



Natural Resources
Canada

Ressources naturelles
Canada

Canada

RETScreen® International

Clean Energy Project Analysis Software

Wind Energy Project Model

Click Here to Start

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Worksheets

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Features

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Clean Energy Decision Support Centre

www.retscreen.net


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

Partners



Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Windfarm Repowering	See Online Manual
Project location		Alberta, Canada	
Wind data source		Wind speed	
Nearest location for weather data		Lethbridge A, AB	See Weather Database
Annual average wind speed	m/s	6.5	
Height of wind measurement	m	10.0	3.0 to 100.0 m
Wind shear exponent	-	0.15	0.10 to 0.40
Wind speed at 10 m	m/s	6.5	
Average atmospheric pressure	kPa	90.7	60.0 to 103.0 kPa
Annual average temperature	°C	6	-20 to 30 °C

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Wind turbine rated power	kW	600	 Complete Equipment Data sheet
Number of turbines	-	32	
Wind plant capacity	kW	19,200	
Hub height	m	40.0	6.0 to 100.0 m
Wind speed at hub height	m/s	8.0	
Array losses	%	1%	0% to 20%
Airfoil soiling and/or icing losses	%	1%	1% to 10%
Other downtime losses	%	2%	2% to 7%
Miscellaneous losses	%	2%	2% to 6%

Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	600	19,200	
	MW	0.600	19.200	
Unadjusted energy production	MWh	2,043	65,375	
Pressure adjustment coefficient	-	0.90	0.90	0.59 to 1.02
Temperature adjustment coefficient	-	1.03	1.03	0.98 to 1.15
Gross energy production	MWh	1,894	60,603	
Losses coefficient	-	0.94	0.94	0.75 to 1.00
Specific yield	kWh/m²	1,228	1,228	150 to 1,500 kWh/m²
Wind plant capacity factor	%	34%	34%	20% to 40%
Renewable energy delivered	MWh	1,783	57,044	
	GJ	6,417	205,360	

[Complete Cost Analysis sheet](#)

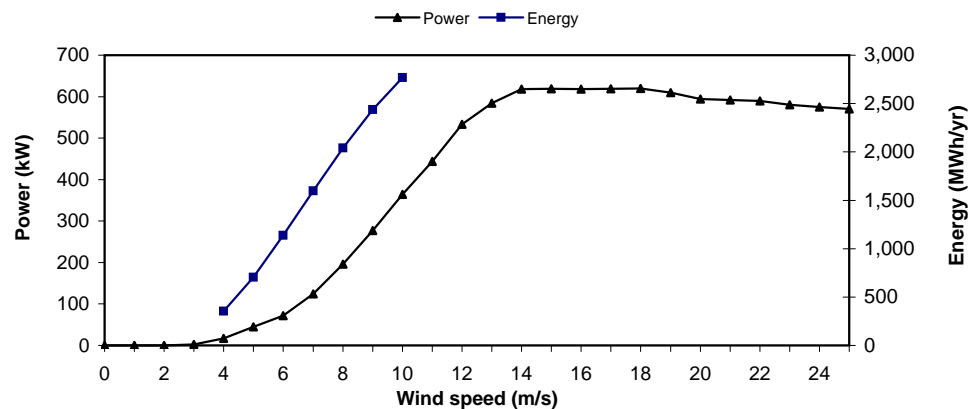
RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	600	See Product Database 6.0 to 100.0 m 7 to 80 m 35 to 5,027 m²
Hub height	m	40.0	
Rotor diameter	m	43	
Swept area	m²	1,452	
Wind turbine manufacturer		Nordex Balcke	Site specific
Wind turbine model		NORDEX N 43/600	
Energy curve data source	-	User-defined	

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	2.0	-
4	17.0	354.0
5	45.0	705.0
6	72.0	1,138.0
7	124.0	1,599.0
8	196.0	2,042.0
9	277.0	2,438.0
10	364.0	2,770.0
11	444.0	-
12	533.0	-
13	584.0	-
14	618.0	-
15	619.0	-
16	618.0	-
17	619.0	-
18	620.0	-
19	610.0	-
20	594.0	-
21	592.0	-
22	590.0	-
23	580.0	-
24	575.0	-
25	570.0	-

Power and Energy Curves



[Return to Energy Model sheet](#)

Type of project: **Custom**Currency: **\$**Cost references: **Canada - 2000**

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Site investigation	p-d	4.0	\$ 800	\$ 3,200		2.0 - 8.0	\$200 - \$800
Wind resource assessment	met tower	0	\$ -	\$ -			\$10K - \$25K
Environmental assessment	p-d	4.0	\$ 800	\$ 3,200		1.0 - 8.0	\$200 - \$800
Preliminary design	p-d	2.0	\$ 800	\$ 1,600		2.0 - 20.0	\$200 - \$800
Detailed cost estimate	p-d	6.0	\$ 800	\$ 4,800		3.0 - 20.0	\$200 - \$800
GHG baseline study and MP	project		\$ -	\$ -			\$40K - \$60K
Report preparation	p-d	2.0	\$ 800	\$ 1,600		2.0 - 15.0	\$200 - \$800
Project management	p-d	2.0	\$ 800	\$ 1,600		2.0 - 11.0	\$300 - \$800
Travel and accommodation	p-trip	2	\$ 300	\$ 600			
Other - Feasibility study	Cost	1	\$ 2,500	\$ 2,500			
Sub-total:				\$ 19,100	0.1%		
Development							
PPA negotiation	p-d	6.0	\$ 800	\$ 4,800		0.0 - 30.0	\$300 - \$1,500
Permits and approvals	p-d	4.0	\$ 800	\$ 3,200		0.0 - 400.0	\$200 - \$800
Land rights	project		\$ -	\$ -			
Land survey	p-d	4.0	\$ 600	\$ 2,400		0.0 - 100.0	\$400 - \$600
GHG validation and registration	project		\$ -	\$ -			\$40K - \$100K
Project financing	p-d	10.0	\$ 1,500	\$ 15,000		3.0 - 100.0	\$500 - \$1,500
Legal and accounting	p-d	10.0	\$ 1,200	\$ 12,000		3.0 - 100.0	\$300 - \$1,500
Project management	p-yr	0.10	\$ 130,000	\$ 13,000		0.20 - 4.00	\$130K - \$180K
Travel and accommodation	p-trip	6	\$ 300	\$ 1,800			
Other - Development	Cost	1	\$ 2,500	\$ 2,500			
Sub-total:				\$ 54,700	0.2%		
Engineering							
Wind turbine(s) micro-siting	p-d	6.0	\$ 800	\$ 4,800		0.0 - 300.0	\$200 - \$800
Mechanical design	p-d		\$ -	\$ -		2.0 - 150.0	\$200 - \$800
Electrical design	p-d	15.0	\$ 800	\$ 12,000		3.0 - 300.0	\$200 - \$800
Civil design	p-d	10.0	\$ 800	\$ 8,000		3.0 - 300.0	\$200 - \$800
Tenders and contracting	p-d	10.0	\$ 800	\$ 8,000		4.0 - 300.0	\$200 - \$800
Construction supervision	p-yr	0.15	\$ 130,000	\$ 19,500		0.00 - 2.00	\$130K - \$180K
Other - Engineering	Cost	2	\$ 3,500	\$ 7,000			
Sub-total:				\$ 59,300	0.2%		
Energy Equipment							
Wind turbine(s)	kW	19,200	\$ 1,200	\$ 23,040,000			\$1,000 - 3,000
Spare parts	%	1.0%	\$ 23,040,000	\$ 230,400		0.0% - 30.0%	
Transportation	turbine	32	\$ 30,000	\$ 960,000			
Other - Energy equipment	Cost	1	\$ 20,000	\$ 20,000			
Sub-total:				\$ 24,250,400	81.6%		
Balance of Plant							
Wind turbine(s) foundation(s)	turbine	32	\$ 50,000	\$ 1,600,000			
Wind turbine(s) erection	turbine	32	\$ 60,000	\$ 1,920,000			
Road construction	km	3.00	\$ 10,000	\$ 30,000			\$0K - \$80K/km
Transmission line	km	4.00	\$ 12,500	\$ 50,000			
Substation	project		\$ -	\$ -			
Control and O&M building(s)	building	1	\$ 10,000	\$ 10,000		0 - 2	
Transportation	project	1	\$ 20,000	\$ 20,000			
Other - Balance of plant	Cost	1	\$ 5,000	\$ 5,000			
Sub-total:				\$ 3,635,000	12.2%		
Miscellaneous							
Training	p-d	10.0	\$ 800	\$ 8,000			\$200 - \$800
Commissioning	p-d	20.0	\$ 800	\$ 16,000			\$200 - \$800
Contingencies	%	3%	\$ 28,042,500	\$ 841,275		5% - 40%	
Interest during construction	5.8%	12 month(s)	\$ 28,883,775	\$ 837,629		3.0% - 15.0%	
Sub-total:				\$ 1,702,904	5.7%		
Initial Costs - Total				\$ 29,721,404	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	\$ 68,000	\$ 68,000			
Property taxes	project	1	\$ 68,000	\$ 68,000			
Insurance premium	project	1	\$ 273,000	\$ 273,000			
Transmission line maintenance	%	40.0%	\$ 50,000	\$ 20,000		3.0% - 6.0%	
Parts and labour	kWh	57,044,441	\$ 0.005	\$ 285,222			\$0.007 - \$0.024
GHG monitoring and verification	project		\$ -	\$ -			
Community benefits	-	1	\$ 5,000	\$ 5,000			
Travel and accommodation	p-trip	12	\$ 300	\$ 3,600			
General and administrative	%	8%	\$ 722,822	\$ 57,826		1% - 20%	
Contingencies	%	5%	\$ 780,648	\$ 39,032		10% - 20%	
Annual Costs - Total				\$ 819,680	100.0%		

Periodic Costs (Credits)	Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Major Component Replacement	Cost	15 yr	\$ 4,500,000		
			\$ -		
			\$ -		
End of project life			\$ -		

[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

Project name Windfarm Repowering
 Project location Alberta, Canada

Project capacity 19.20 MW
 Grid type Central-grid

Global Warming Potential of GHG

21 tonnes CO₂ = 1 tonne CH₄ (IPCC 1996)
 310 tonnes CO₂ = 1 tonne N₂O (IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO ₂ emission factor (kg/GJ)	CH ₄ emission factor (kg/GJ)	N ₂ O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (tCO ₂ /MWh)
Natural gas	100.0%	56.1	0.0030	0.0010	45.0%	12.0%	0.513
Electricity mix	100%	141.7	0.0076	0.0025		12.0%	0.513

Does baseline change during project life?

Proposed Case Electricity System (Wind Energy Project)

Fuel type	Fuel mix (%)	CO ₂ emission factor (kg/GJ)	CH ₄ emission factor (kg/GJ)	N ₂ O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (tCO ₂ /MWh)
Electricity system							
Wind	100.0%	0.0	0.0000	0.0000	100.0%	12.0%	0.000

GHG Emission Reduction Summary

	Base case GHG emission factor (tCO ₂ /MWh)	Proposed case GHG emission factor (tCO ₂ /MWh)	End-use annual energy delivered (MWh)	Gross annual GHG emission reduction (tCO ₂)	GHG credits transaction fee (%)	Net annual GHG emission reduction (tCO ₂)
Electricity system	0.513	0.000	50,199	25,772	0.0%	25,772

[Complete Financial Summary sheet](#)

RETScreen® Financial Summary - Wind Energy Project
Annual Energy Balance

Project name	Windfarm Repowering				
Project location	Alberta, Canada				
Renewable energy delivered	MWh	57,044	Net GHG reduction	t _{CO2} /yr	25,772
Excess RE available	MWh	-			
Firm RE capacity	kW	-			
Grid type	Central-grid				
			Net GHG emission reduction - 25 yrs	t _{CO2}	644,294

Financial Parameters

Avoided cost of energy	\$/kWh	0.0600	Debt ratio	%	70.0%
RE production credit	\$/kWh	-	Debt interest rate	%	8.5%
			Debt term	yr	10
GHG emission reduction credit	\$/t _{CO2}	-	Income tax analysis?	yes/no	Yes
			Effective income tax rate	%	28.0%
			Loss carryforward?	yes/no	Flow-through
			Depreciation method	-	Declining balance
			Depreciation tax basis	%	95.0%
			Depreciation rate	%	30.0%
Energy cost escalation rate	%	0.0%			
Inflation	%	2.5%			
Discount rate	%	8.5%	Tax holiday available?	yes/no	No
Project life	yr	25			

Project Costs and Savings

Initial Costs			Annual Costs and Debt		
Feasibility study	0.1%	\$ 19,100	O&M	\$	819,680
Development	0.2%	\$ 54,700			
Engineering	0.2%	\$ 59,300	Debt payments - 10 yrs	\$	3,170,840
Energy equipment	81.6%	\$ 24,250,400	Annual Costs and Debt - Total	\$	3,990,520
Balance of plant	12.2%	\$ 3,635,000			
Miscellaneous	5.7%	\$ 1,702,904	Annual Savings or Income		
Initial Costs - Total	100.0%	\$ 29,721,404	Energy savings/income	\$	3,422,666
			Capacity savings/income	\$	-
Incentives/Grants	\$	-	Annual Savings - Total	\$	3,422,666
Periodic Costs (Credits)			Schedule yr # 15		
Major Component Replacement	\$	4,500,000			
	\$	-			
	\$	-			
End of project life -	\$	-			

Financial Feasibility

Pre-tax IRR and ROI	%	3.1%	Calculate energy production cost?	yes/no	No
After-tax IRR and ROI	%	3.2%	Calculate GHG reduction cost?	yes/no	No
Simple Payback	yr	11.4			
Year-to-positive cash flow	yr	20.1	Project equity	\$	8,916,421
Net Present Value - NPV	\$	(4,748,917)	Project debt	\$	20,804,983
Annual Life Cycle Savings	\$	(464,025)	Debt payments	\$/yr	3,170,840
Benefit-Cost (B-C) ratio	-	0.47	Debt service coverage	-	0.75

Yearly Cash Flows

Year #	Pre-tax \$	After-tax \$	Cumulative \$
0	(8,916,421)	(8,500,322)	(8,500,322)
1	(588,346)	1,555,483	(6,944,839)
2	(609,350)	795,452	(6,149,387)
3	(630,879)	245,665	(5,903,723)
4	(652,947)	(158,167)	(6,061,890)
5	(675,566)	(461,140)	(6,523,030)
6	(698,751)	(694,928)	(7,217,959)
7	(722,516)	(881,814)	(8,099,773)
8	(746,874)	(1,037,517)	(9,137,290)
9	(771,842)	(1,173,175)	(10,310,465)
10	(797,433)	(1,296,724)	(11,607,189)
11	2,347,175	1,756,962	(9,850,226)
12	2,320,288	1,717,505	(8,132,722)
13	2,292,728	1,683,593	(6,449,129)
14	2,264,480	1,653,405	(4,795,724)
15	(4,281,817)	(3,066,822)	(7,862,546)
16	2,205,846	1,599,469	(6,263,077)
17	2,175,426	1,574,189	(4,688,888)
18	2,144,245	1,549,374	(3,139,514)
19	2,112,284	1,524,707	(1,614,807)
20	2,079,525	1,499,961	(114,846)
21	2,045,946	1,474,974	1,360,128
22	2,011,528	1,449,625	2,809,753
23	1,976,250	1,423,827	4,233,580
24	1,940,089	1,397,513	5,631,093
25	1,903,025	1,371,693	7,002,786

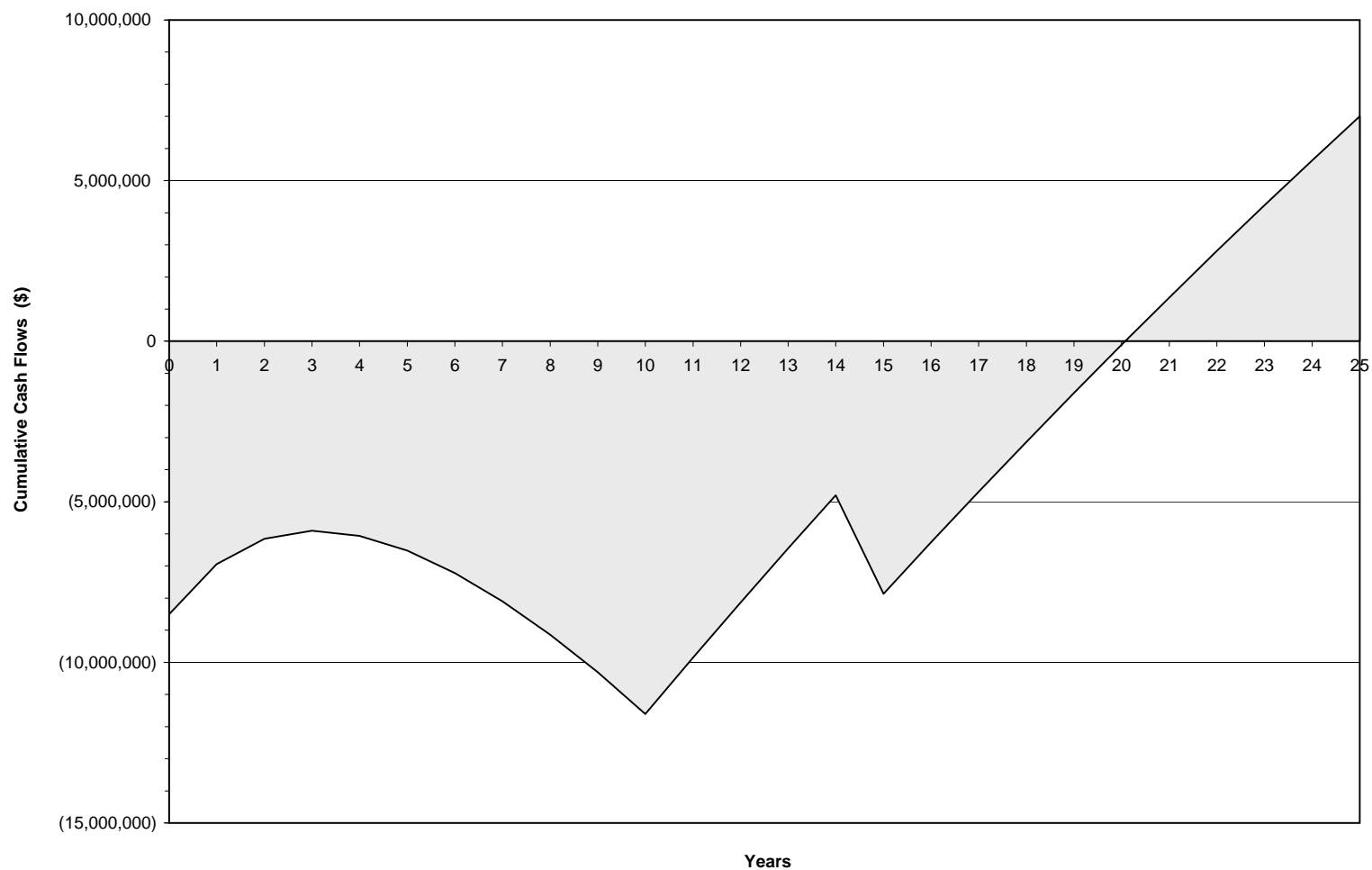
Cumulative Cash Flows Graph

Wind Energy Project Cumulative Cash Flows Windfarm Repowering, Alberta, Canada

Renewable energy delivered (MWh/yr): 57,044

Total Initial Costs: \$ 29,721,404

Net average GHG reduction (tCO₂/yr): 25,772



IRR and ROI: 3.2%

Year-to-positive cash flow: 20.1 yr

Net Present Value: \$ -4,748,917

RETScreen® Sensitivity and Risk Analysis - Wind Energy Project

Use sensitivity analysis sheet?

Yes

Perform risk analysis too?

Yes

Project name

Windfarm Repowering

Project location

Alberta, Canada

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)		0.0480 -20%	0.0540 -10%	0.0600 0%	0.0660 10%	0.0720 20%
45,636	-20%	-8.5%	-5.3%	-2.6%	-0.2%	2.1%
51,340	-10%	-5.3%	-2.3%	0.4%	3.0%	5.5%
57,044	0%	-2.6%	0.4%	3.2%	6.0%	8.8%
62,749	10%	-0.2%	3.0%	6.0%	9.1%	12.3%
68,453	20%	2.1%	5.5%	8.8%	12.3%	15.8%

		Avoided cost of energy (\$/kWh)				
Initial costs (\$)		0.0480 -20%	0.0540 -10%	0.0600 0%	0.0660 10%	0.0720 20%
23,777,124	-20%	0.3%	4.0%	7.7%	11.4%	15.2%
26,749,264	-10%	-1.3%	2.0%	5.2%	8.3%	11.6%
29,721,404	0%	-2.6%	0.4%	3.2%	6.0%	8.8%
32,693,545	10%	-3.7%	-0.9%	1.7%	4.2%	6.7%
35,665,685	20%	-4.7%	-2.0%	0.4%	2.8%	5.0%

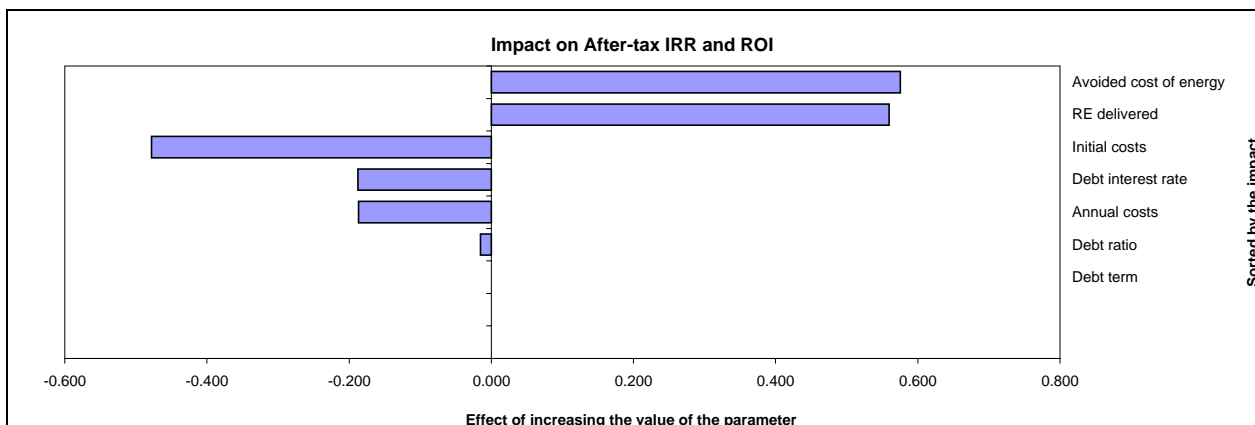
		Avoided cost of energy (\$/kWh)				
Annual costs (\$)		0.0480 -20%	0.0540 -10%	0.0600 0%	0.0660 10%	0.0720 20%
655,744	-20%	-0.6%	2.3%	5.0%	7.7%	10.5%
737,712	-10%	-1.6%	1.4%	4.1%	6.9%	9.7%
819,680	0%	-2.6%	0.4%	3.2%	6.0%	8.8%
901,648	10%	-3.8%	-0.6%	2.3%	5.2%	8.0%
983,616	20%	-5.0%	-1.6%	1.4%	4.3%	7.1%

		Debt ratio (%)				
Debt interest rate (%)		56.0% -20%	63.0% -10%	70.0% 0%	77.0% 10%	84.0% 20%
6.8%	-20%	4.3%	4.3%	4.2%	4.2%	4.1%
7.7%	-10%	4.0%	3.9%	3.7%	3.6%	3.4%
8.5%	0%	3.6%	3.5%	3.2%	3.0%	2.8%
9.4%	10%	3.3%	3.0%	2.8%	2.5%	2.1%
10.2%	20%	2.9%	2.6%	2.3%	2.0%	1.6%

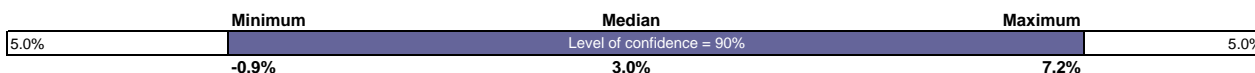
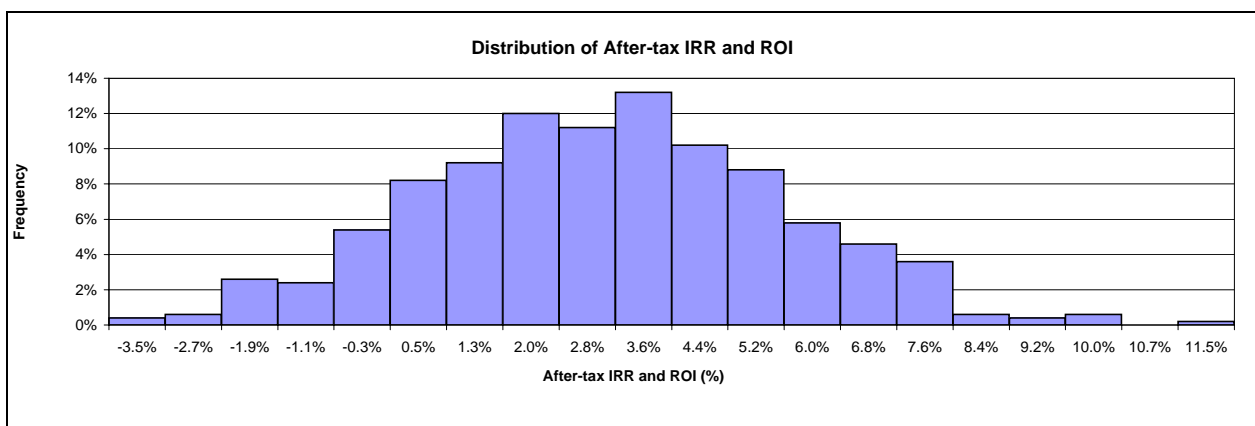
		Debt term (yr)				
Debt interest rate (%)		8.0 -20%	9.0 -10%	10.0 0%	11.0 10%	12.0 20%
6.8%	-20%	4.3%	4.3%	4.2%	4.2%	4.1%
7.7%	-10%	4.0%	3.9%	3.7%	3.6%	3.5%
8.5%	0%	3.6%	3.4%	3.2%	3.0%	2.8%
9.4%	10%	3.3%	3.0%	2.8%	2.5%	2.2%
10.2%	20%	2.9%	2.6%	2.3%	2.0%	1.6%

Risk Analysis for After-tax IRR and ROI

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Avoided cost of energy	\$/kWh	0.0600	15%	0.0510	0.0690
RE delivered	MWh	57,044	15%	48,488	65,601
Initial costs	\$	29,721,404	20%	23,777,124	35,665,685
Annual costs	\$	819,680	15%	696,728	942,632
Debt ratio	%	70.0%	5%	66.5%	73.5%
Debt interest rate	%	8.5%	30%	6.0%	11.1%
Debt term	yr	10	0%	10	10



Median	%	3.0%
Level of risk	%	10%
Minimum within level of confidence	%	-0.9%
Maximum within level of confidence	%	7.2%



- A number of parameters have been “pushed” in order to ensure that a potentially profitable project is not discarded. The debt ratio is relatively high, the discount rate is set to the debt interest rate, and “aggressive” cost estimates have been used. Nevertheless, the internal rate of return remains below 5%: the repowering project is not financially viable.
- Since the existing contract explicitly prevents green power sales and the project does not qualify for immediate expensing of capital costs, other approaches are necessary to achieve financial viability. Possibilities include:
 - Terminating the contract in favour of a new green power sales agreement.
 - Re-examining the premise that the wind shear at the site is anomalous (i.e., that wind speed does not increase with increased height). This would require a new wind energy resource assessment program to determine whether the increased cost of taller towers would be justified by increased energy production.
 - Seeking other cost reductions in the redevelopment program.
 - Exploiting opportunities to document and sell greenhouse gas emissions reductions.
 - Taking advantage of any renewable energy production credits, should they become available in the future.
- It can be expected that at some point during the project major components such as blades or drivetrains will need to be replaced due to failure. A set of blades or a drivetrain costs roughly 20% to 25% of the purchase price of the turbine. This has been accounted for as a periodic cost.
- The insurance premium is relatively high; this reflects actual experience at this site.
- The transmission line maintenance figure of 40% is high simply because the initial transmission line cost of \$50,000 used in the analysis (and on the basis of which the maintenance cost is calculated) is only the upgrade cost of the line.