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INDUSTRIAL APPLICATION OF GAS TURBINES COMMITTEE

Gas Turbines Efficiency in Project Development

by

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of

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Urban received his Master of Science Technology – Civil and Structural Engineering from Chalmers Institute of Technology in Sweden and is a licensed Professional Engineer in Ontario.

Abstract

In developing gas turbine projects many factors needs to be assessed before a viable project is found. The efficiency of a gas turbine can be described in several ways and is affected by a variety of factors such as manufacturer, altitude, metrological conditions, etc. Efficiency (heat rate) is typically described using lower heating value (LHV), but in North America we purchase fuel and quote calorific values using higher heating value. For cogeneration projects the annual efficiency is also a factor that can have a big impact in the determination of project viability. This paper intends to describe the different types of efficiencies that are used and summarize the impact that efficiency has on in the pre-feasibility and feasibility stage of the project development. The paper will use the RETScreen International's Combined Heat and Power model to evaluate a project and show the impact of efficiency. Other factors impacting on the project development will also be discussed such as how a risk and sensitivity analysis can be used.

Table of Contents

Author ... 2
Abstract ... 3
Table of Contents ... 4
Technical Paper ... 5
Introduction ... 5
Definition of efficiency ... 6
Heat rate for gas turbines ... 7
Project definition, Cost and Financial analysis ... 12
Sensitivity and risk analysis ... 14
Greenhouse Gas (GHG) Emission Reduction ... 15
Conclusion ... 16
References ... 17
Appendix ... 18

Technical Paper

Introduction

This paper deals with what should be considered during the pre-feasibility and feasibility stage of project development. Different impacts of efficiencies and their definitions will be discussed. What effect does project location have on the project viability, and is it needed to know the difference between higher and lower heating value. The calculations were all performed using the RETScreen CHP model.

The RETScreen International Clean Energy Project Analysis Software is a decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies. The software also includes product, cost and weather databases; and a detailed online user manual. In early July 2005 there were over 63,000 users world wide. The CHP model is available in 21 interchangeable languages. Various parts of the algorithm have been validated against other programs or against values published in the literature. Despite the simplicity of the model, the accuracy of the model proves acceptable, at least at the pre-feasibility stage, when compared with other software tools or with experimental data. All figures and tables were generated from the RETScreen model and the on-line help feature.

This paper will concentrate on a gas turbine with a HRSG, the fictitious project is an industry that operates 24/7 somewhere in Canada. Part of the load is weather dependent. The project configuration is shown in Figure 1 below.

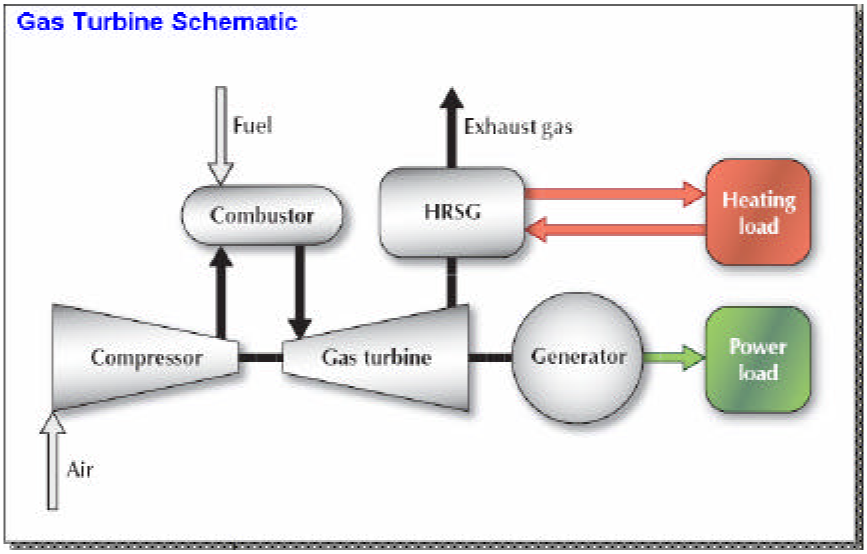


Figure 1: Typical gas turbine schematic.

Definition of efficiency

Definition, for the following discussion Heat rate and Heat recovery efficiency is defined as in the in Figure 2.

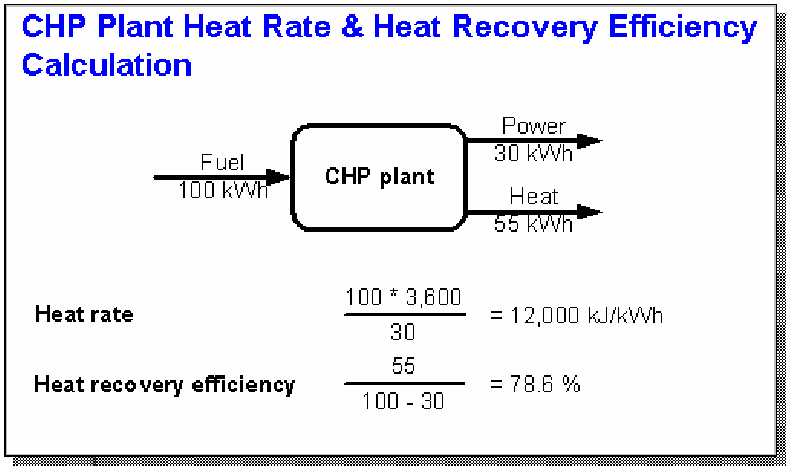


Figure 2: CHP Plant Heat rate and Heat recovery efficiency.

Heat Rate is also used for tax calculations. The definition for the tax calculations are different as it looks at the plants total efficiency (heat & power). Assuming the gas turbine is operating at its highest possible efficiency at all times the heat rate is calculated as shown in Figure 3.

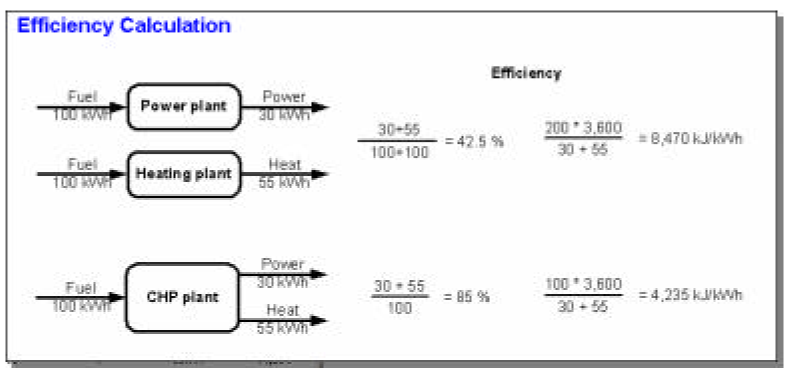


Figure 3: Heat rate definition for tax calculations.

The operating strategy of the gas turbine can change the heat rate (seasonal efficiency) substantially. This definition of heat rate is used for Canadian tax calculations such as class 43.1. Class 43.1 allows for an accelerated capital cost allowance if the energy project meets the specified heat rate (energy efficiency). The tax section of the RETScreen model can be used to calculate the tax benefits of meeting Class 43.1. Fuel consumption should be based on higher heating value. As an example if the waste heat cant be fully used at part of the year the heat rate will increase.

Heat rate for gas turbines

Equipment manufacturers typically quote the heat rate using lower heating values LHV. The figure below shows the quoted heat rate for gas turbines below 5 MW. Lower heating value is used for trading in most countries except for the US and Canada. For North America its very important that these numbers are converted to higher heating value.

Heating value is a measure of energy released when a fuel is completely burned. Depending on the composition of the fuel (amount of hydrogen) the amount of steam in the combustion products varies. Higher heating value (HHV) is calculated assuming the combustion product is condensed and the steam is converted to water. Lower heating value (LHV) is calculated assuming the combustion product stays in a vapour form.

For natural gas the difference between higher and lower heating value is approximately 10.3% and for diesel (#2 oil) it is 5.8%.

The following figures shows the Heat Rates for 34 gas turbines, using lower and higher heating values (natural gas).

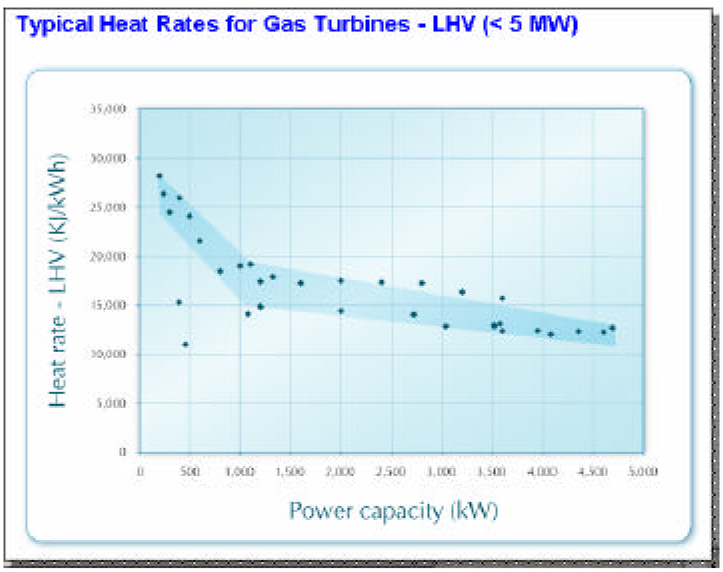


Figure 4: Typical heat rates for gas turbines – LHV (<5 MW).

Figure 5 shows the heat rates converted to HHV for natural gas.

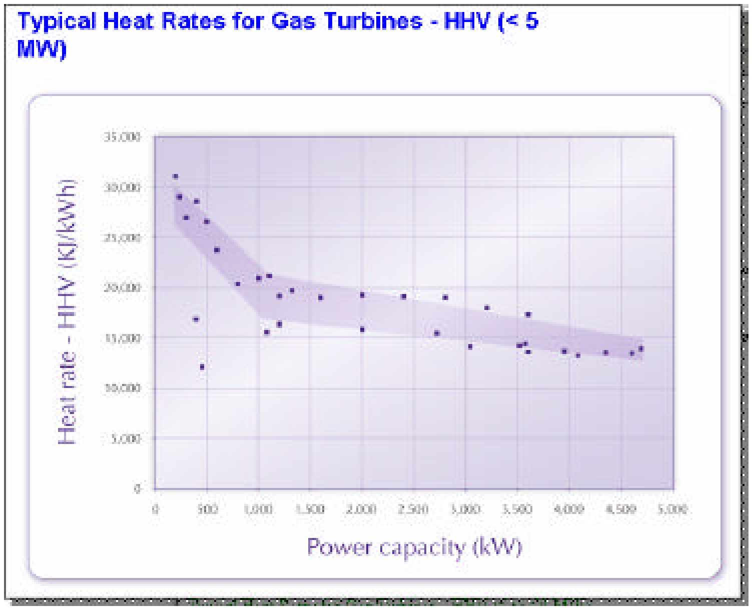


Figure 5: Typical heat rates for gas turbines – HHV (<5 MW).

Heat rates quoted are based on ISO conditions. Several factors affects the heat rate for the gas turbine, such as altitude, humidity, ambient temperature and degradation. The figures and values shown are typical numbers and needs to be confirmed for each individual machine in the design stage of the project development.

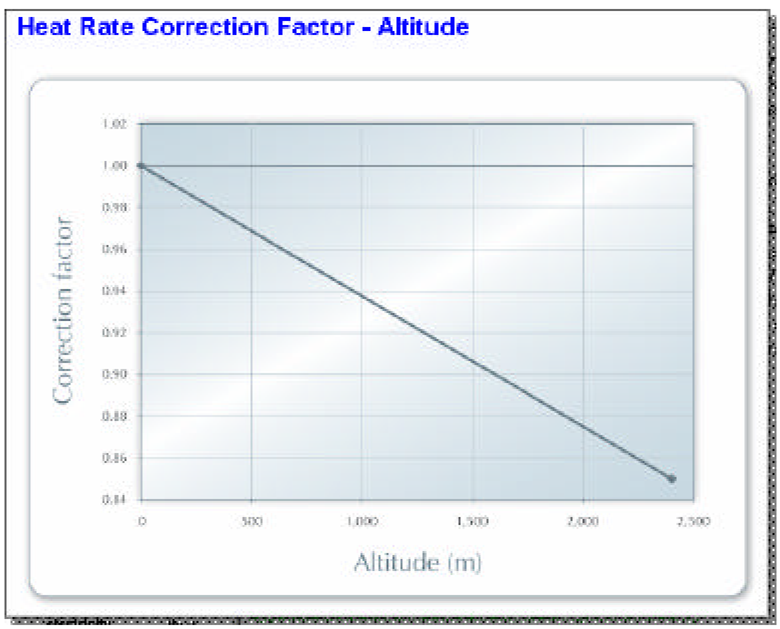


Figure 6: Typical heat rate correction factor for altitude.

Figure 7 shows the distribution of the elevation of 314 Canadian weather stations. The majority of station being below 200 m elevation giving the altitude correction to less than 2%.

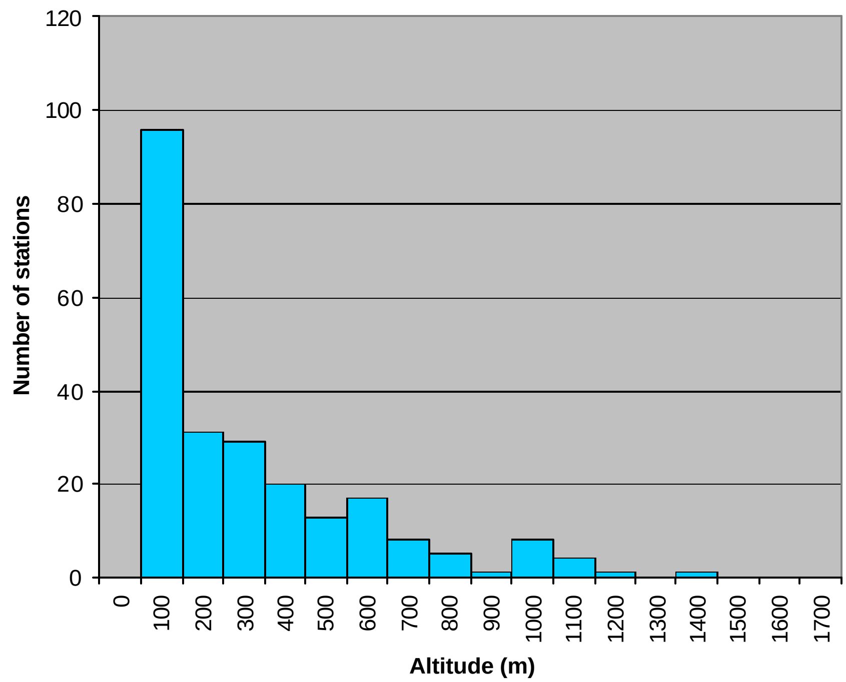


Figure 7: Altitude of Canadian weather stations.

Specific humidity also effects the gas turbine performance. Most weather station data will give a relative humidity calculated. Some station provide relative humidity expressed as two values for every month. The data provided can either be minimum or maximum values or values for the morning and afternoon. The relative humidity will then be converted for the monthly average temperature and converted to specific humidity.

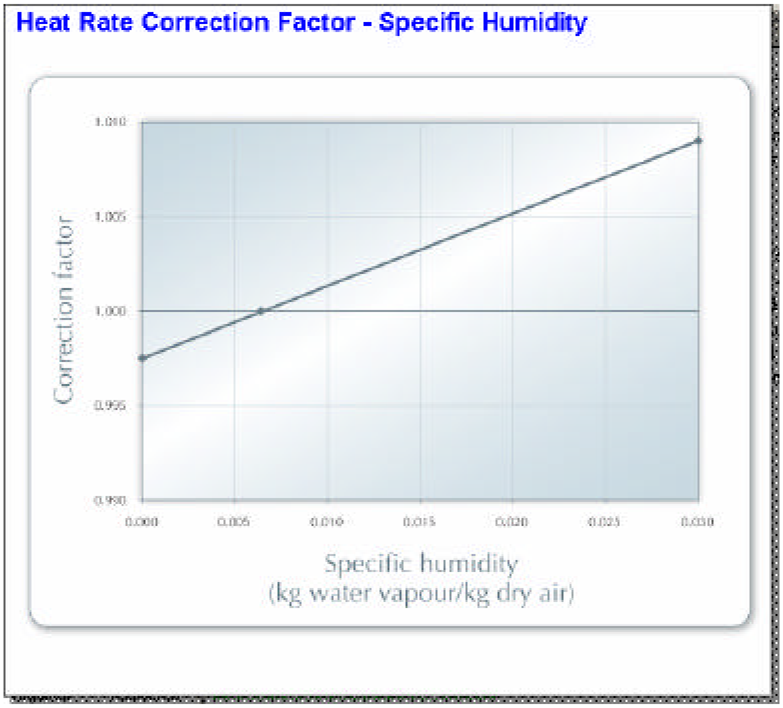


Figure 8: Typical heat rate correction factor for specific humidity.

Ambient temperature also has an effect on the performance of the gas turbine. Figure 9 shows a typical correction factor for the ambient temperature. If the project is viable the manufacturer need to supply the data for the selected equipment. Conditioning of the inlet air will also change the system performance.

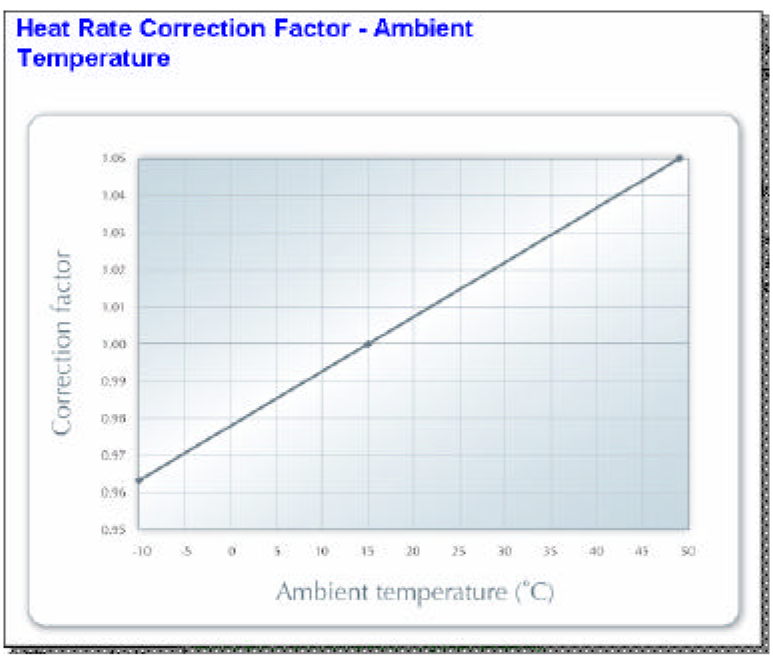


Figure 9: Typical heat rate correction factor for ambient temperature.

In the RETScreen weather database there are 259 stations in Canada that are below 55 degrees North. Plotting the frequency of the yearly average temperature will produce the following graph.

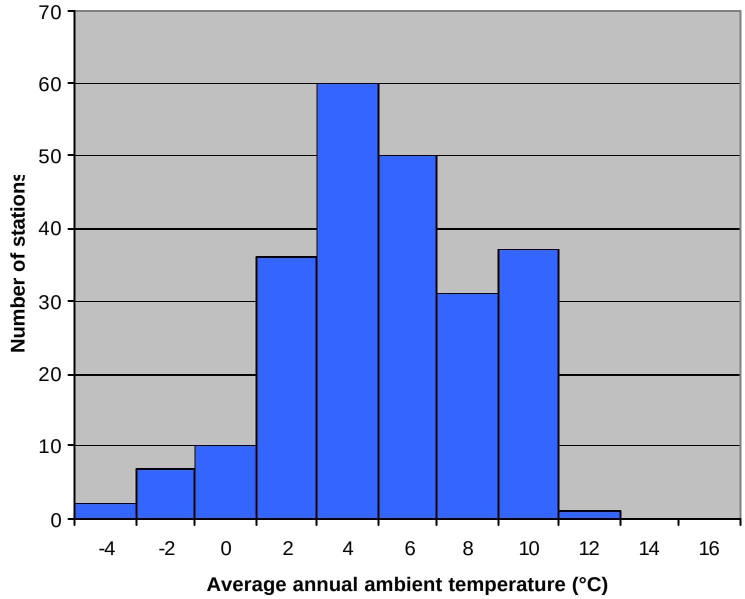


Figure 10: Average annual ambient temperature of Canadian weather stations.

Degradation of the turbine performance will also change the fuel consumption and power produced. Degradation over time can be in the 3% range for a gas turbine.

Figure 11 shows a summary of typical effects of different factors to be considered during the feasibility stage of the project.

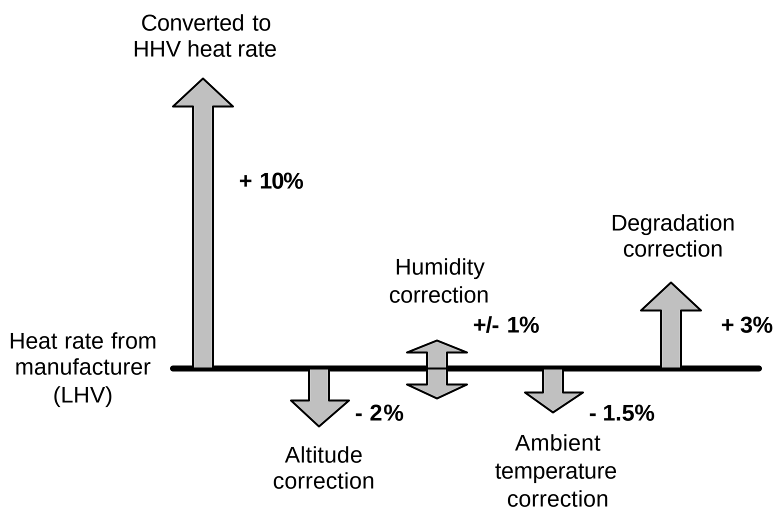


Figure 11: Correction factors for heat rate.

Project definition, Cost and Financial analysis

To study the impact of the heat rate a typical project was defined. The project has a heating and power load characteristics as shown in the figure below. The power load peaks in the summer due to a cooling load. This should initiate an investigation to see if it is financially attractive to introduce absorption cooling. But for this paper this opportunity will ignored.

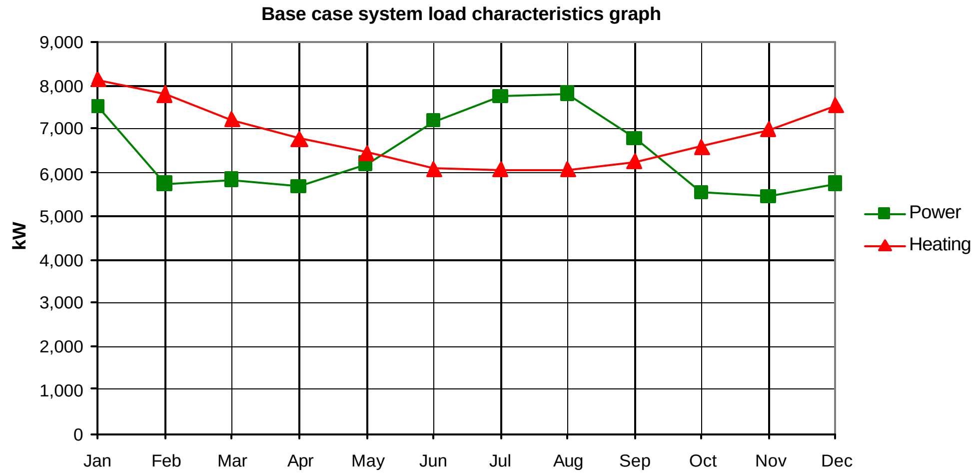


Figure 12: Heating and power load characteristics for project.

The following table summarizes the assumptions made for the project.

Assumptions				
Fuel type		Natural gas - GJ		
Fuel rate	$/GJ	7.50		
Availability	h	8,300		
Power capacity	kW	5,071		
Heat rate	kJ/kWh	13,431		
Heat recovery efficiency	%	62.5%		
Electricity export rate	$/MWh	30		
Electricity rate - proposed case	$/MWh	110		
Electricity rate - base case	$/kWh	100		
End-use energy efficiency measures	%	5.0%	Heating	
End-use energy efficiency measures	%	3.0%	Power	
Operating strategy		Full power capacity output		
Cost analysis				
Base load - Gas turbine	kW	5,071	1,500	$7,606,500
Contingencies	%	10.0%	$7,606,500	$760,650
Interest during construction	8.0%	12	$8,367,150	$334,686
O&M $/MWh	MWh	42,089	7.5	$315,670
Financial Analysis				
Fuel cost escalation rate	%	2.0%		
Inflation rate	%	2.0%		
Discount rate	%	10.0%		
Project life	yr	25		
Debt ratio	%	70.0%		
Debt interest rate	%	7.0%		
Debt term	yr	10		
Effective income tax rate	%	30.0%		

Figure 13: Assumptions made for the proposed project.

The installed cost of a gas turbine varies, but for this exercise it has been assumed to be $1,500/kW installed cost, add 10% contingency and interest during the 12 month construction period and we have a total cost of $8,700,000 ($1,720/kW). The above assumptions are user inputs in the CHP model and the values entered can be considered typical.

The selection of operating strategies will depend on the value of the heat and power. It might also change over the year. Different operating strategies will be tried to gage the impact on the project.

Operating strategy	**Efficiency Heat rate Btu/kWh**
Full power capacity output	5,573
Power load following	5,573
Heating load following	4,703

Figure 14: Efficiency (heat rate) for different operating strategies .

The Financial viability of the project can be presented using different factors. The table below shows the most common methods. This table is calculated using the "Heat load following" operating strategy.

Financial viability		
Pre-tax IRR - equity	%	50.5%
Pre-tax IRR - assets	%	18.2%
After-tax IRR - equity	%	32.0%
After-tax IRR - assets	%	12.2%
Simple payback	yr	4.3
Equity payback	yr	3.5
Net Present Value (NPV)	$	8,168,900
Annual life cycle savings	$/yr	899,952
Benefit-Cost (B-C) ratio	-	4.13
Debt service coverage	-	2.40
GHG reduction cost	$/tCO2	(36)

Figure 15: Financial viability factors– operating strategy - heat load following.

For the same gas turbine using full power capacity output the following table is generated. The After tax IRR on equity for heat load following is slightly lower.

Financial viability		
Pre-tax IRR - equity	%	51.2%
Pre-tax IRR - assets	%	18.4%
After-tax IRR - equity	%	32.5%
After-tax IRR - assets	%	12.3%
Simple payback	yr	4.2
Equity payback	yr	3.4
Net Present Value (NPV)	$	8,309,087
Annual life cycle savings	$/yr	915,396
Benefit-Cost (B-C) ratio	-	4.18
Debt service coverage	-	2.43
GHG reduction cost	$/tCO2	(33)

Figure 16: Financial viability factors – operating strategy – full power capacity output.

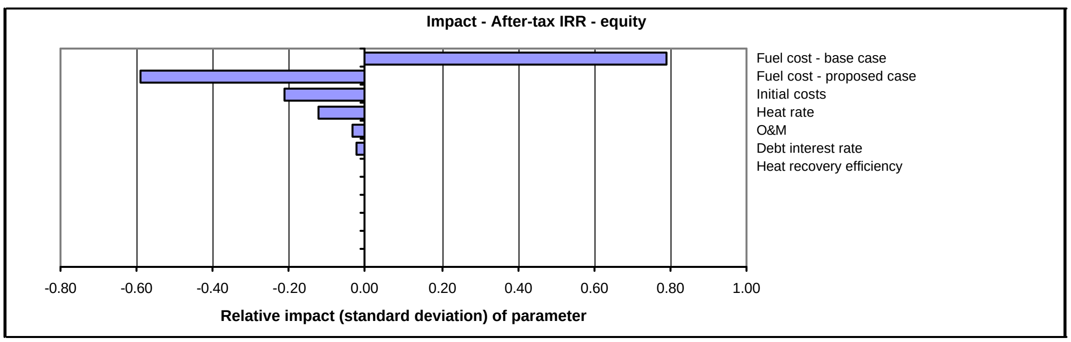
Sensitivity and risk analysis

Risk analysis will show which factors that have the greatest impact the decision making. This risk analysis is using a Monte Carlo simulation recalculating the project 500 times with random combinations of the main parameters for the project. The analysis is performed on the After-tax internal rate of return of the equity. The range of the different parameters are shown below. The table shows the initial selection for the discussed project.

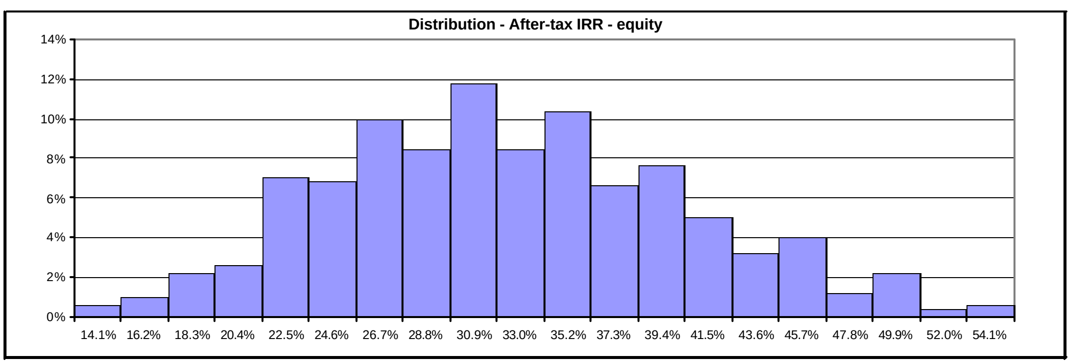
Risk analysis for After-tax IRR - equity

Perform analysis on: After-tax IRR - equity

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	$	8,701,836	10%	7,831,652	9,572,020
O&M	$	315,670	10%	284,103	347,237
Fuel cost - proposed case	$	5,820,424	10%	5,238,381	6,402,466
Fuel cost - base case	$	8,198,696	10%	7,378,827	9,018,566
Heat recovery efficiency	%	63%	5%	59%	66%
Debt interest rate	%	7.00%	10%	6.30%	7.70%
Heat rate	kJ/kWh	13,431	3%	13,028	13,834



Median	%	31.8%
Level of risk	%	20%
Minimum within level of confidence	%	22.6%
Maximum within level of confidence	%	43.3%



	Minimum	Median	Maximum	
10.0%	Level of confidence = 80%			10.0%
	22.6%	31.8%	43.3%	

Figure 17: Risk analysis – assumptions, impact and distribution graph.

The relative impact graph shows clearly that the gas turbine Heat rate and Heat recovery efficiency have a small impact on the project feasibility.

Greenhouse Gas (GHG) Emission Reduction

The RETScreen CHP model also includes a GHG analysis section. There are three different level for the GHG analysis. The user can select from a built-in database the country and fuel that will be replaced, define the fuel mix and electricity generation efficiency using built-in emission factors or with custom input emission factors together with the transmission and distribution losses for the central grid. With these inputs the model then calculates the gross annual GHG emission reduction.

Figure 18 shows the output of the simplified analysis for greenhouse gas emission reduction.

Base case electricity system (Baseline)

Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Canada	Coal	0.867	5.0%	0.913

☐ Baseline changes during project life

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Natural gas	61.8%	92,410	0.179	16,540
Electricity	38.2%	57,036	0.913	52,053
Total	100.0%	149,446	0.459	68,593

Proposed case system GHG summary (Combined heating & power project)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Natural gas	92.4%	161,647	0.179	28,932
Electricity	7.6%	13,236	0.913	12,080
Total	100.0%	174,883	0.235	41,011

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Combined heating & power project	68,593	41,011	27,581	0%	**27,581**

Net annual GHG emission reduction 27,581 tCO2 is equivalent to 5,607 Cars & light trucks not used

Complete Financial Summary sheet

Figure 18: GHG analysis.

Conclusion

As has been demonstrated in this paper, many factors have an influence on the heat rate of a gas turbine. After correcting the initial heat rate for higher heating value other factors can typically be ignored in the feasibility stage of the project. The use of the correct heat rate and heat recovery efficiency of a gas turbine is important. The understanding of factors that will effect the heat rates needs to be understood fully. One of the main factors that can alter the viability of a project is the understanding of how efficiency and heat rate are defined. The reference to lower heating value can create problems but with a full understanding of issues involved errors should be minimized.

It is recommended that a risk analysis is done in the pre-feasibility stage of the project development. This will determine the factors that has the greatest impact on the project viability. Focus to reduce the range of these factors until the value of the financial indicators are satisfactory within the preferred level of confidence.

References

RETScreen International, Combined heat and Power model, spreadsheet and on-line manual, 2005, http://www.retscreen.net/

Personal communication, Martin Lensink, CEM Engineering, St. Catharines, Ontario

Appendix

Natural Resources Canada | Ressources naturelles Canada

Canada

RETScreen® International

Clean Energy Project Analysis Software

Combined Heat & Power Project Model

Click here to Start

- Description & Flow Chart
- Colour Coding
- Online Manual

Worksheets

- Energy Model
- Load & Network
- Equipment Selection
- Cost Analysis
- Greenhouse Gas Analysis
- Financial Summary
- Sensitivity & Risk Analysis
- Tools

Features

- Product Data
- Weather Data
- Cost Data
- Unit Options & Fuel Value Ref.
- Language Options
- Currency Options
- CDM / JI Project Analysis

Clean Energy Decision Support Centre

www.retscreen.net

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

Partners

NASA UNEP GEF

RETScreen Energy Model - Combined heating & power project

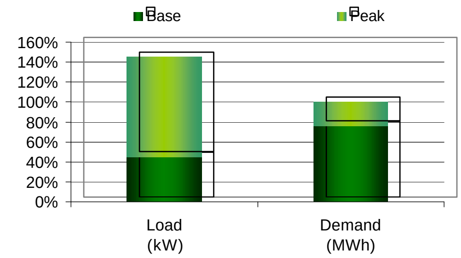
See Online Manual

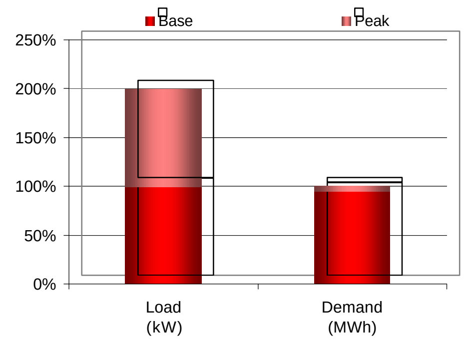
Settings			
Language - Langue	English - Anglais	Online manual - English	
Currency	$	☒ Metric units	☐ Imperial units
Project name	IAGT project		
Project location	Canada	☒ Higher heating value (HHV)	☐ Lower heating value (LHV)
Proposed project	Combined heating & power		

Complete Load & Network sheet

Proposed case system characteristics	Unit	Estimate	%
Power			
Base load power system			
Type		Gas turbine	
Operating strategy		Full power capacity output	
Capacity	kW	5,071	45.3%
Electricity delivered to load	MWh	42,089	76.1%
Electricity exported to grid	MWh	0	
Peak load power system			
Type		Grid electricity	
Suggested capacity	kW	11,198	
Capacity	kW	11,198	100.0%
Electricity delivered to load	MWh	13,236	23.9%
Back-up power system (optional)			
Type			
Capacity	kW	0	
Heating			
Base load heating system			
Type		Gas turbine	
Capacity	kW	8,655.1	99.6%
Heating delivered	MWh	54,062	94.7%
Intermediate load heating system			
Type		Not required	
Peak load heating system			
Type		Boiler	
Fuel type		Natural gas - GJ	
Fuel rate	$/GJ	7.500	
Suggested capacity	kW	8,692.5	
Capacity	kW	8,692.5	100.0%
Heating delivered	MWh	3,002	5.3%
Manufacturer			*See PDB*
Model			
Seasonal efficiency	%	65%	
Back-up heating system (optional)			
Type			
Capacity	kW	0.0	

System design graph





Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)	Clean Energy production credit?
Power						
Base load	Natural gas	GJ	565,306	5,071	42,089	☐
Peak load	Electricity	MWh	13,236	11,198	13,236	☐
			Total	**16,269**	**55,325**	
Heating						
Base load	Recovered heat			8,655	54,062	☐
Peak load	Natural gas	GJ	16,624	8,693	3,002	☐
			Total	**17,348**	**57,063**	

Complete Cost Analysis sheet

RETScreen Load & Network Design - Combined heating & power project

Heating project	Unit		
Site conditions		**Estimate**	**Notes/Range**
Nearest location for weather data		Toronto	*See Weather Database*
Heating design temperature	°C	-17.1	-40 to 15 °C
Annual heating degree-days below 18°C	°C-d	4,051	*Complete Monthly inputs*
Domestic hot water heating base demand	%	10%	0% to 25%
Equivalent degree-days for DHW heating	°C-d/d	1.2	0 to 10 °C-d/d
Equivalent full load hours	h	6,565	

Monthly inputs

Month	°C-d <18°C	Month	°C-d <18°C	Month	°C-d <18°C
January	778	May	174	September	84
February	678	June	18	October	282
March	583	July	0	November	447
April	351	August	0	December	657

See Weather Database

Base case heating system		Single building - space & process heating
Heated floor area for building	m²	45,000
Fuel type		Natural gas - GJ
Seasonal efficiency	%	65%
Heating load calculation		
Heating load for building	W/m²	70.0
Peak process heating load	kW	6,000.0
Process heating load characteristics		Standard
Equivalent full load hours - process heating	h	8,760
Space heating demand	MWh	7,506
Process heating demand	MWh	52,560
Total heating demand	MWh	**60,066**
Total peak heating load	kW	**9,150.0**
Fuel consumption - annual	GJ	332,676
Fuel rate	$/GJ	7.500
Fuel cost		$ 2,495,067
Proposed case energy efficiency measures		
End-use energy efficiency measures	%	5%
Net peak heating load	kW	8,692.5
Net heating demand	MWh	57,063

RETScreen Load & Network Design - Combined heating & power project

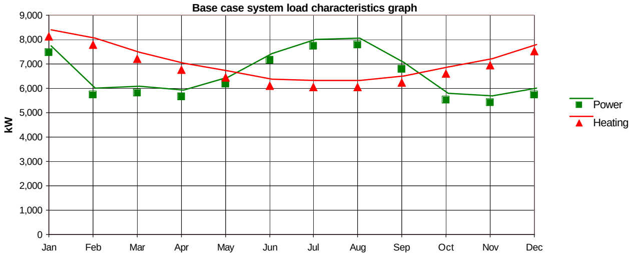
Power project	Unit	
Base case power system		
Grid type		Central-grid

Base case load characteristics

Month	Power gross average load kW	Power net average load kW	Heating average load kW
January	7,480	7,480	8,127
February	5,740	5,740	7,780
March	5,820	5,820	7,205
April	5,650	5,650	6,766
May	6,180	6,180	6,460
June	7,160	7,160	6,097
July	7,740	7,740	6,054
August	7,800	7,800	6,065
September	6,780	6,780	6,246
October	5,530	5,530	6,594
November	5,420	5,420	6,956
December	5,740	5,740	7,530

	Unit			
System peak electricity load over max monthly average		48.0%		
Peak load - annual		11,544	11,544	9,150
Electricity demand	MWh	57,036	57,036	
Electricity rate - base case	$/kWh	0.100	0.100	
Total electricity cost		$ 5,703,629	$ 5,703,629	

Base case system load characteristics graph



Proposed case energy efficiency measures

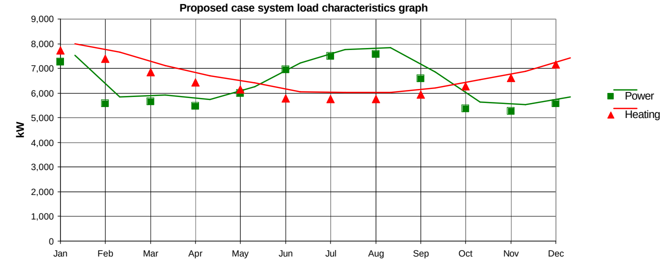
	Unit	
End-use energy efficiency measures	%	3%
Net peak electricity load	kW	11,198
Net electricity demand	MWh	55,325

Complete Equipment Selection sheet

Proposed case load characteristics

Month	Power net average load kW	Heating net average load kW
January	7,256	7,721
February	5,568	7,391
March	5,645	6,844
April	5,481	6,428
May	5,995	6,137
June	6,945	5,792
July	7,508	5,752
August	7,566	5,762
September	6,577	5,934
October	5,364	6,264
November	5,257	6,608
December	5,568	7,154
Peak load - annual	11,198	8,693

Proposed case system load characteristics graph



Proposed case load and demand	Unit	Power	Heating
System peak load	kW	11,198	8,692.5
System energy demand	MWh	55,325	57,063

Complete Equipment Selection sheet

RETScreen Equipment Selection - Combined heating & power project

☐ Show alternative units

Proposed case power system

System selection		Base load system		
Base load power system				
Type		Gas turbine		
Availability	h	8,300		94.7%
Fuel selection method		Single fuel		
Fuel type		Natural gas - GJ		
Fuel rate	$/GJ	7.500		
Gas turbine				
Power capacity	kW	5,071	45.3%	*See product database*
Minimum capacity	%	40%		
Electricity delivered to load	MWh	42,089	76.1%	
Electricity exported to grid	MWh	0		
Manufacturer		Solar Turbines		
Model		Taurus 60		1 unit(s)
Heat rate	kJ/kWh	13,431		
Heat recovery efficiency	%	63%		
Fuel required	GJ/h	68.1		
Heating capacity	kW	8,655.1	99.6%	

Operating strategy - base load power system

Fuel rate - base case heating system	$/MWh	41.54
Electricity rate - base case	$/MWh	100.00
Fuel rate - proposed case power system	$/MWh	27.00
Electricity export rate	$/MWh	30.00
Electricity rate - proposed case	$/MWh	110.00

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Heat recovered MWh	Remaining heat required MWh	Power system fuel MWh	Operating profit (loss) $	Efficiency Btu/kWh
Full power capacity output	**42,089**	**0**	**13,236**	**54,062**	**3,002**	**157,029**	**2,082,410**	**5,573**
Power load following	42,089	0	13,236	54,062	3,002	157,029	2,082,410	5,573
Heating load following	31,674	0	23,651	54,062	3,002	118,173	1,985,899	4,703

Select operating strategy: Full power capacity output

Return to Energy Model sheet

RETScreen Cost Analysis - Combined heating & power project

Settings - IAGT project - Canada			
Pre-feasibility analysis	Cost reference	Cost reference	None
Feasibility analysis	Second currency		

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost	1		$ -	
Sub-total:				**$ -**	0.0%
Development					
Development	cost	1		$ -	
Sub-total:				**$ -**	0.0%
Engineering					
Engineering	cost	1		$ -	
Sub-total:				**$ -**	0.0%
Power system					
Base load - Gas turbine	kW	5,071	$ 1,500	$ 7,606,500	
Peak load - Grid electricity	kW	11,198		$ -	
Road construction	km			$ -	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures	project	1		$ -	
Custom	credit	1		$ -	
				$ -	
Sub-total:				**$ 7,606,500**	87.4%
Heating system					
Base load - Gas turbine	kW	8,655.1		$ -	
Peak load - Boiler	kW	8,692.5		$ -	
Energy efficiency measures	project	1		$ -	
Custom	cost	1		$ -	
				$ -	
Sub-total:				**$ -**	0.0%
Balance of system & miscellaneous					
Balance of system & miscellaneous	cost	1		$ -	
Contingencies	%	10.0%	$ 7,606,500	$ 760,650	
Interest during construction	8.00%	12 month(s)	$ 8,367,150	$ 334,686	
Sub-total:				**$ 1,095,336**	12.6%
Total initial costs				**$ 8,701,836**	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
O&M					
Parts & labour	project	1		$ -	
O&M	cost	42,089	$ 7.50	$ 315,670	
Contingencies	%		$ 315,670	$ -	
Sub-total:				**$ 315,670**	5.1%
Fuel					
Natural gas	GJ	581,930	$ 7.500	$ 4,364,474	
Electricity	MWh	13,236	$ 110.000	$ 1,455,949	
Sub-total:				**$ 5,820,424**	94.9%
Total annual costs				**$ 6,136,093**	100.0%

Periodic costs (credits)	Unit	Year	Unit cost	Amount
				$ -
				$ -
				$ -
End of project life				**$ -**

Go to GHG Analysis sheet

RETScreen Greenhouse Gas (GHG) Emission Reduction Analysis - Combined heating & power project

Settings - IAGT project - Canada

- [x] GHG Analysis
- [ ] Potential CDM project

- (selected) Simplified analysis
- Standard analysis
- Custom analysis

Base case electricity system (Baseline)

Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Canada	Coal	0.867	5.0%	0.913

- [ ] Baseline changes during project life

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Natural gas	61.8%	92,410	0.179	16,540
Electricity	38.2%	57,036	0.913	52,053
Total	100.0%	149,446	0.459	68,593

Proposed case system GHG summary (Combined heating & power project)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Natural gas	92.4%	161,647	0.179	28,932
Electricity	7.6%	13,236	0.913	12,080
Total	100.0%	174,883	0.235	41,011

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Combined heating & power project	68,593	41,011	27,581	0%	**27,581**

Net annual GHG emission reduction	27,581	tCO2	is equivalent to	5,607	Cars & light trucks not used

Complete Financial Summary sheet

RETScreen Financial Summary - Combined heating & power project

Annual fuel cost summary - IAGT project - Canada

Base case system	Peak load kW	Energy demand MWh	End-use energy rate $/MWh	Fuel cost $
Power	11,544	57,036	100.00	5,703,629
Heating	9,150	60,066	41.54	2,495,067
Fuel cost - base case				**8,198,696**

Proposed case system	Capacity kW	Energy delivered MWh	End-use energy rate $/MWh	Fuel cost $
Power	16,269	55,325	102.95	5,695,745
Heating	17,348	57,063	2.18	124,679
Fuel cost - proposed case				**5,820,424**

Yearly cash flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(2,610,551)	(2,610,551)	(2,610,551)
1	1,236,593	733,353	(1,877,197)
2	1,278,670	753,549	(1,123,648)
3	1,321,589	773,686	(349,962)
4	1,365,366	793,730	443,767
5	1,410,018	813,645	1,257,412
6	1,455,564	833,391	2,090,803
7	1,502,020	852,925	2,943,728
8	1,549,406	872,201	3,815,929
9	1,597,739	891,168	4,707,097
10	1,647,039	909,770	5,616,867
11	2,564,587	1,795,211	7,412,078
12	2,615,879	1,831,115	9,243,194
13	2,668,197	1,867,738	11,110,931
14	2,721,561	1,905,092	13,016,024
15	2,775,992	1,943,194	14,959,218
16	2,831,512	1,982,058	16,941,276
17	2,888,142	2,021,699	18,962,976
18	2,945,905	2,062,133	21,025,109
19	3,004,823	2,103,376	23,128,485
20	3,064,919	2,145,444	25,273,929
21	3,126,218	2,188,352	27,462,281
22	3,188,742	2,232,119	29,694,401
23	3,252,517	2,276,762	31,971,162
24	3,317,567	2,322,297	34,293,459
25	3,383,919	3,383,919	37,677,378

Financial parameters

General		
Fuel cost escalation rate	%	2.0%
Inflation rate	%	2.0%
Discount rate	%	10.0%
Project life	yr	25
Finance		
Incentives and grants	$	
Debt ratio	%	70.0%
Debt	$	6,091,285
Equity	$	2,610,551
Debt interest rate	%	7.00%
Debt term	yr	10
Debt payments	$/yr	**867,262**
Income tax analysis		
Effective income tax rate	%	30.0%
Loss carryforward?		No
Depreciation method		None
Tax holiday available?	yes/no	No

Project costs and savings/income summary

Initial costs			
Feasibility study	0.0%	$	-
Development	0.0%	$	-
Engineering	0.0%	$	-
Power system	87.4%	$	7,606,500
Heating system	0.0%	$	-
Balance of system & misc.	12.6%	$	1,095,336
Total initial costs	100.0%	**$**	**8,701,836**
Annual costs and debt payments			
O&M		$	315,670
Fuel cost - proposed case		$	5,820,424
Debt payments - 10 yrs		$	867,262
Total annual costs		**$**	**7,003,355**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	8,198,696
Total annual savings and income		**$**	**8,198,696**

Annual income

Customer premium income (rebate)

Electricity export income

Clean Energy (CE) production income

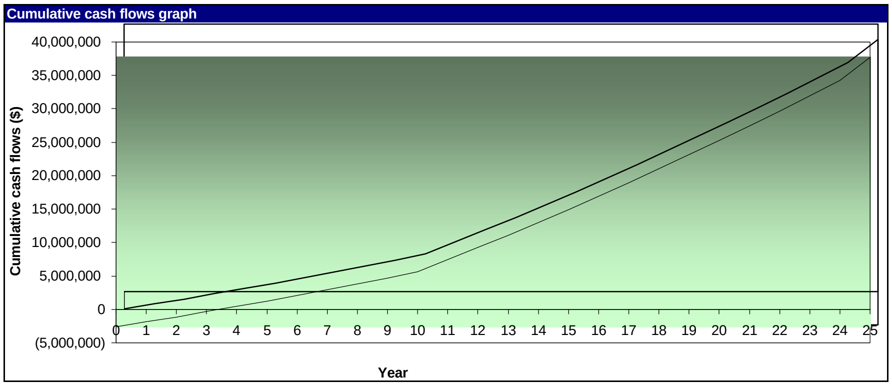
GHG reduction income

Net GHG reduction	tCO2/yr	27,581
Net GHG reduction - 25 yrs	tCO2	689,535

Financial viability

Pre-tax IRR - equity	%	51.2%
Pre-tax IRR - assets	%	18.4%
After-tax IRR - equity	%	32.5%
After-tax IRR - assets	%	12.3%
Simple payback	yr	4.2
Equity payback	yr	3.4
Net Present Value (NPV)	$	8,309,087
Annual life cycle savings	$/yr	915,396
Benefit-Cost (B-C) ratio	-	4.18
Debt service coverage	-	2.43
GHG reduction cost	$/tCO2	(33)

Cumulative cash flows graph



RETScreen Sensitivity and Risk Analysis - Combined heating & power project

Sensitivity analysis for After-tax IRR - equity

Perform analysis on	After-tax IRR - equity
Sensitivity range	20%
Threshold	12 %

				Initial costs		$
Debt interest rate		6,961,469	7,831,652	**8,701,836**	9,572,020	10,442,203
%		-20%	-10%	0%	10%	20%
5.60%	-20%	46.5%	39.1%	33.5%	29.1%	25.5%
6.30%	-10%	45.9%	38.6%	33.0%	28.6%	25.1%
7.00%	0%	45.3%	38.1%	**32.5%**	28.1%	24.6%
7.70%	10%	44.8%	37.5%	32.0%	27.6%	24.2%
8.40%	20%	44.2%	37.0%	31.4%	27.2%	23.7%

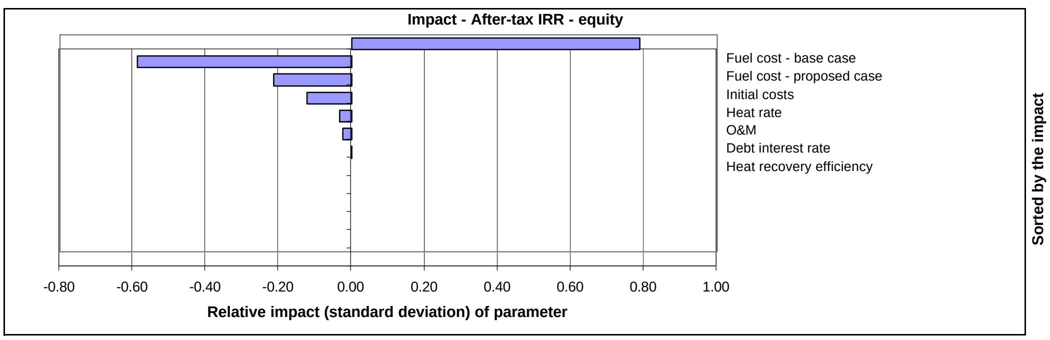
				Initial costs		$
Fuel cost - proposed case		6,961,469	7,831,652	**8,701,836**	9,572,020	10,442,203
$		-20%	-10%	0%	10%	20%
4,656,339	-20%	84.3%	72.1%	62.5%	54.7%	48.2%
5,238,381	-10%	64.6%	54.8%	47.1%	40.9%	35.9%
5,820,424	0%	45.3%	38.1%	**32.5%**	28.1%	24.6%
6,402,466	10%	27.6%	23.0%	19.6%	17.0%	14.8%
6,984,508	20%	12.8%	10.5%	8.7%	7.2%	5.9%

				Initial costs		$
Debt interest rate		6,961,469	7,831,652	**8,701,836**	9,572,020	10,442,203
%		-20%	-10%	0%	10%	20%
5.60%	-20%	46.5%	39.1%	33.5%	29.1%	25.5%
6.30%	-10%	45.9%	38.6%	33.0%	28.6%	25.1%
7.00%	0%	45.3%	38.1%	**32.5%**	28.1%	24.6%
7.70%	10%	44.8%	37.5%	32.0%	27.6%	24.2%
8.40%	20%	44.2%	37.0%	31.4%	27.2%	23.7%

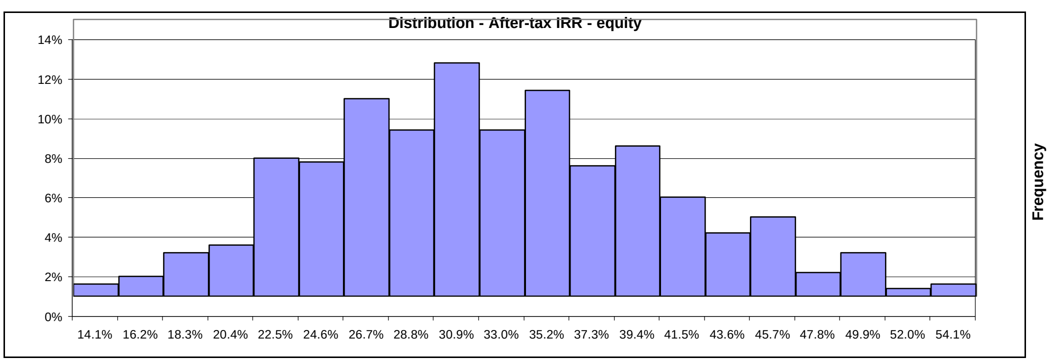
Risk analysis for After-tax IRR - equity

Perform analysis on: After-tax IRR - equity

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	$	8,701,836	10%	7,831,652	9,572,020
O&M	$	315,670	10%	284,103	347,237
Fuel cost - proposed case	$	5,820,424	10%	5,238,381	6,402,466
Fuel cost - base case	$	8,198,696	10%	7,378,827	9,018,566
Heat recovery efficiency	%	63%	5%	59%	66%
Debt interest rate	%	7.00%	10%	6.30%	7.70%
Heat rate	kJ/kWh	13,431	3%	13,028	13,834



Median	%	31.8%
Level of risk	%	25%
Minimum within level of confidence	%	23.3%
Maximum within level of confidence	%	42.1%



	Minimum	Median	Maximum	
12.5%	Level of confidence = 75%			12.5%
	23.3%	**31.8%**	**42.1%**	