



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

# RETScreen® International

Clean Energy Project Analysis Software

## Wind Energy Project Model

### Click Here to Start

- Description & Flow Chart
- Colour Coding
- Online Manual

### Worksheets

- Energy Model
- Equipment Data
- Cost Analysis
- Greenhouse Gas Analysis
- Financial Summary

### Features

- Product Data
- Weather Data
- Cost Data
- Unit Options
- Currency Options
- CDM / JI Project Analysis
- Sensitivity Analysis



### Clean Energy Decision Support Centre

[www.retscreen.net](http://www.retscreen.net)

- Training & Support
- Internet Forums
- Marketplace
- Case Studies
- e-Textbook

### Partners




Version 3.0

© Minister of Natural Resources Canada 1997-2004.

NRCan/CETC - Varennes

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		<b>Large Wind Turbines</b>	<a href="#">See Online Manual</a>
Project location		<b>Niedersachsen, Germany</b>	
Wind data source		Wind speed	
Nearest location for weather data		Bremen	<a href="#">See Weather Database</a>
Annual average wind speed	m/s	6.4	
Height of wind measurement	m	65.0	3.0 to 100.0 m
Wind shear exponent	-	0.14	0.10 to 0.40
Wind speed at 10 m	m/s	4.9	
Average atmospheric pressure	kPa	101.5	60.0 to 103.0 kPa
Annual average temperature	°C	9	-20 to 30 °C

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Wind turbine rated power	kW	1,650	 <a href="#">Complete Equipment Data sheet</a>
Number of turbines	-	6	
Wind plant capacity	kW	9,900	
Hub height	m	67.0	6.0 to 100.0 m
Wind speed at hub height	m/s	6.4	
Wind power density at hub height	W/m <sup>2</sup>	312	
Array losses	%	2%	0% to 20%
Airfoil soiling and/or icing losses	%	2%	1% to 10%
Other downtime losses	%	3%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	1,650	9,900	
	MW	1,650	9,900	
Unadjusted energy production	MWh	3,141	18,848	
Pressure adjustment coefficient	-	1.00	1.00	0.59 to 1.02
Temperature adjustment coefficient	-	1.02	1.02	0.98 to 1.15
Gross energy production	MWh	3,204	19,225	
Losses coefficient	-	0.90	0.90	0.75 to 1.00
Specific yield	kWh/m <sup>2</sup>	846	846	150 to 1,500 kWh/m <sup>2</sup>
Wind plant capacity factor	%	20%	20%	20% to 40%
Renewable energy delivered	MWh	2,895	<b>17,372</b>	
	GJ	10,423	62,540	

[Complete Cost Analysis sheet](#)

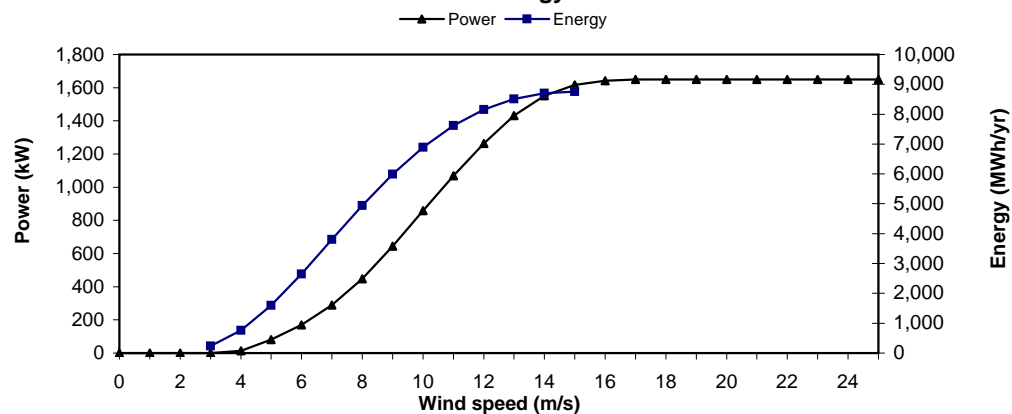
# RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	1,650	<a href="#">See Product Database</a> 6.0 to 100.0 m 7 to 80 m 35 to 5,027 m²
Hub height	m	67.0	
Rotor diameter	m	66	
Swept area	m²	3,421	
Wind turbine manufacturer		Vestas Wind Systems	Rayleigh wind distribution
Wind turbine model		VESTAS V66-1.65MW	
Energy curve data source	-	Standard	
Shape factor	-	2.0	

## Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	0.0	-
1	0.0	-
2	0.0	-
3	0.0	237.1
4	13.5	761.7
5	80.8	1,595.2
6	169.0	2,649.4
7	289.0	3,800.8
8	448.0	4,940.4
9	644.0	5,988.8
10	858.0	6,892.1
11	1,069.0	7,618.0
12	1,263.0	8,155.0
13	1,431.0	8,509.8
14	1,552.0	8,701.6
15	1,617.0	8,755.9
16	1,642.0	-
17	1,649.0	-
18	1,650.0	-
19	1,650.0	-
20	1,650.0	-
21	1,650.0	-
22	1,650.0	-
23	1,650.0	-
24	1,650.0	-
25	1,650.0	-

Power and Energy Curves



[Return to  
Energy Model sheet](#)

Type of project: **Custom**Currency: **Euro symbol**  
Second currency: **User-defined**Cost references: **DEM**  
Rate: €/DEM **0.51130**  
Second currency: **0.51130**

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	% Foreign	Foreign Amount
<b>Feasibility Study</b>							
Site investigation	p-d	5.0	€ 350	€ 1,750		100%	DEM 3,423
Wind resource assessment	met tower	2	€ 10,200	€ 20,400		100%	DEM 39,898
Environmental assessment	p-d	5.0	€ 350	€ 1,750		100%	DEM 3,423
Preliminary design	p-d	20.0	€ 350	€ 7,000		100%	DEM 13,691
Detailed cost estimate	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
GHG baseline study and MP	project		€ -	€ -			DEM -
Report preparation	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
Project management	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
Travel and accommodation	p-trip	5	€ 520	€ 2,600		100%	DEM 5,085
			€ -	€ -			DEM -
Sub-total:				€ 44,000	0.5%	100%	DEM 86,055
<b>Development</b>							
PPA negotiation	p-d	20.0	€ 350	€ 7,000		100%	DEM 13,691
Permits and approvals	p-d	250.0	€ 350	€ 87,500		100%	DEM 171,132
Land rights	project	1	€ 127,800	€ 127,800		100%	DEM 249,951
Land survey	p-d	50.0	€ 350	€ 17,500		100%	DEM 34,226
GHG validation and registration	project		€ -	€ -			DEM -
Project financing	p-d	100.0	€ 350	€ 35,000		100%	DEM 68,453
Legal and accounting	p-d	100.0	€ 350	€ 35,000		100%	DEM 68,453
Project management	p-yr	0.20	€ 102,300	€ 20,460		100%	DEM 40,016
Travel and accommodation	p-trip	18	€ 520	€ 9,360		100%	DEM 18,306
			€ -	€ -			DEM -
Sub-total:				€ 339,620	3.5%	100%	DEM 664,228
<b>Engineering</b>							
Wind turbine(s) micro-siting	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
Mechanical design	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
Electrical design	p-d	5.0	€ 350	€ 1,750		100%	DEM 3,423
Civil design	p-d	5.0	€ 350	€ 1,750		100%	DEM 3,423
Tenders and contracting	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
Construction supervision	p-yr	0.15	€ 102,300	€ 15,345		100%	DEM 30,012
			€ -	€ -			DEM -
Sub-total:				€ 29,345	0.3%	100%	DEM 57,393
<b>Energy Equipment</b>							
Wind turbine(s)	kW	9,900	€ 640	€ 6,336,000		100%	DEM 12,391,942
Spare parts	%	3.0%	€ 6,336,000	€ 190,080		100%	DEM 371,758
Transportation	turbine	6	€ 25,600	€ 153,600		100%	DEM 300,411
			€ -	€ -			DEM -
Sub-total:				€ 6,679,680	69.4%	100%	DEM 13,064,111
<b>Balance of Plant</b>							
Wind turbine(s) foundation(s)	turbine	6	€ 39,900	€ 239,400		100%	DEM 468,218
Wind turbine(s) erection	turbine	6	€ 26,600	€ 159,600		100%	DEM 312,146
Road construction	km	8.50	€ 25,600	€ 217,600		100%	DEM 425,582
Transmission line	km	8.50	€ 70,000	€ 595,000		100%	DEM 1,163,700
Substation	project	1	€ 760,000	€ 760,000		100%	DEM 1,486,407
Control and O&M building(s)	building	1	€ 63,900	€ 63,900		100%	DEM 124,976
Transportation	project	1	€ 34,800	€ 34,800		100%	DEM 68,062
			€ -	€ -			DEM -
Sub-total:				€ 2,070,300	21.5%	100%	DEM 4,049,091
<b>Miscellaneous</b>							
Training	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
Commissioning	p-d	10.0	€ 350	€ 3,500		100%	DEM 6,845
Contingencies	%	5%	€ 9,169,945	€ 458,497		100%	DEM 896,728
Interest during construction	0.0%	12 month(s)	€ 9,628,442	€ -			DEM -
Sub-total:				€ 465,497	4.8%	100%	DEM 910,419
<b>Initial Costs - Total</b>				€ 9,628,442	100.0%	100%	DEM 18,831,297

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	% Foreign	Foreign Amount
<b>O&amp;M</b>							
Land lease	project		€ -	€ -			DEM -
Property taxes	project		€ -	€ -			DEM -
Insurance premium	project		€ -	€ -			DEM -
Transmission line maintenance	%	2.0%	€ 1,355,000	€ 27,100		100%	DEM 53,002
Parts and labour	kWh	17,372,346	€ 0.012	€ 208,468		100%	DEM 407,722
GHG monitoring and verification	project		€ -	€ -			DEM -
Community benefits	-		€ -	€ -			DEM -
Travel and accommodation	p-trip	5	€ 520	€ 2,600		100%	DEM 5,085
General and administrative	%	6%	€ 238,168	€ 14,290		100%	DEM 27,949
			€ -	€ -			DEM -
Contingencies	%	10%	€ 252,458	€ 25,246		100%	DEM 49,376
<b>Annual Costs - Total</b>				€ 277,704	100.0%	100%	DEM 543,133

Periodic Costs (Credits)	Period	Unit Cost	Amount	% Foreign	Foreign Amount
		€ -	€ -		DEM -
		€ -	€ -		DEM -
		€ -	€ -		DEM -
End of project life	-	€ -	€ -		DEM -

[Go to GHG Analysis sheet](#)

# **RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Wind Energy Project**

Use GHG analysis sheet?   
 Potential CDM project?

Type of analysis:

## **Background Information**

Project Information			Global Warming Potential of GHG		
Project name	Large Wind Turbines	Project capacity	9.90 MW	21 tonnes CO <sub>2</sub> = 1 tonne CH <sub>4</sub>	(IPCC 1996)
Project location	Niedersachsen, Germany	Grid type	Central-grid	310 tonnes CO <sub>2</sub> = 1 tonne N <sub>2</sub> O	(IPCC 1996)

## **Base Case Electricity System (Baseline)**

Fuel type	Fuel mix (%)	CO <sub>2</sub> emission factor (kg/GJ)	CH <sub>4</sub> emission factor (kg/GJ)	N <sub>2</sub> O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (tCO <sub>2</sub> /MWh)
Coal	44.0%	94.6	0.0020	0.0030	35.0%	8.0%	1.069
Natural gas	5.0%	56.1	0.0030	0.0010	45.0%	8.0%	0.491
#6 oil	36.0%	77.4	0.0030	0.0020	30.0%	8.0%	1.018
Nuclear	14.0%	0.0	0.0000	0.0000	30.0%	8.0%	0.000
Wind	1.0%	0.0	0.0000	0.0000	100.0%	8.0%	0.000
Electricity mix	100%	237.0	0.0070	0.0068		8.0%	0.861

Does baseline change during project life?

## **Proposed Case Electricity System (Wind Energy Project)**

Fuel type	Fuel mix (%)	CO <sub>2</sub> emission factor (kg/GJ)	CH <sub>4</sub> emission factor (kg/GJ)	N <sub>2</sub> O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (tCO <sub>2</sub> /MWh)
<b>Electricity system</b>							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	8.0%	0.000

## **GHG Emission Reduction Summary**

	Base case GHG emission factor (tCO <sub>2</sub> /MWh)	Proposed case GHG emission factor (tCO <sub>2</sub> /MWh)	End-use annual energy delivered (MWh)	Gross annual GHG emission reduction (tCO <sub>2</sub> )	GHG credits transaction fee (%)	Net annual GHG emission reduction (tCO <sub>2</sub> )
<b>Electricity system</b>	0.861	0.000	15,983	13,767	0.0%	<b>13,767</b>

[Complete Financial Summary sheet](#)

**RETScreen® Financial Summary - Wind Energy Project**

Annual Energy Balance					
Project name	Large Wind Turbines				
Project location	Niedersachsen, Germany				
Renewable energy delivered	MWh	17,372	Net GHG reduction	t <sub>CO2</sub> /yr	13,767
Excess RE available	MWh	-			
Firm RE capacity	kW	-			
Grid type	Central-grid		Net GHG emission reduction - 25 yrs	t <sub>CO2</sub>	344,163

Financial Parameters					
Avoided cost of energy	€/kWh	0.0910	Debt ratio	%	31.0%
RE production credit	€/kWh	-	Debt interest rate	%	5.8%
			Debt term	yr	15
GHG emission reduction credit	€/t <sub>CO2</sub>	-	Income tax analysis?	yes/no	No
Energy cost escalation rate	%	0.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	25			

Project Costs and Savings					
<b>Initial Costs</b>			<b>Annual Costs and Debt</b>		
Feasibility study	0.5%	€ 44,000	O&M	€	277,704
Development	3.5%	€ 339,620			
Engineering	0.3%	€ 29,345	Debt payments - 15 yrs	€	303,322
Energy equipment	69.4%	€ 6,679,680	<b>Annual Costs and Debt - Total</b>	€	<b>581,026</b>
Balance of plant	21.5%	€ 2,070,300			
Miscellaneous	4.8%	€ 465,497	<b>Annual Savings or Income</b>		
<b>Initial Costs - Total</b>	100.0%	€ <b>9,628,442</b>	Energy savings/income	€	1,580,883
Incentives/Grants	€	-	Capacity savings/income	€	-
			<b>Annual Savings - Total</b>	€	<b>1,580,883</b>
<b>Periodic Costs (Credits)</b>					
	€	-			
	€	-			
	€	-			
End of project life -	€	-			

Financial Feasibility					
Pre-tax IRR and ROI	%	14.1%	Calculate energy production cost?	yes/no	No
After-tax IRR and ROI	%	14.1%	Calculate GHG reduction cost?	yes/no	No
Simple Payback	yr	7.4			
Year-to-positive cash flow	yr	6.8	Project equity	€	6,643,625
Net Present Value - NPV	€	3,002,083	Project debt	€	2,984,817
Annual Life Cycle Savings	€	305,631	Debt payments	€/yr	303,322
Benefit-Cost (B-C) ratio	-	1.45	Debt service coverage	-	4.27

Yearly Cash Flows			
Year #	Pre-tax €	After-tax €	Cumulative €
0	(6,643,625)	(6,643,625)	(6,643,625)
1	992,915	992,915	(5,650,710)
2	985,799	985,799	(4,664,911)
3	978,505	978,505	(3,686,406)
4	971,029	971,029	(2,715,377)
5	963,365	963,365	(1,752,012)
6	955,510	955,510	(796,502)
7	947,459	947,459	150,957
8	939,206	939,206	1,090,164
9	930,748	930,748	2,020,911
10	922,077	922,077	2,942,989
11	913,190	913,190	3,856,179
12	904,081	904,081	4,760,259
13	894,744	894,744	5,655,003
14	885,173	885,173	6,540,177
15	875,364	875,364	7,415,540
16	1,168,630	1,168,630	8,584,170
17	1,158,324	1,158,324	9,742,494
18	1,147,760	1,147,760	10,890,254
19	1,136,932	1,136,932	12,027,186
20	1,125,833	1,125,833	13,153,019
21	1,114,457	1,114,457	14,267,476
22	1,102,796	1,102,796	15,370,272
23	1,090,844	1,090,844	16,461,116
24	1,078,593	1,078,593	17,539,709
25	1,066,036	1,066,036	18,605,745

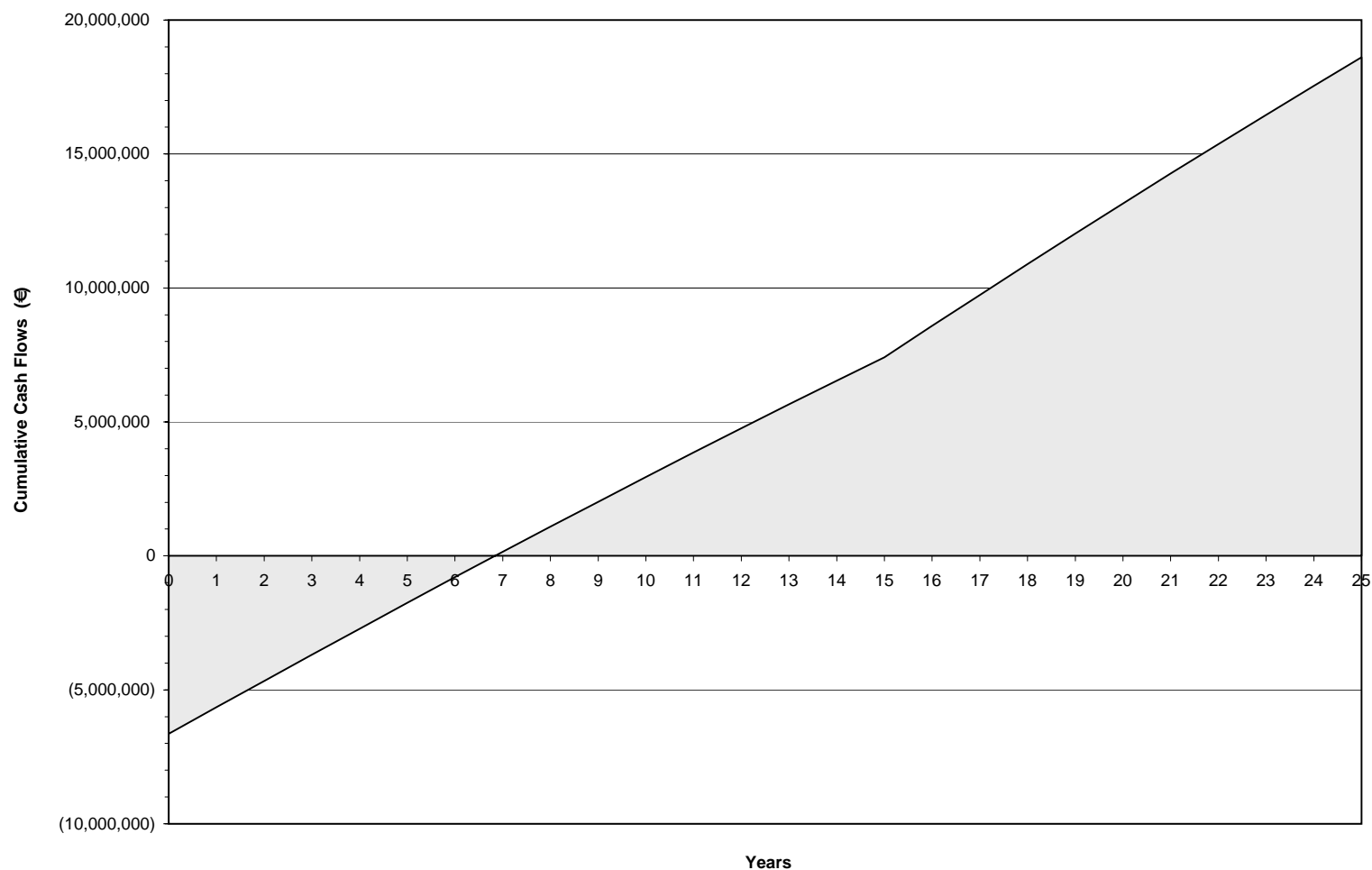
Cumulative Cash Flows Graph

## Wind Energy Project Cumulative Cash Flows Large Wind Turbines, Niedersachsen, Germany

Renewable energy delivered (MWh/yr): 17,372

Total Initial Costs: € 9,628,442

Net average GHG reduction (t<sub>CO2</sub>/yr): 13,767



IRR and ROI: 14.1%

Year-to-positive cash flow: 6.8 yr

Net Present Value: € 3,002,083

# RETScreen® Sensitivity and Risk Analysis - Wind Energy Project

Use sensitivity analysis sheet?

Yes

Perform risk analysis too?

Yes

Project name

Large Wind Turbines

Project location

Niedersachsen, Germany

Perform analysis on

After-tax IRR and ROI

Sensitivity range

20%

Threshold

15.0

%

## Sensitivity Analysis for After-tax IRR and ROI

		Avoided cost of energy (€/kWh)				
RE delivered (MWh)		0.0728 -20%	0.0819 -10%	0.0910 0%	0.1001 10%	0.1092 20%
13,898	-20%	4.0%	6.5%	8.8%	11.0%	13.1%
15,635	-10%	6.5%	9.1%	11.5%	13.9%	16.2%
<b>17,372</b>	0%	8.8%	11.5%	<b>14.1%</b>	16.7%	19.1%
19,110	10%	11.0%	13.9%	16.7%	19.4%	22.1%
20,847	20%	13.1%	16.2%	19.1%	22.1%	25.0%

		Avoided cost of energy (€/kWh)				
Initial costs (€)		0.0728 -20%	0.0819 -10%	0.0910 0%	0.1001 10%	0.1092 20%
7,702,754	-20%	12.8%	16.0%	19.1%	22.2%	25.3%
8,665,598	-10%	10.6%	13.5%	16.4%	19.1%	21.9%
<b>9,628,442</b>	0%	8.8%	11.5%	<b>14.1%</b>	16.7%	19.1%
10,591,286	10%	7.3%	9.9%	12.3%	14.6%	16.9%
11,554,131	20%	6.0%	8.5%	10.7%	12.9%	15.0%

		Avoided cost of energy (€/kWh)				
Annual costs (€)		0.0728 -20%	0.0819 -10%	0.0910 0%	0.1001 10%	0.1092 20%
222,163	-20%	10.0%	12.7%	15.2%	17.7%	20.2%
249,934	-10%	9.4%	12.1%	14.7%	17.2%	19.7%
<b>277,704</b>	0%	8.8%	11.5%	<b>14.1%</b>	16.7%	19.1%
305,474	10%	8.2%	11.0%	13.6%	16.1%	18.6%
333,245	20%	7.5%	10.4%	13.0%	15.6%	18.1%

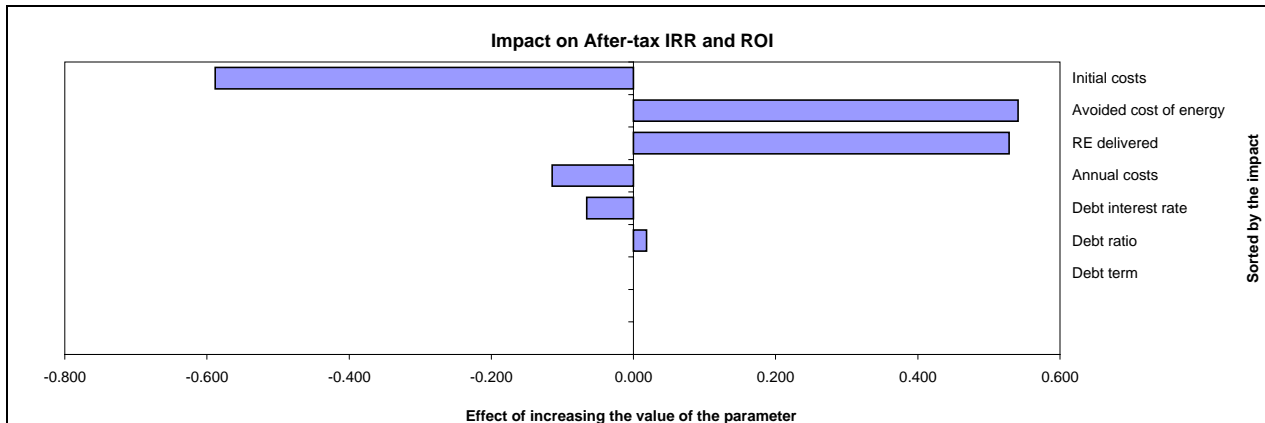
		Debt ratio (%)				
Debt interest rate (%)		24.8% -20%	27.9% -10%	31.0% 0%	34.1% 10%	37.2% 20%
4.6%	-20%	13.9%	14.2%	14.5%	14.8%	15.1%
5.2%	-10%	13.8%	14.0%	14.3%	14.6%	14.9%
<b>5.8%</b>	0%	13.6%	13.9%	<b>14.1%</b>	14.4%	14.7%
6.4%	10%	13.5%	13.7%	14.0%	14.2%	14.5%
7.0%	20%	13.4%	13.6%	13.8%	14.0%	14.3%

		Debt term (yr)				
Debt interest rate (%)		12.0 -20%	13.5 -10%	15.0 0%	16.5 10%	18.0 20%
4.6%	-20%	14.1%	14.4%	14.5%	14.7%	14.8%
5.2%	-10%	14.0%	14.2%	14.3%	14.5%	14.6%
<b>5.8%</b>	0%	13.8%	14.1%	<b>14.1%</b>	14.3%	14.4%
6.4%	10%	13.7%	13.9%	14.0%	14.1%	14.2%
7.0%	20%	13.5%	13.7%	13.8%	13.9%	14.0%

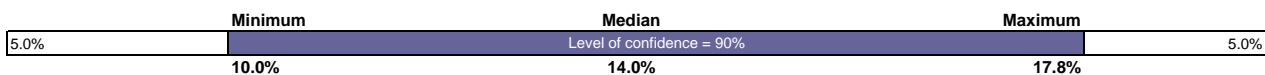
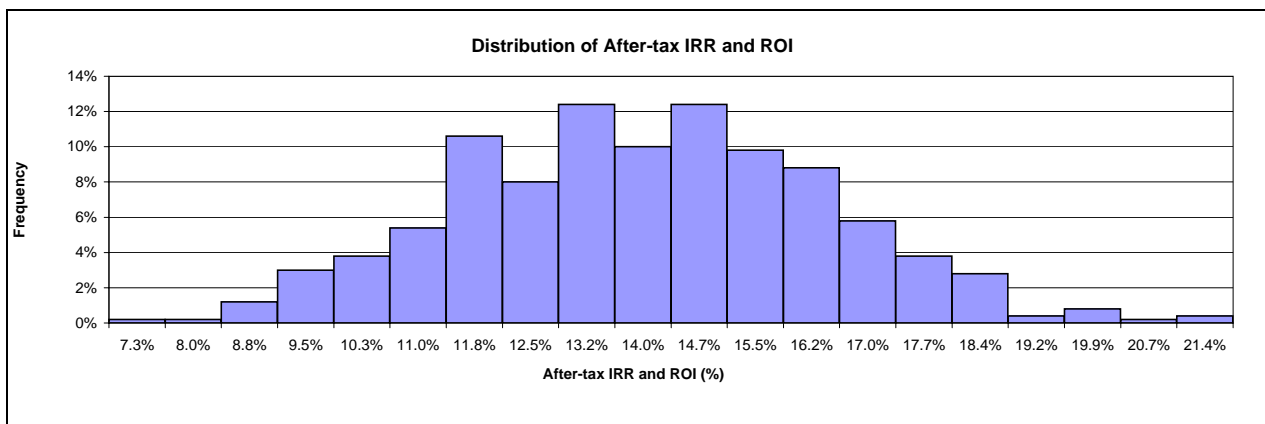


Risk Analysis for After-tax IRR and ROI

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	€/kWh	0.0910	15%	0.0774	0.1047
RE delivered	MWh	17,372	15%	14,766	19,978
Initial costs	€	9,628,442	20%	7,702,754	11,554,131
Annual costs	€	277,704	15%	236,048	319,360
Debt ratio	%	31.0%	5%	29.5%	32.6%
Debt interest rate	%	5.8%	30%	4.1%	7.5%
Debt term	yr	15	0%	15	15



Median	%	14.0%
Level of risk	%	10%
Minimum within level of confidence	%	10.0%
Maximum within level of confidence	%	17.8%



- The windfarm uses a state-of-the art surveillance and control system the cost of which has been included under the “Control and O&M building(s)” category in the Cost Analysis worksheet.
- The cost of replacement of components such as the blades and the drive train are included in the operation and maintenance contract with the service company. These costs are annualized under the “Parts and labour” category in the Cost Analysis worksheet.
- The Cost Analysis has been performed in Euros (€). However, for reference purposes, costs are also displayed in Deutsch Marks (DEM) using the Second Currency feature in RETScreen.