410 55	7361 85	\$ 801.08 5	57361 5	57361 4.	32 212 8 i	8 80 198 8	\$ 861.068	557361 3	802 165 7	507410 4	232 212 8	8 801 98 8	861 068 8	557361 3	802 165 7	507 410 5	557361 3	802 165 7:	507 410 42	32 212 4.
February	4.9	1.1666	641 8504.	30 6805	3 436 3 6.	3 320 6 80	3 436 77.	598 65	803 436 7	79598 7	79 598 4.	727 258 6	803 436 6	803 436 ;	779 598 3	673320 6	803 436 4	483 758 +	483 758 5	3 300 063 4	4 727 258 3	716 188 1	577 029 1	577 029 7	716 188 6	803 436 47	27 258 4
March	4.0	1.1671	737 55651	07 7495	5 900 54.	18 155 887	6 568 97	78319 74	495 900 9	2 618319 5	78319 6.	560 068 7.	495 900 7.	495 900 5	378319 5	438155 8	876 568 2	\$96 836	896 836 1	1 814 186 4	4 225 724 1	814186 1	690 536 1	690 536 7	826 555 8	876.568 3.7	96335 6.
April	4.7	1.1667	713 86734	80 6344	4 604 63.	4 604 4 08	6931 16.	35 011 63	344 604 1	635 011 1	635 011 7.	3 200 6.	344 604 6.	344 604 1	754 600 6	344 604 4	086 931 5	946187	946187 1	1 635 011 6	5 344 604 1	635 011 3	671 646 9	046187 7	249 700 6.	344 604 17	54 600 7.
May	6.0	1.1670	737 18141	19 5437	7 953 7 49	15 621 5 43	7 953 18.	14119 54	437 953 1	814 119 1	814119 7.	826 264 5 -	437 953 5.	437 953 1	690 473 7	495 621 6	559 824 1	690 473 1	690 473	978 283 2	\$ 876 238	978 283	556486 8	896 803 6	559 824 4	225 566 1 6	90 473 7.
June	7.9	1.1686	689 39556	577 3955	5 677 73.	6 396 6 14	0.844 35.	53 729 35	955 677 3	553 729 3	553 729 8.	109 307 3	955 677 3:	955 677 3	553729 7	326396 5	090 627 1	698 250 1	, 698 250	839 524 3	7 326 396	839 524 8	839 524 3	553 729 5	090 627 5 (	090 627 9.	5 799 8.
July	8.6	1.1698	737 54509.	49 3805	5 267 8 89	7 452 1 69	4513 42.	35 665 3 8	805 267 4	235 665 4	235 665 5.	57816 5.	57816 3.	805 267 5	450 949 8	897452 1	818 455 3	805 267 3	3 805 267	557816	7 513 536	557816 5	980 621 4	235 665 4	235 665 1 (	694 513 89	8 946 5
August	9.6	1.1677	737 74997.	787 1815	5 127 18.	5 127 181	5127 88	3 1 1/1 18.	815 127 5	440 975 5	440 975 8.	97 302 8.	97302 1,	815 127 4	227915 1	815127 1	691413 5	: 440 975 7	7 830 614 7	7 830 614	897302 4	227915 7	830 614 5	440 975 1	815 127 1	815 127 52	6 795 8
September	10.1	1.1657	713 85769.	1635 1635	3 475 1 6.	3 475 3 66	8 197 7 50	62 383 I ¢	533 475 6.	338 644 6	338 644 9.	15 298 9.	45 298 1.	633 475 6	338 644 1	633475 3	668 197 6	338 644 7	7 242 889 7	7 242 889	945 298 3	254 599 8	576 955 6	338 644 1	633 475 3 (	668 197 63	38 644 9
October	9.7	1.1645	737 78090	182 976	135 97	5135 55:	: 264 74:	79 165 9.	76135 7	479 165 7	479 165 1 0	86 762 I (	586 762 9.	76135 8	826 751 \$	76 135 5	55 264 7	479 165 6	545 422 6	5 545 422	1 810 136 6	545 422 4	216 289 7	479 165 5	076135 9	76135 88	56 751 1
November	9.2	1.1638	689 61155	-94 836	072 83	5 072 836	072 61.	15 594 8:	36 072 7.	296 271 7.	296 271 1 (	(61 267 10	591 267 8.	36 072 7	296 271 8	36 072 8	36 072 7	. 296 271 5	: 069 696 5	2 069 696	1 575 994 6	9 610 886	115 594 7	296 271 8	836 072 8.	36 072 72	96 271 1
December	7.6	1.1651	737 37900	114 555	580 55.	5 580 976	690 54	29 099 52	55 580 8.	801786 8	861 786 3.	20 014 3	790 014 5.	55 580 7	483 417 2	55 580 9	76 690 8	861 786 4	1218 687 4	4 218 687	3 790 014 3	813 521 5	429 099 8	861 786 5	555 580 5.	55 580 74	83 417 3
Annual	7.4	1.1666	8 600 48 979 6	624 48 54	19 424 48:	94 102 48 3	09 002 49 (	021 215 48	1 549 424 4	8 970 644 4	3 970 644 45	473 266 45	496 226 45	8 549 424 4	8 968 028 4	8 794 102 4	8 470 887 4	19 169 824 4	19 318 276	48 922 388	48 589 860 4	8 172 649 4	8 991 802 4	8 874 151 4	8 297 112 48	393 836 48	547 502 48
le S.2 Energ	gy produc	stion map of	the wind farm f	for Corvo	Island (Pc	rtugal)		wit	th sensitivi	ty analysis	of O&M man	ig(B) + Epi	(Case 1)														
Months	$V_{HC}$	-	H <sub>prod</sub>												AEF	$a_{val}(kWh)$											
SHIDDA	(m/s) (.	$(kg/m^3)$	(h) $yr_I$	yı	r2 .	2F3 Y	T4	yr s	$yr_6$	yr 7	$yr_8$	$yr_{g}$	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	124
January	11.7	1.2313	740 14490	462 144:	(90 462 14	490 462 14.	190 462 14	: 490 462 I.	4 490 462	1 490 462	0 871 408 1	1 801 408 1	4 490 462 1	10 871 408	10 871 408	10 871 408	14 490 462	10 871 408	10 871 408	14 490 462	10 871 408	10 871 408	10 871 408	10 871 408	10 871 408 1	0 871 408 10	871 408 1
February	11.5	1.2345	648 12 092	721 4 29.	3 137 12	992 721 12 t	92 721 12	092 721 3.	417 096	12 092 721	2 715 785 I	795 784 3	417 096 1.	12 715 785	1 795 784 5	1 244 173	12 092 721 6	6 674 015	12 715 785	4 293 137	5 486 290	3417096	2 815 600	12 092 721 2	2 106 703 6	674 015 12	092 721 1
March	10.5	1.2329	736 10486.	228 3 19.	3 907 13	717 510 13 ;	717 510 13	717510 6.	223 433	1 217 510	3717510 2	389 762 3	193 907 1.	13 717 510 2	389 762	13 717 510	13 717 510 6	6 223 433	13 717 510	3 876 220	7 570 742	4 869 967	13 717 510	14 424 289 2	2 037 067 1	0 486 228 14	424 289 3
April	9.5	1.2317	712 7316:	597 73IA	6 597 10	458 483 10 4	158 483 10	458 483 7.	316 597	4 88 483 4	706 485 3	086 689 7	316 597 1.	13 257 022 .	3 086 689	13 257 022 4	1 706 485 4	4 706 485	13 257 022	3 086 689	10 134 212	3 086 689	13 940 075	13 257 022 3	3 086 689 3	086 689 13	257 022 3
May	8.2	1.2282	736 48510	676 104.	46 845 10	446 845 10 4	146 845 62	1 650 002	0 446 845 1	1 578 977 0,	0 446 845 3	861 662 6	200 059 1.	10 446 845	3 861 662	14 370 115 1	10 446 845	3 861 662	10 446 845	2 380 787	13 665 991	5 200 059 2	2 380 787	10 446 845 3	3 861 662 1	4 370 115 10	446 845 4
June	7.1	1.2224	696 2 994	461 12 8t	92 016 09:	97 981 7 09	9 L 186 Le	н 186 160	0 145 990 4	565 858	2 860 910 4	565 858 1	0 145 990 7	7 097 981 ×	4 565 858 3	7 097 981 2	240 532 2	2 994 461	7 097 981	1 909 861	12 860 910	7 097 981	198 606 1	7 097 981 4	1 565 858 1	2 860 910 7	97.981 5
July	6.1	1.2154	736 2 008	118 135.	22 571 4 8	00 760 61.	34 992 10	337 209 L	3 522 571 7	463 154 3	148 518 6	134 992 2	008 118 6	5 134 992 C	5134992 6	134 992 2	2 811 800	2 355 801 (	6 134 992	6 134 992	14 219 306	10 337 209 .	3 821 135 6	5 134 992 6	5 134 992 1	3 522 571 3.	21 135 7
August	6.4	1.2075	736 23404	496 10 51	6 899 86:	96310 373	36310 37	796310 1.	3 434 719 6	095 134 3	796310 7	414 668 2	340 496 4	( 769 571 )	7 414 668 4	1 126 571	10 598 668	1 995 072	4 769 571	13 434 719	1 995 072	13 434 719 4	4 769 571 4	1269 571 7	74146684	769 571 3	28 063 1
eptember	7.6	1.2064	712 3 669	202 1 92.	8 273 5 8	91 057 4 60	19876 46	509 876 4.	609 876 1	928273 5	891 057 9	9261899	926189 3	\$ 669 202	3 926 189	1 669 202 5	5 101 022	9 926 189	3 669 202	12 984 898	2 262 132	12 984 898	5 891 057 3	8 669 202 9	926189 3	669 202 2.	62 132 1
October	8.9	1.2126	736 6121(	079 612	1 0 20 3 1	41378 20	13 564 31	141 378 2	003 564 2	350 459 7	446 229 1	3 491 905 1	3 491 905 3	8 141 378	13 491 905	3 141 378	7 446 229	13 491 905	3 141 378	10 643 782	3 141 378	2 003 564	7 446 229 3	8 141 378	13 491 905 2	350 459 2	03 564 2
November -	11.5	+617.1	171 01 060	20 0 000	77 67463	77 04100	77 04100	c 0/0100	c 360 0L1	7 0/7/06	1 010 100	+ 0/6 670 7	7 0/0 #CC	C#1 CC7 2	- 0/6 670 71	< 010 100 7 041 007 3	077 /06 2	0/6 670 71	. UNA 100 C	10/ /00 6	072 000 0	C#1 CC77	7 10/ /00	- C#1 CC7 2	7 105 916 51	F 010 201	1 073 000
raumanar	C'11	1077.1	+10 CT 0.C/	107 404	17 1061	1 6 740 17	17 (())	C 740 170	C CCD D/T	7 647 /40	740 170	T 104 010 4	7 404 410 0	740 170 3	* 10± 010 ±1	740 170 3	647 /40	104 010 41	740 170 7	0/1 +1/ /	00C CC0 +	10+ 01C +1	7 404 410 01	740 170 3	0 104.010.41	+ 0160/1	1 000 00
Annual	1.6	1.2222	8 616 90 107	610 907.	69 774 90	190 491 90.	253 921 90	198 973 9	1 016 328	<i>10 443 405</i>	9 858 042 5	9 685 374 5	0 700 678 5	90 078 677	90 685 374	90 530 336	90 473 134	90 246 888	90 078 677	90 557 464	90 666 434	90 855 213	6 982 978	90 162 393	90 643 598 9	0 743 354 90	029 500 8
le S.3 Energ	gy produc	stion map of	the wind farmf	for Cape S	Saint James	(Canada)		wit	th sensitivit	ty analysis	of O&M man	g(B) + Epi	(Case 1)		4 2 0	1144											
Months	<sup>7 wc</sup> (m/s) (i	La/m3 )	(h) Vr.	10		.r.,		Wr e	vr.	21-	21.0	Wr.o.	WF 10	VF	W 10	VF 13	VF 1.1	21.10	21.16	21.17	21 10	VF 10	NF 10	21.72	21.11	27.13	27.14
January	15.4	1.2561	738 32 734	798 32 75	34 798 32	734 798 32 7	34 798 32	734 798 32	2 734 798 3	12 734 798 3	2 734 798 3.	734 798 3.	2 734 798 3.	12 734 798 8	3 013 494	12 734 798 3	12 734 798	32 734 798	32 734 798	32 734 798	32 734 798	12 734 798	40 754 809	32 734 798	32 734 798 2	8 019 994 8	13 494 7
February	14.7	1.2522	641 24319.	291 14 50	59 106 60.	32 878 262	05 527 14	1 106 602 .	4 509 901 2	6 305 527 2	6 305 527 6	932 878 1	4 509 901 1.	1 209 901	772 679	16 305 527 6	932 878	17 428 282 €	6 932 878 6	6 932 878	6 932 878	5 932 878	22 528 524	26 305 527	26 305 527 2	9 044 609 7	72 679 1
March	12.7	1.2495	737 18 273.	052 18 27	73 052 8 9	18 969 275	V05 823 12	408 183 12	8 273 052 2	7 905 823 2	7 905 823 8	918 969 1.	2 408 183 1.	18 273 052 5	395 395 :	17 905 823 8	. 696 816 :	30 184 982	, 696 816 8	8 918 969	8 918 969	. 696 816 8	23 050 141	27 905 823	27 905 823 3	1 495 010 9	97 395 1
April	12.4	1.2490	713 16100.	080 193.	38 295 96	67 330 242	04 422 <b>9</b> 6	567 330 IS	9 338 295 2	7 57 452 7	4 894 425 9	667330 9	667 330 1	19 338 295 5	9 667 330	24 894 425 9	1 667 330	26 984 508	9 667 330	29 188 421	9 667 330	9 667 330	22 244 176	20 024 605	24 894 425 2	4 985 682 9	67 330 1
May	11.2	1.2425	737 12 338.	025 25 59	56 #18 86:	40 868 192	185 473 9 5	040 868 2:	5 598 814 1	1 822 473	9 885 473 9	940 868 9	940 868 2.	25 598 814	12 338 025	19 885 473 9	940 868 .	25 598 814	9 940 868	27 748 037	9 940 868	1 940 868 .	21 042 787	19 885 473	19 885 473 1	9 137 999 12	338 025 1
June	10.4	1.2351	689 92371	631 25 72	785 086 11	465 208 16 2	184 369 82	241 161 2:	5 785 086	1 698 300 1	6 884 369 1	1 465 208 8	241 161 2.	25 785 086	15 384 455	16 884 369	11 465 208	16 884 369	11 465 208	23 787 904	11 465 208	11 465 208	169 100 21	16 884 369	16 884 369 1	6 806 455 12	384 455 1
July	10.0	1.2275	737 87612	837 29 6:	63 191 16	356 443 16.	156 443 7 8	815 162 23	9 653 191	1 875 443	6 356 443 1.	5 356 443 7	815 162 2	29 653 191	17 951 122	16 336 443	16 356 443	7 815 162	16 356 443	19 646 221	16 356 443	16 356 443	15 570 355	16 087 422	16 356 443 1	6 802 962 15	951 122 8
August	9.7	1.2216	737 7777:	512 12 I.	30 855 17	864 641 12 1	30 855 17	. 864 641 17	2 130 855 1	1 130 855 1	2 130 855 1	7 864 641 1	7 864 641 1.	12 130 855	19 551 573	12 130 855 1	17 864 641 2	8 719 626	17 864 641	17 864 641	17 864 641	17 864 641	12 936 052	15 417 110	12 130 855 1	2 621 116 15	551 573 7
eptember	10.4	1.2234	713 9469	157 753.	84 977 18	941 875 9 41	59 157 26	431 347 7.	534 977 9	469 157 9	469 157 1	\$ 941 875 2.	6 431 347 7	7 534 977	24 384 108 5	1 469 157	5 541 875	9 469 157	18 941 875	15 770 041	18 941 875	18 941 875	12 353 594	13 310 548 9	0 469 157 8	865 389 24	384 108 1
October	13.1	1.2327	737 19729	237 8 79.	38 861 29	778 493 9 81	\$2 764 25	397 690 8	2 198 861	862 764 5	862 764 2	9 778 493 2.	5 397 690 8	8 798 861	27 530 026 5	362 764 2	25 397 690	9 862 764	25 397 690	12 241 087	29 778 493	25 397 690	12 273 661 8	8 881 296 9	9 862 764 8	143 371 23	530 026 2
lovember	14.3	1.2429	689 23 939	450 929	<b>36 482 25</b>	949 356 8 21	13 664 28	: 068 725 9.	296 482 8	t 293 664 8	293 664 2	5 949 356 2	8 068 725 9	1 296 482	28 068 725 2	3 293 664 2	25 949 356	11 538 250	25 949 356	9 296 482	25 949 356	25 949 356	7 443 284 8	8 293 664 8	8 293 664 8	895 126 28	068 725 2
December	15.1	1.2528	737 30 263	395 10 0.	023 366 25	811 256 79.	75 983 20	050 501 11	0 023 366 7	975 983 7	975 983 2	5 811 256 2.	9 050 501 IV	20.072 266	5 581 5KS	0025.000	10 10 100	10 100 11	200 000 000	375 cc0 ci	756 110	100000					
Annual	5 61	FOFC 1	0.000 0.000	10 010 miles									- 1. a	000 070 0	000 100 70	C C06 C/6	C62 207 D	10 093 020	C65 207 DC	00C C70 01	0.07 119 02	CAS 507 DI	200 001	7 975 983 7	7 975 983 9	187 032 32	+ XOC 18C

Months	Vwc											mun oper	ed data ser n	es for simule	ttions (m/s)											
	(m/s)	$yr_1$	$yr_2$	yr 3	yr 4	yr5	yr 6	yr7	yr 8	yr9	$yr_{10}$	yr 11	yr 12	yr 13	yr 14	yr 15 .	Vr16 )	117 3	r18 )	r 19 y.	r20 y	r21 yr	22 yr.	23 yr.	4 yr 2	<u>ا</u> م
January	5.8	5.8	10.1	7.6	9.6	4.0	10.1	4.0	4.0	7.9	10.1	10.1	4.0	7.6	9.6	7.9	10.1 1	1.0	4.0	7.6	. 9.0	4.0 7	.6	6 7.	9	
Febmary	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6 1	0.1	5.0	6.0 10	6 I'i	7 8.	6 8.	
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8 9	.7 10.	І 7.	<i>6</i>	
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	0.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	.0.2	4.9 9	.6 9.	2	6	
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9 1	0.1	4.9	. 0.1	4.7 9	.2	9 5.	8 9.	
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7 4.	1.7	7.6 8	.6 8.	6 4.	9 IO.	
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0 4	6.1	7.9 7	.9 5.	8	7 4.	~
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	2.9 5	0.7	8.6 6	0.0	0 4.	0 4.	
September	1.01	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6 IL	1.0	9.2 5	.8 7.	6	2.4.	
October	0.7	9.7	4.0	4.0	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.0	4.0	9.6	9.2	9.2	6.0	9.2	6.2	9.6	4	01 6	1 5	
Manuhar		6	17	2.4	- F F	60	L V	2.0	2.0	202	202	L V	0.7	2.4	2.1	2.0	1 0	1 0		9 Y C		20				
Deserver	1.6	7.6	, .	i i		7.6		1.01	1.01	2.6	2.6		 	( <del> </del>		1.01	2.0	0.0	2.6		1 2 2				5 6	
December	0./	0.7	4.0	4.0	4.4	0.0	4.0	1.01	1.01	0./	0./	4.0	0.6	4.0	4.9	1.01	1.7	1.7	0./		0.0	4 C 7 C		0 1	- T	- 1 -
	t. `	£	ţ	ţ	t.		#.\.	ţ.	t.	t.	ŧ.	t	ţ	r. (	t.	t. \	r.	t.	t.	E	ţ	t	t	÷	*	.1
le S.5 Wind	s peed serie	s simulation:	s for $AEP_{aw}$	ail in Corvo	Island (Po	ortugal)		with s	ensitivity a	nalysis of C	&M manag(B)	$\frac{1}{1000} + Epi(Ca)$	I data sovies	to be clauded	tions ( m/s)											1
tonths	Vwc											wina speed	a aata serte.	sjorsimua	nons (mvs)											1
	(m/s)	yrı.	yr2 .	yr3	yr 4	yr 5	$yr_6$	yr7	$yr_8$	$yr_9$	yr 10	Vr11	yr 12	yr 13	Vr 14 3	Vr IS )	T16 y.	r17 y	r 18 yi	r 19 yı	20 yı	r21 yr	22 yr;	23 yr.	4 yr 2	ı.
January	11.7	11.7 1	1.7 I.	1.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	0.6	10.6	10.6	1.7 1	10.6 1	0.6 1.	I.7 II	).6 II	).6 IL	.6 I(	0.6 10	.6 10.	6 10.	5 10.	
eb nua ry	11.5	11.5	8.2 I.	1.5 1	11.5	11.5	7.6	11.5	11.7	6.1	7.6	1.7	. 1.0	10.5	11.5	9.5 1	1.7	8.2	8.9	. 9.2	п г.	1.5 6	.4	5 11.	5 11.	
March	10.5	10.5	7.1 1.	1.5 1	11.5	11.5	8.9	11.5	11.5	6.4	7.1	1.5	6.4	11.5	11.5	8.9 1	1.5	2.6	9.5	8.2 11	5	1.7 6	10.	5 11.	7.	
April	0.9 0.0	C.9	1 C.V	0.0	10.0	10.6	c.e . 2	0.01	8.2	1.1	 	5.11 2.0	17		8.2	8.2 1	2.1 2.2	V 17	<u>.</u>	ч ,		5.			20	
May	7.0	7.0		, <u>,</u>	5.01	0.9 0.5	5.01	C.01	5.01	0./	0.9	5.07	0./	11./	C.U1	1 0./	50	0.4 1		2.2	4	/ ° ~ ~	0.	- 10. -	6°	
aunf		1 17	C.1	C.V.	0.6	5.01	10.0	8.2 0 F		Q.2	10.0	0.0	۵.2 ۵.0	0.0	4.0	17		- T - T-0				0, 0 0 0		с, г С, г	ν σ	
(mr	1.0	1 1.0	20	2.6	0.9	57	511	0.6	1.1	0.5	0.1	0.0 C 0	0.7 0.5	0.9 6 7	1.0	6.1	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	1.5		, s,	<u>.</u>	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~		~ r		
in Surt	7.6	7.6	61 5	0.0	, c 8	c 8	22	61	0 X	10.5	10.5	76 1	10.5	76	8.0	50.	76 1		1 12		10	26 10		: v ; v		
October	0.7	, 0 <i>8</i>	8.0	7.1	7.0	7.0	70	1.0	0.5	5 11	5 11	1 12	115	7.1	1 50	1.5	1 12	90	1 12	13		11 12	. v	5 0 7 7		
ovember	10.6	10.6	7.6 (	6.4	6.4	6.4	6.4	1.7	6.4	11.5	8.2	6.4	11.5	6.4	1 1.2	1.5	5.4 10	2.5	7.6 6	5.4 10	5	5.4 11	5.0	8	9 11	
December	11.5	11.5	6.4 (	6.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1 1	11.7	6.1	7.6 1	1.7	6.1 9	9.5	8.2 11	17 11	.5	11 13	.7 8.	9.8.	2 11.	
Annual	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	1.6	1.6	9.1	9.1	9.1	9.1	9.1	9.1	6.I	1.6	5 1.6	5 I.C	5 <i>I</i> 0	9 I.G	. I.	1 9.	I 9.	Ι.
le S.6 Wind	speed serie	s simulations	s for AEP are	aii in Cape S	Saint James	(Canada)		with s	ensitivity an	1alysis of <i>G</i>	&M manag(B)	+ <i>Epi</i> ( <i>Ca</i>	se 1)								2					1
Amethe	V wc											Wind speed	t data serie:	s for simula.	tions $(m/s)$											
CHING I	(m/s)	yr 1	yr2 3	yr3	yr 4	yr 5	$yr_6$	yr 7	$yr_8$	yrg	yr 10 3	VELL S	yr12 3	yr 13 3	Vr 14 )	Vr 15 y	r16 y.	r 17 y.	r 18 yı	19 yı	-20 yı	r21 yr	22 yr.	23 yr.	4 yr 2	in l
January	15.4	15.4 I.	'5.4 I.	5.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4 1	15.4 1	15.4 I	5.4 1.	5.4 I.	5.4 1:	5.4 16	19 D	5.4 15	4 14.	7	7 9.	
February	14.7	14.7 I.	2.4	9.7 1	15.1	12.4	12.4	15.1	15.1	9.7	12.4	2.4	10.01	15.1	9.7 1	13.1	9.7	9.7	9.7 5	9.7 14	(3 15	5.1 15	.1 15.	6 10.	9 13.	
March	12.7	12.7 1.	'2.7 Iv	1 0.0	14.7	11.2	12.7	14.7	14.7	10.0	11.2 1	12.7	10.4 1	14.7	10.0	15.1 1	0.0 1(	9.0 h	9.0 IL	čI 0.0	.8 14	4.7 14	7 15.	3 10.	4 12.	~
April	12.4	12.4 I.	3.1 h	0.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4 1	13.1	10.4	14.3	10.4 1	14.7 1	0.4 1.	5.I II	).4 I.(	i.4 I.5	:8 I:	3.3 14	.3 14.	3 10.	4 12.	_
May	11.2	11.2 I.	4.3 h	0.4	13.1	10.4	14.3	13.1	13.1	10.4	10.4	14.3	11.2	13.1 1	10.4 1	14.3 1	0.4 1-	4.7 II	).4 It	čI 1.	.4 I.	8.1 13	.1 13.	0 11.	2 12.	
June	10.4	10.4 I.	4.7 I.	1.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	1.2 1	12.7 1	I.2 I.	4.3 I.	1.2 1.	1.2 12	.8 12	2.7 12	.7 12.	7 12.	4 12.	
Judy	10.0	10.0 I.	'5.1 I.	2.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7 I	2.4 1.	3.I I.	2.4 1.	2.4 12	.2 12	2.3 12	.4 12.	5 12.	7 10.	_
August	9.7	9.7 I	'1.2 I.	2.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	1.2	13.1	11.2	12.7 1	10.0 1	2.7 1.	2.7 I.	2.7 I.	1.7 II	.4 12	11 17	.2 11.	4 13.	1 9.	
epteniber	10.4	10.4	9.7 I.	3.1 1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1 1	10.4 1	3.1 1.	2.4 I.	3.1 1.5	11 18	4 11	1.7 10	4 10.	2 14.	3 13.	
October	13.1	13.1 I	'0.0 I.	5.1 1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	0.0	14.7	10.4	14.3 1	10.4 1	4.3 1.	I.2 I.	5.1 IA	4.3 11	.2 10	01 10	.4 9.	8 14.	7 13.	
loveniber	14.3	14.3 I	0.4 I·	4.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	0.4	15.1	10.01	14.7 1	1.2 1	4.7 II	9.4 I·	4.7 IA	4.7 5	.7 H	0.0 10	0 10	3 15.	I 13.	
December	15.1	15.1 I.	0.4 I.	4.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	0.4	15.4	9.7	15.1 1	12.4 1	5.1 11	0.4 I.	4.3 I:	5.1 5	0.0	0.7 9	.7 10.	1 15.	4 I6.	~
Annual	12.5	12.5 1.	2.5 1.	2.5 1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5 1	12.5 1	2.5 1.	2.5 L.	2.5 I.	<u>2.5 Iž</u>	5 12	2.5 12	5 12.	5 12.	5 12.	

ble S./ kWh per Hprod											<i>T</i> 11	yr 12	. /												
Sites	1 yr2	yr.3	yr4	yr:	5 yı	r6 y	r7 y	r8 y.	r9 y.	r 10 )			yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	yr 23	yr 24	yr 2
Aracari (Brazil) 5 69	6 5646	5 674	5 628	5 700	564	16 565	15 56:	95 5 6:	37 56	39 56	46 5	. 694	5 674	5 636	5 718	5 735	5 689	5 650	5 602	5 697	5 683	5 616	5 628	5 645	5 63.
Corvo Island 10.45. (Portugal)	8 10 535	10467	10 475	10 468	3 10.56	53 1049	7 104.	29 105	25 105	27 104	154 10	525 1(	1 207 1	9 500 I	.0 474	10 454	10 510	10 523	10 545	10 560	10 464	10 520	10 532	10 452	1040
Cape Samt James 24 76. (Canada) 24 76.	2 24 848	24 927	24 734	24 784	4 24 84	48 247.	34 247.	34 249.	27 247	84 241	848 24	797 2.	1734 2	4 936 2	24 875	24 936	24 903	24 927	24 936	24 835	24 851	24 734	24 886	24 797	24 88
Table S.8 Cashflow for 25 years o.	f the wind farn	1 project	50 000	kW	Aracati (Bri	azil)			wi	h sensitivity	analysis of	O&M manage	B) + Epi(Ca)	se 1)											
Item	0	-	2	3	4	5	9	7	8	6	10	=	Years 12	13	14	5	6	7 18	19	20	21	22	23	24	25
(-) I CC CM	00 300 09																								
WT CM	27 686 27	, 													,							'		'	'
$T_{CM}$	2421929.	5 -	,	,	'	•	,	,	,	,	,	,	,	,	,	,	,	,			,		'	'	1
LWTG <sub>CM</sub>	1 959 78		•	•	•	•																	'	'	'
CP CM	1545 34	9									,		,			,	,								
ID CM	402 971 C																								
PO CM	1 796 87/	- 0		,					,							,								'	'
$F_{CM}$	188 55	- 6			,								,			,									
CCC CH	120 21	1 -	-	-	-		-		-	-	-					-		-	-						
LCPM WF (KWh/yr)		48979624	48 549 424	48 794 102	200.645.84	012 120 49 1	42 549 424	48 9/0 644 4	89/0644 4	54/3/200 48	490.220 48	5349 424 48	968 028 48	794 102 484	1.088/ 491	69 824 49 5 10 760 7 30	18 2/6 48 92	2388 48 58.	9860 48 1/2	164.9 48.991	802 48 8/4 I	1/62/84 16	12 48 393 8.	0 4854/50	= 484/32
(+) AAK (\$M/yr) PPAR		4 308 015	4 376 931	4 508 965	4 584 266	4 759 280	4 831 313	4 995 061	5 119 937	194634 5	327022 5	466 187 5	6 ICI ICO . 9 ISI ISI ISI	771 856 58	376 963 61	10 750 6 28	52 450 0.30 12 430 6 38	7799 6502	0000 1667 3031 6608		- 121				
EMP			•																		- 4 930 7.	88 49943	86 512945	8 5274431	5 398 0
(-) O&M WFCM		3 958 388	4 021 593	4 142 789	4 211 857	4 372 535	4 459 642	4 610 143	4724747	1793 035 4	914544 5	5 042 290 5	212 260 5	322 943 54	419 232 56	34 158 57.	91.793 5.88	8285 599.	3824 6 090	278 63480	036 5 8565 137 4 324 34	505 59314 07 11077	02 609121	1 6262682	64087
O& M fixed		6/7 100 7	000 COV 7	714 C0/ 7	0761007	1 432 493	400 406 7 101 517 1	260 000 0	1 261 914	5 016 007 0	2 0C/ 067	2 47/0/00	C COK NKH:	10 140 000	.C C/+0C0	9 C CA9 #/	0.846 1.94	10 + 0000 4701 7400	200 4 661 /	207 5 007	13051 0/1	18 15738	V 07C + 014	3404054 44	1 645 0
(+) LRCM		863 268	884 850	906971	929 646	952 887	976709	1 001 127	1 026 155	051809 1	078 104 1	105 057 1	132 683 1	161 000 11	190 025 12	19 776									
(+) Depreciation		2423217	2 483 797	2 545 892	2 609 539	2 674 778	2 741 647	2 810 188	2 880 443	3952454 3	026265 3	101 922 3	179 470 3.	258 957 3 5	340 431 34	23 942 3 54	19 540 3 59	7279 368	7211 3779	391 3.8731	376 3 970 7.	723 40699	91 417174	0 4276034	43829.
(=) Profit before tax	•	3 636 112	3 723 985	3 819 039	3 911 594	4 014410	4 090 027	4 196 233	4 301 788 .	1405862 4	516847 4	1630 876 4	751 044 4	868 870 45	988 187 51	20 309 4 0	0 176 4 09	6793 4190	5378 4297	445 4414.	561 3 045 0	06 31329	75 321001	8 3 2 8 7 7 82	3 372 10
(-) Revenue tax	-	1 292 405	1 313 079	1 352 689	1 375 280	1 427784	1 449 394	1 498 518	1 535 981	1 558 390 1	598107 1	639 856 1	695 345 1	731 557 1.	763 089 18	33 225 18	84 729 1 91	6340 195	0.897 1.982	500 2 066.	616 1 479 2	236 14983	16 15388:	0 1582325	16194
(+) KEPIM RFI CIA	1 200 271 1	C7/1	900 T	0001	0001	+0C T		- 1	1641	104-1	- 200 1														
REPCH	-	1725	1 668	1 636	1583	1564	1512	1 487	1451	1 401	1 368														
OREP CM	259 395																								
$GHG.R_{CM}$		'	'	,	,		,							,								'	'		'
(=) Profit after tax w/out interes	IS	2 345 433	2 412 574	2 467 986	2 537 897	2 588 190	2 642 145	2 699 202	2767258	3848873 2	920108 2	991 020 3	055 699 3	137 313 32	225 098 32	87 084 21.	15 448 2 18	0453 224:	5480 2314	945 2 3479	744 1 565 7	<sup>1</sup> 69 1 634 6	59 167116	8 1705453	175270
(-) Debt payments		•	3 136 538	3 2 14 9 5 1	3 295 325	3 377 708	3 462 151	3 548 705 3	637 422 3	728 358 3 2	\$21567 31	917 106 41	015 034 4 1	15410 421	18 295 4 32	3 752									'
$(+) RCM_{WF}$		2 621 739	2 687 282	2 754 464	2 823 326	2 893 909	2 966 257	3 040 413	3116424	3194334 3	274193 3	3356.047 2	439 949 3	525 947 3t	614 096 37	04 448 37.	97 060 3 85	1986 398:	9286 4089	018 4 191.	243 4 2960	124 44034 32 19299	125 451351	1 4626348	4742.0
(+) Depreciation (=) Free net cashflow	-59 102 84	2 425 217	4 447 116	2 545 892 4 553 391	2 609 539 4 675 437	4 779 169	2 741 647 4 887 898	2 810 188 5 001 099	2 880 443 5 126 703 5	2952454 3	026265 3 399000 5	5 101 922 2 531 884 5	179470 5 660084 5	258 957 5. 306 808 59	340.431 34 061.330 6.0	23 942 55 91 722 9 42	99.540 3.55 12.047 9.66	7279 308 9718 9921	7211 3779	(391 38/3. 354 10413(	876 39/U/ )63 98325	723 40695	91 4171 /z 74 1035641	0 427605 9 10607835	4382 9. 10877 70
$\Sigma$ freenet animal cashflo	, i	-51 712 455	-47 265 339	-42 711 948	-38 036 511	-33 257 342	-28 369 445 -	23 368 346 -11	3 241 643 -12	974339 -7	575340 -2	043 456 3	616 628 9.	423 436 15 3	384 766 21 4	76 488 30 8	8 535 40 56	8 253 50 49(	0.230 60 673	584 71 0860	547 80 919 1	63 91 027 2	38 101383 62	7 111 991 492	122 869 1:
	LCOE ***	, 67.67	67.82	68.03	68.19	68.45	68.63	68.88	60.69	69.27	65.49	69.73	70.01	70.24 7	70.45 7.	2.78 61	181 70.	01 70	21 70.4	1 70.75	70.38	70.56	70.83	11712	71.38

Table S.9 Cashflow for 25 years of the	e wind fam pr	oject	50 000 kV	N N	orvo Island	(Portugal)			with	sensitivity a	malysis of 0	& M manag(B)	+ Epi (Cas Veare	(1)											
Item	0	-	2	3	4	5	6	7	8	6	10	11	2	3 1	4	16	17	18	19	20	21	22	23	24	25
(-) I CCCM	100 225 001																								
WT CH	27 686 278																								
$T_{CM}$	24 219 295			,	,			,			,	,	,	,		,									
LWTG CM	1 959 783				•	•	,		,	,		,	,			,					•	•	•	•	
CP ar	1 545 346																								
STOR	768716																								
POG	1 796 870											,													
For	188 559																					•	•		
CCC ar	120211				•																•	•	•	•	
$LCPM_{WF}$ (kWh/yr)	-	9 107 610 5	07697749	0 190 491 9	0 253 921	90 198 973	01016328 9	0 443 405 89	858.042 90	685 374 90 3	06 829 00,	78 677 90 6	85 374 90 5	30 3 36 90 47	3 134 90 24	5 888 90 078	677 90 557.	464 90 666	434 90 855 2	13 90 985 97	8 90 162 393	90 643 598	90743354	90 02 6 20 0	89 <i>6</i> 70 <i>5</i> 77
(+) AAR(SM/yr)		15 046 124 1	5 535 609 1	5 822 374	6 229 340	16 624 945	7 194 985 1	7 513 916 1	835 578 18	449 787 18 9	14 223 19	254 127 19 8	68 402 203	30 2 95 20 82	5386 2129	2 641 21 784	277 22 447	567 23 036	443 23 661 5	18 24 287 96	3 17 268 871	17 795 063	18 260 013	18 575 463	8 957 626
PPAR		15 046 124 1	5 535 609 1	5 822 374	6 229 340	16 624 945	1 194 985 1	7513916 1	835 578 18	449 787 18 9	14 223 19 3	254 127 19 8	68 402 20 3	30 295 20 82	5386 2129	2 641 21 784	277 22 447	567 23 036	443 23 661 5	18 24 287 96		-	-	-	-
EMP		- 111 660			- 101 61	10010701		- 200 2000								- 10 00		-		- 10131 02	17 268 871	17 795 063	18 260 013	18 575 463	8 957 626
(-) OCM WECH		1 005 012	HOL 071 6	2100066	170 100 2	106 108 01	1 7/10/2/0	1 160 1061	9 005 200	0 11 761 060	171 0H0 CC	571 C010H	171 0/000	20 CT 7 CT 61	20 21 200 0	070 CT / CD 1	140 7 204	118-81 100	C 700 #1 C CC	20 10 10 10 10	1071701 0	1407 CTO CT	216.0/6.01	0 624 720	0 010 200
Oct M fixed		CH4 C60 +	117 COD C	07C 0HI C	0146 0.07 0	#/0.60# C	2122313	000 050 2	255.420 5	10 00+000	0 6/040	+0 6/100	0.0 /00.00	110 700 CL	760 6440	0400 / 000	+00 / 20+	200 1 492	7660 / 1020	21 0067 44	100/2013 30	5 242 217	2010 001 0	907 400 0	202 210 0
(±) LPCM		896 298	884.850	120 900	9199000	062 272 4	002.926	202 007 0	1 251.200	01 808 190	C 000.674	11 22030	10 170 00	20 000 0110	101 2000	04-C0 20C2			7 CM / 7C	17 167 / 46	-chronic o	in nere .	100 704 C	004//00	100760 C
(+) Densectation		2.416.502	200 100	CE0 825 C	200 000 0	2 667 466	0.1010	2 802 506	C 695 CL8	044383 36	17 003 3/	03 443 31	CE 0424 04	23 232	1200 3.41	1582 3.400	046 3587	145 3.677	131 3 769 0	386375	3 050 865	4.058.865	4 160 336	345 436 4	4 370 954
(=) Profit hefore tax		8 911 435	9 176 763	9368.266	9 606 864	COF 100 -	0 147 375 1	0359.653 10	01 222313	111 982.206	76.673 11.4	0.6441 11.7	41 486 12.0	20111123	7.857 12.60	2010 11 655	166 11 212	561 12:301	0.000 0.0000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.0000	12.95691	2 8015924	8 238 634	8 449 437	8 627 664	8.824.163
(-) Revenue tay		4513837	4 660 683	4746712	4 868 802	4 987 484	\$ 158.496	521 120 2	350.673 5	234 0366 57	5 L9C PL	76738 59	0 2 105 09	7C 9 080 00	7616 638	1702 6535	127 6734	0109 024	7 008 4	25 728635	2 2 180 661	5 338 510	5 478 004	5 577 639	5 687 788
(+) REPIM	1 284 621	1 253	1 231	1 193	1165	1 136	1118	1 084	1051	1 035	010	978	961	936	12 8	88	-	-	+	-		-	-	-	-
RELOV	863 662																				'	,	,		,
REPCH		1 253	1 231	1 193	1165	1 136	1 118	1 084	1 05 1	1 035	010	978	961	936	12 8	88						,		,	
OREP	420.959																		'	'	,		,		,
GHGR	-		,	,	,	,	,	,			,	,	,	,	,							,			,
(=) Profit after tax w/out interest	,	4 398 850	4517311	4 622 747	4 739 227	4 857 019	4 989 997	5 106 562	225 651 5	368,885 5.5	03416 54	31 182 57	81 926 5 9	23.958 6.02	1154 621	037 5120	429 5.257	301 5301	08 5 529 5	5670.52	3 2835263	2 900 115	2.971.434	3 055 025	3 136 875
(-) Deht navments	,	-	127 964	3 206 163	3 286 317	3 368 475	3 452 687 3	539 004 3	627 479 37	18 1 66 3 81	1 120 3 90	6 398 4 00	1 0.58 4 10	160 4 206	764 4311	33									
(+) RCM we	,	2.621.739	2 687 282	2 7 54 464	2 823 326	2 893 909	2 966 257	3 040 413	116424 3	194334 33	74 193 3	856.047 3.4	30 949 35	25.947 3.61	4.096 3.70	1 448 3 7 97	060 3.891	3 989	286 4 089 0	18 419124	3 4 296 024	4 403 425	4513511	4 626 348	4 742 007
(+) Depreciation		2416592	2 477 007	2 538 932	2 602 406	2 667 466	2734153	2 802 506	872.569 2	944383 3(	17 993 3 (	93 443 3 1	70 779 32	50.048 3.33	1 299 3 41	1582 3499	946 3.587	445 3 677	131 37690	30 386325	6 3 95 9 868	4 058 865	4 160 336	4 264 345	4 370 954
(=) Free net cath flow	-58 941 280	9 437 182	6 553 636	6 709 981	6 878 642	7 049 919	OCT TECT	7410477	587164 7	789.436 7.6	84481 8	14 273 83	88 505 85	05.704 8.80	0.785 9.02	5135 12 417	435 12.736	22 13 057	022133876	11 13 725 05	3 11/09/15	11 362 405	11 645 281	11 945 718	2 249 836
$\Sigma \sim 100$		19 504 098 -4	0.950.462 -3	6 240 481 -	20 361 839 .	- 006 118 00	5 074 200	1663 723	7 105291	12 878 154	01350 231	21 632 32.2	0 222 408	2001 49.66	5807 58.69	101 12 170	377 83 846	100 06 003	514 110 201 2	65 124 01631	8 135 107 474	146 469 878	158 115 159	170 060 877	182 310 713
- free net annual cashflow		0.00 4.00 64	0- 40L 0/07 4	10101-7		- 000 110 -000	007410.0	0.000		1010 101			0.04 Jan 00	N /1 190.0			AF0 00 110		TOTOT AND				and all part		
Table S.10 Cashflow for 25 years of	the wind farm	project	50 000 1	kW	Cape Saint	James (Canae	la)		wi	h sensitivity	analysis of	$O\& M_{manag(B}$	) + Epi (Ca	te 1)											
Item .	¢			¢		,		t	c	4	9	:	Years	9		2	ŝ	9	2	ę	5	00	50		20
	0	-	7	m	4	2	¢	-	×	6	9	=	12	13	4	9		8	19	R	21	77	57	24	8
(-) LCCCM <sub>WF</sub>	60 225 901				•																				
WT <sub>CM</sub>	27 686 278	•	•	•	'	•	•	•			,		,	,						'	'	'	•	•	,
$T_{CM}$	24 219 295	•		•	•	•																•	•		
LWTG CH	1 959 783			•	'								,		,							'			,
CPON	1 545 346			•																		•			
TS CH	572 832	,				,	,		,			,				,				,	,		,		,
SI ou	2 136 726																								
DO	1 796 870																								
1 O CM	0/00//1																								
L CK	110.001																								
CCC CM	117 071			-											-	-	-	-						-	
LCPM WF (KWh/yr)		212 943 465	213 677 678	214 362 116	212 699 281	213 130 306	213 677 678	212 699 281	212 699 281 2	4 362 116 21	3 130 306 21	3 677 678 213	240 500 212	699 281 214	433 451 213 5	13 741 214 43	3 451 214 152	844 214 36	116 214 433	51 213 565 6	75 213 706 61	212 699 281	214 004 745	213 240 500	213 962 451
(+) AAR (5Mbr)		30 196 663	31 058 298	31 936 726	32 481 214	33 360 711	34 282 550	34 978 715	5 853 182 3 r oct 102 2	036811 37	744 583 38	787.558 394	575.905 403	64 585 41 9	17 697 42 80	1 506 44 039	781 45 081	704 46 253	902 47 426 0 002 47 426 0	27 48 414 95	54 34 760 65	35 461 726	36 571 360	37 351 777	88 41 5 192
EMP			0.67 0 00 10	07/06616	+17 10+70	11/ 000 00			c 701 cc0 c	/c 110.0cn	00 000 ++-/	16C 0CC 101	.0÷ 00€016	6 14 000 40	- 140 1		100.0% 10/	CC7 0+ +0/		- 	34760.65	- 35.461 726		- 135 177	2 415 102
March 1		10.622.040	102 000 10	00200010	- 101 540	000 202 00	13 130 167	102,000,50	0 211 007 10	30 132 306	20002002	20 192 009		200 616211	1 120 20 20	6 001 30 000	- 20.000	- 21 602	1 100 00 000	- 020 22 02	1000/100 VC	201023000	200010000	111 100 10	761 014-00
D.E.M		11 570 156	100 000 11	070 770 17	287 247 77	L34 C87 C1	13 135 671	171 000 07	3 737461 1	P1 620 0001	07 07 07 07 1	201 222 107 20C	17 070 COL	10 412 140	27 0CT 14	02000 1200	171 17 773	385 17777	912181 515	12 18 550 57	2890001 50	295 010 00 0	20012000	SUL SIVE OF	921 200 10
D& M		9 0K3 703	9 322 210	9 585 754	6 749 063	0012 022	10 289 486	10 498 314	0.760.654 1	11 0/2 511	328.084 11	640.988 11	007.483 12	74.075 12.5	8 CI 270 08	3 178 13 216	625 13 529	743 13 880	2 007 14 232 5	X 662 71 97	10 430 415	10.643.217	10.976.136	11 210 244	1 529 285
		000 000	004 000	120 200	212.000	200 030	002.300	2011001	1 000 1 55	000100	1 100 000	1 100,000	1 000 001	11 00012		0.776	0.00 FT		0 m/m 1 1 1 00						004 646 1
		007 000	2000 #000	1/6006	040 676	100 706	201 0/6	171 100 1	001 070 1	1 400 100	1 +01 0/0	1 100.001	1 000.701			0116				- 2010 0		1010101			
(+) Depreciation		+10 /0C 7	CDC / ++-7	194 90C 7	661 1/07	6/10/02/11	000 10/ 7	106.00/ 7	071 000 7	7 0/0 606	C CD0 106	C 000000	10 101 701	7.0 0/0113		10+C 000C	++CC 116	00001 002		K010C 00	00716C N		0 +01 IO	012 012 4	100000000000000000000000000000000000000
(=) Proju before lax	,	020 512 71	216/01 CT	000 67 0 01	010/9/01	880 CCI 4I	804 000 41	14 848 021	1 046 617 0		01 707 10	440 707 101	/1 81/100	1/1 446.61	1 21 766 76	005/1 2706	C78 / I CI6	C07 01 CDC	1 CH/ 21 21C	2170161 97	67 517 6 55	0.001 0 10 10 10 10 10 10 10 10 10 10 10 1	CC/ /20 6	000 606 6	1/7 / / 0
(-) Revenue tax		9 (158 999	9317489	9 581 018	9 744 364	10 008 213	10 284 765	10 493 614	0 755 955 1	111 043 11	323 375 11	636.267 11	902 772 12	69 376 12 5	75 309 12 8	8 452 13 211	934 13 524	511 13 876	171 14 2278	08 14 524 48	36 10.428 190	10 638 518	10.971 408	11 205 533	11 524 558
(+) KE $PIM$	/04 166 1	148	<u>‡</u>	141	15/	5	151	171	124	771	118														
VEL CH	700 002	'	' :	' :		'	' :		' !			,				,							,		,
REP CM		148	14	141	137	<u>x</u>	131	12/	124	122	118										•	•	•		
OKEP CM	112/ /45																								
$GHG.R_{CM}$	'	'		•		•	'		,			,				,				'		•	•		
(=) Profit after tax w/out interest	'	3 754 834	3 850 603	3 948 688	4 043 283	4145609	4 250 834	4 354 534	4 463 515	580 023 4	690 995 4	809 934 4	928 947 5 (	150 568 51	82 628 53	0576 4194	981 4298	992 4407	347 45179	20 4 627 6	98 -1 214 906	-1 220 382	-1 283 673	-1 295 895	-1 347 286
(-) Debt payments			3 090 455	3 167 717	3 246 910	3 328 082	3 411 284	3 496 567	3 583 981 3	673.580 3.	65 420 3 8	199.555 391	56 044 4 02	4 945 4 15	5319 4260	227									
$(+) RCM_{WF}$		2 621 739	2 687 282	2754464	2 823 326	2 893 909	2 966 257	3 040 413	3 116 424	194334 3	274 193 3	356.047 3.	139.949 3.	25 947 36	14 096 3 70	4 448 3797	060 3891	986 3989	286 40890	18 41912	13 429602/	4 403 425	4513511	4 626 348	4 742 007
(+) Depreciation		2 387 614	2 447 305	2 508 487	2 571 199	2 635 479	2 701 366	2 768 901	2 838 123	909 076 2	981 803 3	056348 3	132 757 3.	11 076 32	91 353 33	3 636 3 457	977 3544	427 3 633	037 37238	63 381690	50 391238	4 010 194	4110448	4 213 210	4318540
(=) Free net cashflow	-58 234 494	8 764 187	5 894 735	6 043 923	6 190 898	6346915	6 507 173	6 667 281	6.834.081	009 853 7	181 571 7	362.775 7.	545 608 7	32 646 79	31 757 8 12	8 434 11 450	018 11 735	404 12 029	670 123308	01 12 635 90	2 699350	7 193 237	7 340 286	7 543 663	7 713 261
$\Sigma$ free net annual cathflow		-49 470 300	-43 575 572 -	-37 531 648	-31 340 750	-24 993 855	-18 486 662 -	11 819 381	4 985 300	024553 9	206 124 10	568 899 24	114.507 313	47 153 39 /	78 910 47 94	7 344 59 357	362 71 092	766 83 1:22	436 95 453 2	37 108 089 1	39 115 082 641	122 275 878	129 616 105	137 159 827	144 873 088
	$LCOE_{unv}$	84.34	85.02	85.71	86.17	86.87	87.59	88.17	88.87	89.78	90.37	91.19	5 1610	2.63 9.	3.67 94	.44 94.1	1 94.9	2 95.8	2 96.72	97.50	93.98	94.68	95.73	96.51	97.52

## **APPENDIX T**

Laped         Note of the second of the	LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
$ \frac{1}{10} $	Legend				_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Green cells indicate information and ar automatically based on user input into	re updated vellow cells.		O&M warranty condition	15	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Number of the product of the	Yellow cells are for use input informatio	on about the project.		Costs covered by manufacturer $(O \& M_{out})$	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Wind During Information	ĺ	Notes	Levelized Penlagement (	Cost Model	Notes	Wind Farm Pamonal C.	ort Model	Natas	Panawahla Enargy Public In	contine Model	Neter	Wind Farm Life	Cycle Prod	uction Model	Neter
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Project Name	Firestar Wind Farm	ivoles	AR cu	16 8442	(\$/kW)	DCM we	1 339 9154	INDIES [S/kW]	Relew	67 4078	[S/kW_]	WE cu	-cjele 1764	50.000	[kW_/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Project Location	Aracati (Brazil)		Depr	76.9840	[\$/kW]	RM <sub>WT</sub>	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	WF our		50 000	[kW]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Turbine Size	2 000	[kW]	Ν	25	[yr]	Mhrman	100	[m-h]	$\Psi_{astal}$	20.00%	[%]	N row		5	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMBrana	85.00	[\$/m-h]	n <sub>v</sub>	4	[yr]	N col		5	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>mmur</sub>	3	[-]	REP CM	0.00002465	[\$/kWeh]	D		90.0	[m]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	$Y_{RC}$	15	[yr]		2.0	[d]	AEP avail/H prod	5 696	[kW/yr]			1 800	[m]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	C mf mt gr	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Wind speed measured at $(H_0)$	10.0	[m]	11	1 /98 /43	[\$/kW]	RM cr	20.1954	[S/KW]	E	0.1404	[S/KW <sub>e</sub> h]	SD		450	[m]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Peta Limit's coefficient (C )	0.14		V	237 699 000	[KW] (LW)	WF cap	30 000	[KW]	2 <sub>0</sub>	0.099530	[5/KWen]	ELH .		8 760	[m]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Lifetime of Wind Farm (N)	0.3920	[**]	Vo	1.457.72	[KW] [\$/VW]	M.	30	[=] [m-h]	OREP	23 7020	(S/FW )	PC		8700	[II/y1]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Production Efficiency (WF as)	11.2%	[%]	PR	0.70	[-]	C	85.00	[S/m-h]	LCCCM	5.0125	[5/kW]	AEP		48 979 674	[kW h/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	A vailability	98.2%	[%]	h	-1 94	[-]	N	3	[-]	LCCCM me	1 204 5180	[\$/kW]	n		20.98%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $		358	[d/yr]	IRCM	16 8443	[\$/kW]	D_ "mcr	20	ran -	WACC	4 9000%	[%/yr]	η		25.00%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $			(# 7·1	Laten	10.0445	[wkn]	$C_{ml}^{m_{Bl}}$	3 500.00	[\$/d]	W sets	20.0%	[%]	P&D.		0.839325	[-]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Wind Farm Life-Cycle Capite	al Cost Model	Notes	Wind Farm O&M Cost M	Aodel	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	Nwr	Jactor	25	(-)
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WLey	553,7256	[\$/kW]	O&M and	0.098275	[\$/kWh]	WF	50 000	[kW]	n_	14	[vr]	A		6 361.7	[m <sup>2</sup> ]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	CMWT	265.32	[\$/kW]	LCCCM	1 204.5180	[\$/kW]	NWT	25	[-]	CR,	40.0%	[%]	AEP rated		438 000 000	[kW_h/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	AWT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	2 910.3377	[\$/tCO2]	P&D <sub>IM</sub>			
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	CkW	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	Mbr sarr	3.0	[m-h]	$LCER_{co}$ ,	39.8	[tCO2/MWah]	λa		7.00%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	IPT	10.00%	[%]	N	25	[yr]	$C_{Mbr_{extry}}$	85.00	[S/m-h]	$\sum AEP_{mail}$	48 856	[MWeh]	2,41		0.00%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	N <sub>m</sub>	3	[-]	n ,	25	[yr]	Âd		5.00%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Tmaxx	138 000	[kg]	O&M variable or	0.025839	[\$/kWh]	D <sub>m<sub>saas</sub></sub>	3.0	[d]	$GHG_{IM_{SCO_2}}$	0.00089	[tCO2/MWah]	λ"		5.00%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	RC T	26.30%	[%/\$/kW]	MLC	71.5608	[S/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	GHG <sub>EM<sub>unit</sub> co.,</sub>	0.00008	$[tCO_2/MW_ih]$	LCPM WF		48 979 624	$[kW_eh/yr]$
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	RVM WF	61.0184	[\$/kW]	E <sub>c</sub>	39.4247	[\$/tCO2]			,	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	LWTG CM	39.1957	[\$/m/kW]	R <sub>tasas</sub>	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\zeta_1 REI_{CM}$	10.0%	[%]	Debt ratio		50.0%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Lg	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\zeta_2 REP_{CM}$	50.0%	[%]	Debt term		14	[yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	CAB cost	2 000.00	[\$/m]	n <sub>mth</sub>	72	[h]	ifr	2.50%	[%/yr]	$\zeta_3 OREP_{CM}$	20.0%	[%]	Debt gr	ice period	1	[yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	CP CM	30.9069	[S/KW]	n th	90	[n]	N	25	[yr]	54 GHG.R <sub>CM</sub>	20.0%	[%]	Debt in	erest rate	5.00%	[%/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	EF c	400.00	[5/KW]	AAR	4 202 942	[\$M]	WI weight	200 000	[Kg]	REPIM	593.548/	[\$/proj]	Debi value		29 977 388	[5]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	5	0.08%	[%]	AEP anall	48 979 624	[KWh/yr]	C steel	0.1900	[5/kg]			N. (	Debt pa	yments	3 028 433	[5/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	TS CM	11.4566	[\$/kWe]	O&M WFCM	0.124114	[\$/kWh/yr]	TS <sub>VM</sub>	0.9965	[\$/kW]	Exchange rates	1 2252	Notes	Equity rati	,	50.0%	[%]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	11L <sub>c</sub>	0.0400	[5/m]	0.014	г	N .	WF cap	50 000	[KW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29977588	[5]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	TL,	1 200	[1/kW]	O&M O&Mmanag(B)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $		3 000	[m]	SC ORM	0.000105	[\$/KWh]	N T	25	[yr]	BRL/USD dec2010	0.5986	[-]	Initial Day 1	c	- CLCOF	Neter
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	SB <sub>c</sub>	113.00	[5/kWh]	work days	3.0		I main	138 000	[kg]	0 Fr. 6 1000	1	N. (	initial Kesults	summary	J LCOE wie	ivotes
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	SI CM	42.7345	[\$/m²/kW]	Feb/Jun/Nov	9	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wiso		Notes	67.6693	yr i	70.7843	yr 15
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WP cap	50 000	[KW]	Hours required	72.0	[h]				O&M WFCM			67.8196	$yr_2$	69.8148	yr 15
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	WI inst	42.5238	[\$/kW]	USC DEM	0.000229	[\$/KWN]	Hours Distribution	FLH <sub>wf</sub> [n]	H prod [N]	O&M con	1	[1/0]	68.0301	yr3	70.0062	yr 16
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Bld cost	500.00	[\$/m <sup>*</sup> ]	NWT	25	[-]	January	744	738	(%) ccm	80.0%	[%]	68.1907	$yr_4$	70.2090	yr 17
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Bla area	25 0274	[m <sup>-</sup> ]	Prequency Prenaistime	1.8	[per yr]	rebruary Marsh	744	727	REFIN			68,4432	yr <sub>3</sub>	70.4052	yr 18
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	FS FS	10.88	[\$/kW]	Hours required	90.0	(n) (h)	Anril	720	713	č. RELou	1	[1/0]	68 8776	37.6 X7.2	70.3784	37 19 NT 20
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	DT	87.77	[\$/kW]	SC osw+USC osw	162.0	[h/vr]	Max	744	737	E REP ou		[1/0]	69.0932	yr /	70,5607	37 20 X7 41
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	FG	404 57	[\$/kW]	ORM -COC ORM	0 000324	(\$4;Wh/wr)	Jung <sup>(*)</sup>	720	689	Č. OREP.CH		[1/0]	69 2651	77 8 NT 0	70.8306	37 21 NT 22
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Fou	3 7712	[\$/kW]		0.000534	(*******)/	July	744	737	ŠA GHG R CH		[1/0]	69 4927	VT 10	71 1149	37 22 VE 23
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	WACC	4 900%	[%/vr]		Г		August	744	737	P&DIM	1	[1/0]	69 7293	VF 11	71 3767	37 25 VE 25
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	R fin	1.0	[yr]				September	720	713	λ.	1	[1/0]	70.0108	VF 12	69.6873	Mean
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	W <sub>Eau</sub>	0.30%	[%]				October	744	737	λ <sub>sāi</sub>	0	[1/0]	70.2358	yr 13	1.0827	SD
K         0.29%         [%]           December         744         737         λ <sub>n</sub> 1         [109]         LC0E sug         69.6873         US8/MWh         valid !	CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	689	24	1	[1/0]	70.4493	yr 14	-0.4490	Y (skewness)
LOE	ĸ	0.20%	[%]				December	744	737	λ.,.	1	[1/0]	LCOF	69.6873	US\$/MWh	valid !
LCCCM <sub>WF</sub> 1 204.5180 [\$/kW] Total [h/yr] 8 760 8 600 p.s.: 1= yes and 0=n0 0.069687 U\$\$/kWh	LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 600		p.s.: 1= yes at	nd 0=no	LCOE NTO	0.069687	US\$/kWh	

**Figure T.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* 2). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend				_					Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and ar automatically based on user input into	ve updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_{cos})	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty $(n_w)$	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Proiect Information	Г	Notes	Levelized Replacement (	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR CM	16.8442	[\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI <sub>CM</sub>	67.4078	[\$/kWe]	WF CM		50 000	[kW <sub>o</sub> /yr]
Project Location	Corvo Island (Portugal)		Depr <sub>WTout</sub>	76.9840	[\$/kW]	$RM_{WT}$	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW		WT <sub>CM</sub>	553.7256	[\$/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N <sub>WT</sub> )	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	Nwr	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	M <sub>MMar</sub>	100	[m-h]	$\varphi_{a a a a}$	20.00%	[%]	N row		5	
Rotor Diamenter (D)	90.0	[KW]	tfr Denr.	60 1398	[%/yr] [\$/vW]	N Moreaux	3.00	[5/m-n]	RFP out	0.00000951	[yr] (\$/FW-b)	IN col		90.0	[=] [m]
Swept Area per Turbine (A)	63617	[m] [m <sup>2</sup> ]	Vac Vac	15	[3/K/Y] [VT]	D_	20	[-] [d]	AFP and/Hand	10.458	[3/KW off]	L		1.800	[m]
Hub height (H)	105.0	[m]	TOCH	0.000033	[\$/kW]	C <sub>ml</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	L <sup>1</sup> ~~~		2 430	[m]
Wind speed measured at (Ho)	10.0	[m]	TI	1 798 743	[\$/kW]	RM CT	20.1954	[\$/kW]	e	0.0994	[\$/kW_h]	$SD_x^{X_{col}}$		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000	[kW]	WF cap	50 000	[kW]	$\mathcal{E}_0$	0.063750	[\$/kW_h]	SD <sub>scol</sub>		540	[m]
Betz Limit's coefficient (C PBetz)	0.5926	[-]	$V_{\theta}$	6 100 000	[kW]	NWT	25	[-]	n <sub>x</sub>	18	[yr]	$FLH_{vf}$		8 760	[h/yr]
Lifetime of Wind Farm (N)	25	[yr]	CO	1 457.72	[\$/kW]	M <sub>krmcr</sub>	3.0	[m-h]	OREP CM	39.4264	[\$/kW <sub>e</sub> ]	PC PM			
Production Efficiency (WF PE)	20.6%	[%]	PR	0.70	[-]	CMBURG	85.00	[\$/m-h]	LCCCM <sub>WFORSTICM</sub>	4.5411	[\$/kW]	AEP avail		90 107 610	[kWeh/yr]
Avälability	98.4%	[%]	b	-1.94	[-]	N <sub>mmcr</sub>	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wes}$		20.98%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]		2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{wacx_{(nd)}}}$		25.00%	[%]
min maines			The serve of	г		C <sub>nd ma</sub>	3 500.00	[\$/d]	$\Psi_{hotal}$	20.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	
wina Farm Life-Cycle Capite	il Cost Model	Notes	wind Farm O&M Cost M	Model	Notes	S&RV	1 297.3916	[S/KW]	ifr	2.5%	[%/yr]	N <sub>WT</sub>		25	
WI CM	353.7256	[\$/KW] (\$/14W)	LCCCM	0.098275	[\$/kWh]	WF cap	50 000	[KW]	n ,,	18	[yr]	AFR		6.361.7	[m*]
RC	73 70%	[3/KW] [%/\$/FW]	m	0.0000001%	[3/6/1]	A wr	43.00	[-] (-2())	GHG R	1.496.9316	[%]	R&D		438 000 000	[Kw cu/yi]
C un	400.00	[5/kW]	шc	0.0530	[~]	M <sub>WT</sub>	3.0	[m/wt] [m-h]	LCER	73.1	ICO/MW.bl	h.		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	C <sub>Mu</sub>	85.00	[\$/m-h]	$\sum AEP_{aud}$	89 657	[MW_h]	2.41		0.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50%	[%/yr]	Nm	3	[-]	n ,	25	[yr]	Âd		5.00%	[%]
Tmax	138 000	[kg]	O&M variable or	0.048925	[\$/kWh]	D <sub>m</sub> unv	3.0	[d]	GHG <sub>IM</sub> g on	0.00089	[tCO2/MWah]	λm		5.00%	[%]
RC T	26.30%	[%/\$/kW]	MLC	71.5608	[S/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	GHG <sub>EM</sub>	0.00008	[tCO2/MWah]	LCPM WF		90 107 610	[kWeh/yr]
C steel	0.1900	[\$/kg]	TLC	124.5688	[\$/h]	$RVM_{WF}$	61.0184	[\$/kW]	E <sub>c</sub>	11.0500	[\$/tCO2]				
LWTG CM	39.1957	[\$/m/kW]	R <sub>tater</sub>	30.00%	[%]	NWT	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\tilde{\zeta}_1 REI_{CM}$	10.0%	[%]	Debt ratio		50.0%	[%]
Lg	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\zeta_2 \operatorname{REP}_{CM}$	50.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n mih	48	[h]	ifr	2.50%	[%/yr]	$\zeta_3 \text{ OREP }_{CM}$	20.0%	[%]	Debt gri	ice period	1	[yr]
CF CM FF	400.00	[\$/KW] [\$/FW]	n th AAP	14 679 146	[II] [SM]	WT	200.000	[yr] [ke]	DEDIM	20.0%	[%]	Debt value	erest rate	20 808 067	[%/yr]
C C	0.08%	[96]	AFP	90 107 610	[.pivi]	C	0.1900	[%g]	REI IM	514.0124	[\$/proj]	Debt na	vmante	3 020 512	[0]
75.00	11.4566	[%]	O&M	0 147200	[KWII/yr] [S&Wh/yr]	TS	0.9965	(\$/JW)	Frehange rates		Notes	Equity ratio	2	50.0%	[96]
77.	0.0400	[\$/m]	O'CLIM WFCM	0.147200	(********)*)	WF	50.000	[JAW]	EUR/USD + 2010	1 3252	[-]	Fauity	alue	29 898 967	[3]
77.	1 200	[1/kW]	0&Mary	Г	Notes	ifr	2 50%	[%/yr]	CAN/USD 4=2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
1.	3 000	[m]	SC on M	0.000038	(\$/kWh]	N	25	[vr]	RRI/USD 4-2010	0.5986	[-]			,	(10.74)
SB .	113.00	[S/kWh]	Work days	2.0	[d]	T	138 000	[kg]	000 000 0000			Initial Results	Summarv	of LCOE	Notes
SLOW	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6	ra	RCMWE	1 278,8970	[\$/kW]	Conditions for LCOE		Notes	73.1255	NT.	78.4712	NT 15
WF care	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			73.5187	yr2	77.6515	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000138	[\$/kWh]	Hours Distribution	$FLH_{vf}[h]$	H mod [h]	O&M con	1	[1/0]	73.7873	YF 3	78.1612	YT 16
Bld cont	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	74.1334	yr <sub>4</sub>	78.6268	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.0	[per yr]	February <sup>(*)</sup>	672	648	REPIM			74.4746	yr 5	79.1175	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	4.0	[h]	March	744	736	REPIM distribution			74.9273	$yr_6$	79.6115	yr 19
FS	19.88	[\$/kW]	Hours required	100.0	[h]	April	720	712	$\xi_1 REI_{CM}$	1	[1/0]	75.2253	yr 2	77.7347	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	148.0	[h/yr]	May	744	736	$\xi_2 REP_{CM}$	1	[1/0]	75.5275	$yr_8$	78.2446	yr 21
EG	404.52	[\$/kW]		0.000176	[\$/kWh/yr]	June <sup>(*)</sup>	720	696	$\xi_3 OREP_{CM}$	1	[1/0]	76.0152	yr 9	78.7103	yr 22
F <sub>CM</sub>	3.7712	[\$/kW]		-		July	744	736	$\hat{\varsigma}_4 GHG.R_{CM}$	1	[1/0]	76.4118	yr 10	79.0644	yr 23
WACC proj	4.900%	[%/yr]				August	744	736	P&D <sub>LM</sub>		64.002	76.7332	yr 11	79.4723	yr 25
n <sub>fin</sub>	0.30%	[yr] [96]				September October	720	712	λ	1	[1/0]	77.2289	yr 12	76.8666	Mean SD
WFON CCCCCH	2.4042	[%]				November <sup>(*)</sup>	720	696	A.ai 1.	1	[1/0]	78.0589	yr 13 Yr 14	-0.4631	Y (skewnerr)
ĸ	0.20%	[%]				December	744	736	λ_	1	[1/0]	10.0.037	76.8666	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]				Total [h/vr]	8 760	8 616	- 44	p.s.: 1= yes at	nd 0=no	LCOE wro	0.076867	US\$/kWh	
-		-				Citrated of low bound for much	and an								

**Figure T.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* <sub>2</sub>). Source: Own elaboration

LCOE wso Mode	l Inputs								-		Financial Ind	exes		Notes
Legend						r		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
automatically based on user input into	vellow cells.		O&M warranty condition	ns Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[S/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input informatio	m about the project.		Cons covered by manufacturer $(O \Delta M_{\rm con})$	80.00% [%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.09684	[S/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5 [yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information		Notes	Levelized Replacement	Cost Model Notes	Wind Farm Removal C	Cost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm		AR CM	16.8442 [\$/kW]	DCM WF	1 339.9154	[\$/kW]	REI CM	67.4078	[\$/kWe]	WF CM		50 000	$[kW_o/yr]$
Project Location	Cape Saint James (Canada)		Depr <sub>WTmr</sub>	76.9840 [\$/kW]	RM wr	22.3284	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Turbine Model	Vestas V90-2MW	( )	WT CM	553.7256 [S/kW]	WF cap	50 000	[kW]	LRCM	16.8443	[\$/kW]	N <sub>WT</sub>		25	[-]
Number of wind Turbines (N <sub>WT</sub> )	2000	[-]	I CM	464.5659 [5/kW] 25 [vr]	M WT	100	[=] [m.h]	tfr W	2.30%	[%/yr]	WI rated		2000	[KW]
Wind Farm Canacity (WF )	50.000	[kW]	ifr	2.50% [9/yr]	C <sub>Mar</sub>	85.00	[\$/m-h]	P total	2000/6	[70] [vr]	N internet		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>r-</sub>	60.1398 [\$/kW]	N <sub>m</sub>	3	[-]	REP CM	0.00000048	[\$/kW,h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15 [yr]	D <sub>n Mar</sub>	2.0	[d]	AEP avail /H prod	24 762	[kW/yr]	$L_s$		1 800	[m]
Hub height (H)	105.0	[m]	TO CM	0.000033 [S/kW]	$C_{ml_{ml_{WT}}}$	2 500.00	[\$/d]	ifr	2.50%	[%/yr]	$L_{x_{col}}$		2 4 3 0	[m]
Wind speed measured at $(H_0)$	10.0	[m]	Π	1 798 743 [\$/kW]	RM CT	20.1954	[\$/kW]	3	0.0120	$[kW_{e}h]$	SD <sub>s</sub>		450	[m]
Terrain rugosity factor (a)	0.14	[-]	V	237 699 000 [kW]	WF cap	50 000	[kW]	$\varepsilon_0$	0.008498	$[kW_{e}h]$	$SD_{s_{col}}$		540	[m]
Betz Limit's coefficient (C PBetz)	0.5926	[-]	$V_0$	6 100 000 [kW]	NWT	25	[-]	n <sub>z</sub>	14	[yr]	FLH <sub>wf</sub>		8 760	[h/yr]
Latetime of Wind Farm (N)	25	[yr]	c 0	1 457.72 [\$/kW]	M <sub>1rma</sub>	3.0	[m-h]	UKEP CH	103.0468	[\$/kWe]	PC PM		212.042.077	0.001.0.0
Aváilability	48.6%	[%]	PR	0.70 [-]	N N	85.00	[5/m-h]	LCCCM <sub>WFORDCM</sub>	1 204 5190	[\$/kW] [\$/kW]	AEP avail		212 943 465	[KWeh/yr]
e e e una d'ille y	20.2%	[20] [d/sel	IRCM	16 8443 [\$/k-W7	D	20	171 141	WACC	4.90000	[3/6.97]	n		20.33%	[96]
		[d/yi]	LICH	10.0445 [\$/K #]	C	3 500.00	[u] (\$/4]	WACC proj	20.0%	[96]	Photosoft R&D		0.814145	[70]
Wind Farm Life-Cycle Capita	al Cost Model	Notes	Wind Farm O&M Cost N	Model Notes	S&RV	1 297 3916	[\$/kW]	ife	2.5%	[%/yr]	Nwr	factor	25	[-]
WTex	553 7256	[S/kW]	O&M sud	0.098275 [S/kWb]	WF	50.000	[kW]	i); B -	14	[vr]	A		6 3 6 1 7	[m <sup>2</sup> ]
CM WT	265.32	[\$/kW]	LCCCMWF	1 204.5180 [\$/kW]	NWT	25	[-]	CR	40.0%	[%]	AEP rated		438 000 000	[kWeh/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001% [%]	Awr	43.00	[m <sup>2</sup> /wt]	GHG.R CM	8 186.2796	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
CAW	400.00	[\$/kW]	LLC	0.0530 [\$/kWh]	M	3.0	[m-h]	$LCER_{CO_2}$	173.2	[tCO2/MWah]	λa		7.00%	[%]
IPT	10.00%	[%]	N	25 [yr]	$C_{Mhr_{surv}}$	85.00	[\$/m-h]	$\sum AEP_{max}$	212 467	[MWeh]	$\lambda_{xAi}$		3.00%	[%]
T <sub>CM</sub>	484.3859	[\$/kW]	ifr	2.50% [%/yr]	N <sub>m</sub>	3	[-]	n <sub>v</sub>	25	[yr]	$\lambda_d$		5.00%	[%]
Tmass	138 000	[kg]	O&M <sub>variable cu</sub>	0.041526 [S/kWh]	D <sub>m saw</sub>	3.0	[d]	$GHG_{IM_{SCO_2}}$	0.00089	[tCO2/MWah]	λm		5.00%	[%]
RC <sub>T</sub>	26.30%	[%/\$/kW]	MLC	71.5608 [\$/h]	C <sub>md saw</sub>	3 500.00	[\$/d]	$GHG_{EM_{max}CO_2}$	0.00008	[tCO2/MWah]	LCPM WF		212 943 465	$[kW_eh/yr]$
C steel	0.1900	[\$/kg]	TLC	124.5688 [\$/h]	RVM WF	61.0184	[\$/kW]	Ec	25.5000	[S/tCO <sub>2</sub> ]			r	
LWTG CM	39.1957	[\$/m/kW]	R tasus	30.00% [%]	N <sub>WT</sub>	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing		Notes
WF cap	50 000	[kW]	tfr N	2.50% [%/yr]	WTS VM	1.4442	[\$/kW]	$\zeta_1 REI_{CM}$	10.0%	[%]	Debt ratio		50.0%	[%]
	2,000,00	[m] [\$/m]		25 [yi] 72 [b]	WF cap	2 50%	[KW] [96/vr]	ζ <sub>2</sub> REP <sub>CM</sub> č ORFP m	20.0%	[%]	Debt erm	ice neriod	14	[yr]
CAB out CP cu	30 9069	[3/II] [\$/kW]	n mih	90 [b]	ijr N	2.30%	[%/y1] [vr]	ζ <sub>3</sub> OKEF CM ζ, GHGR cu	20.0%	[%]	Debt in	erest rate	5.00%	[96/yr]
FF-	400.00	[5/kW]	AAR	29.460.159 [\$M]	WT	200.000	[ke]	REPIM	1 664 6060	[\$/nroil	Debt value	creat rune	29 580 865	[50/91]
5	0.08%	[%]	AEP	212 943 465 [kWh/yr]	Currel	0.1900	[\$/kg]			14-191	Debt pa	ments	2 988 376	[\$/yr]
TS cu	11.4566	[\$/kW_]	O&M <sub>WECM</sub>	0.139801 [\$/kWh/yr]	TSvm	0.9965	[\$/kW]	Exchange rates	Ī	Notes	Equity rati	,	50.0%	[%]
TL.	0.0400	[\$/m]	hrea		WF can	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 580 865	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanae(B)	Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
L	3 000	[m]	SC ORM	0.000024 [\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0 [d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE was	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9 [d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE was		Notes	84.3448	$yr_1$	94.4360	yr 15
WF cap	50 000	[kW]	Hours required	72.0 [h]				O&M WFCM			85.0205	yr <sub>2</sub>	94.1138	yr 15
WTinat	42.5238	[\$/kW]	USC OBM	0.000053 [\$/kWh]	Hours Distribution	FLH wf [h]	H prod [h]	O&M con	1	[1/0]	85.7100	$yr_3$	94.9205	yr 16
Bld cost	500.00	[S/m <sup>2</sup> ]	NWT	25 [-]	January	744	738	(%) ccm	80.0%	[%]	86.1734	$yr_4$	95.8186	yr 17
Bld area	300.0	[m <sup>2</sup> ]	Frequency	1.8 [per yr]	February <sup>(*)</sup>	672	641	REPIM			86.8681	$yr_S$	96.7191	yr 18
PO <sub>CM</sub>	35.9374	[\$/kW]	Repair time	2.0 [h]	March	744	737	REPIM distribution			87.5940	$yr_6$	97.4969	yr 19
FS	19.88	[\$/kW]	Hours required	90.0 [h]	April	720	713	REI CM	1	[1/0]	88.1682	yr 9	93.9817	yr 20
DT	87.22	[\$/kW]	SC O&M+USC O&M	162.0 [h/yr]	May	744	737	REP CM	1	[1/0]	88.8666	$yr_8$	94.6831	yr 21
EG	404.52	[\$/kW]		0.000077 [\$&Wh/yr]	June	720	689	OREP CM	1	[1/0]	89.7788	$yr_9$	95.7335	yr 22
F CM WACC	3.7712	[S/kW]			July	744	737	GHG.R CM	1	[1/0]	90.3684	yr 10	96.5076	yr 23
WACC proj	4.900%	[%/yr]			Santambar	744	713	1 ccD IM	1	[1/0]	91.1898	yr 11	91.5244	yr <sub>25</sub> Mean
W <sub>E</sub>	0.30%	[%]	1		October	744	737	λ	1	[1/0]	92.6296	97 12 VF 13	4.1987	SD
CCC CM	2.4042	[\$/kW]	1		November <sup>(*)</sup>	720	689	λd	1	[1/0]	93.6712	yr 14	-0.3338	Y (skewness)
ĸ	0.20%	[%]	1		December	744	737	λm	1	[1/0]	LCOP	91.7691	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]	1		Total [h/yr]	8 760	8 600		p.s.: 1 = yes an	d 0=no	LCOE was	0.091769	US\$/kWh	
					(*)Period of less hours for produ	uction								

**Figure T.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* <sub>2</sub>). Source: Own elaboration

Table T.1 Energy	productic	on (AEP and	ui map of the	e wind farn	n for Aracati	(Brazil)		with sen	sitivity ana	lysis of O&A	$M_{manag(B)}$ + .	Epi (Case 2,															
Months	Vuc m/s) /L-	H (f)	prod					1 4 5	- 415					AL	avail(KWh)												
Ianuan	5 8 1	1665	738 1603	1 22 8 800	108 2 807	3 yr 4	10 55736	71 8 800 10	8 557 36	1 557 361	016 616 1	91.10 8.800.108	91 11 8 800 108	557 361	3 802 165 7	y14	727717 8	91 16 800 108 8	9117 800.108 5	57 361 23	91 10 1K5 7 1	y1 20 507 410 54	57 361 28	91 22 y	1 23 97 410 4 23	24 27	1 25
February	4.9 1.	.1666	641 8504	130 6803	436 3 673	320 68034	36 779 59.	18 680343	10 120 59	8 779598	3 4 72 7 258	6 8 03 436	6 8 03 436	779 598	3 673 320 6	- 01+70C	483 758 4	020120 0	300.063 4.2	727 258 7:	716188 12	577 029 15	77 029 77	16 188 6 80	03 436 4 72	7 258 4 72	7 258
March	4.0 I.	1671	737 5565	:07 7495	900 5438	155 887650	68 978 31.	19 7 495 90	0 97831	9 978 315	0 6560068	7 495 900	7 495 900	978319	5438155 8	876 568	896836	396 836 1	814 186 4	225 724 1 2	814 186 1 0	90 230 J 6	90 536 78	26 555 8 87	76 568 3 79	6335 656	0 068
April	4.7 1.	.1667	713 8673	180 6344	604 6344 c	604 4 086 9.	31 1 635 01	11 6344 60	4 163501	1 1 635 011	1 7 249 700	6344604	6344604	1 754 600	6344604 4	1 086 931	946187	046187 1	635 011 6 :	344 604 1 0	635 011 34	571 646 94	46 187 72	49 700 634	44 604 175	4 600 7 24	00 700
May	6.0 I.	1670	737 1814	119 5437	953 7495 t	621 5 437 9:	53 1814 11	19 5 437 95	3 181411	511 7 181 6.	7 7 82 6 264	5 437 953	5 437 953	1 690 473	7 495 621 6	\$ 559 824 1	690 473 1	690 473	78 283 82	876 238 9.	78 283 5:	56 486 89	96 803 65	59 824 4 22	25 566 1 69	0 473 7 82	6 264
June	7.9 1.	.1686	689 39550	677 3 955	677 7326	396 6140 8-	44 3 553 72	29 3 955 67	7 355372	9 3 553 725	7 8309307	3 955 677	3 955 677	3 553 729	7326396 5	: 090 627 1	698 250 1	698 250	39 524 7	326396 8.	39 524 8.	39 524 35	53 729 5 6	90 627 5 09	90 627 915	260 830	9 307
VIII	86 1	1698	737 54500	340 3805	267 8 807 4	425 1 604 2	13 4235 66	55 3 805 26	1 423560	5 4235665	5 557 816	557816	3 805 267	070 057 5	8 807 452 1	818455 3	805 267 3	805 267	2 91825	5 925215	57.816 90	80.621 42	35,665 42	32 665 1 60	34 513 898	646 55	7816
Auoust	1 90	1677	737 7400	2101 202	100 107	1 21 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2	21 188 8 24	1 18181 12	20 0VV 2 24	2000VV 2 2.	2010/00	807 307	107 000 0	102004	1 201 2181	5 217 109	0 10 00 00 1	930.614 7	530.614 BI	07 202 4	4 2 210 LUC	230.614 5.4	51 52000	18 1 201 51	222 2022	705 80	2 302
icnSnc 5	1 1 1 1	1101	// ///////////////////////////////////	101 101	C10 1 /71	1 010 1 171	11 100 0 17	71 010 1 1/	20110 1	Venter o	700 200 0	700 210	171 010 1	C16 177 1	- /71 (101		C/COLL	/ 1000 CFC	0 470.000	15 200 21	1 016177	50 ±1000		10 I 17 I 01	0.00 121.01	10 00	200
September	10.1	/01.	0/08 21/	550 I CC6	- 1 033 -	4/2 3 008 1.	9/ / 502 58	85 1 055 47	0 0 2 2 8 0	4 0.338.04	4 942 298	867 298	C/4 200 I	0 338 044	1 033 4/2	161 800 8	338 044 /	242 889 /	242 889 9	.c 867.ch	254 599 8.	50 556 0/0	38 044 1 0	02 4/2 200	0 250 191 0 250	8 044 94.	267 0
October	9.7 I.	.1645	737 78091	082 976.	135 9761	135 555 21	54 7479 16	65 976 13	5 7479 h	5 747916.	5 1 686 762	1 686 762	976135	8 856 751	976135	555 264 3	479 165 6	545 422 6	545 422 I <	810136 6.	545 422 4.	216289 74	(79 165 97	76 135 970	6135 885	6 751 1 68	<i>16 762</i>
November	9.2 I.	.1638	689 6115	594 8361	972 8360	172 836 05	72 6115 59	94 836 07.	2 72962;	71 729627 <sub>4</sub>	1 1 691 267	1 691 267	836072	7296271	836072	836072 7	296271 5	069 696 5	1 969 690	575 994 61	988 019 61	115 594 72	96 271 83	16 072 83	6 072 7 29	6 271 169	1 267
December	7.6 1.	.1651	737 37900	014 555.	580 5555	580 976 65	90 542905	99 555 58	0 886175	16 8 801 78r	5 3790014	3 790 014	555 580	7483417	555 580	976 690 8	861 786 4	218 687 4	218 687 3 ;	7 410 064	813 521 54	429 099 88	101 786 55	55 580 55.	5 580 748.	3417 379	0 014
Annual	7.4 1.	.1666 8	8 600 48 979	624 48 549	1 424 48 794	102 48 399 0	05 49 021 21	15 48 5 49 42	24 48 970 6-	44 48 970 64	4 48 473 266	48 496 226	48 549 424	48 968 028	48 794 102 4	18 470 887 4	19 169 824 4	9318276 4	8 922 388 45	\$ 589 860 45	3 172 649 48	991 802 48	874 151 48	297 112 48 3	393 836 48 54	47 502 48 4	73 266
Table T.2 Ene	upord uga	action map o	of the wind fa	um for Corv	'o Island (Po	utugal)		with s	ensitivity a	nalysis of Oc	& M manag(B).	+ Epi (Case	2)														
Mande	V <sub>NC</sub>		$H_{prod}$											A	EP avail (k Wh	(1											
MONINS	(m/s)	$(kg/m^3)$	(4)	yr 1	yr2	yr3 yi	r4 yr	r5 yr	6 yr	7 yr8	yr9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22 )	Vr 23 yı	r24 y	r 25
January	11.7	1.2313	740 14	: 490 462 1.	4 490 462 14	490 462 14 4.	90 462 14 45	90 462 14 49.	0 462 14 45	0 462 10 871	408 10 871 -	408 14 490 40	10 871 40.	8 10 871 408	10 871 408	14 490 462	10 871 408	10 871 408	14 490 462	10 871 408	10 871 408	0 871 408 1	0 871 408 10	0 871 408 10	871 408 10 5	271 408 10	871 408
February	11.5	1.2345	648 12	092 721 4	293 137 12	0 21 12 0	92 721 12 09	92 721 3 41;	7 096 12 09	2 721 12 715	1 262 1 262 2	784 341709	16 12 715 78.	5 1 795 784	9 244 173	12 092 721	6 674 015	12 715 785	4 293 137 :	5 486 290 3	3 417 096 2	815 600 1	2 092 721 2	106703 66	574 015 12 6	92 721 12	715 785
March	10.5	1.2329	736 10	1486 228 3	193 907 13	717510 137.	17 510 13 71	17 510 6 225	3 433 13 71	7510 13717	510 23897	762 3 193 96	17 13 717 51	0 2389762	13 717 510	13 717 510	6 223 433	13 717 510	3 876 220	7 570 742 4	4 869 967	3 717 510	4 424 289 2	037 067 10	486 228 14 4	(24 289 3 1	93 907
April	9.5	1.2317	712 73	316 597 7.	316 597 10	458 483 10 4.	58 483 10 45	58 483 7 3 IC	597 1045	8 483 4 706	485 3 086 6	89 731659	7 13 257 02.	2 3 086 689	13 257 022	4 706 485	4 706 485	13 257 022	3 086 689	10 134 212 3	3 086 689	3 940 075 1	3 257 022 3	086 689 3 0	386 689 13 2	57 022 3 7	46 098
May	8.2	1.2282	736 48	851 676 h	9 446 845 10	446 845 10 4	46 845 6 200	0 059 10 44	6 845 10 44	6 845 10 446	845 38616	62 6 200 05	-9 10 446 84.	5 3 861 662	14 370 115	10 446 845	3 861 662	10 446 845	2 380 787	13 665 991 6	5 200 059 2	380 787 1	0 446 845 3	861 662 14	370 115 104	146 845 48	51 676
June	1.7	1.2224	696 25	394 461 I.	2 860 910 76	90.7 186 7 09	1 1 1 2 002	7 981 10 14	5 990 4 562	: 858 12 860	910 45658	10 142 90	-00 7 097 98,	1 4 565 858	186 260 7	2 240 532	2 994 461	7 097 981	1 909 861	12 860 910 7	1 186 260 7	909 861 7	097 981 4	565 858 12	860 910 7 05	7 981 58	34 806
July	6.1	1.2154	736 2(	208 118 I.	3 522 571 4 8	800 760 6 13	4 992 10 33	37 209 13 52.	2 571 7 46.	154 3148.	518 61349	11 800 2 260	8 613499.	2 6134992	6 134 992	2 008 118	2 355 801	6 134 992	6 134 992	14 219 306	10 337 209 5	821 135 6	134 992 6	134 992 13	522 571 3 82	21135 74	63 154
August	6.4	1.2075	736 2.3	340 496 h	9 598 668 37	796310 379	16310 379t	6310 1343	14 719 6 09.	134 3796.	310 74146	68 234049	16 476957.	1 7414668	4 769 571	10 598 668	1 995 072	4 769 571	13 434 719	1 995 072	13 434 719 4	769 571 4	769 571 7	414 668 47	769 571 3 12	28 063 10.	270 051
September	7.6	1.2064	712 34	669 202 1	928 273 5 8	891 057 4 66	9 876 4 60	9 876 4 605	3 876 1 92k	1 273 5 891	057 9 926 1	89 992618	39 3 669 20.	2 9 926 189	3 669 202	5 891 057	9 926 189	3 669 202	12 984 898	2 262 132	12 984 898 5	. 891 057 3	669 202 9	926189 36	<b>569 202 2 2 6</b>	52 132 19	28 273
October	. 8.9	1.2126	736 61	121 079 6	121 079 31	141 378 2 06	3 564 3 14.	1 378 2 00.	3 564 2 351	1459 7446	229 13 491	905 13 491 90	95 3 141 37.	8 13 491 905	3 141 378	7 446 229	13 491 905	3 141 378	10 643 782	3 141 378 2	3 003 564	446 229 3	141 378 1.	3 491 905 23	850 459 2 00	3564 23	50 4 59
November	. 10.6	1.2194	01 969	121586 3	625 425 22	235 143 2 23	15 143 2 23.	5143 223	5 143 2 98;	7 258 2 235	143 12 829 :	976 4 554 87	76 2 2 35 14.	3 12 829 976	5 2 2 3 5 1 4 3	2 987 258	12 829 976	2 235 143	9 807 761	3 625 425 2	235143 5	807 761 2	235 143 1.	2 829 976 1 9	05 267 5 82	20 771 12.	829 976
December	. 11.5	1.2237	736 13	1 614 984 2	371 901 26	721 842 317	0 035 2 021	1842 3170	1035 384;	7 249 2 021	842 14316.	481 13 614 9.	94 2 021 84.	2 14 316 481	2 021 842	3 847 249	14 316 481	2 021 842	7514158 +	4 833 568	14 316 481	3 614 984 2	021 842 1-	1316481 61	176 918 4 83	33 568 13	514 984
Annual	1.6	1.2222	8 616 90	107 610 94	0 769 774 90	190 491 90 2.	53 921 90 15	98 973 91 01	6 328 90 44	3 405 89 858	: 042 90 685 ;	374 90 700 65	78 90 078 67.	7 90 685 374	90 530 336	90 473 134	90 246 888	90 078 677	90 557 464	90 666 434	90 855 213 5	0 985 978 9	0 162 393 9	0 643 5 98 90	743 354 90 6	029 500 89	570 577
Table T.3 En	npour Aar	iction map 6	of the wind fa	um for Cane	Saint James	t (Canada)		with	enstitvity a	alvsis of Od	Wa	+ Eni (Case	-														
TAUK L'I SINK	ungy prout	nonon mab		ann tot cap	C Sallt Jallic	s (callana)		2 IIIM	CUISILIVILY 6	naiyara ur U.	CALINI manag(B)	+ Thi Case	27														1
Months	Vuc	1. 1. 3.	H prod								1	1	1	4	AEP avail(KW)					1	-						
Innun	15.4	1 7561	738 32	73.4 708 20	7734 708 27	734 708 32 7-	34 708 32 73	24 708 27 72	14 00 F	1 708 27 734	5 PEL CE 802	01 10 702 22 734 70	11 1/ 10	8 8.012.404	37 734 708	27 724 708	37 734 708	91 16 302 734 708	71 17	27 724 708	y1 19 22 734 708 4	yr 20 10 754 800 - 3	7724 708 2	yr 22 y 734.708 28	010 004 8 01	24 9	0.033
February	14.7	1.2522	641 24	319 291 14	1 209 901 6.9	132 878 26 31	95 527 14 50	06 001 14 20	9 901 26 30	5 527 26 305	527 6 932 8	78 14 509 96	1 14 509 90	022222	26 305 527	6 932 878	17 428 282	6 932 878	6 932 878 6	5 932 878 6	5 932 878	2 528 524 2	6 305 527 21	5 305 527 29	044 609 777	72 679 17	402 199
March	12.7	1.2495	737 18	1 273 052 12	\$ 273 052 8 9	18 969 27 %	05 823 12 40	98 183 18 27.	3 052 27 90	5 823 27 905	823 89189	69 12 408 18	13 18 273 05.	2 9 997 395	27 905 823	8 918 969	30 184 982	8 918 969	3 696 816 8	8 918 969 8	2 696 816 8	3 050 141 2	7 905 823 2:	7 905 823 31	495 010 9 96	7 395 18	969 625
April	12.4	1.2490	713 16	100 080 13	9 338 295 9 6	67 330 24 8.	94 425 9 667	7 330 19 33.	8 295 24 89	4 425 24 894	425 9 667 3	30 9 667 33	0 19 338 29.	5 9 667 330	24 894 425	9 667 330	26 984 508	9 667 330	29 188 421 5	9 667 330 5	9 667 330	2 244 176 2	0 024 605 2-	1 894 425 24	985 682 9 66	57 330 18	186 892
May	11.2	1.2425	737 12	338 025 22	5 598 814 9 9	240 868 19 8	85 473 9 940	0 868 25 59	8 814 19 85	5 473 19 885	473 9 940 8	98 0 6 6 89	8 25 598 81-	4 12 338 025	. 19 885 473	9 940 868	25 598 814	9 940 868	27 748 037 5	9 940 868 9	2 898 076 c	1 042 787 1	9 885 473 1	9 885 473 19	137 999 12 3	138 025 16.	209 586
June	10.4	1.2351	689 92	237 631 2:	5 785 086 11	465 208 16 8.	84 369 8 241	1 161 25 78	5 086 16 85	4 369 16 884	369 11 465	208 8 241 16	<li>Z5 785 08.</li>	6 15 384 455	16 884 369	11 465 208	16 884 369	11 465 208	23 787 904	11 465 208	11 465 208 1	1 169 100 2	6 884 369 11	5 884 369 16	806 455 15 3	84 455 14	990 327
July	10.0	1.2275	737 8;	761 837 25	9 653 191 16	356 443 16 3.	56 443 7 812	5 162 29 65.	3 191 1633	6 443 16 356	443 16 356 -	443 781516	2 29 653 19.	1 17 951 122	16 356 443	16 356 443	7 815 162	16 356 443	19 646 221	16 356 443	16 356 443	15 570 355 h	6 087 422 h	5 356 443 16	802 962 17 9	051 122 86	47 175
August	9.7	1.2216	737 7;	777 512 1.	2 130 855 17	864 641 12 1.	30 855 17 86	64 641 12 13	0 855 12 15	0 855 12 130	1855 178640	641 17 864 64	11 12 130 85.	5 19 551 573	12 130 855	17 864 641	8 719 626	17 864 641	17 864 641	17 864 641	17 864 641	2 936 052 1	5 417 110 1.	2 130 855 12	621116 195	51 573 7 I.	30 060
September	10.4	1.2234	713 94	469 157 7	534 977 18	: 941 875 9 46	0 157 26 45	31 347 7 534	4 977 9 465	157 9469	157 18 941	875 26 431 34	17 753497.	7 24 384 105	9 469 157	18 941 875	9 469 157	18 941 875	15 770 041	18 941 875	18 941 875	1 353 594 I	3 310 548 9	469 157 88	865 389 24 3	184 108 19	980 004
October	13.1	1.2327	737 19	729 237 8	798 861 29	778 493 9 86	\$2 764 25 35	97 690 8 795	8 861 9 86.	: 764 9862	764 29 778.	493 25 397 69	90 8 798 86.	1 27 530 026	9 862 764	25 397 690	9 862 764	25 397 690	12 241 087	29 778 493	25 397 690	2 273 661 8	881 296 9	862 764 81	143 371 27 5	30 026 21	651 123
November	. 14.3	1.2429	689 23	1 939 450 9	296 482 25	949 356 8 29	3 664 28 0t	68 725 9 290	5482 829.	8 664 8 293	664 25 949.	356 28 068 7.	25 9 2 96 48.	2 28 068 725	8 293 664	25 949 356	11 538 250	25 949 356	9 296 482	25 949 356	25 949 356 7	443 284 8	293 664 8	293 664 88	895 126 28 0	<b>68</b> 725 22 1	100 110
December	15.1	1.2528	737 30	1 263 395 1	0 023 366 25	811 256 7 97	5 983 20 0.	50 501 10 02	3 366 7 97.	5 983 7 975	983 25 811	256 20 050 5	01 10 023 36	6 32 581 568	7 975 983	30 263 395	16 693 026	30 263 395	10 023 366	25 811 256	30 263 395 (	366 601 7	975 983 7	975 983 91	187 032 32 5	81 568 42	583 526
Annual	12.5	1.2404	8 600 212	2 943 465 21.	3 677 678 214	362 116 212 6	99 281 213 1:	30 306 213 67	7 678 212 69	9 281 212 699	281 214 362	116 213 130 3.	96 213 677 67	8 213 240 500	212 699 281	214 433 451	213 913 741	214 433 451	214 152 844 2	214 362 116 2	14 433 451 2.	3 565 675 21	3 706 617 21.	2 699 281 214	004 745 213 2	240 500 213	962 451

Table T.4 Win	d speed se	ries simulati	ions for AE	Pavail in AI	racati (Brazi	(1)		wi	th sensitivi	ty analysis	of O&M man	ag(B) + Epi(	Case 2)													1
Months	$V_{we}$ – (m/s)	VF. /	VF 2	$VF_2$	Nr.4	VF 5	VF.6	VF 7	VF o	VFO	VF 10	VF 11	vr 17	vr 12	vr 11	(S) VF 15	VFie	VF 17	VFis	VF10	VF 20	VF 21	VF 33	VF 23	VF 24	VF 25
Ianuary	5.8	5.8	1.01	76	90	40	101	40	40	7.0	101	101	40	2.6	9.6	70	101	101	40	26	9.6	40	7.6	9.6	7.0	70
February	4.9	4.9	1.01	2.9	0.2	4.7	1.01	4.7	4.7	8.6	1.01	7.07	4.7	2.9	0.7	4.0	4.0	7.6	8.6	10.1	6.0	6.0	10.1	0.7	8.6	8.6
March	4.0	4.0	9.6	8.6	101	4.0	9.6	4.0	4.0	0.2	9.6	9.6	4.0	8.6	101	4.7	4.7	6.0	7.0	6.0	5.8	5.8	9.7	101	7.6	6.0
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2	6.0	9.6
May	6.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	7.9	5.8	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6	4.9	10.1
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	5.8	4.7	4.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	7.9	9.7	8.6	6.0	6.0	4.0	4.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6	9.2	4.9
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9	10.1	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	9.7	6.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	101	1.01	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9	7.9	7.6	9.7	8.6	1.01	4.0	4.0	9.6	7.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
				) 		é																				
Table 1.5 WIN	u speeuse	sries simulati	IONS FOF AL	<i>P</i> avait III CC	orvo Island	(Forugal)		ШM	n sensitivit	y anarysis (	JI U&M man	$\frac{g(B) + Ept}{Wind sp_{\ell}}$	eed data ser	ies for simu	lations (m/s											1
Months	( <i>m</i> / <i>s</i> )	$yr_{I}$	$yr_2$	yr 3	yr 4	yr5	yr 6	yr7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	yr 20	yr 21	yr22	yr 23	yr 24	yr 25
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	10.6	11.7	10.6	10.6	11.7	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	11.7	8.2	8.9	7.6	7.1	11.5	6.4	9.5	11.5	11.7
March	10.5	10.5	1.7	11.5	11.5	11.5	8.9	11.5	11.5	6.4	1.7	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	11.5	11.7	6.1	10.5	11.7	7.1
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	1.7	9.5	11.5	1.7	11.5	8.2	8.2	11.5	1.7	10.5	7.1	11.7	11.5	1.7	1.7	11.5	7.6
May	8.2	8.2	c.01	c.01	c.01	8.9	C.01	C.01	c.01	0./	8.9	c.01	0./	////	C.01	0./	c.01	0.4	C11	8.9 	0.4	c.01	0./		c.01	8.2
June	17	17	211		C.9	5.6 2.07	10.0	8.2	C.11	8.2	0.01	C.V 0 0	8.2	ر. <i>۷</i> م	0.4	1.1	6.9 0.9	0.1	C.11	2.6	1.0	0.9 0.9	8.2	511 211	0.6 2 F	8.9
Anonet	1.0	1.0	901	7.6	0.9 7.6	2.6	511	08	7.6	0.5	1.0	e.o e e e	0.5	6.9 6 8	106	t 9	6.0 6.8	0.9	19	5 11	0./ 8.2		0.5	C 8 2	0.7	105
Sentember	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	11.5	8.9	7.6	10.5	7.6	6.4	6.1
October	8.9	8.9	8.9	7.1	6.1	1.7	6.1	6.4	9.5	11.5	11.5	7.1	11.5	7.1	9.5	11.5	1.7	10.6	7.1	6.1	9.5	7.1	11.5	6.4	6.1	6.4
Noveniber	10.6	10.6	7.6	6.4	6.4	6.4	6.4	1.7	6.4	11.5	8.2	6.4	11.5	6.4	7.1	11.5	6.4	10.5	7.6	6.4	10.5	6.4	11.5	6.1	8.9	11.5
December	11.5	11.5	6.4	6.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2	11.7	11.5	6.1	11.7	8.9	8.2	11.5
Annual	1.6	9.1	1.6	9.1	9.1	I.6	9.1	1.6	1.6	9.1	1.6	9.1	9.1	1.6	9.1	9.1	1.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Table T.6 Winc	1 speed sei	ries simulatic	ions for AE.	P <sub>avai</sub> in Ca	pe Saint Jar	nes (Canada	Ē	wit	1 sensitivit	y analysis o	f O&M mana	$_{o(R)} + Epi$ ((	Case 2)													
Months	V nc											Wind spe	eed data ser	ies for simu	lations (m/s	(1										
SUBIORI	(m/s)	$yr_{I}$	$yr_2$	yr 3	yr 4	$yr_5$	yr 6	yr7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr 16	yr 17	yr 18	yr 19	$yr_{20}$	yr 21	$y_{r_{22}}$	yr 23	yr 24	yr25
January	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4	15.4	15.4 0.7	15.4 0.7	15.4	15.4	16.6	15.4	15.4	14.7	9.7	9.3
rebruary	14./	14./	12.4	1.6	1.61	4.71	4.71	1.61	1.61	1.6	4.71	12.4	10.01	1.61	1.6	13.1	1.60	1.6	7.6	1.6	14.5	1.61	1.61	0.01	10.0	13.1
Andren	1.21	1.21	12.1	10.01	14./	7.11	121	14./	14.7	0.01	7.11	12.1	+01	14.7	10.01	1.01	0.01	151	0.01	10.0	12.0	14./	14./	C.CI	10.4	6.71
nude	11.7	6 11	1.01	104	1.51	10.4	1.01	1.51	1.51	104	±-01	1.61	11.2	13.1	104	14.3	10.4	1.01	10.4	104	13.4	1.81	131	13.0	11.2	12.3
June	10.4	10.4	14.7	11.2	12.7	10.0	14.7	12.7	12.7	11.2	10.0	14.7	12.4	12.7	11.2	12.7	11.2	14.3	11.2	11.2	12.8	12.7	12.7	12.7	12.4	12.2
July	10.0	10.0	15.1	12.4	12.4	9.7	15.1	12.4	12.4	12.4	9.7	15.1	12.7	12.4	12.4	9.7	12.4	13.1	12.4	12.4	12.2	12.3	12.4	12.5	12.7	10.0
August	9.7	9.7	11.2	12.7	11.2	12.7	11.2	11.2	11.2	12.7	12.7	11.2	13.1	11.2	12.7	10.0	12.7	12.7	12.7	12.7	11.4	12.1	11.2	11.4	13.1	9.4
September	10.4	10.4	9.7	13.1	10.4	14.7	9.7	10.4	10.4	13.1	14.7	9.7	14.3	10.4	13.1	10.4	13.1	12.4	13.1	13.1	11.4	11.7	10.4	10.2	14.3	13.2
October	13.1	13.1	10.0	15.1	10.4	14.3	10.0	10.4	10.4	15.1	14.3	10.0	14.7	10.4	14.3	10.4	14.3	11.2	15.1	14.3	11.2	10.1	10.4	9.8	14.7	13.5
November	14.3	14.3	10.4	14.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	10.4	15.1	10.0	14.7	11.2	14.7	10.4	14.7	14.7	9.7	0.01	10.0	10.3	15.1	13.9
December	15.1	15.1	10.4	14.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	10.4	15.4	9.7	15.1	12.4	15.1	10.4	14.3	15.1	9.0	9.7	9.7	10.1	15.4	16.9
Annuai	C.21	C.21	C.21	C.21	C.21	C.21	C.21	C.21	C.21	C71	C.21	12.5	C.2.1	C.21	C.21	C.21	C.21	C.21	C.21	12.5	C.21	C.21	C.21	C.21	2.21	6.21

Table T.7 kWh per H <sub>prod</sub>							with sen.	sitivity anal	sis of O&	$M_{manag(B)} +$	- Epi (Case	? 2)													
Sites												kW/	ʻyr												ĺ
yr ,	1 yr2	yr 3	yr4	yr 5	yr	6 yı	1. L. L.	.8 yr	9 yr	10 yr.	u yı	r12 y.	r13 )	4114	yr 15	yr 16	yr 17	yr 18	yr 19	yr20	yr 21	yr 22	yr23	yr 24	yr 25
Aracari (Brazil) 5 696	5 646	5674	5 628	5 700	5 64	6 569.	5 569	5 563.	7 563	9 564	6 56.	94 56	74 51	536 5	718 5	735 5	689 5	650	. 602	5 697	5 683	5 616	5 628	5 645	5 637
Corvo Island 10.458 (Portugal)	10 535	10467	10 475	10 468	10 56.	3 1049	7 1042	9 1052.	5 10 52	7 1045	4 105.	25 105	:01 10:	500 10	474 10	454 10	510 10	523 11	11 245 11	9560 Iv	0 464 I	0 520	10532	10 452	10 407
Cape Saint James 24 762 (Canada) 24 762	24 848	24927	24 734	24 784	24 84	8 2473	4 2473	4 2492.	7 24 78	4 2484	8 247.	97 247	34 245	936 24	875 24	936 24	903 24	927 24	936 24	4835 2.	4 851 2	4 734 2	24886	24 797	24 881
(cumun)																									
Table T.8 Cashflow for 25 years of	f the wind farm	Aproject	50 000	, kw	Aracati (Bra	(izi)			with	sensitivity a	nalysis of O	& M manage (B)	+ Epi(Case	(2)											
ltem		.			,			t					Years				ţ	9	9	6	;		ç	2	22
	0	-	7	2	4	0	9	,	×	9	10		7	3	4	10	E.	18	61	50	17	77	52	54	3
(-) LCCCM <sub>WF</sub>	60 225 90	'	•			•	,	,	,	,	,	,	,	,				'	•	•	,		,	,	
WI CM T CM	77 090 /7	· ·																							
IMTGou	1 959 78										,									,			,		,
CPCN	1 545 340																								
IS ST	572.83.																								
SIGN	2 136 720	5 -	•	•														'	'	•					
$PO_{CM}$	1 79687	- 6	,	•	,	,	•	,	,		,	,	,	,				'	'	'	•	•	•	,	,
FCM	188 55.		•																						
	17.071		-		-		- 1010101				- 20 - 20 -	- 10.04	- 000 40 00			- 10.010.0		- 10 002 07 00	- 40 177 64	-		-	- 200 000 08		- 100 000
LULMWF (KWIL)T) (+) AAR(SMArt)		40 9/9 024	4 376 931	4 508 965	4 584 266	4759.280	4831313	4 4995 061 5	5 126611	+0- 200 +0-	20 220 403 27 (02 54	66 187 5.65	00 U20 40 /2 31 151 577	1826 587t	0.00/ 49.105 5.963 6.110	750 6287.4	1226 04 017	10.600.0F 00 00.072.0F 00	1 6.608332	100 146 04 0	101 4/0 04	4 994 386	- 000 070 040 5 129 498	5 274 431	398 025
PPAR		4 308 015	4 376 931	4 508 965	4 584 266	4759280	4831313	4 995 061 5	119937 5	194 634 53	27 022 54	66 187 5 65	51 151 577	1856 5870	5 963 6 110	750 6 282 4	130 63877	99 6 502 99	1 6 608 332	6 888 721	-	-	-	-	-
EMP									,			,	,	,				'	'		4 930 788	4 994 386	5 129 498	5 274 431	5 398 025
$(-) O \& M_{WFCM}$		3 958 388	4 021 593	4 142 789	4 211 857	4372535	4459642	4610143 4	724747 4	793 035 45	14 544 50	42 290 5 2.	12 260 5 32	2 943 541	9 232 5 634	158 5 791	793 58882	85 5 993 82	4 6 090 278	6 348 036	5 856 505	5 931 402	6 091 221	6 262 682	5408 790
O&M fixed		2 661 279	1 2 703 850	2 785 412	2 851 928	2 940 042	2 984 539	3 085 692	162.833 3 561.014 1	208.975 32	90.756 35 72.700 1.6	66 724 34	90.983 350 11.776 1.75	7 206 1 706	0.4/5 3.7/4 2.757 1.950	-895 3880 762 1010	948 3.9460 346 1.0400	58 4 017 IS	5 4 082 268	5 4 255 476	4 351 38/	1 572 500	4 5 26 7 44	4 654 645	1/63 714
(+) LRCM		863 268	884850	0/6/001	929 646	952 887	976709	1 001127	026155 1.	051 809 10	78 104 11/	05 057 113	2 683 116	0/1 0/2 /	0.025 1.219				0		-				-
(+) Depreciation		2 458 162	2 519 616	2 582 607	2 647 172	2713351	2781185	2 850 715 2	921982 2	995 032 3 0	69 908 31	46 655 322	25 322 3 30	6 955 338	8 604 3 473	319 3 560	52 3 649 1.	56 3 740 38	5 3 833 894	3 929 742	4 027 985	4128685	4 231 902	4 337 699	1446 142
(=) Profit before tax		3 671 058	3 759 805	3 855 754	3 949 226	4052984	4129565	4236759 4	343 328 4	448 440 45	60.490 4.6	75 610 475	36 896 491	5 868 5 03	5 360 5 169	687 4 050.	788 41486	70 4 249 55	2 4 351 948	4 470 427	3 102 268	3 191 669	3 270 179	3 349 448	3 435 376
(-) Revenue tax	'	1 292 405	1 313 079	1 352 689	1 375 280	1 427 784	1449394	1 498 518 1	535 981 1	558 390 15	91 101 86	39 856 1 69	95 345 175	31 557 176.	3 089 1 833	225 1 884	729 19163	40 1 950 85	7 1 982 500	2 066 616	1479236	1 498 316	1 538 850	1582329	619 407
(+) REPIM	270724	3 747	3 639	3 584	3 485	3 461	3 361	3 326	3 263	3 170 3	113 3	061 3,	032 25	968 28	98 45	58 47/	) 478	487	495	516	528	534	549	564	578
$REI_{CM}$	33 704	•																	•	•	•				
REP CH	-	3 424	3311	3 247	3142	3 105	3 000	2 952	2 880	2 781 2	715 2	651 2	609 25	536 24	58										
OKEP CM	257 020	' ?	' 6	- 5	' ç	-	' ç	- F	- 6	- 000	- 000	- 004	- 64	- 2		- 0	' Ę	- 6	- 104		- 002		- 10	-	' Ľ
UTU-N CM	, ,	C7 C C	070346	000 2002 0	040 7 577 A27	7679660	202 527	2741567 C	019/019	202 770 7.0	57 40.6 2.0	-407 29.914 - 2.10	912 205 M		+0 4. 5 160 2 226	010 21664	10 12 12 10 10 10 10 10 10 10 10 10 10 10 10 10	700-0-01	1 7 260.044	010	1672540	1 602 997	1 721 979	1 767 692	916 546
(=) Frojti ajter tax Wout intere. (_) Døht navmønts			3 181 700	2 261 315	3342 848	3 426 419	3 512 079	7 /0C1+/7	2 010 010	27 077 060	JC 044-00	3595 4072	01.C COC +0 035 4174	12 C NOZ 10	JCC C 601 0	.001 2 100. 16	- -	-16677 60	++6 600 7 1	070 101-7 1			9/010/1	- 10/ 00	
(+) RCM w r		2 621 739	2 687 282	2 754 464	2 823 326	2 893 909	2 966 257	3 040 413 3	116424 3	194 334 32	74 193 33.	56 047 3 43	9949 352	5 947 3 61-	1 096 3 704	448 3 797(	160 3 891 91	36 3 989 28	5 4 089 018	4 191 243	4 296 024	4 403 425	4513511	4 626 348	1742 007
(+) Depreciation		2 458 162	2 519 616	2 582 607	2 647 172	2713351	2781185	2 850 715 2	921 982 2	995 032 3 0	69 908 31	46 655 3 22	25 322 3 30	6 955 338	3 604 3 473	319 3 560	52 3 649 1.	56 3 740 38	5 3 833 894	3 929 742	4 027 985	4128685	4 231 902	4 337 699	1446 142
(=) Free net cashiftow	-59 955 17.	5 7 462 301	4 475 492	4 582 405	4 705 082	4 809 502	4918895	5 032 813 5	159138 5	300 461 54	32.918 55	67 922 56	96918 584	4 423 5 99	9 741 6 128	581 9 523	741 97739.	50 10 028 81	2 10 292 855	10 525 311	9 947 569	10 225 997	10 477 291	0.731.730 1	004 695
4 free net annual califito		D/076+7C-	COC / IN 0+- 0	0/6 +0+ 0+-	060 671 00-	+4C 076 CC-	- mc mn 67-	01- 000 006 C	C1- 6+C 600	10- 000 400	7- 601 0/	1 C 0+7 00	70.6 0/0 00	CU CI +40 C	101 17 000 7	C00 0C 01+	1.60% 0% /01	16/06/00 /0	11 100 100 6	CON DOC 1/ +	+0 0 07 10	1006/+16	786 006 101	7/0 000 711	100 060 07
	LUDE	, 0/.D/	0/.82	08.05	67.90	CF-X0	08.03	68.88	69.09	59.27 G	9.49 0	9.75 11	201 107	124 / U	45 / U.	8 09.0.	/0.0/	17.0/	/0.41	10.11	/0.38	00.0/	/0.85	1112	85.17
Table T.9 Cashflow for 25 years of th	e wind farm pr	oject	50 000 kW	Con	'o Island (Pe	ortugal)			with ser	is it iv ity an al	ysis of O&M	manag(B) + Ep	i (Case 2)												I
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Item	0	-	5	3	4	5	6	3 2	6	10	11	12 12	ars 13	14	15	16	17	18	19	20	21 22	2	24	25	11
(-) TC CCW ***	60 225 901	,	,	,	,	,	,	,	,			,	,	,			,			,				,	
WTCM	27 686 278	,		,		,	,	,						,		,	,				,	,			
$T_{CM}$	24219295		,		,				,	,		,	•			,						,		'	
$LWTG_{CM}$	1 959 783			,	,			,					,	,						,	,			'	
CP CM	1 545 346				,																			'	
1.5 CM	700 7/ 0																								
POCH	1 796 870																								
For	188 559	,	,	,	,	,	,	,	,			,	,	,			,			,				,	
CCC CM	120 211		,						,	,		1	•	•	•							,		'	
LCPM WF (kWh/yr)	-	9 107 610 5	076977490	190.491 90	253 921 90	0 19 8 973 91 0	16328 904	43 405 89 85	8 042 90 685	374 90 700 6	578 90.078.6	77 90 685 374	1 90 530 336	90 473 134	90246888	9 078 677 9	0 557 464 90	0 666 434 90	855 213 90 9	85 978 90 1	62 393 90 64	3 598 90 74	354 90.0595	00 89 670 577	~
(+) AAR (SM/yr)	-	15 046 124 1	5 5 3 5 6 0 9 15	822.374 16.	229.340 164	624 945 17 1	94 985 17 5	13 916 17 83	5 578 18 449	787 18 914 2	23 19 254 L	27 19 868 400	20 330 295	20 825 386	21 292 641	21784277 2	2 447 567 2	3 036 443 23	661 518 24:	87 963 17 2	68 871 17 79.	5 063 18 26	013 185754	63 18 957 626	9
PPAR		15 046 124 1	5 535 609 15	822374 16.	229.340 161	624945 171	94985 175	13 916 17 85	5 578 18 449	787 189142	23 19 254 1	27 19 868 402	2 20 330 295	20 825 386	21 292 641	21784277 2	2 447 567 2	3 036 443 23	661 518 24:	287 963				,	
EMP				,		,	,						•	•	,					- 17.2	68 871 17 79.	5 063 18 26	013 18 575 4	63 18 957 626	ç
(-) $O\& M_{WFCM}$	,	9414550	9 720 704 9	900.012 10	154527 10	401 931 100	758472 109	57 897 11 15	9 028 11 543	192 11 833 6	546 12 046 1	85 12 430 378	3 12 719 232	13 028 853	13 321 057	13 628 511 1	4 043 351 1/	4411 633 14	802 558 15	94336 132	12815 1361	5 294 13 97	912 142121	44 14 504 416	ç
$O\&M_{fixed}$	,	4 895 943	5 055 217 5	148 526 5.	280 948 5.	409 674 5 5	95159 56	98 935 5 80	3 599 6 003	456 61545	579 6265 ľ	79 6 465 053	0 6 615 352	6 776 449	6 928 488	7088460	7 304 288	7 495 901 7	699 294 7	03132 80	27 381 8 27	1977 848	105 8 634 7	38 8812 382	0
$O\&M_{variable}$	,	4518607	4 665 487 4	751486 4	873.579 4.	992.258 51	63313 52	58962 535	5 430 5 5 39	736 5679(	68 57810	06 5 965 321	6 103 880	6 252 405	6392569	6540051	6739 063 4	6915732 7	103 264 7:	91205 51	85 434 5 34	3317 548	807 55774	06 5692034	4
(+) LRCM		863 268	884 850	906971	929 646	952887 5	76709 10	01127 102	6 155 1 051	809 1 078	04 1105 0	57 1 132 683	3 1 161 000	1 190 025	1 219 776	,				,	,	,		'	
(+) Depreciation		2451715	2513008 2	575 833 2.4	540.229 2	706235 25	73 891 28	43 238 291	4 319 2 987	177 30618	856 31384	03 3 216 862	3 297 284	3 379 717	3 464 209	3 550 815	3 639 585	3 7 30 575 3	823 839 3	919435 40	17421 411	7856 422	803 43263	23 4434481	_
(=) Profit before tax		8 946 558	92127639	405 167 9	544 687 9	882136 101	87113 104	00384 1061	7 023 10 945	580 11 220 5	537 11 451 4	02 11 787 570	0 12 069 347	12 366 274	12 655 569	11 706 581 1	2 043 801 1	2 355 385 12	682 799 13 (	013 061 8 0	03477 829	7 625 8 50	904 86896	42 8887 690	
(-) Revenue tax		4513837	4 660 683 4	746712 4	S68 802 4 :	987484 51	58496 52	54175 535	0 673 5 5 34	936 56742	267 57762	38 5 960 521	6 099 089	6 247 616	6387792	6535283	6734 270	6910933 7	098 455 7:	286389 51	80 661 5 33	8519 547	1004 55726	39 5 687 288	œ
(+) REPIM	427 968	2 591	2555	2485	2 435	2383 2	2355 2	293 2.	232 2.20	7 2 164	2 107	2 080	2.036	1 997	1954	1 915	1 890	1 858	262	269	273 2	181	38 292	299	
$REI_{CM}$	33 704	,	,	,	,	,	,	,	,			'	•	,	,	,	,	,	,	,	,	,		'	
$REP_{CM}$		2 425	2383	2310	2256	2199 2	2165 2	099 2.1	334 2 00	3 1955	1 894	1860	1812	1766	1719	1 674	1 642	1 604		,		,			
$OREP_{CM}$	394 264			,	,	,	,	,	,						,	,				,		,			
$GHG.R_{CM}$		166	172	175	179	184	190	194	197 20	4 205	213	220	225	230	235	241	248	255	262	269	273 2	281	38 293	299	
(=) Profit after tax w/out interest		4435 312	45546364	660 940 4	778 320 4	897 035 5 (	30.973 5.1	48 502 5 24	8 581 5412	851 55484	134 56772	70 5 829 129	5 972 295	6 120 655	6269731	5 173 212	5 311 421	5446310 5	584 605 5	726941 28	93 089 2 95	9388 303	188 31172	96 3 2 00 7 02	0
(-) Debt payments		1	3 173 426 31	252.761 3.3.	34 080 3 4.	17 432 3 50	2 868 3 59	3 440 3 680	201 377220	6 386651	1 3 963 174	4 062 253	4 163 810	4 267 905	4 374 602						,	,		'	
$(+) RCM_{WF}$	,	2 621 739	2 687 282 2	754 464 2.	923 326 24	893.909 2.5	966257 30	40413 311	6 424 3 194	334 32741	93 33560	47 3 439 949	3 525 947	3 614 096	3 704 448	3 797 060	3 891 986	3 989 286 4	089 018 4	91243 42	96 024 4 40	3 425 4 51	511 46263	48 4742 007	6
(+) Depreciation		2451715	2513008 2	575 833 24	\$40.229 2.	706235 27	73 891 28	43 238 2 91	4 319 2 987	177 3 061 8	31384	03 3 216 863	3 3 297 284	3 379 717	3 464 209	3 550 815	3 639 585	3 7 30 575 3	823 839 3	019435 40	17421 411	7856 422	803 43263	23 4434481	_
(=) Free net cashflow	-59 797 933	9 508 766	6581500 6	738476 6	1 267.706	079747 72	568 252 74	41713 761	9 123 7 822	156 80179	72 82085	47 8 423 687	8 631717	8 846 563	9 063 787	12 521 086 1	2 842 992 1	3 166 170 13	497 462 13 1	37 619 11 2	06534 1148	0 669 11 76	502 120699	68 12377 190	0
$\Sigma$ free set annual cathlaw	1	50 289 167 -4	3 707 667 -36	06- 061 696	161 395 -22	981 649 -157	13 397 -8 2	71 683 -65	2560 7169	596 15187 5	568 23 396 1	14 31 819 802	2 40 451 519	49 298 082	58361868	70 882 955 8	13 725 947 9	6 892 117 11	0 389 579 124	227 199 135	433 732 146 9	14 402 158 6	0.903 170.750	371 183 128 061	_
- h ee ver muner man	LCOE	73.13	73.52	73.79	4.13	74.47 7.	4.93 7:	123 75.	53 76.0.	2 76.41	76.73	77.23	77.63	78.06	78.47	77.65	78.16	78.63	79.12	9.61 7	7.73 78.	24 78.	20.07	29.47	1
Table T.10 Cashflow for 25 years of t	he wind farmp	roject	50 000 kW	Cap	e Saint Jame	s (Canada)			with ser	is it iv ity an al	ysis of O&M	$\frac{manag(B) + Ep}{Va}$	i (Case 2)												ī
Item	0	-	6	6	4	÷	9	2	0	10	=	12	13	14	15	16	17	18	61	00	21 22	2	24	25	1
																									i
(-) LC CCM WF	60 225 901																								
WTCM	27 686 278				,		,								'					,		,			
Tav	24 219 295																							'	
LWIGCH	1 928/ 929	,		,	,	,	,	,	,			,			,	,	,		,	,	,	,			
$CP_{CM}$	1545346			,		,	,	,	,				•	•	'						,				
$TS_{CM}$	572 832	,	,	,		,	,	,	,			•	•	•	,	,	,	,	,		,				
SICM	2130.720	,		,	,	,	,	,	,			'			,	,	,		,	,	,	,			
POCM	1 796 870																					,			
1 Of	600 881				,	,	,		,										,	,					
CCC CM	117.071																				,	,			
LCPM WF (KWh/yr)		212 943 465	213 677 678 21	4362116 212	0.0000000000000000000000000000000000000	3 130 306 213	677 678 212	699 281 212 ¢	09 281 214 362	116 213 130	306 213 6776	78 213 240 500	212 699 281	214 433 451	213 913 741	214 433 451	214 152 844 2	14 362 116 21	4 433 451 213	565 675 213	706.617 212.69	99 281 214 0	4 7 45 213 2 40	213 962 451	_ ,
		- con oct oc	10 000 000 10	70 07/006	12121 20 10 10 10 10 10 10 10 10 10 10 10 10 10	740 11/000	5+C 0CC703	-0.00 01/0/	00010 2010		10/00 000000	-06 510 6C 9C	202120704 0	160/16 14	202 120 74	10/ 600 11	+ +0/ 100 G	14 706 6670	420 021 48	1 40 406414	0+15 150.00	1000 07/1	10010 000	761 01+00 11	4
PPAK		20190-061.05	16 867 800 19	72 07/026	481 214 33	300/11 34.	\$45 066782	8 CF CT / 8/	0 182 3/ 030	21/442	2 / 2 / 2 / 2 / 2 / 2 / 2	106 C/9 65 80	C8C 10C 0F 0	41 91 / 69/	47 80L 100	44 0.59 /81 4	17 180 C	14 706 507 0	420 071 48	14 954					,
EMP		- 000 000 01											-	-	-						00.00 00.000	10.00 02/1	100/0 000	261 014 80 1/	3
(-) OC M WFON		1 000 000 11	17 100 000 1	77 070 770	77 205 201	107 600 C61	4 CT / / CT CT+	00/21 2445	000111 1312	106/07 10/	20202 02	70 601 /7 10	11/01/ /7 0	001 140 07	160 007 67	5 040 060 06	C 970 709 0	70 774 000 I	00 201 101	0 01 3C3 610	00 00 00 00 00 00 00 00 00 00 00 00 00	66 DC 00 C	1001 20102	007 000 000 000 000 000 000 000 000 000	
Doctor Direct		· 001 0/011	71 +67 006 11	71 000007	21 00101	101 /0570/	+CT 1/0/CC	701 10470	061 11 101 0	712 14402	/ 100 + 1 + 001 /	**1707 C1 C/	740740 CT 4	160 100 01	CT / 77+01	1/1+/001	1 000 017 /	01 010 77/ /	01 / 10 1/1	0.6T C7C0C	15.61 0.000	10.07 /000	C+++ 07 106		
OCM variable		201 200 4	9 322 210 9	6 #C/ CQC	01 C00.64/	101 226710	201 001 001 001	101 1021	CIT 11 + c0 0	97611 6//	01011 1000	201 100 100 100	00017171	140.080 1	9/100271	7/0017 01	1 017 6700	H /06.089.0	. +I 0+C 7C7	+ 01 C07 670	10 01 91670	16.01 /17.0	01711 0010	027 67 011 114	0
(+) TKCM		802 208	884 800 0.495 870 - 0	1/6006	050 051 05	199706	10/0/0	101 /7110	101 001 000	10/01 10/01	0.01 1100	207011 /0	1 101 000	C20.061.1	0//6171	-									,
(+) Depreciation		2425 051	2 480 2/2 2	248428 2	012 139 2	6//445 2.	44379 28	12.988 2.88	CC67 515 5	202 202	0 001 2 182	13 3 182 638	5 202 204	66/ 545 5	565/245	/202122	2 000 803	3 090 884	5 OCI 58/	6 5 5 7 1 1 5	146/9 40/	4 040 4 1/	89/ 4.280	94 438/302	3
(=) Profit before tax		12.851 /02 1	0.017 400 0	- 20 200 13	828450 14	241 260 691 143	0.8480 148	12 51 601 76	727 12 /3/	10001 1007	6 10 10 10 10 10 10 10 10 10 10 10 10 10	00 188 01 00	7/01/7/11 0	1/ 810.545	19 020 400	1 C/6195/1	1 666 6/ 8 /	8 341 302 145 8 2 0 0 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	61 170 008	7.6 006717	00 10 10 10 10 10 10 10 10 10 10 10 10 1	C/ 6 9861	19/66 1811	22 10 246 033	
(-) Kevenue tax		666 850 6	9 31/489 9	6 810185	/44.564 10	008 213 10.2	284 /00 104	93614 1072		043 11 523	2 0 0 11 0/9	7/ 706 11 / 9	12 109 3 /0	605 6/6 21	758 858 71	1 466 112 51	3524511	38/01/1 14	FI 808 /77	24480 IU 4	28 190 10 03	/6.01 81C8	S07 11 804	355 11 52 525 11 55	×
	1/1 +001	1 200	1 220	1 240	0171	1 007 1	1 0671	.1 000	CC 1 C70	500 1	C6C 1 .	1410	000+1	14/3	1 200	C7C 1	+cc 1	060 1	C7+1	1 004	c 1 76+	7	- 1 00:	640 1	
KEI CH	50 MH				'														,	,					
KEP CM	- 000 100	543	/ 87	197	717	007	7007	747	540 FZ	7257	720	477	817	214											
OKEP CH	1 0.30 468			1 0 1 0									-		- 000			- 900							
GHG.K CH		/06	933	006	9/6	1 002 001	1 060 I	1 10	11 //	5 I 154	C011 1100	7611	617.1	667.1	1.288	1 323	1 354	1 390	1 4/25	1 000000	21 244	21	- 1 00: 	1 049 I	
(=) Profit after tax w/out interest	,	5085615	5 040 068 5	4 47 48	4 555 580	188 /00 4.	C 4 000 C62	164 86/ 66	9 904 4 62/	66/4 0/0	6 6 6 8 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	94 4 980 244	221 201 5 4	100 957 0	080 095 0	4 251 364	78/ 022 4	4 400 284 4	0 / 2 / 2 / 2 / 2 / 2 / 4 / 4 / 4 / 4 / 4	1 1- 876.68	CI I- 6111C	17.1- 200.0	/77 1- 000	0/29/71-200	0
(-) Debt payments			3 139 663 3.	218154 32	98.608 3.3.	81 074 3 46	5 600 3 55 	2 240 3 641	046 37320	3 382537	4 3921009	4019 034	4119510	4 222 498	4 328 060										,
(+) KCM WF		2 621 /39	2 08/ 282 2	2 104 404 2	22 320 21	22 606568	06 /07 00	40413 31.	0.424 3.194	334 3.2/4 J	0.0000000000000000000000000000000000000	4/ 3 439 949	19602000	3 014 090	3 /04 448	000/6/5	3 891 980	5 989 280 4	089 018 4	91.245 4.2	96024 440	124 2749	1070 4 070	48 4 / 42 00/	
(+) Depreciation	042 191 02	100 0747	2 480 212 2	248428 2 m1467 6	2 61210	0//440 2.	144379 20	12,988 2.04	0.012 2028 0	1270 2062 L	0.0015 182	15 315230	W077076 5	2201202	002/782	1000102	2 000 802	3 090 884 5	CI CI0 021 08/.	4 C C C C C L L I S	14 0/9 4 0/-	4040 417	102 1 2001	211 4 2 2 1 2 1 2 1 2 1 2 1 2 2 2 2 2 2	3 -
(=) Flee net custifiction $\sum v_{version contrast}$ cathologe		50.320.456 -4	4 395 919 -38	32,1453 -32 (	222 1.5V V	770 278 -19 1	80.238 -12.4	79.280 -5.61	0.686 1434.	547 8 652 3	369 160524	14 23 636211	31 407 985	39 379 849	47 549 170	59 110 630	0.960 261 8	3 107 015 95	557 827 108	316733 115	19 20+ 1 June 436 317 122 7!	28780 1302	1 533 137 910	00 / 00/4 7/00 401	o -
	LCOE un	84.34	85.02	85.71 8	6.17 8	96.87 8	7.59 82	17 88	87 89.7.	8 90.37	61.19	16.16	92.63	93.67	94.44	11.40	94.92	95.82	96.72	7.50 9.	3.98 94.	68 95	73 96.51	97.52	a

## **APPENDIX U**

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend	•	1							Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty conditio	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.08581	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (OAM_m)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.06007	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (nw)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
Wind Project Information	E	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In	centive Model	Notes	Wind Farm Life	-Cycle Prod	rction Model	Notes
Project Name	Aracati (Brazil)		Denr	76 9840	[\$/KW] [\$/VW]	DC M WF PM ww	22 3284	[\$/KW] [\$/FW]	ICCCM we	1 204 5180	[S/KWe] [S/VW]	WF CM		50.000	[KW@yr]
Turbine Model	Vestas V90-2MW		WT cu	553,7256	[\$/kW]	WF	50 000	[kW]	LRCM	16.8443	[\$/kW]	Nwr		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	$M_{hr_{mbyr}}$	100	[m-h]	$\Psi_{aotal}$	15.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMINEMAT	85.00	[\$/m-h]	n ,	3	[yr]	N col		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depry	60.1398	[\$/kW]	N <sub>manyo</sub>	3	[-]	REP CM	0.00000594	[\$/kW <sub>e</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	D <sub>maner</sub>	2.0	[d]	AEP avail/H prod	5 696	[kW/yr]			1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	C <sub>md<sub>may</sub></sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Termin measured to faster $(\pi)$	10.0	[m]	<i>n</i>	1 /98 /43	[\$/kW]	RM cr	20.1954	[\$/KW]	E C	0.0339	[\$/kW_h]	SD		450	[m]
Betz Limit's coefficient (C as . )	0.5926	[ <sup>-1</sup>	V.	5 100 000	[KW] [FW]	WF cap N www.	25	[-]	<i>n</i>	0.023377	[37 K W di ] [57 ]	EIH (		8 760	[hij]
Lifetime of Wind Farm (N)	25	[vr]	v 0 C 0	1 457.72	[k/f]	Mw	3.0	[m-h]	OREP CH	21.6787	[\$/kW_]	PC BM		0 100	[17]
Production Efficiency (WF PF)	11.2%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[\$/m-h]	LCCCMWFeeter	4.5846	[\$/kW]	AEP and		48 979 624	[kW_h/yr]
Availability	98.2%	[%]	ь	-1.94	[-]	Name	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{max}$		20.98%	[%]
	358	[d/yr]	LRCM	16.8443	[\$/kW]	D <sub>m</sub> <sub>max</sub>	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{out}}$		25.00%	[%]
				_		C <sub>md stor</sub>	3 500.00	[\$/d]	$\Psi_{aotal}$	15.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT CM	553.7256	[\$/kW]	O&M <sub>fund</sub>	0.098275	[\$/kWh]	WF cap	50 000	[kW]	n ,,	15	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	NWT	25	[-]	$CR_f$	25.0%	[%]	AEP rated		438 000 000	[kW_eh/yr]
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	3 868.4070	[\$/tCO2]	P&D <sub>IM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>br sur</sub>	3.0	[m-h]	$\sum_{AEP} LCER_{CO_2}$	56.2	[tCO2/MWah]	2		7.00%	[%]
IPT T	10.00%	[%] (\$/1432)	N	25	[yr]	C <sub>Mbr<sub>saw</sub></sub>	85.00	[\$/m-h]	$\sum n m a = m m m m m m m m m m m m m m m m m$	48 856	[MW <sub>e</sub> h]	2 241		0.00%	[%]
T CM	484.3839	[5/KW]	ur O&M	0.025839	[%/yr] [\$//Wb]	D N <sub>m</sub> <sub>sur</sub>	30	[-]	n <sub>v</sub> GHG	0.00123	[yr]	2		5.00%	[%]
P marr	26 30%	[%5]	MIC	71 5608	[\$/b]	C .	3 500.00	[6]	GHG	0.00008	ICO AW N	ICPM		48 979 674	[/w]
Canal	0 1900	[%/\$/ke]	TIC	124 5688	[5/h]	RVM w.s	61 0184	[S/kW]	E EM united	37 1056	[\$/(CO <sub>2</sub> )]	Let in wr		40 777 024	[k ((a)))
LWTG cu	39,1957	[\$/m/kW]	R	30.00%	[%]	Nwr	25	[-]	REPIM distribution	100.0%	[%]	Project Finan	cing	Г	Notes
WF can	50 000	[kW]	ifr	2.50%	[%/yr]	WTS VM	1.4442	[\$/kW]	$\xi_1 REI_{CM}$	0.0%	[%]	Debt ratio	0	50.0%	[%]
L <sub>g</sub>	13 950	[m]	N	25	[yr]	WF cap	50 000	[kW]	$\xi$ , REP <sub>CM</sub>	0.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00	[\$/m]	n <sub>mlh</sub>	72	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3 \text{ OREP }_{CM}$	50.0%	[%]	Debt gr	ace period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	90	[h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	50.0%	[%]	Debt in	terest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	4 202 942	[\$M]	WTweight	200 000	[kg]	REPIM	1 945.0428	[\$/proj]	Debt value		29 841 967	[\$]
ç	0.08%	[%]	AEP avail	48 979 624	[kWh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	3 014 754	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.124114	[\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity rati	0	50.0%	[%]
$TL_c$	0.0400	[\$/m]		-		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity	alue	29 841 967	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanag(B)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	it rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000105	[\$/kWh]	N	25	[yr]	BRL/USD dec2010	0.5986	[-]				
SB <sub>c</sub>	113.00	[S/kWh]	Work days	3.0	[d]	Tmass	138 000	[kg]				Initial Results	Summary	of LCOE win	Notes
SI <sub>CM</sub>	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	9	[d]	RCM <sub>WF</sub>	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	67.6693	yr i	70.7843	yr 15
WF cap	50 000	[kW]	Hours required	72.0	[h]				O&M WFCM			67.8196	yr <sub>2</sub>	69.8148	yr 15
WT inst	42.5238	[\$/kW]	USC ORM	0.000229	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	68.0301	yr3	70.0062	yr 16
Bld cost	500.00	[\$/m <sup>*</sup> ]	NWT	25	[-]	January	/44	738	(%) ccm	80.0%	[%]	68.1907	$yr_4$	70.2090	yr 17
Bld area	35.9374	[m <sup>2</sup> ]	Prequency Renair time	1.8	(per yr)	March	744	737	REPIM distribution			68.6285	yrs yrs	70.4052	yr 18
FS	19.88	[\$/kW]	Hours required	90.0	[11] [b]	April	720	713	č. RELou	1	[1/0]	68 8776	NT 2	70 3784	JF 19
DT	87.22	[\$/kW]	SC on USC on the	162.0	[h/vr]	May	744	737	Č, REP cu	1	[1/0]	69.0932		70.5607	71 20 VI 21
EG	404.52	[\$/kW]	Own Court Own	0.000334	\$\%Wh/yrl	June <sup>(*)</sup>	720	689	$\xi_3 OREP_{CM}$	1	[1/0]	69.2651		70.8306	YT 22
F <sub>CM</sub>	3.7712	[\$/kW]				July	744	737	$\xi_{4}$ GHG.R <sub>CM</sub>	1	[1/0]	69.4927	yr 10	71.1149	yr 23
WACC proj	4.900%	[%/yr]		Г		August	744	737	P&D <sub>LM</sub>			69.7293	yr 11	71.3767	yr 25
n fin	1.0	[yr]				September	720	713	λ.,	1	[1/0]	70.0108	yr 12	69.6873	Mean
WFCM	0.30%	[%]	1			October	744	737	λ <sub>sdi</sub>	0	[1/0]	70.2358	yr 13	1.0827	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	689	$\lambda_{d}$	1	[1/0]	70.4493	yr 14	-0.4490	Y (skewness)
ĸ	0.20%	[%]	1			December	744	737	λ	1	[1/0]	LCOE was	69.6873	US\$/MWh	valid !
		15/1-11/1	1			Total [h/yr]	8 760	8 600	1	p.s.: 1= yes as	nd U=no	1	0.069687	US\$/kWh	

**Figure U.1** *I-O representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Aracati (Brazil) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* 3). Source: Own elaboration

LCOE wso Mode	l Inputs											Financial Ind	exes		Notes
Legend		ĺ		_			_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and an automatically based on user input into	re updated yellow cells.		O&M warranty condition	ns	Notes	Depreciation		Notes	Power Purchase Agreement Rate	0.16291	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.		Costs covered by manufacturer (O&M_m)	80.00%	[%]	Depreciation rate per year	4.00%	[%/yr]	Expected Market Price	0.11403	[\$/kWh]		WACC proj	4.9000%	[%/yr]
Gray cells are not used.			Period of warranty (n w)	5	[yr]	Period of depreciation	25	[yr]	PPAR and EMP ratio	70.00%	[%]		UCRF	0.070243	[-]
				а Г											
Wind Project Information	F	Notes	Levelized Replacement	Cost Model	Notes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public Inc	centive Model	Notes	Wind Farm Life	Cycle Prodi	ction Model	Notes
Project Name	Corvo Island (Portural)		Denr	76 9840	[\$/KW] [\$/VW]	DC.M WF PM ww	22 3284	[S/KW] [S/FW]	ICCCM we	1 204 5180	[5/KWe] [5/VW]	WF CM		50.000	[KW@yr]
Turbine Model	Vestas V90-2MW		WT CM	553.7256	[\$/kW]	WF com	50 000	[kW]	LRCM	16.8443	[\$/kW]	NWT		25	[-]
Number of Wind Turbines (N WT)	25	[-]	T <sub>CM</sub>	484.3859	[\$/kW]	NWT	25	[-]	ifr	2.50%	[%/yr]	WT rated		2 000	[kW]
Turbine Size	2 000	[kW]	N	25	[yr]	Mhran	100	[m-h]	$\psi_{actal}$	15.00%	[%]	N row		5	[-]
Wind Farm Capacity (WF cap)	50 000	[kW]	ifr	2.50%	[%/yr]	CMBreakyr	85.00	[\$/m-h]	n ,,	3	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0	[m]	Depr <sub>Yac</sub>	60.1398	[\$/kW]	N <sub>mawar</sub>	3	[-]	REP CM	0.00000831	[\$/kW <sub>e</sub> h]	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7	[m <sup>2</sup> ]	Y <sub>RC</sub>	15	[yr]	D <sub>m sweet</sub>	2.0	[d]	AEP anait/H prod	10 458	[kW/yr]	L <sub>x</sub>		1 800	[m]
Hub height (H)	105.0	[m]	TO <sub>CM</sub>	0.000033	[\$/kW]	C <sub>mfmyr</sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
Wind speed measured at $(H_0)$ Termin measured to faster $(\pi)$	10.0	[m]	<i>TI</i>	1 798 743	[\$/KW]	RM cr	20.1954	[S/KW]	E	0.0869	[\$/kW_h]	SD		450	[m]
Betz Limit's coefficient (Cas. )	0.5926	[-]	V.	£ 100,000	[KW] [FW]	WP cap N mm	25	[_]	n	0.000000	[3/K// ell]	EIH (		8 760	[hij]
Lifetime of Wind Farm (N)	25	[vr]	v 0 C 0	1 457.72	[\$/kW]	Mw	3.0	[m-h]	OREP CH	39,8043	[\$/kW_]	PC BM	- 1	0.100	[17]
Production Efficiency (WF PF)	20.6%	[%]	PR	0.70	[-]	C <sub>Mm</sub>	85.00	[\$/m-h]	LCCCM	4.5846	[\$/kW]	AEP annil		90 107 610	[kW_h/yr]
Aváilability	98.4%	[%]	Ь	-1.94	[-]	N	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{max}$		20.98%	[%]
	359	[d/yr]	LRCM	16.8443	[\$/kW]	$D_{m_{BUCC}}$	2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{wecz_{out}}$		25.00%	[%]
				_		C <sub>md mer</sub>	3 500.00	[\$/d]	$\Psi_{astal}$	15.0%	[%]	P&D <sub>LM</sub>	factor	0.839325	[-]
Wind Farm Life-Cycle Capit	al Cost Model	Notes	Wind Farm O&M Cost M	Model	Notes	S&RV	1 297.3916	[\$/kW]	ifr	2.5%	[%/yr]	$N_{WT}$		25	[-]
WT <sub>CM</sub>	553.7256	[\$/kW]	O&M <sub>ful cu</sub>	0.098275	[\$/kWh]	$WF_{cap}$	50 000	[kW]	n ,.	15	[yr]	Α		6 361.7	[m <sup>2</sup> ]
$CM_{WT}$	265.32	[\$/kW]	LCCCM WF	1 204.5180	[\$/kW]	NWT	25	[-]	CRf	25.0%	[%]	AEP rated		438 000 000	$[kW_eh/yr]$
RC WT	73.70%	[%/\$/kW]	σ	0.0000001%	[%]	$A_{WT}$	43.00	[m <sup>2</sup> /wt]	GHG.R CM	2 487.1430	[\$/tCO2]	P&D <sub>LM</sub>			
C <sub>kW</sub>	400.00	[\$/kW]	LLC	0.0530	[\$/kWh]	M <sub>br un</sub>	3.0	[m-h]	$\sum_{AED} AED$	103.2	[tCO2/MW2h]	2		7.00%	[%]
IPT	10.00%	[%]	N	25	[yr]	CMbrsanv	85.00	[S/m-h]	null_mull_p_1===p_n	89.657	[MW <sub>e</sub> h]	× 141		0.00%	[%]
T CM	484.3839	[5/KW]	ogen	0.048925	[%/yr] [\$/bWb]	D N <sub>m</sub> <sub>un</sub>	30	[-]	n, GHG	0.00123	[yr]	2.3		5.00%	[%]
P marr	26 206	(*5)	MIC	71 5609	(((4)))	C .	2 500.00	[0] [\$/4]	GHG	0.00008	peopany p	ICPM		90 107 610	() W b/m
C	0.1900	[%/3/KW]	TIC	124 5688	[3/1] [\$/b]	PVM wer	61.0184	[3/0] [\$/FW]	C C C C C C C C C C C C C C C C C C C	13,0000	[8/(CO <sub>2</sub> )	LCI M WF		30 107 010	[K W du yi ]
I WIG out	39 1957	[3/ kg] [S/m/kW]	R.	30.00%	[3/1]	N wa	25	[3/4/17]	Berein REPIM distribution	100.0%	[%]	Project Finan	ina	ſ	Notes
WF	50 000	[kW]	ifr	2.50%	[%/vr]	WTS vie	1.4442	[\$/kW]	ξ, RELOV	0.0%	[%]	Debt ratio	- mg	50.0%	[%]
L,	13 950	[m]	Ň	25	[yr]	WF	50 000	[kW]	ζ, REP CH	0.0%	[%]	Debt term		14	[yr]
CAB cont	2 000.00	[\$/m]	n <sub>mth</sub>	48	[h]	ifr	2.50%	[%/yr]	$\tilde{\zeta}_3$ OREP CM	50.0%	[%]	Debt gr	ice period	1	[yr]
CP CM	30.9069	[\$/kW]	n <sub>tih</sub>	100	[h]	Ν	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	50.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00	[\$/kW]	AAR	14 679 146	[\$M]	WTweight	200 000	[kg]	REPIM	1 263.4736	[\$/proj]	Debt value		29 615 397	[\$]
ç	0.08%	[%]	AEP anail	90 107 610	[kWh/yr]	C steel	0.1900	[\$/kg]				Debt pa	yments	2 991 865	[\$/yr]
TS CM	11.4566	[\$/kWe]	O&M <sub>WFCM</sub>	0.147200	\$/kWh/yr]	$TS_{VM}$	0.9965	[\$/kW]	Exchange rates		Notes	Equity ratio	,	50.0%	[%]
TL <sub>c</sub>	0.0400	[\$/m]		_		WF cap	50 000	[kW]	EUR/USD dec2010	1.3252	[-]	Equity v	alue	29 615 397	[\$]
TL,	1 200	[1/kW]	O&M O&Mmanag(B)		Notes	ifr	2.50%	[%/yr]	CAN/USD dec2010	0.9998	[-]	Discour	t rate	9.00%	[%/yr]
$L_t$	3 000	[m]	SC ORM	0.000038	[\$/kWh]	Ν	25	[yr]	BRL/USD dec2010	0.5986	[-]			r	
SB <sub>c</sub>	113.00	[\$/kWh]	Work days	2.0	[d]	Tmass	138 000	[kg]		i i		Initial Results	Summary	of LCOE win	Notes
SI CM	42.7345	[\$/m <sup>2</sup> /kW]	Feb/Jun/Nov	6	[d]	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE wso		Notes	73.1255	yr i	78.4712	yr 15
WF cap	50 000	[kW]	Hours required	48.0	[h]				O&M WFCM			73.5187	$yr_2$	77.6515	yr 15
WT inst	42.5238	[\$/kW]	USC OBM	0.000138	[\$/kWh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M con	1	[1/0]	73.7873	yr 3	78.1612	yr 16
Bld cost	500.00	[\$/m <sup>2</sup> ]	NWT	25	[-]	January	744	740	(%) ccm	80.0%	[%]	74.1334	$yr_4$	78.6268	yr 17
Bld area	300.0	[m <sup>4</sup> ]	Frequency	1.0	[per yr]	February	672	648	KEPIM			74.4746	yr <sub>5</sub>	79.1175	yr 18
FC CM	35.9374	[\$/KW] (\$/14W)	Kepair time	4.0	[n] (b)	March	744	730	EFIM distribution	1	[1/0]	74.9275	yr <sub>6</sub>	79.0115	yr 19
r3 DT	19.88	[3'KW] [\$/FW]	SC USC	148.0	[II]	May	744	736	E REP	1	[1/0]	75 5275	97.7 VF.	78 2446	yr 20
FG	404 52	[5/kW]	SC OEM TO SC OEM	0 000176	54Wh/wr	Jung <sup>(*)</sup>	720	696	Č, OREP.CH	1	[1/0]	76.0152	37.8 XF.0	78 7103	37 21
EG	3 7712	[\$/kW]		0.0001/0 [		July	744	736	ŠA GHG R CH		[1/0]	76.4118	VT 10	79.0644	37 22 VE 23
WACC arei	4.900%	[%/yr]		Г	1	August	744	736	P&D <sub>LM</sub>		[1/0]	76.7332	yr 11	79.4723	yr 25
n <sub>fin</sub>	1.0	[yr]				September	720	712	λa	1	[1/0]	77.2289	yr 12	76.8666	Mean
W <sub>FOV</sub>	0.30%	[%]	1			October	744	736	λ <sub>sdi</sub>	0	[1/0]	77.6321	yr 13	2.0151	SD
CCC CM	2.4042	[\$/kW]				November <sup>(*)</sup>	720	696	$\lambda_d$	1	[1/0]	78.0589	yr 14	-0.4631	Y (skewness)
ĸ	0.20%	[%]				December	744	736	λ,,,	1	[1/0]	LCOE	76.8666	US\$/MWh	valid !
LCCCM WF	1 204.5180	[\$/kW]				Total [h/yr]	8 760	8 616		p.s.: 1= yes at	nd 0=no		0.076867	US\$/kWh	

**Figure U.2** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Corvo Island (Portugal) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case* 3). Source: Own elaboration

LCOE wso Mode	l Inputs										Financial Ind	exes		Notes
Legend						_		Revenues		Notes	Inflation	rate (ifr)	2.50%	[%/yr]
Green cells indicate information and a	re updated	0& M warranty conditi	Ne	tes	Depreciation		Notes	Power Purchase Agreement Rate	0.13835	[\$/kWh]		$MC_A$	50	[\$/kW]
Yellow cells are for use input information	on about the project.	Concerned to manufactures (0.6M	80.00%	61	Depreciation rate per year	4.00%	[%/vr]	Expected Market Price	0.09684	[S/kWh]		WACC	4 9000%	[%/yr]
Grav calls are not used		Daried of moments (m. )	5 (		Bariad of dampsistion	25	(10.74) food	DBAB and EMD main	70.00%	(0.1.1.)		UCPE	0.070242	1.1
		relied of wallanty ( <i>n</i> y)	L	(A)	renou or depreciation	20	64		70.0070	[/0]		0 ciu	0.070245	
Wind Project Information	Note:	Levelized Replacement	Cost Model No	tes	Wind Farm Removal C	ost Model	Notes	Renewable Energy Public In-	centive Model	Notes	Wind Farm Life	-Cycle Prod	uction Model	Notes
Project Name	Firestar Wind Farm	AR CM	16.8442 [S/	kW]	DCM WF	1 339.9154	[\$/kW]	REI CM	65.7637	[\$/kWe]	WF CM		50 000	[kW <sub>o</sub> /yr]
Project Location	Cape Saint James (Canada)	Depr <sub>WT<sub>mi</sub></sub>	76.9840 [S/	kW]	RM WT	22.3284	[\$/kW]	LCCCM <sub>WF</sub>	1 204.5180	[\$/kW]	WF cap		50 000	[kW]
Number of Wind Turbines (Num)	25 [-]	WI CM	484 3859 [5/	kw] kW]	WF cap N um	25	[KW]	LRCM	2 50%	[\$/KW] [%/yr]	W WT		2.000	[=] (kW)
Turbine Size	2 000 [kW	N	25	(r)	M	100	[m-h]	W united	15.00%	[%]	N raw		5	[-]
Wind Farm Capacity (WF cap)	50 000 [kW	ifr	2.50% [%	/yr]	CMarawar	85.00	[\$/m-h]	n ,,	3	[yr]	N <sub>col</sub>		5	[-]
Rotor Diamenter (D)	90.0 [m]	Depr <sub>Yac</sub>	60.1398 [\$/	kW]	N <sub>manar</sub>	3	[-]	REP CM	0.00000053	$[kW_{e}h]$	D		90.0	[m]
Swept Area per Turbine (A)	6 361.7 [m <sup>2</sup> ]	Y <sub>RC</sub>	15 [	(r)	D <sub>m</sub> <sub>max</sub>	2.0	[d]	AEP anail/H prod	24 762	[kW/yr]	L <sub>x</sub> ,		1 800	[m]
Hub height (H)	105.0 [m]	TO CM	0.000033 [S/	kW]	C <sub>nd<sub>mar</sub></sub>	2 500.00	[\$/d]	ifr	2.50%	[%/yr]			2 430	[m]
wind speed measured at $(H_0)$ Terrain measure factor $(a)$	0.14 [m]	11 V	237 699 000	w)	KM CT	20.1934	[5/KW] [//W]	ь Е.	0.007398	[\$/KW_cfl] [\$/VW_b]	SD		450	[m]
Betz Limit's coefficient (C PBetz)	0.5926 [-]	Va	6 100 000 [k	wi	N <sub>WT</sub>	25	[-]	-0 n <sub>c</sub>	20	[yr]	FLH <sub>vd</sub>		8 760	[h/yr]
Lifetime of Wind Farm (N)	25 [yr]	C 0	1 457.72 [\$/	kW]	MAN	3.0	[m-h]	OREP CM	83.3033	[\$/kWe]	PC PM			
Production Efficiency (WF PE)	48.6% [%]	PR	0.70	-]	$C_{Mir_{k_{T}}}$	85.00	[\$/m-h]	LCCCM <sub>WFORGGM</sub>	4.0521	[\$/kW]	AEP avail		212 943 465	[kW <sub>e</sub> h/yr]
Aváilability	98.2% [%]	b	-1.94	-]	N <sub>mmcr</sub>	3	[-]	LCCCM WF	1 204.5180	[\$/kW]	$\eta_{wecs}$		20.35%	[%]
	358 [d/yr	LRCM	16.8443 [\$/	<i>w]</i>		2.0	[d]	WACC proj	4.9000%	[%/yr]	$\eta_{_{\mathrm{NMCS}_{\mathrm{brid}}}}$		25.00%	[%]
Wind From Life Cords Conie	-I Cost Madal Nata	West From ORM Cod	M-d-l	4.4.4	C and MCT	3 500.00	[\$/d]	ψ <sub>total</sub>	15.0%	[%]	P&D <sub>LM</sub>	factor	0.814145	
wina Farm Life-Cycle Capit	553 7256 ISVW	O&M	0.008275 (SA	whi	S&RV	1 297.3916	[\$/KW]	ifr	2.5%	[%/yr]	N WT		63617	[-]
CM <sub>wr</sub>	265.32 (S/kW	LCCCM	1 204,5180 [\$/	kW1	Nwr	25	[-]	CR	25.0%	[%]	AEP		438 000 000	[m] [kW_h/yr]
RC WT	73.70% [%/\$/k	σ	0.0000001% [	6]	AWT	43.00	[m <sup>2</sup> /wt]	GHG.R CM	10 881.1639	[\$/tCO <sub>2</sub> ]	P&D <sub>LM</sub>			
$C_{kW}$	400.00 [\$/kW	LLC	0.0530 [\$/1	Wh]	MARTIN	3.0	[m-h]	$LCER_{CO_2}$	244.5	[tCO2/MWah]	λ <sub>a</sub>		7.00%	[%]
IPT	10.00% [%]	N	25	(r]	$C_{Mhr_{MRV}}$	85.00	[\$/m-h]	$\sum AEP_{aval} = \dots = $	212 467	[MWeh]	λ <sub>nāi</sub>		3.00%	[%]
T <sub>CM</sub>	484.3859 [S'kW	ifr	2.50% [%	/yr]	N <sub>m xany</sub>	3	[-]	n,	25	[yr]	2.1		5.00%	[%]
T <sub>merr</sub>	138 000 [kg]	D MC	0.041526 [\$4	Whj	D <sub>msaw</sub>	3.0	[d]	GHG <sub>IM F int</sub>	0.00123	[tCO2/MW,h]	λ <sub>m</sub>		5.00%	[%]
RC T	28.30% [%/5/k	MLC TIC	/1.5008 [3	/nj /h)	DVM	5 500.00	[\$/d] (\$/kW)	GHG <sub>EM</sub> <sub>unicol</sub>	24,0000	[ICO/MW,h]	LCFM <sub>WF</sub>		212 943 403	[K w <sub>e</sub> n/yr]
LWTGey	39.1957 [\$/m/k]	/ Rime	30.00% [	61 61	Nwr	25	[3'KW]	REPIM distribution	100.0%	[%]	Project Finan	ina	1	Notes
WF cm	50 000 [kW	ifr	2.50% [%	/vrl	WTS VM	1.4442	[\$/kW]	ξ, RELON	0.0%	[%]	Debt ratio		50.0%	[%]
Lg	13 950 [m]	N	25 [	yr]	WF cap	50 000	[kW]	$\xi_2 REP_{CM}$	0.0%	[%]	Debt term		14	[yr]
CAB cost	2 000.00 [\$/m]	n <sub>mlb</sub>	72 [	h]	ifr	2.50%	[%/yr]	$\xi_3 OREP_{CM}$	50.0%	[%]	Debt gr	ice period	1	[yr]
CP CM	30.9069 [S/kW	n <sub>ifh</sub>	90 [	h]	N	25	[yr]	$\tilde{\zeta}_4$ GHG.R <sub>CM</sub>	50.0%	[%]	Debt int	erest rate	5.00%	[%/yr]
EF c	400.00 [\$/kW	AAR	29 460 159 [S	M]	WI <sub>weight</sub>	200 000	[kg]	REPIM	5 482.2336	[\$/proj]	Debt value		29 071 659	[\$]
5	0.08% [%]	AEP anail	212 943 465 [kW	h/yr]	C steel	0.1900	[\$/kg]	Eucleman anti-	1	Neter	Debt pa	yments	2 936 934	[\$/yr]
13 CM	0.0400 [\$/kw	Occ 31 WFCM	0.139801 [58	(n/yr)	13 <sub>VM</sub>	0.9963	[5/KW]	EURIUSD	1 2252	Notes	Equity ratio	, 	20.071.650	[%]
1L <sub>c</sub> 71	1 200 [1///W	0&M	N	tes	in cap	2 50%	[% /vr]	CAN/USD 4 dec2010	0.9998	[-]	Discour	t rate	9.00%	[3] [96/vr]
1.	3 000 [m]	SC on M	0.000024 (\$/k	Wh1	N	25	[vr]	BRI/USD 4=2010	0.5986	[-]			7.00%	[/0/]1]
SB .	113.00 [\$/kW	Work days	3.0	d)	Tmm	138 000	[kg]	000 202070	0.0700		Initial Results	Summary	of LCOE was	Notes
SI CM	42.7345 [\$/m <sup>2</sup> /k	[V] Feb/Jun/Nov	9	d)	RCM WF	1 278.8970	[\$/kW]	Conditions for LCOE was	j	Notes	84.3448	yr i	94.4360	yr 15
WF cap	50 000 [kW]	Hours required	72.0	h]				O&M WFCM			85.0205	$yr_2$	94.1138	yr 15
WTinat	42.5238 [\$/kW	USC ORM	0.000053 [\$/k	Wh]	Hours Distribution	FLH <sub>wf</sub> [h]	H prod [h]	O&M ccm	1	[1/0]	85.7100	yr 3	94.9205	yr 16
Bld cost	500.00 [\$/m <sup>2</sup>	NWT	25	-]	January	744	738	(%) ccm	80.0%	[%]	86.1734	$yr_4$	95.8186	yr 17
Bld area	300.0 [m <sup>2</sup> ]	Frequency	1.8 [pe	r yr]	February <sup>(*)</sup>	672	641	REPIM			86.8681	$yr_S$	96.7191	yr 18
PO <sub>CM</sub>	35.9374 [S/kW	Repair time	2.0	h] 51	March	744	737	REPIM distribution	1	[1/0]	87.5940	yr 6	97.4969	yr 19
rs DT	19.88 [3'KW 87.22 [5/AK	SC+USC	162.0 //-	wrl	Max	744	737	REP out	1	[1/0]	88.8666	37.7	93.9817	yr 20
FG	404.52 [S/kW	SC O&M+USC O&M	0.000077 /541	yr i Vh/srl	June <sup>(*)</sup>	720	689	OREP CH	1	[1/0]	89.7788	37.8 VL 0	95,7335	yr 21 YF 22
F <sub>CM</sub>	3.7712 [S/kW		01000077 (000	39	July	744	737	GHG.R CM	1	[1/0]	90.3684	yr 10	96.5076	yr 23
WACC proj	4.900% [%/y	I			August	744	737	P&D <sub>IM</sub>			91.1898	yr 11	97.5244	yr 25
n <sub>fin</sub>	1.0 [yr]				September	720	713	λa	1	[1/0]	91.9082	yr 12	91.7691	Mean
W <sub>F<sub>CH</sub></sub>	0.30% [%]				October	744	737	să i	1	[1/0]	92.6296	yr 13	4.1987	SD
K K	2.4042 [S/kW 0.20% [%]	11			November ''	720	689	24	1	[1/0]	93.6712	91 7691	-0.3338	I (skewness) valid !
LCCCM <sub>wr</sub>	1 204.5180 /\$/₽₩	1			Total [h/wr]	8 760	8 600	~ m	p.s.: ] = yes m	1d 0=no	LCOE was	0.091760	IS\$/kWh	sum :
WCCIM WF	1 204.3100 [\$/KM				Control actions to a control of the	0700	5 000	L	p.s., 1 - yes u		L	0.091/69		

**Figure U.3** *I-O system representation* of  $LCOE_{wso}$  algorithm calculations for the hypothetical 50MW<sub>e</sub> wind farm in Cape Saint James (Canada) with sensitivity analysis of  $O\&M_{manag(B)}$  and  $E_{pi}$  (*Case <sub>3</sub>*). Source: Own elaboration

Table U.1 Energy production (AEP $_{out}$ ) map of the wind farm for Anacati (Brazil) with sensitivity analysis of $O\&M_{manager}$ + $E_{pi}$ (Case 3)	<sub>2μ</sub> ( <i>Cave 3</i> )
Months Vec Head AEPani	$AEP_{anul}(kWb)$
$(ms)(\kappa_{S}m^{-1})(n)(y_{1})(y_{2})(y_{2})(y_{3})(y_{4})(y_{7})(y_{8})(y_{7})(y_{8})(y_{7})(y_{10})(y_{11})(y_{12})(y_{7$	$y_{10}$ $y_{11}$ $y_{12}$ $y_{13}$ $y_{14}$ $y_{15}$ $y_{16}$ $y_{17}$ $y_{18}$ $y_{19}$ $y_{20}$ $y_{21}$ $y_{22}$ $y_{23}$ $y_{23}$ $y_{23}$
anuary 5.05 1.1005 7.35 1.049 132 8.349/132 5.391/142 5.42 10.57.501 8.399/136 7.551 8.05 10.12 8.251 2.62 17.5	8800 98 8890 98 8890 98 557 501 3 802 105 7 507 410 4 252 212 8 890 198 8 890 198 5 57 501 3 802 105 7 507 410 7 522 212 4 252 212
February 4.9 1.1666 641 850430 6803436 3673320 6803436 779598 6803436 779598 779598 779598 4727258 6803436 6803436 779598 3673	6 803 436 6 803 436 779 598 3 673 320 6 803 436 483 758 483 758 3 300 063 4 727 258 7 716 188 1 577 029 1 577 029 7 716 188 6 803 436 4 727 258 4 727 258
March 4.0 1.1671 737 556507 7495900 5438155 8775568 978319 7495900 978319 978319 6560068 7495900 7495900 978319 5438	7495900 7495900 978319 5438155 8876568 896836 1814186 4225724 1814186 1690536 1690536 7826555 8876568 3796335 6560068
April 4.7 1.1667 713 867 380 6 344 604 6 34 604 4 088 931 1 6 34 604 1 6 35 011 1 6 35 011 7 249 700 6 344 604 6 344 604 1 754 600 6 344	6344 604 6344 604 1754 600 6344 604 4.086 931 946 187 946 187 1 633 011 6 344 604 1 635 011 3 671 646 187 7 249 700 6 344 604 1 754 600 7 249 700
W E. D. 11670 737 1814110 5437053 7405671 5437053 1814110 5437053 181410 7837053 5437053 181410 5437053 181410	2 1 1 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2
SAN GARAGE GALARE GALARE AND A CHARLES CARACTERISTICA CARACTERISTICA CARACTERISTICA CONTROL OF AND A CARACTERISTICA CARACTERISTICA CONTROL OF AND A CARACTERISTICA C	MALANDI ONCATA MARCED CONTRA MARCED COTAL DIALOND COTAL CANADA CANADA CANADA CANADA CANADA CANADA CANADA CANADA MALANDI ONCATA MARCED CONTRA MARCED COTAL MARCED CANADA CANADA CANADA CANADA CANADA CANADA CANADA CANADA CANADA
0251 V21 800 6 1/0 604 6 1/0 604 6 1/0 404 8 V21 800 6 V10 604 6 V10 604 6 V10 604 6 V10 604 6 1/0 604 6 V10 604 6 V10 4 V	106.005 66/116 /20100 /20100 67/555 675650 775650 06025/ 775650 162.860 162.8601 /20100 685025/ 67/5555 1/0555 1/0555
July 8.0 1.1098 737 5450 949 3.805 267 8.807 452 1694 513 4.255 665 3.805 265 4.255 665 4.255 665 4.255 665 3.57 816 3.805 267 5 450 949 8.897	25/816 3 805 267 5 450 949 8 807 452 1818 455 3 805 267 3 805 267 55/816 7 513 556 55/816 980 621 4 255 665 4 255 665 1 694 513 898 946 55/816
August 9.6 1.1677 737 7499787 1815127 1815127 1815127 8881171 1815127 5440975 5440975 897302 897302 1815127 4227915 1815	897302 1815127 4227915 1815127 1691413 5440975 7830614 7830614 897302 4227915 7830614 5440975 1815127 1815127 556795 897302
September 10.1 1.1657 713 8.576.955 1633.475 1633.475 3668.197 7.562.383 1633.475 6.338.644 6.338.644 945.208 945.208 1633.475 6.338.644 1633	945 298 1633 475 6338 644 1633 475 3 668 197 6 338 644 7 242 889 7 242 889 945 208 5 254 599 8 576 955 6 338 644 1633 475 3 668 197 6 338 644 945 208
0. 11645 737 700000 076135 555 764 7420 165 175 076 175 1720 167 1720 167 1760 177 1760 177 1760 177 1760 177	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
November 9.2 1.1638 689 6115 594 836 072 836 072 6115 594 836 072 7 296 271 7 296 271 1691 267 1 691 267 836 072 7 296 271 836	1691267 836 072 7296271 836 072 7296271 5 069 696 5 069 696 1575 994 6 988 019 6 115 594 7 296 271 836 072 836 072 7 296 271 1 691 267
December 7.6 1.1651 737 3790014 555580 555580 976690 5429099 555580 8861786 8861786 3790014 3790014 555580 7483417 555	3790014 555580 7483417 555580 976690 8861786 4218687 4218687 3790014 7813521 5429099 8861786 555580 555580 7483417 3790014
Ammuni 7.4 [1666 8600] 48.979.624 48.549.427 48.794.102 48.399.005 49.0212 48.549.424 48.970.644 48.973.647 48.496.226 48.549.424 48.988.028 48.79	48 406 226 48 549 23 48 204 102 48 470 887 49 160 824 40 318 276 48 922 388 48 580 860 48 172 649 48 601 802 48 874 151 48 207 112 48 308 886 48 547 502 48 473 266
ALON ON ONCO MARKAN NUTRAL MODICA MODICA MODICA NAMARA UTITAL DALEA DALEA TALAN MARKAN ANALIA DALEA DALEA DALEA	
Table U.2. Energy production map of the wind farm for Corvo Island (Portugal) with sensitivity analysis of $O \& M_{manag}(B) + E_{pi}$ (Case 3)	$\Sigma_{\mu}(Cae3)$
AEP aui Accord AEP aui AEP aui	$AEP_{const}(kWh)$
Months $(m/s)$ $(k_0/m^3)$ $(h)$ $vr_1$ $vr_2$ $vr_3$ $vr_3$ $vr_4$ $vr_4$ $vr_5$ $vr_6$ $vr_{10}$ $vr_{11}$ $vr_{12}$ $vr_{13}$	VEGA VEGA VEGA VEGA VEGA VEGA VEGA VEGA
	7.10 7.11 7.12 7.13 7.14 7.13 7.10 7.17 7.10 7.19 7.20 7.21 7.22 7.22 7.24 7.23
January 11.7 1.2313 740 14490 462 14490 462 14490 462 14490 462 14490 462 14490 462 14490 462 10871 408 10871 408 10871 408 10871 408 1087	14 499 462 10 871 408 10 871 408 10 871 408 14 490 462 10 871 408 14 490 462 10 871 408 10 871 408 10 871 408 10 871 408 10 871 408 10 871 408 10 871 408
February 11.5 1.2345 648 12092721 4293137 12092721 12092721 12092721 3417096 12092721 12715785 1795784 3417096 12715785 1795784 924	3417096 12715785 1795784 9244173 12092721 6674015 12715785 4293137 5486290 3417096 2815600 12092721 2106703 6674015 12092721 12715785
March 10 \$ 12320 234 103 001 11211 11211 11211 11211 11211 11211 11211 11211 11211 11210 11210 11210 11210 1121	3 105 002 13 21 200 202 13 21 21 200 202 13 21 21 21 20 202 202 202 200 200 200 200
April 9.5 1.2317 712 7316597 7316597 10458483 10458483 10458483 10458483 7316597 10458483 7710485 3086689 7316597 13257022 3086689 1325	7316597 13257022 3086689 13257022 4706485 4706485 13257022 3086689 10134212 3086689 1340075 13257022 3086689 3086689 13257022 3746098
May 8.2 1.2282 736 4851676 10446845 10446845 10446845 6200059 10446845 10446845 10446845 3861662 6200059 10446845 3861662 1437	6 200 059 10 446 845 3 861 662 14 370 115 10 446 845 3 861 662 10 446 845 2 380 787 13 665 991 6 200 059 2 380 787 10 446 845 3 861 662 14 370 115 10 446 845 4 851 676
Lune 7.1 1.2224 696 2.904461 12.869.910 7.007.081 7.007.081 7.007.081 0.045.999 4.565.858 12.869.90 4.565.858 10.145.990 7.007.081 4.565.858 7.002	10 145 900 7 007 081 4 565 858 7 1007 081 2 240 532 2 904 461 7 1007 981 1 2 800 910 7 1007 981 4 565 858 1 2 800 910 7 1097 981 5 834 806
	401004 001700 007701 7664010 7664010 001700 677000 0043741 7664010 100002 7010007 7664010 7664010 7664010 001007
August 0.4 1.20/3 /36 2.340.496 10.5% 68 3/36.310 3/36.310 13434.719 0.095.134 3/36.310 7.414.668 2.340.496 4.769.571 7.414.668 4.76	2340496 4769571 7414668 4769571 1030868 1995072 4769571 13434719 1995072 13434719 4769571 4769571 7414668 4769571 3128063 10270151
September 7.6 1.2064 712 3669202 1928273 5891057 4609876 4609876 4609876 1928273 5891057 9926189 3669202 9926189 3669	926189 3669202 9926189 3669202 5891057 926189 3669202 12944888 2262132 12944888 5891057 3669202 9926189 3669202 2262132 1928273
October 8.9 1.2126 736 6121079 6121079 3141378 2003564 3141378 2003564 2350459 7446229 13491905 13491905 3141378 13491905 314	13401 905 3141378 13401 905 3141378 7446 229 13401 905 3141378 10643782 3141378 2003 564 7446 229 3141378 13401 905 2380 459 2003 564 2350 459
November 10.6 1.2194 696 10.121566 3655.425 2235.143 2235.143 2235.143 2345.143 2947.558 2235.143 12.829.056 223	4544876 2335143 12829.08 2335143 2087258 1282906 2335143 9807761 3 655425 2335143 98017261 2235143 12829976 1015267 5 820771 12829976
Decomber 11 5 1237 736 (1644.084 2721.001) 2011.842 3170.035 3427240 2021.842 146.481 2420 1431.440.04 2021.842 146.481 202	10 19 19 19 19 19 19 19 19 19 19 19 19 19
Annual 9.1 1.2222 8616 90107610 9076974 90190491 9025921 9018953 91016328 90443405 9085574 9070678 90078677 9068374 905	0 700 678 90 078 677 90 685 574 90 530 504 90 473 134 90 246 888 90 078 677 90 557 464 90 666 434 90 855 213 90 985 978 90 162 393 90 643 598 90 743 534 90 059 500 89 670 577
Table U.3 Energy production map of the wind farm for Cape Saint James (Canada) with sensitivity analysis of O&M manag(B) + E <sub>H</sub> (Case 3)	$p_{i}$ (Care 3)
$H_{pred}^{\mu_{ord}} = H_{pred}^{\mu_{ord}}$	$AEP_{auxil}(k W h)$
$_{\rm MOMUN}$ (mbs) (kg/m <sup>3</sup> ) (h) yr <sub>1</sub> yr <sub>2</sub> yr <sub>3</sub> yr <sub>4</sub> yr <sub>5</sub> yr <sub>6</sub> yr <sub>7</sub> yr <sub>8</sub> yr <sub>9</sub> yr <sub>10</sub> yr <sub>11</sub> yr <sub>12</sub> yr <sub>1</sub>	yrio yrii yri2 yri3 yri4 yri5 yri6 yri7 yri8 yri9 yr20 yr21 yr22 yr24 yr24 yr25
January 15,4 1,2561 738 32734798 32734798 32734798 32734798 32734798 32734798 32734798 32734798 32734798 32734798 3013404 3273	22.24.298 22.24.298 2013.404 22.24.798 22.24.798 22.74.798 22
February 147 1552 641 24310.201 6053.878 25.305.327 14.509.901 14.509.901 26.305.327 56.327 56.328 14.509.901 14.399.901 7727.670 25.30	01 200 01 14 200 01 7 7 7 20 20 20 20 20 20 20 20 20 20 20 20 20
Moved 17 12405 1877165 1877165 1877165 2018.060 72.005.833 13.408.183 1877165 72.005.833 2018.060 13.408.183 18.77165 0.007.365 77.00	50 00 80 50 200 00 50 20 20 20 20 20 20 20 20 20 20 20 20 20
του το έξειξες το ποιετά το δείδο. Ο το το ποιετά το ποτές το	and a second second Second (SEC) (SECOND SECOND
May 112 1242 73 121 12100 140 140 140 140 140 140 140 140 140	95:07.01 CT 95:7.1 66.7.1.61 E4 CS8.61 E4 CS8.61 22.761.7 908.016.6 980.016.6 278.927 300.016.6 415.86.57 908.016.6 E1 CS8.61 CT 95:7.1 19.86.57 908.016.6
June 10.4 1.2.591 089 9.257/631 25785.086 11.465.208 16.884.569 8.241/161 25785.086 16.884.569 16.884.569 11.465.208 8.241/161 25785.086 15.384.455 16.88	8 241 191 22 350 089 12 384 422 10 884 360 11 402 208 10 864 360 11 402 208 11 402 208 11 402 208 11 402 208 11 402 308 12 001 10 884 360 10 884 360 10 884 361 10 10 22 38 12 384 420 10 10 10 10 10 10 10 10 10 10 10 10 10
July 10.0 1.2275 737 8761837 29633191 16356443 16356443 7815162 29633191 16356443 16356443 16356443 7815162 29633191 17951122 16356	7815162 29 653191 17 951122 16 356 443 16 356 443 7815162 16 356 443 19 646 221 16 356 443 16 356 443 15 356 443 16 356 16 356 15 356 16 356 156
August 9.7 1.2216 737 777512 12130 855 17864 641 12130 855 17864 641 12130 855 12130 855 12130 855 17864 641 12130 855 19 551 573 1213	17 864 641 12 130 855 19 551 573 12 130 855 17 864 641 87 864 641 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 841 17 864 84
September 10.4 1.2234 713 9469157 7534977 18941875 9469157 26431347 7534977 9469157 9469157 18941875 26431347 7534977 24384108 9469	26 431 347 7 5549 077 24 364 108 9 469 157 18 441 875 18 441 875 18 770 041 18 941 875 18 941 875 12 353 541 13 10 548 9 469 157 8 865 389 24 364 108 19 080 064
October 13.1 1.2327 737 19729 237 8798 861 29789 962 764 25 397 660 8 798 861 9 862 764 9 862 764 29 778 493 25 397 660 8 798 861 27 530 025 9 862	25 397 600 8 796 861 27 530 236 9 862 764 25 397 660 12 241 087 29 778 493 25 397 660 12 253 661 8 8881 296 9 862 764 8 143 371 27 530 236 21 651 123
November 14.3 1.2429 689 23939450 9296482 25949356 8293664 2808575 9206482 8293664 82926664 82926664 25949356 2808725 8293	28 068725 9 206 482 28 068725 8 293 664 25 492 56 11 588 26 0 296 482 25 949 556 25 949 556 7 443 284 8 293 664 8 293 664 8 895 126 28 068725 22 011 001
December 15.1 1.2528 737 30 263 395 10 023 366 25 811 256 7 975 983 20 03 301 10 023 366 7 975 983 25 811 256 20 030 301 10 023 366 32 881 586 3975	20 020 20 10 023 260 23 2581 268 2 972 968 20 269 269 26 269 269 269 278 279 269 26 269 269 269 269 269 269 269 269
Annual 12:5 1.2404 8 600 21294346 213077678 21436216 212699281 213139306 213077678 212699281 21269281 21436216 213139 306 213677678 213240 500 21269	213 100 300 315 677 678 213 200 502 502 301 314 433 451 219 013 741 214 433 451 214 132 544 214 302 451 451 451 215 105 605 213 766 517 212 600 281 200 28

Months												Wind sp.	eed data ser	in for cine	ations (m/s	( )										I
	Vwc [m/e]	. 414		. 414	. 417	. 411	. 414	- 411		. 40				mine rol car				414			UF					
January	5.8	5.8	10.1	7.6	5.6	4.0	10.1	4.0	4.0	7.9	10.1	10.1	4.0	7.6	9.6	7.9	10.1	10.1	4.0	7.6	9.6	4.0	7.6	5 9.6	6 6	62
February	4.9	4.9	9.7	7.9	9.7	4.7	9.7	4.7	4.7	8.6	9.7	9.7	4.7	7.9	9.7	4.0	4.0	7.6	8.6	10.1	6.0	6.0	10.1	9.7 8	0	8.6
March	4.0	4.0	9.6	8.6	10.1	4.9	9.6	4.9	4.9	9.2	9.6	9.6	4.9	8.6	10.1	4.7	4.7	6.0	7.9	6.0	5.8	5.8	9.7	: I'0.	9	9.2
April	4.7	4.7	9.2	9.2	7.9	5.8	9.2	5.8	5.8	9.6	9.2	9.2	6.0	9.2	7.9	4.9	4.9	5.8	9.2	5.8	7.6	4.9	9.6	9.2 (	0	9.6
May	0.0	6.0	8.6	9.6	8.6	6.0	8.6	6.0	6.0	9.7	8.6	8.6	5.8	9.6	9.2	5.8	5.8	4.9	10.1	4.9	4.0	4.7	9.2	2.9	80	9.7
June	7.9	7.9	7.9	9.7	9.2	7.6	7.9	7.6	7.6	10.1	7.9	7.9	7.6	9.7	8.6	6.0	6.0	4.7	9.7	4.7	4.7	7.6	8.6	8.6 4	1 6	1.0
July	8.6	8.6	7.6	10.1	5.8	7.9	7.6	7.9	7.9	4.0	4.0	7.6	8.6	10.1	6.0	7.6	7.6	4.0	9.6	4.0	4.9	7.9	7.9	5.8 4	5	1.0
August	9.6	9.6	6.0	6.0	6.0	10.1	6.0	8.6	8.6	4.7	4.7	6.0	7.9	6.0	5.8	8.6	9.7	9.7	4.7	7.9	9.7	8.6	6.0	6.0 4	. 0.	1.7
September	10.1	10.1	5.8	5.8	7.6	9.7	5.8	9.2	9.2	4.9	4.9	5.8	9.2	5.8	7.6	9.2	9.6	9.6	4.9	8.6	10.1	9.2	5.8	7.6 9		6.4
October	9.7	9.7	4.9	4.9	4.0	9.6	4.9	9.6	9.6	5.8	5.8	4.9	10.1	4.9	4.0	9.6	9.2	9.2	6.0	9.2	7.9	9.6	4.9	4.9 I(	r.	5.8
November	9.2	9.2	4.7	4.7	4.7	9.2	4.7	9.7	9.7	6.0	6.0	4.7	9.7	4.7	4.7	9.7	8.6	8.6	5.8	9.6	9.2	9.7	4.7	4.7	2	5.0
December	7.6	7.6	4.0	4.0	4.9	8.6	4.0	10.1	10.1	7.6	7.6	4.0	9.6	4.0	4.9	10.1	7.9	7.9	7.6	9.7	8.6	10.1	4.0	4.0 9	.0	2.6
Annual	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4 7	4	4.7
Table U.S Wind	V we	es simulatic	ons for AEI	wait In Col	rvo Island (	(Portugal)		WIL	h sensitivit	/ analysis o	t U&M mana	$\frac{g(B) + E_{pi}}{Wind SDe}$	Case 3) sed data ser	ies for simi	lations (m/s	(8										1
Months	( <i>m</i> /s)	VF 1	vr,	$VF_2$	VLA	VFs	Vrk	VF 7	$VF_S$	VF 0	VF 10	VLI	VL	VF 1.2	VLIA	Vris	VLIK	VF 17	VF 18	VF 10	VF 20	VF 21	VF 22	17.32 VI	A FC	7 35
January	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	10.6	10.6	11.7	10.6	10.6	10.6	11.7	10.6	10.6	11.7	10.6	10.6	10.6	10.6	10.6	0.6 10	1 91	0.6
February	11.5	11.5	8.2	11.5	11.5	11.5	7.6	11.5	11.7	6.1	7.6	11.7	6.1	10.5	11.5	9.5	11.7	8.2	8.9	7.6	1.7	11.5	6.4	9.5 11	5 1	1.7
March	10.5	10.5	1.7	5.11	11.5	11.5	8.9	11.5	11.5	6.4	7.1	11.5	6.4	11.5	11.5	8.9	11.5	7.6	9.5	8.2	11.5	11.7	6.1	0.5 11	2	Γ.
April	9.5	9.5	9.5	10.6	10.6	10.6	9.5	10.6	8.2	1.7	9.5	11.5	7.1	11.5	8.2	8.2	11.5	1.7	10.5	7.1	11.7	11.5	1.7	11 1.7	5	2.6
May	8.2	8.2	10.5	10.5	10.5	8.9	10.5	10.5	10.5	7.6	8.9	10.5	7.6	11.7	10.5	7.6	10.5	6.4	11.5	8.9	6.4	10.5	7.6	1.7 10	رج ،	8.2
June	1.7	7.1	11.5	9.5	9.5	9.5	10.6	8.2	11.5	8.2	10.6	9.5	8.2	9.5	6.4	7.1	9.5	6.1	11.5	9.5	6.1	9.5	8.2	J.5 51	S	8.9
July	6.1	6.1	11.5	8.2	8.9	10.5	11.5	9.5	1.7	8.9	6.1	8.9	8.9	8.9	6.1	6.4	8.9	8.9	11.7	10.5	7.6	8.9	8.9	1.5	.6	9.5
August	6.4	6.4	10.6	7.6	7.6	7.6	11.5	8.9	7.6	9.5	6.4	8.2	9.5	8.2	10.6	6.1	8.2	11.5	6.1	11.5	8.2	8.2	9.5	8.2	u r.	).5
September	7.6	7.6	6.1	8.9	8.2	8.2	8.2	6.1	8.9	10.5	10.5	7.6	10.5	7.6	8.9	10.5	7.6	11.5	6.4	11.5	8.9	7.6	10.5	7.6 0	4	1.2
October	8.9	8.9	8.9	7.1	6.1	1.7	6.1	6.4	9.5	11.5	11.5	7.1	11.5	7.1	9.5	11.5	7.1	10.6	1.7	6.1	9.5	7.1	11.5	6.4 (	7	5.4
November	10.6	10.6	7.6	6.4	6.4	6.4	6.4	1.7	6.4	11.5	8.2	6.4	11.5	6.4	1.7	11.5	6.4	10.5	7.6	6.4	10.5	6.4	11.5	6.1 8	1 6.	1.5
December	11.5	11.5	6.4	6.1	7.1	6.1	7.1	7.6	6.1	11.7	11.5	6.1	11.7	6.1	7.6	11.7	6.1	9.5	8.2	11.7	11.5	6.1	11.7	8.9 8	.2 1.	1.5
Annual	1.6	9.1	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	<i>I.6</i>	1.6	1.6	9. I.Q	E E	7.
Table U.6 Wind	speed seri	es simulatio	ons for AEP	P avail in Cap	pe Saint Jar	rres (Canad	a)	wit	h sensitivity	/ analysis o	f O&M mana.	$g(B) + E_{pi}$ (.	Case 3)													I
Months	Vwc											Wind sp.	eed data ser	ries for simu	lations (m/s	8)										1
	(m/s)	yr 1	$yr_2$	yr3	yr.4	yr5	yr6	yr7	$yr_8$	yr 9	yr 10	yr 11	yr 12	yr 13	yr 14	yr 15	yr16	yr 17	yr 18	yr 19	yr 20	yr 21	yr 22	ir 23 yı	24 y	r 25
January	15.4	15.4	15.4	15.4 2 -	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	9.7	15.4	15.4 2 -	15.4	15.4	15.4 2 -	15.4	15.4	16.6	15.4	15.4	4.7	5	с.
r ebruary	14.7	14./	4.71	7.6	1.61	4.71	4.71	1.61	1.61	7.6	4.71	4.71	10.0	1.61	7.6	13.1	7.6	7.6	7.6	7.6	14.5	1.61	1.01	)/ //	0	
March	12.7	12.7	17.7	0.01	14./	7.11	17.7	14./	14./	0.01	11.2	12.7	10.4	14./	10.0	1.61	10.0	10.0	10.0	10.0	13.8	14./	14./	). ) 	4	6.7
April	12.4	12.4	13.1	10.4	14.3	10.4	13.1	14.3	14.3	10.4	10.4	13.1	10.4	14.3	10.4	14.7	10.4	1.61	10.4	10.4	13.8	13.3	14.3	4.3 10	4	6.5
May	7.11	7.11	14.5	4.01	13.1	10.4	14.5	13.1	13.1	10.4	10.4	14.5	7.11	13.1	10.4	14.3	10.4	14./	10.4	10.4	13.4	13.1	13.1	5.0 7 1	7	Ĵ, ĉ
aunc	10.4	10.4	14.7	7.11	1.21	0.01	14./	/ 71	/ 71	7.11	0.01	14.7	4.71	/ 7 /	7.11	1.21	7.11	C:+1	7.11	7.11	0.21	12.7	17.1			7 0
ymr	0.01	0.01	1.61	4.71	4.71	1.6	1.61	4.71	4.71	4.71	7.6	1.61	1.21	4.71	12.4	7.60	4.71	13.1	4.71	7.21	7.71	1.21	4.71	C7		0. 7
August Santambar	1.6	1.6	7.11	12.1	7.11	1.21	7.11	7.11	7.11	12.1	1.21	2.11	1.61	7.11	121	10.0	12.1	121	12.1	121	11.4	1.21	7.11			t. c
Jeptember Octoher	13.1	13.1	10.0	1.51	10.4	14.2	10.01	10.4	10.4	1.51	14.3	10.01	147	104	1.01	104	2.61	11 2	151	1.61	511 J	1.01	r + 01	-1 7.0		4 K
November	14.3	14.3	10.4	14.7	10.0	15.1	10.4	10.0	10.0	14.7	15.1	10.4	15.1	10.0	14.7	11.2	14.7	10.4	14.7	14.7	9.7	10.0	10.01	1 E.0		6.8
December	15.1	15.1	10.4	14.3	9.7	13.1	10.4	9.7	9.7	14.3	13.1	10.4	15.4	9.7	15.1	12.4	15.1	10.4	14.3	15.1	9.0	9.7	9.7	51 1.0	4 11	5.9
Annual	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	2.5 12	.5 L	5.5

Table U.7 kWh per H <sub>prod</sub>							with sen	sitivity anal	ysis of O&	$M_{manag(B)} +$	$E_{pi}$ (Case	3) kW/yr												
Siles	"1 yr2	yr3	yr4	yr 5	уr	1 A	7 yi	r8 yı	9 yr	10 yr.	1 yr.	12 yr 1	'3 yr	14 yı	15 yr	16 yr	17 yr 1	8 yr Is	9 yr 20	yr 21	yr2.	2 yr:	3 yr2.	yr 2
Aracari (Brazil) 5 65	6 5646	5674	5 628	5 700	5641	6 569.	5 569	5 5 63	7 563	9 564	6 569	4 5.67.	4 565	6 57.	18 57.	35 568	9 5651	1 5602	5692	5 683	5 610	6 562	\$ 5645	5 63;
Corvo Island 10 45 (Portugal)	8 10535	10467	10 475	10 468	1056	3 1049	7 1042	9 10 52	5 1052	7 1045	4 1052	5 1050.	7 1050	0 104;	74 10 42	54 1051	0 10.52	10545	10560	10 464	10 520	0 1053	2 10452	10 403
Cape Saint James 24 76 (Canada) 24 76	2 24848	24927	24 734	24 784	24848	8 2473.	4 2473	4 2492	7 2478	14 2484	8 2479	7 24 73.	4 2495	6 248.	75 24 9.	36 24 90	3 24 92;	7 24936	5 24835	24 851	24 734	4 2488	5 24793	24 88.
(Cumu)																								
Table U.8 Cashflow for 25 years	of the wind fam	nproject	50 000	kW ,	Aracati (Bra.	( <b>[z</b> ])			witt	ι sensitivity α	1 alysis of Od	$\epsilon M_{manag(B)} +$	E <sub>pi</sub> (Case 3.	-										
Item		-		6		u		ť	•			- -	Years		15	14	Ē	ġ	10	, ,	ć	ŝ	10	зc
( ) ICCOM	0 200 20	-	7	0	+	0	•	_	0	4	-	71 1	cr	ž	C	9	-	9	6	7	17	7	5	3
(-) DCCCMWF	16 077 00																							
WI CM	12 989 12	2 4																						
I UNC	02 017 12	- -																						
LWIGCM CP	1 545 34	2.4																						
TS 52	572.83	5 0																						
SICU	2 13672	, 1																						
POCH	1 796 87	- 0	•		•																			
$F_{CM}$	188 55	- 6	,	•	,	•	•		,		,				'	•			,	,				'
CCC CM	12021	•	•																					
$LCPM_{WF}$ (k Wh $\Delta r$ )	'	48 979 624	48 549 424	48 794 102	48 399 005	49 021 215	48 549 424	48 970 644 4;	8 970 644 48	473 266 484	96 226 48 54	9 424 48 968	028 48 794	102 48 470 8	87 49 169 82	14 49 318 276	48 922 388 4	18 5 89 8 60 48	172 649 485	91 802 48 87	4 151 48 29'	7112 48 393	836 48 547 5	02 48 473 26
(+) AAR $(SM/yr)$		4 308 015	4376931	4508965	4584266	4759280	4 831 313	4 995 061	5 119 937 5	194 634 53.	27 022 5 46	6 187 5 651	151 5771.	356 58765	63 6 110 75	0 6 282 430	6387799	6 502 991 6	608332 68	88 721 493	0 788 4 99	4386 5129	498 52744	31 5 398 02
PPAR		4 308 015	4376931	4508965	4584266	4759280	4 831 313	4 995 061	5 119 937 5	194 634 53	27 022 5 46	6 187 5 651	151 5771	856 58769	63 611072	0 6 282 430	6387799	6 502 991 6	5608332 68	88 721				'
EMP		2 050 200	- 1001 502	- 147 700		- 273 626	- 450.647		- DATACT	- 					20 5 62415	- 5 201 702	- 000 705	- 100 5 00 5	- 000.770 6.2	- 493 40.026 505	0.788 4999 6 sos sos	1 402 6 001	498 5 2744	51 5 398 02 51 6 406 70
O& M Bund		2 661 279	2703850	2785 412	2 831 928	2 9 4 0 0 4 2	2 984 539	3 085 692	3 162 833 3	208975 32	90.756 3.37	6 724 3 490	983 3566	547 3 6304	75 3 774 89	5 3 880 948	3 946 038	4017195 4	082.268 42	55 476 435	1 387 440	7510 4520	744 4 654 6	45 4 763 71
$O\&M_{urlable}$	'	1 297 109	1 317 743	1 357 376	1 379 929	1 432 493	1 475 103	1 524 451	1 561 914 1	584 059 1 6	23 788 1 66	6 566 1 721	276 1757.	396 17887	57 1 859 26	3 1 910 846	1 942 247	1 976 628 2	008 010 20	92 560 1 50	6 118 152	3 892 1 564	477 1 608 0	38 1 645 07
(+) LRCM		863 268	884 850	906 971	929 646	952 887	976709	1 001 127	026155 1	051809 10	78104 110	6 067 1132	683 1161	000 1 1900	25 1 219 77	- 9.								
(+) Depreciation		2 447 041	2508217	2.570 923	2 635 196	2701076	2 768 603	2 837 818	2 908 763 2	981482 30	56019 313	2 420 3 210	730 3 290	998 3 3732	73 3 457 60	5 3 544 045	3 632 647	3 7 23 4 63 3	816549 35	11 963 400	9 762 4110	0.006 4.212	756 43180	75 4 426 02
(=) Profit before tax		3 659 937	3 748 406	3 844 070	3 937 250	4 040 708	4 116 983	4 223 862	4 330 109 4	434.890 45	46 601 4 66	al 374 4782	304 4900	912 5 021 (	80 5 153 97	73 4 034 682	4 132 161	4 232 630 4	1334 603 44	52 648 308	4 045 3 17.	2 990 3 251	034 3 329 8	24 3 415 26
(-) Revenue tax		1 292 405	1 313 079	1352 689	1375 280	1 427 784	1 449 394	1 498 518	1 535 981 1	558390 15	98107 165	9856 1695	345 1731	557 1763(	89 18332.	5 1884729	1916340	1 950 897	982500 2(	66 61 6 147	9 236 1 49	8316 1538	850 1 5823	29 1 619 40
(+) REPIM	541967	1 072	1 089	1 122	1 141	1 184	1 202	1243	1 274	1 293 1	326 1 :	360 140	V6 143.	5 1463	1521	1563	1590	1 618	1645 1	714 1.7	53 17	776 18	4 1875	1919
$REI_{CM}$		•														•								
$REP_{CM}$	'		,	•	•	•	•				,				'		•							'
$OREP_{CM}$	541967	1		1	'	1		•		•					' :	1	•	•	•					1
GHG-K CH		10/2	1 (189	1 122	1 141	1 184	707.1	1 243	12/4	1 567.1	526 1.	560 1.40	1 45	140:	1521	1 203	0651	1 618	1 045	/14 1	1	//0 18	6/81 4	1919
(=) Profit after tax w/out inter	est -	2 368 604	2436416	2 492 503	2 563 111	2 614 108	2 668 791	2 726 587	2 795 401 2	877793 25	49.820 3.02	2 878 3 088	365 3170	791 3 2594	03 3 322 2t	9 2151516	2217411	2 283 351 2	2 353 748 20	87 746 1 60	6 562 1 67	6450 171	008 1 749 3	71.107.1 68
(+) RCM we		2 621 739	2 687 282	2.754.464	2823 326	2,893,909	2 966 257	3 040413 3	3116424 3	194334 3.2	74193 335	6.047 3.439	949 3.525	M7 36140	96 3 704 44	8 3 797 060	3 891 986	3 989 286 4	089.018 41	- 91 243 4 29	6 024 440	3 425 4 513	511 4 6263	4 4 742.00
(+) Depreciation		2 447 041	2508217	2.570.923	2 635 196	2 701 076	2 768 603	2 837 818 2	2 208 763 2	981482 3.0.	\$6019 313	2 420 3 210	730 3 290	98 3 373 2	73 3 457 60	5 3 544 045	3 632 647	3 7 23 4 63 3	816549 35	11 963 4 00	9 762 4110	0 006 4 212	756 43180	75 4 426 02
(=) Free net cashflow	-59 683 93	14 7 437 385	4 464 539	4571 330	4 693 909	4798176	4 907 460	5 021 223	5 147 403 5	288 594 54	20 892 5 55	5 727 5 684	535 5831	365 59870	04 611806	0 9492621	9 742 043	9 996 099 10	1259315 104	90 952 9 91	2 348 10 189	9 881 10 440	275 10 6937	33 10 965 80
$\Sigma$ free net annual cash!	ъ	-52 246 549	-47 782 010	-43 210 680 -	-38 5 16 771	-33 718 595	-28 811 135 -	23 789 912 -1.	8 642 509 -13	353.915 -79	33 023 -2 37	7 296 3 307	239 9139	104 15 1261	09 21 244 1(	8 30 736 789	40 478 833	50 474 932 66	1734 247 712	25 200 81 13	7 548 91 32	7 429 101 76	703 112 461 4	96 123 427 30
	LCOE	。 67.67	67.82	68.03	68.19	68.45	68.63	68.88	60.09	69.27 6.	2.49 69.	.73 70.0	1 70.2	4 70.45	70.78	69.81	70.01	70.21	70.41 7	0.77 70	38 70.	56 701	3 71.11	71.38

with s Corvo Island (Portugal) 50 000 kW Table U.9 Cashflow for 25 years of the wind farm project

Table U.9 Cashflow for 25 years of th	he wind farm p	roject	50.000 K	M N	<b>Corvo Is land</b>	(Portugal)			with	sensitivity a	nalysis of Oc	& M manag(B)	$+ E_{pi}$ (Case.	3)											
Items													Years												
Tiem	0	-	2	3	4	5	9	7	8	9 1	0 1	11 11	2 13	14	15	16	17	18	19	20	21	22	23	24	25
(-) <i>LC CCM wF</i>	60 225 901			,						,		,					,				,		,	,	
$WT_{CM}$	27 686 278	•	•	,	,	•	,	,	,	,		,	,			1	1	'	,			,			,
$T_{CM}$	24 219 295	,	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	,
LWTG CH	1 959 783	,	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	,
$CP_{CM}$	1 545 346	,	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	,
$TS_{CM}$	572 832	,	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	,
SICM	2 136 726	,	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	,
PO CH	1 796 870		,	,					,							'	'	•	,		,		,	,	,
$F_{CM}$	188 559	,	,	,	,	,	,	,	,	,	,	,	,	,		'	'	,	,	,	,	,	,	,	,
CCCCM	120211	,	,		,		,		,		,	,	,			1	,	,	,	,	,	,	,	,	,
LCPM WF (kWh/yr)	,	90 107 610	90 769 774 5	90 190 491	90 253 921	90 198 973 5	91 016 328 9	0 443 405 89	858 042 90,	\$85374 9070	0 06 878 90 07	78 677 90 68	5 374 90 530	336 90473	134 90 246 8	38 90 078 67.	7 90 557 464	90 666 434	90 855 213 9	0 985 978 90	0 162 393 90	0.643.598 90	743 354 900	59 500 89 6	577 577
(+) AAR $(SM/yr)$	,	15 046 124	15 535 609	15 822 374	16 229 340	16 624 945	17 194 985 1	7513916 17	835 578 18.	149 787 18 9	14 223 19 25	54127 1986	8 402 20 33(	295 20825	386 21 292 6	11 21 784 277	7 22 447 567	23 036 443	23 661 518 2	4 287 963 1	7 268 871 17	7 795 063 18	260.013 18.5	75 463 18 9	67 626
PPAR	,	15 046 124	15 535 609	15 822 374	16 229 340	16 624 945	17 194 985 1	7513916 17	835 578 18.	149 787 18 91	14 223 19 25	54127 1986	8 402 20 33(	295 20 825	386 21 292 6	11 21 784 277	7 22 447 567	23 036 443	23 661 518 2	4 287 963	,	,	,	,	,
EMP	,	,	,	,	,	,	,	,	,	,	,	,	,	,		1	1	'	,	-	7 268 871 15	7 795 063 18	260 013 18 5	75 463 18 9	67 626
(-) O& M wFCH	,	9414550	9 720 704	9 900 012	10 154 527	10401931	10 758 472 1	11 7957897 11	159 028 11.	543 192 11 82	33 646 12 04	46185 1243	0 378 12 715	9 232 13 028	853 13 321 0	57 13 628 511	1 14 043 351	14 411 633	14 802 558 1	5 194 336 1	3 21 2 81 5 13	3 615 294 13	970.912 14.2	212 144 14 5	04416
$O \& M_{fixed}$		4 895 943	5 055 217	5 148 526	5 280 948	5 409 674	5 595 159	5 698 935 5	803 599 64	03456 615	54 579 6 2t	55179 646	5 057 6615	5352 6776	449 69284	88 7 088 460	7 304 288	7 495 901	7 699 294	7 903 132	8 027 381 8	8 271 977 8	488 105 86	634 738 8 8	112 382
O&M variable	,	4518607	4 665 487	4751486	4 873 579	4 992 258	5 163 313	5 258 962 5	355 430 5.	539736 56	79 068 578	\$1 006 5 96	5 321 6102	3880 6252	405 63925	59 6 540 051	1 6739 063	6 915 732	7 103 264	7 291 205	5 185 434	5 343 317 5	482 807 5 5	77 406 5 6	92 034
(+) LRCM		863 268	884850	906 971	929 646	952 887	976709	1 001 127 1	026 155 1 4	351 809 1 07	78 104 1 10	95 057 113.	2 683 116	000 1190	025 12197		'	,	,			,			
(+) Depreciation		2 428 463	2 489 174	2551403	2 615 189	2 680 568	2 747 582	2816272 2	886 679 2:	358.846 3.02	32 817 3 10	98 637 3 18	16 353 3 2 64	5012 3347	662 34313	54 3 517 138	3 3 605 066	3 695 193	3 787 573	3 882 262	3 979 319 4	4 078 802 4	180772 42	85 291 43	92 423
(=) Profit before tax	,	8 923 305	9 188 929	9 380 737	9 619 647	9 856 469	10 160 805 1	0373418 10	589 383 10 1	211249 1119	91 497 11 42	21 636 11 75.	7 060 12 038	8075 12334	220 12 622 7	14 11 672 90	1 12 009 282	12 320 003	12 646 533 1	2 975 888 1	3 035 375 8	8 258 571 8	469.873 8.6	48 610 8 8	45 633
(-) Revenue tax	,	4513837	4 660 683	4746712	4 868 802	4 987 484	5 158 496	5 254 175 5	350 673 5.	534 936 5 6.	74 267 5 7.	76238 596	0.521 6.095	0.89 6.247	616 63877	2 6 535 28	3 6734 270	6 910 933	7 098 455	7 286 389	5 180 661	5 338 519 5	478.004 5.5	72 639 56	87 288
(+) REPIM	995 107	691	713	727	745	764	064	804	819	847	869	884 9	a12 9.	34 95	6 978	1 000	1 031	1 058	1 087	1 115	1 133	1 167	198 1	219 1	244
$REI_{CM}$	'	,	•	,	,	,	,	,	,	,	,	,	,	,		'	•	'	,	,	,	,	,	,	,
$REP_{CM}$	,	,	,	,	,	,	,	,	,	,		,				'	'	,	,	,	,	,		,	,
$OREP_{CM}$	995 107	,	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	,
$GHG.R_{CM}$	'	691	713	727	745	764	064	804	819	847	869	884 9	12 9.	34 95	6 978	1 000	1 031	1 058	1 087	1 115	1 133	1 167	1 198 1	219 1	244
(=) Profit after tax w/out interest		4410 159	4 528 960	4 634 751	4 751 590	4 869 749	5 003 099	5 120 048 5	239 529 5.	383 160 5 51	18 099 5 64	46282 579	77 452 5935	920 6087	561 62358	99 5 138 621	1 5 276 043	5 410 128	5 549 164	5 690 615	2 855 846	2 921 219 2	93 067 30	777 190 3 1	59589
(-) Debt payments	,	,	3 143 328	3 221 911	3 302 459	3 385 021	3 469 646 3	:556387 3 v	45 297 37.	3 825 3 825	3 9 25	586 4023	726 4 124.	319 4 227 4	27 4 333 113	'	'	,	,	,	,	,	,	,	,
$(+) RCM_{WF}$	,	2 621 739	2 687 282	2754464	2 823 326	2 893 909	2966257	3 040 413 3	116 424 3	194334 32.	74 193 3 35	56047 343	9 949 3 52:	5947 3614	096 37044	18 3 797 060	3 891 986	3 989 286	4089018	4 191 243	4 296 024 4	4 403 425 4	513511 46	526 348 4 7	42 007
(+) Depreciation		2 428 463	2 489 174	2551403	2 615 189	2 680 568	2 747 582	2816272 2	886 679 2:	358.846 3.02	32 817 3 10	08 637 3 18,	16 353 3 2 64	5012 3347	662 34313	54 3 517 138	3 3 605 066	3 695 193	3 787 573	3 882 262	3 979 319 4	4 078 802 4	180772 42	85 291 43	92 423
(=) Free net cashflow	-59 230 794	9 460 360	6 562 088	6718708	6 887 646	7 059 206	7 247 292	7 420 346 7	597 334 7	90 116 66L	95 269 8 15	85381 840	0 028 8 60%	7561 8821	892 90385	39 12 452 818	3 12773 095	13 094 606	13 425 755 1	3 764 120 1	1131189 11	1 403 446 11	\$87349 115	88 829 12 2	94019
$\Sigma$ freend amual cashflow		49 770 434 -	-43 208 345 -	36489638 -	-29 601 992 -	22 542 786	15 295 494 -	7 875 149	277 814 7.	522.096 15.5	17 365 23 70	02746 3210	2 774 40 71(	335 49 532	227 585708	16 71 023 63	5 83796730	96 891 337	110 317 091	24 081 212 1	35 212 401 1	46 615 847 151	303 196 170	292 025 182	586 044
	$LCOE_{win}$	23.13	73.52	73.79	74.13	74.47	74.93	75.23	75.53	76.02 71	5.4.1 76	6.73 77.	:23 77.	53 78.0	6 78.47	77.65	78.16	78.63	79.12	19.61	77.73	78.24	8.71 7	9.06	9.47

with sensitivity analysis of  $O\&M_{manog(B)} + E_{pl}$  (Case 3) Cape Saint James (Canada) κw 50.000 Table U.10 Cashflow for 25 years of the wind farm project

Table U.10 Cashflow for 25 years of th	he wind farm.	noject	50 000 kW	r Cap	e Saint Jame	es (Canada)			with s	ensitivity an	alysis of O&	$M_{manog(B)} +$	$E_{pi}$ (Case 3												1
Item													Years												
	0	1	2	6	4	5	9	7	8	10	11	12	13	14	15	16	17	18	19	20	21 21	22	3 24	. 25	1
(-) ICCCM <sub>WF</sub>	60 225 901	,			,	,		,																	,
$WT_{CM}$	27 686 278		,	,					,							'							,	,	
T <sub>CM</sub>	24 219 295	,	,	,		,		,	,	,	,	,			'	,	,	,	,	,	,		,		
LWTG CM	1 959 783	,	,	,		,		,	,	,	,				'	'	,	,	,	,	,		,		
$CP_{CM}$	1 545 346	,	,	,		,		,	,	,	,				'	'	,	,	,	,	,		,		
$TS_{CM}$	572 832		,		,		,		,	,					'	'	,			,		,			,
SICM	2 136 726		,		,		,		,	,					'	'	,			,		,			,
POCH	1 796 870		,	,					,							'							,	,	
$F_{CM}$	188 559			,	,	,		,		,					1		,						,		,
CCC <sub>CM</sub>	120211			,	,	,		,		,					1		,						,		,
LCPM WF (kWh/yr)	,	212 943 465	213 677 678 21	14 362 116 212	699 281 21	3 130 306 21:	677 678 212	699 281 212	699 281 214 3	52 116 213 13	0306 21367	7 678 213 240	500 212 699	281 2144334	51 213 913 74	214 433 451	214 152 844	143621162	14 433 451 21	3 5 65 67 5 21 3	706 617 212 4	699 281 214	04745 213 24	0 500 213 962	2 451
(+) AAR $(SM/yr)$	,	30 196 663 3	1 058 298 31	936 726 32	481214 33	360 711 34	282.550 34	978715 358	53 182 37 03	6811 3774	1 583 38 787	558 39 675	905 40 564.	585 41 917 6	7 42 861 50	44 039 781	45 081 704	6 253 902 47	426 027 48	414 954 347	00 655 354	61 726 36 5	71360 3735	1 777 38 415	192
PPAR	,	30 196 663 3	1 058 298 31	936 726 32	481214 33	360 711 34	282.550 34	978715 358	53 182 37 03	6811 3774	1 583 38 787	558 39 675	905 40 564.	585 41 917 6	7 42 861 50	44 039 781	45 081 704	6 253 902 47	426 027 48	414954			,		,
EMP	,		,	,					,							,	,			- 347	160 655 35 4	61 726 36 5	11360 3735	1777 38 415	192
(-) O& M WFCH	,	20 633 860 2	1 222 504 21	822 620 22	194549 22	795 389 23	425 157 23	900721 244	98 115 25 30	6751 25790	238 26 502	1761 27109	626 27716	717 28 641 1	8 29 285 89	30 090 843	30 802 628	1 603 422 32	104 162 33	079730 294	159748 300	63 783 30 9	94 073 31 65	5 349 32 556	6460
$O\&M_{fixed}$	'	11 570 156 1	1 900 294 12	236 866 12	445 485 12	782 467 13	135 671 13	402 407 137	37 461 14 19	0 972 14 46	2 154 14 861	773 15 202	144 15 542	542 16 061 0	1 1642271	16 874 171	17 273 385	7 722 515 18	171617 18	550 525 19(	26830 194	10 567 20 0	17 937 20 44	5 105 21 027	176
$O\&M_{variable}$	,	9 063 703	9 322 210 9	585 754 9	749.063 10	012 922 10	289 486 10	498314 107	60 654 11 11	5779 11328	3 084 11 640	706 11 886 0	483 12 174	075 125800	17 12 863 171	13 216 672	13 529 243	3 880 907 14	1232546 14	529 205 10 4	132.918 10.6	43 217 10 5	76136 11210	0 244 11 529	285
(+) LRCM	,	863 268	884 850	906 971	929 646	952 887	976709 1	001127 10	26 155 1 05	1 809 1 078	3 104 1 105	057 1132	683 1161	0 061 1 000	5 1219 774		,			,		,			,
(+) Depreciation		2 383 876	2 443 473 2	504 560 2	567174 2	631 353 2	597137 2	764565 28	33 679 2 90	4521 297	7 134 3 051	563 3127	852 3 206	348 328619	9 336835	1 3 452 563	3 538 877	3 627 349	1718 033 3	810.984 35	06258 40	03 915 4 1	4013 420	5613 4311	778
(=) Profit before tax	,	12 809 947 1	3 164 117 13	525 637 13	783 484 14	149 562 14	531238 14	843 686 15 2	14 902 15 68	6390 1600	583 16 441	417 16826	813 17214	916 1775273	4 1816374	5 17 401 501	17 817 953	8 277 830 18	139 898 19	146 209 92	207165 94	11 857 9 6	31300 990	3 041 10 170	510
(-) Revenue tax	,	9 058 999	9 317 489 9	581 018 9	744364 10	008 213 10	284765 10	493 614 107	55 955 11 11	1 043 11 32	3 375 11 636	5267 11902	772 12 169	376 12 575 30	9 12 858 45	13 211 934	13 524 511	3 876 171 14	1 227 808 14	524486 104	28196 106	38 518 10 5	71408 1120	5 533 11 524	1558
(+) REPIM	2 082 583	3 015	3 101	3 188	3 2 4 3	3 331	3 423	3 492 3	579 30	98 37	68 38'	72 396	1 4 050	4 185	4 279	4 397	4 501	4618	4735	4 834 4	958 5	058 5	216 53	27 547	8
$REI_{CM}$	'	,	,	,	,	,	,	,	,	,	,	,			'	'	,	,	,	,	,	,	,	,	,
$REP_{CM}$	•	,	,	,		,		,	,	,	,					,	,	,	,	,	,		,	,	,
OREP CM	2 082 583		,	,					,							,	•						,	,	,
$GHG.R_{CM}$	'	3 015	3 101	3 188	3 243	3 331	3 423	3 492 3	579 34	98 37	68 38'	72 396	1 405	4185	4 279	4397	4 501	4618	4735	4834 4	958 5	058 5	216 53	27 547	R
(=) Profit after tax w/out interest	'	3 753 963	3 849 728 3	947 808 4	042363 4	144 679 4	249 896 4	353 564 44	62 527 4 57	9 044 4 68	977 4805	021 4928	003 5 049.	591 51816	9 530957	4 193 964	4 297 943	4 406 277 4	516824 4	626556 -12	216073 -12	21 603 -12	84 892 -1 29	7 165 -1 348	569
(-) Debt payments	,		085 617 3	162 757 3 2	41 826 33	22.872 3.4	15 943 3 4	91.092 3.57	8369 3667	829 3 759	524 3853.5	12 3 9 4 9 8	90 4 048 59	6 4 149 811	4 253 557	,	,	,	,	,	,		,	,	,
$(+) RCM_{WF}$	,	2 621 739	2 687 282 2	754 464 2	823 326 2	893 909 2	966257 31	040413 31	16 424 3 19	4334 327/	1 193 3 356	6047 3439	949 3 525	947 36140	6 370444	3 797 060	3 891 986	3 989 286	1089 018 4	191 243 42	96024 44	03 425 4 5	3511 462	5 348 4 742	002
(+) Depreciation		2383876	2 443 473 2	504 560 2	567174 2	631 353 2	597137 2	764565 28	33 679 2 90	4521 297.	7 134 3 051	563 3127	852 3 206	348 328619	9 336835	1 3 452 563	3 538 877	3 627 349 3	1718 033 3	810984 35	06258 40	03 915 41	4013 420	5613 4311	778
(=) Free net cashflow	-58 143 317	8759578	5 894 866 6	044 075 6	191 037 6	347 070 6.	507346 6	667450 68	34 260 7 01	0 071 7 18	1779 7 362	1119 7545	953 7732	990 79321-	3 8128819	0 11 443 586	11728 806	2 022 912 13	323 875 12	628783 69	86209 71	85 737 73	32 631 7 53	5 797 7 705	217
$\Sigma$ freens amual cashflow		49 383 739 -4	3 488 873 -37	444 798 -31	253 761 -24	906 692 -18	399 345 -11	731 895 -48	97 634 2 11	2437 929	1 216 16 657	336 24203	289 31 936	278 39 868 43	2 47 997 24	59 440 827	71169633	3 192 545 95	516420 10	3 145 203 115	131 412 122	317 149 129	49 780 137 18	5 577 144 890	0.793
	$LCOE_{wro}$	84.34	85.02	85.71		86.87	87.59	88.17 8	8.87 89	78 90.	37 91	91.9	1 92.6.	93.67	64.44	11.40	94.92	95.82	96.72	97.50 9	13.98 9.	4.68 9	.73 96.	51 97.5	52

## **APPENDIX V**

Variables	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
LCOE <sub>wso</sub>	69.6991	76.8666	91.8264
$v_{wc}$ (m/s)	7.4	9.1	12.5
Source: Own ela	boration. Note	e: Correlation Coeff.= 0.99	996
	<b>T</b> Z · .·	24.2%	36.4%
	variations:	10.3%	19.5%

**Table V.1** Relation  $v_{wc}$  and  $LCOE_{wso}$ 

 Table V.2 Impact of O&M programs on LCOE<sub>wso</sub>

	Aracati (Brazil)		Corvo Island (Portugal)	Cape Saint James (Canada)
<i>O&amp;M</i> <sub>manag(STD)</sub>	69.6792		76.8138	91.7081
$O\&M_{manag(A)}$	69.6991		76.8666	91.8264
$O\&M_{manag(B)}$	69.6873		76.8666	91.7691
Source: Own	elaboration			
Variations:	0.03%	0.07%		0.13%
	0.01%	0.07%		0.07%

Table V.3 Impact of O&M programs on wind farm availability

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O&M programs	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
O&M <sub>manag(STD)</sub>	0.9793	0.9793	0.9793
$O\&M_{manag(A)}$	0.9836	0.9836	0.9836
$O\&M_{manag(B)}$	0.9817	0.9836	0.9817
Source: Own elabo	ration		
Variations:	0.44% 0.24%	$0.44\% \\ 0.44\%$	$0.44\% \\ 0.24\%$

Layouts $(L_{wt})$	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)		
5D4D	69.6792	76.8138	91.7081		
5D7D	69.8318	76.9663	91.8606		
5D10D	69.9843	77.1188	92.0131		
6D12D	70.3401	77.4747	92.3690		
Source: Own elaboration					
	0.22%	0.20%	0.17%		
Variations:	0.44%	0.40%	0.33%		
	0.95%	0.86%	0.72%		

**Table V.4** Impact of  $L_{wt}$  on  $LCOE_{wso}$ 

**Table V.5** Impact of  $E_{pi}$  on  $LCCCM_{WF}$ 

	Item	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
F	Base-case	1 196.8218	1 194.7880	1 185.8714
$M_W$	Case $_{1}$	1 182.0575	1 178.8311	1 164.6862
CCC	Case $_2$	1 199.1041	1 195.9638	1 183.2312
Γ	Case 3	1 193.6800	1 184.6289	1 162.8596
Source: Own elaboration				
		-1.23%	-1.34%	-1.79%
	Variations:	0.19%	0.10%	-0.22%
		-0.26%	-0.85%	-1.94%

**Table V.6** Impact of  $L_{wt}$  on  $LCCCM_{WF}$ 

V	Variables	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
F	5D4D	1 204.5180	1 204.5180	1 204.5180
$M_W$	5D7D	1 207.5681	1 207.5681	1 207.5681
CCC	5D10D	1 210.6183	1 210.6183	1 210.6183
Г	6D12D	1 217.7353	1 217.7353	1 217.7353
Source	: Own elaboration			
		0.25%	0.25%	0.25%
	Variations:	0.51%	0.51%	0.51%
		1.10%	1.10%	1.10%

	U	1150;	101110(11)	p:	
	Item		Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
				$O\&M_{manag(A)}$	
	Reference		69.6792	76.8138	91.7081
$E_{wso}$	Case $_1$		69.6991	76.8666	91.8264
LCO	Case $_2$		69.6991	76.8666	91.8264
1	Case <sub>3</sub>		69.6991	76.8666	91.8264
So	urce: Own elaboration				
			0.03%	0.07%	0.13%
		Variations:	0.03%	0.07%	0.13%
			0.03%	0.07%	0.13%

**Table V.7** Relation among  $LCOE_{wso}$ ,  $O\&M_{MANAG(A)}$  and  $E_{pi}$ 

Table V.8	Relation among	LCOE	O&MMANACIP	and $E_{n}$
	reenance announg			, and Dn

	Item		Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
				$O\&M_{manag(B)}$	
	Reference		69.6792	76.8138	91.7081
$E_{\scriptscriptstyle WSO}$	Case $_1$		69.6873	76.8666	91.7691
LCO	Case $_2$		<i>69.6873</i>	76.8666	91.7691
I	Case 3		69.6873	76.8666	91.7691
Sou	rce: Own elaboration				
			0.01%	0.07%	0.07%
		Variations:	0.01%	0.07%	0.07%
			0.01%	0.07%	0.07%

Item		Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
<u>,</u>	Base-case	69.6792	76.8138	91.7081
$E_{wsc}$	Case $_1$	69.6792	76.8138	91.7081
CO	Case 2	76.8138	76.8138	91.7081
Π	Case 3	69.6792	76.8138	91.7081
Source	: Own elaboration			
		0.00%	0.00%	0.00%
		10.24%	0.00%	0.00%
		0.00%	0.00%	0.00%

**Table V.9** Impact of  $E_{pi}$  on  $LCOE_{wso}$ 

Items	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
LCCCM <sub>WF</sub>	1 204.52	1 204.52	1 204.52
LCOE <sub>wso</sub>	69.68	76.81	91.71

Table V.10 Relation between *LCCCM<sub>WF</sub>* and *LCOE<sub>wso</sub>* 

Source: Own elaboration

**Table V.11** Relation between  $v_{wc}$  and  $L_{wt}$ 

Variables	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
$v_{wc}(m/s)$	7.4	9.1	12.5
5D7D	69.8318	76.9663	91.8606
5D10D	69.9843	77.1188	92.0131
6D12D	70.3401	77.4747	92.3690

Source: Own elaboration

Variables	Aracati (Brazil)	Corvo Island (Portugal)	Cape Saint James (Canada)
Simple variable	7.4 m/s	9.1m/s	12.5m/s
$\mathcal{V}_{wc}$	100.00%	100.00%	100.00%
$L_{wt}$			
5D7D	0.00%	0.00%	0.00%
5D10D	0.00%	0.00%	0.00%
6D12D	0.00%	0.00%	0.00%
$O\&M_{manag}$			
$O\&M_{manag(A)}$	0.45%	0.43%	0.44%
$O\&M_{manag(B)}$	0.24%	0.43%	0.23%
Epi			
Case 1	0.00%	0.00%	0.00%
Case 2	0.00%	0.00%	0.00%
Case 3	0.00%	0.00%	0.00%
Multiples variables			
$O\&M_{manag(A)}$ + Case 1	0.45%	0.43%	0.44%
$O\&M_{manag(A)}$ + Case <sub>2</sub>	0.45%	0.43%	0.44%
$O\&M_{manag(A)}+ Case_3$	0.45%	0.43%	0.44%
$O\&M_{manag(B)}+ Case_1$	0.24%	0.43%	0.23%
$O\&M_{manag(B)}+ Case_2$	0.24%	0.43%	0.23%
$O\&M_{manag(B)}+ Case_{3}$	0.24%	0.43%	0.23%

**Table V.12** Percentual variations of  $v_{wc}$ ,  $L_{wt}$ ,  $O\&M_{manag}$  and  $E_{pi}$ 

Source: Own elaboration

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