

# RETScreen® Software Online User Manual



## Combined Heat & Power Project Model



## **Background**

This document allows for a printed version of the RETScreen® Software Online User Manual, which is an integral part of the RETScreen Software. The online user manual is a Help file within the software. The user automatically downloads the online user manual Help file while downloading the RETScreen Software.

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ISBN: 0-662-40895-0

Catalogue no.: M39-121/2005E-PDF

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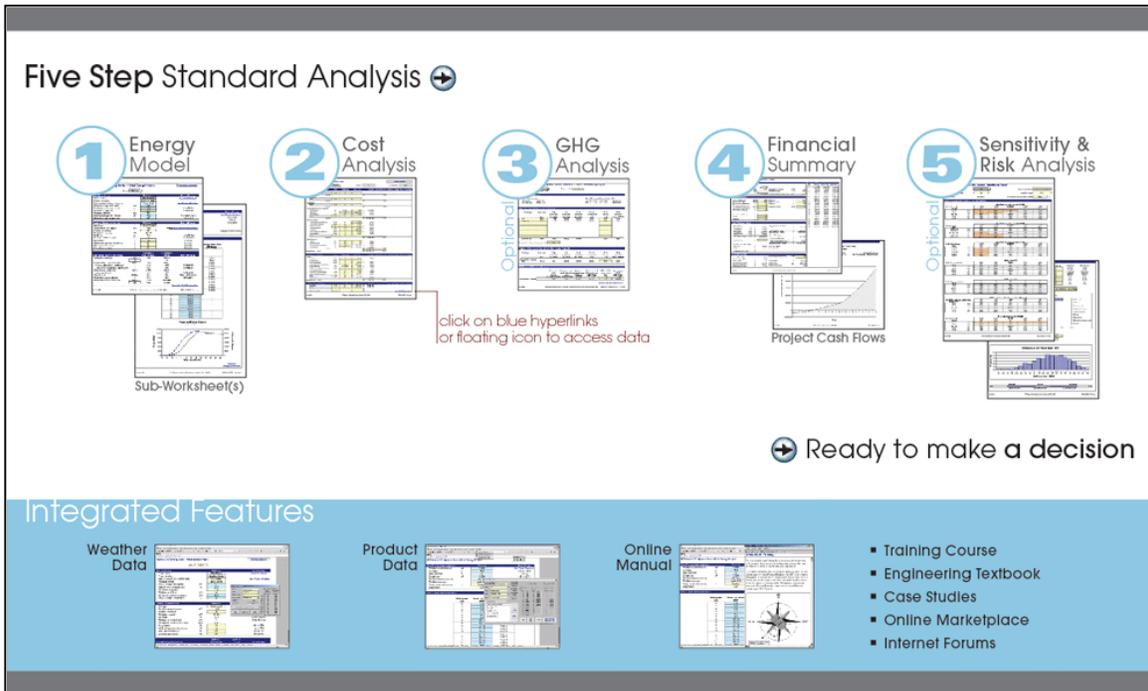
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## Brief Description & Model Flow Chart

**RETScreen® International** is a clean energy awareness, decision-support and capacity building tool. The core of the tool consists of a standardised and integrated clean energy project analysis software that 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 (RETs). Each RETScreen technology model (e.g. Combined Heat & Power Project, etc.) is developed within an individual Microsoft® Excel spreadsheet "Workbook" file. The Workbook file is in-turn composed of a series of worksheets. These worksheets have a common look and follow a standard approach for all RETScreen models. In addition to the software, the tool includes: product, weather and cost databases; an online manual; a Website; an engineering textbook; project case studies; and a training course.

### Model flow chart

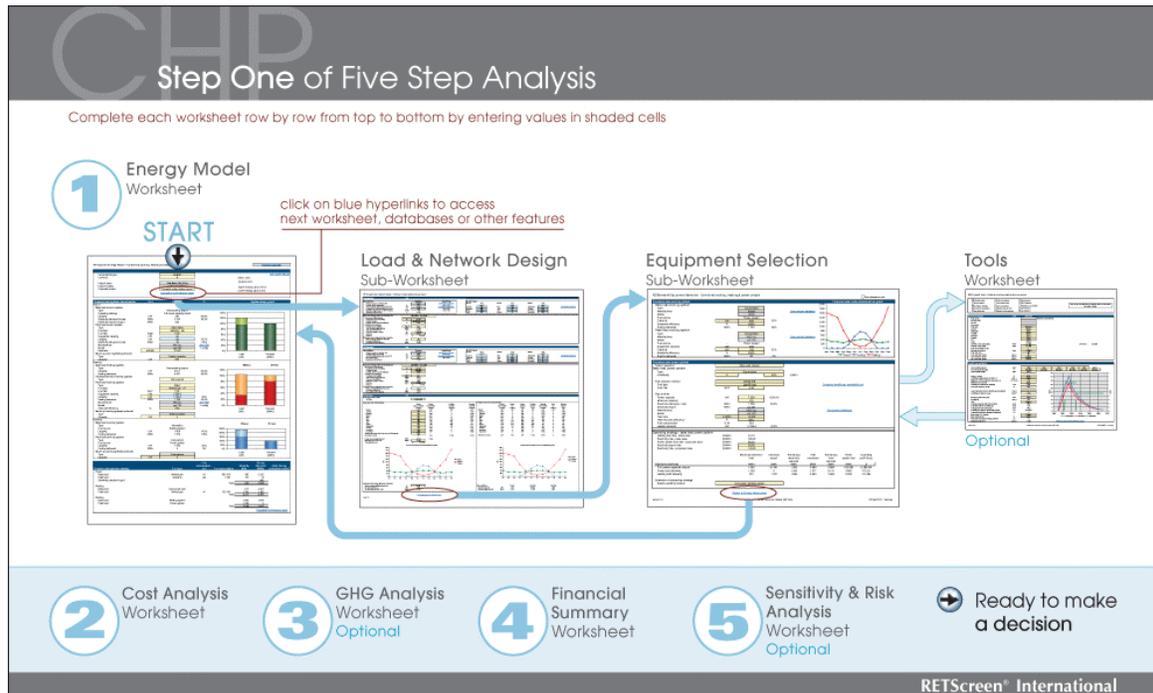
Complete each worksheet row by row from top to bottom by entering values in shaded cells. To move between worksheets simply "click" on the tabs at the bottom of each screen or on the "blue-underlined" hyperlinks built into the worksheets as presented in the RETScreen Model Flow Chart.



**RETScreen Model Flow Chart**

## CHP model flow chart

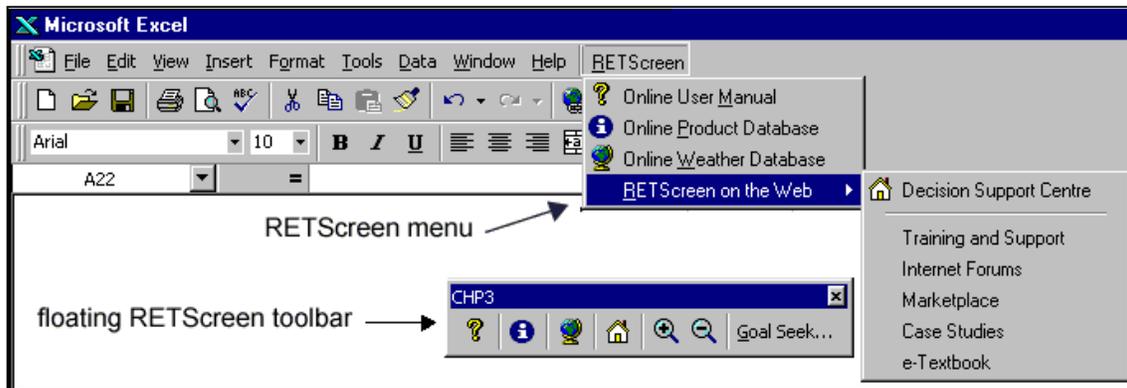
Complete each worksheet row by row from top to bottom by entering values in shaded cells. To move between worksheets simply "click" on the tabs at the bottom of each screen or on the "blue-underlined" hyperlinks built into the worksheets as presented in the RETScreen CHP Model Flow Chart.



RETScreen CHP Model Flow Chart

## Data & help access

The RETScreen Online User Manual, Product Database and Weather Database can be accessed through the Excel menu bar under the "RETScreen" option, as shown in the following figure. The icons displayed under the RETScreen menu bar are displayed in the floating RETScreen toolbar. Hence the user may also access the online user manual, product database and weather database by clicking on the respective icon in the floating RETScreen toolbar. For example, to access the online user manual the user clicks on the "?" icon.



**RETScreen Menu and Toolbar**

The RETScreen Online User Manual, or help feature, is "cursor location sensitive" and therefore gives the help information related to the cell where the cursor is located.

To access the product database specific to the type of system being considered, the user should click on the "blue-underlined" hyperlink next to the entry cell that says "see product database" or "see PDB."

## Cell colour coding

The user enters data into "shaded" worksheet cells. All other cells that do not require input data are protected to prevent the user from mistakenly deleting a formula or reference cell. The RETScreen Cell Colour Coding chart presents the colour coding for input and output cells.

<u>Input and Output Cells</u>	
<b>White</b>	Model output - calculated by the model.
<b>Yellow</b>	User input - required to run the model.
<b>Blue</b>	User input - required to run the model and online databases available.
<b>Grey</b>	User input - for reference purposes only. Not required to run the model.

**RETScreen Cell Colour Coding**

## Currency options

To perform a RETScreen project analysis, the user may select a currency of their choice from the "Currency" cell in the *Energy Model* worksheet.

The user selects the currency in which the monetary data of the project will be reported. For example, if the user selects "\$," all monetary related items are expressed in \$.

Selecting "User-defined" allows the user to specify the currency manually by entering a name or symbol in the additional input cell that appears adjacent to the currency switch cell. The currency may be expressed using a maximum of three characters (\$US, £, ¥, etc.). To facilitate the presentation of monetary data, this selection may also be used to reduce the monetary data by a factor (e.g. \$ reduced by a factor of a thousand, hence k\$ 1,000 instead of \$ 1,000,000).

If "None" is selected, all monetary data are expressed without units. Hence, where monetary data is used together with other units (e.g. \$/kWh) the currency code is replaced with a hyphen (-/kWh).

The user may also select a country to obtain the International Standard Organisation (ISO) three-letter country currency code. For example, if Afghanistan is selected from the currency switch drop-down list, all project monetary data are expressed in AFA. The first two letters of the country currency code refer to the name of the country (AF for Afghanistan), and the third letter to the name of the currency (A for Afghani).

Name of unit	Symbol for unit
ampere	Amp
atmosphere	atm
British thermal unit	Btu
calorie	cal
day	d
degree Celsius	°C
degree Fahrenheit	°F
degree Rankine	°R
dollar	\$
feet	ft
gallon <sup>1</sup>	gal
gram	g
hectare	ha
hertz	Hz
horse power	hp
hour	h
imperial gallon	imp gal
inch	in
joule	J
Kelvin	K
litre	L
metre	m
mile	mi
million Btu	mmBtu
pascal	Pa
percentage	%
person-day	p-d
person-hour	p-h
person-trip	p-trip
person-year	p-yr
pound	lb
pound-force per square inch absolute	psia
pound-force per square inch gauge	psig
refrigerant tonne	RT
revolution per minute	rpm
second	s
tonne <sup>2</sup>	t
United States gallon	US gal
watt	W
year	yr

Name of prefix	Symbol for prefix
kilo	k
milli	m
mega	M
giga	G
tera	T
num	million

1. The gallon (gal) unit used in RETScreen refers to US gallon and not to imperial gallon, unless otherwise specified.
2. The tonne (t) unit used in RETScreen refers to metric tonnes

### List of Units, Symbols and Prefixes

For information purposes, the user may want to assign a portion of a project cost item in a second currency, to account for those costs that must be paid for in a currency other than the currency in which the project costs are reported. To assign a cost item in a second currency, the user must select the option "Second currency" from the "Cost reference" drop-down list cell in the *Cost Analysis* worksheet.

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings of the sheet. The user can increase the zoom to see those symbols correctly. Usually, symbols will be fully visible on printing even if not fully appearing on the screen display.

## Units, symbols & prefixes

The previous table presents a list of units, symbols and prefixes that are used in the RETScreen model.

### Unit options

To perform a RETScreen project analysis, the user must choose between "Metric" units or "Imperial" units by clicking on the appropriate radio button. The user should not change this selection once the analysis has started.

If the user selects "Metric," all output values will be expressed in metric units. But if the user selects "Imperial," output values will be expressed in imperial units where applicable. In the *Equipment Selection* worksheet, both types of units can be shown simultaneously by ticking the "Show alternative units" check box.

Note that if the user switches between "Metric" and "Imperial," input values will not be automatically converted into the equivalent selected units. The user must select the units preferred for each input cells and ensure that values entered in input cells are expressed in the units shown.

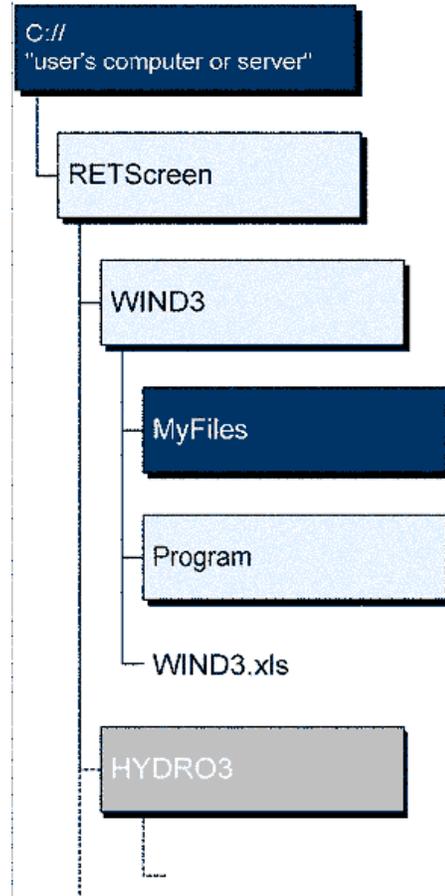
### Language options

To perform a RETScreen project analysis, the user may select a language from the "Language - Langue" cell in the *Energy Model* worksheet.

## Saving a file

To save a RETScreen Workbook file, standard Excel saving procedures should be used. The original Excel Workbook file for each RETScreen model can not be saved under its original distribution name. This is done so that the user does not save-over the "master" file. Instead, the user should use the "File, Save As" option. The user can then save the file on a hard drive, diskette, CD, etc. However, it is recommended to save the files in the "MyFiles" directory automatically set by the RETScreen installer program on the hard drive.

The download procedure is presented in the following figure. The user may also visit the RETScreen Website at [www.retscreen.net](http://www.retscreen.net) for more information on the download procedure. It is important to note that the user should not change directory names or the file organisation automatically set by RETScreen installer program. Also, the main RETScreen program file and the other files in the "Program" directory should not be moved. Otherwise, the user may not be able to access the RETScreen Online User Manual or the RETScreen Weather and Product Databases.



RETScreen Download Procedure

## Printing a file

To print a RETScreen Workbook file, standard Excel printing procedures should be used. The workbooks have been formatted for printing the worksheets on standard "letter size" paper with a print quality of 600 dpi. If the printer being used has a different dpi rating then the user must change the print quality dpi rating by selecting "File, Page Setup, Page and Print Quality" and then selecting the proper dpi rating for the printer. Otherwise the user may experience quality problems with the printed worksheets.

## Combined Heat & Power Project Model

The RETScreen® International Combined Heat & Power (CHP) Project Model can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for combined heat & power projects. It can be used to evaluate any one or combination of the following applications: power; heating; cooling; single buildings or multiple buildings; industrial processes; communities; district heating and district cooling. Further, it permits analysis with a wide range of renewable and non-renewable fuels (which can be used in parallel), including landfill gas; biomass; bagasse; biodiesel; hydrogen; natural gas; oil/diesel; coal; municipal waste, etc. Finally, these fuels can be evaluated using multiple types of power, heating and/or cooling equipment, including reciprocating engines; gas turbines; gas turbine - combined cycle; steam turbines; geothermal systems; fuel cells; wind turbines; hydro turbines; photovoltaic modules; boilers; heat pumps; biomass systems; heaters; furnaces; compressors; absorption chillers, etc., all working under various operating conditions (base load, intermediate load and/or peak load).

Eight worksheets (*Energy Model*, *Load & Network Design (Load & Network)*, *Equipment Selection*, *Cost Analysis*, *Greenhouse Gas Emission Reduction Analysis (GHG Analysis)*, *Financial Summary*, *Sensitivity and Risk Analysis (Sensitivity)* and *Tools*) are provided in the Combined Heat & Power Project Workbook file.

The *Energy Model*, *Load & Network* and *Equipment Selection* worksheets are completed first. The *Cost Analysis* worksheet should then be completed, followed by the *Financial Summary* worksheet. The *GHG Analysis* and *Sensitivity* worksheets are optional analyses. The *GHG Analysis* worksheet is provided to help the user estimate the greenhouse gas (GHG) mitigation potential of the proposed project. The *Sensitivity* worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. The *Tools* worksheet is optional and is provided to help the user calculate certain inputs required to use the model, such as the amount of landfill gas available for the project. In general, the user works from top-down for each of the worksheets. This process can be repeated several times in order to help optimise the design of the combined heat & power project from an energy use and cost standpoint.

In addition to the worksheets that are required to run the model, the *Introduction* worksheet and *Blank Worksheets (3)* are included in the Excel Workbook file. The *Introduction* worksheet provides the user with a quick overview of the model. *Blank Worksheets (3)* are provided to allow the user to prepare a customised RETScreen project analysis. For example, the worksheets can be used to enter more details about the project, to prepare graphs and to perform a more detailed sensitivity analysis.

## Energy Model

As part of the RETScreen Clean Energy Project Analysis Software, the *Energy Model* worksheet presents the proposed case system summary (fuel types, fuel consumption, capacity and energy delivered) based upon system characteristics and calculations in the *Load & Network Design* and *Equipment Selection* worksheets. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies and fuels.

## Settings

For more information on how to use the RETScreen Combined Heat & Power (CHP) Project Model, refer to the CHP Model Flow Chart and the Proposed project section.

The user selects the language of the online manual from the drop-down list. For more information on how to use the RETScreen Online User Manual, Product Database and Weather Database, see Data & help access.

## Unit Options & Fuel Value Reference

### Language - Langue

The user selects a language from the drop-down list.

L'utilisateur choisit une langue à partir de la liste déroulante.

### Currency

To perform a RETScreen project analysis, the user may select a currency of their choice from the "Currency" cell in the *Energy Model* worksheet.

The user selects the currency in which the monetary data of the project will be reported. For example, if the user selects "\$," all monetary related items are expressed in \$.

Selecting "User-defined" allows the user to specify the currency manually by entering a name or symbol in the additional input cell that appears adjacent to the currency switch cell. The currency may be expressed using a maximum of three characters (\$US, £, ¥, etc.). To facilitate the presentation of monetary data, this selection may also be used to reduce the monetary data by a factor (e.g. \$ reduced by a factor of a thousand, hence k\$ 1,000 instead of \$ 1,000,000).

If "None" is selected, all monetary data are expressed without units. Hence, where monetary data is used together with other units (e.g. \$/kWh) the currency code is replaced with a hyphen (-/kWh).

The user may also select a country to obtain the International Standard Organisation (ISO) three-letter country currency code. For example, if Afghanistan is selected from the currency switch drop-down list, all project monetary data are expressed in AFA. The first two letters of the country currency code refer to the name of the country (AF for Afghanistan), and the third letter to the name of the currency (A for Afghani).

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings of the sheet. The user can then increase the zoom to see those symbols correctly. Usually, symbols will be fully visible on printing even if not fully appearing on the screen display.

## **Metric or Imperial units**

To perform a RETScreen project analysis, the user must choose between "Metric" units or "Imperial" units by clicking on the appropriate radio button. The user should not change this selection once the analysis has started.

If the user selects "Metric," all output values will be expressed in metric units. But if the user selects "Imperial," output values will be expressed in Imperial units where applicable. In the *Equipment Selection* worksheet, both types of units can be shown simultaneously by ticking the "Show alternative units" check box.

Note that if the user switches between "Metric" and "Imperial," input values will not be automatically transformed into the equivalent selected units. The user must select the units preferred for each input cell and ensure that values entered in input cells are expressed in the units shown.

## **Project name**

The user-defined project name is given for reference purposes only.

## **Project location**

The user-defined project location is given for reference purposes only.

## **Higher or Lower heating value**

The user must choose between "Higher heating value (HHV)" or "Lower heating value (LHV)" by clicking on the appropriate radio button. The user should not change this selection once the analysis has started.

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.

Higher heating value is typically used in Canada and USA, while lower heating value is used in the rest of the world.

Refer to the "Heating value & fuel rate" section in the *Tools* worksheet to calculate the heating value for various fuels on a dry basis.

## Proposed project

The user selects the proposed project type considered from the seven options in the drop-down list: "Heating only," "Power only," "Cooling only," "Combined heating & power," "Combined cooling & power," "Combined heating & cooling," or "Combined cooling, heating & power." Note that the use of the word "power" means "electricity generation" in the RETScreen Combined Heat & Power (CHP) Project Model.

See one of the following figures:

[Heating Only Project](#)

[Power Only Project](#)

[Cooling Only Project](#)

[Combined Heating & Power Project](#)

[Combined Cooling & Power Project](#)

[Combined Heating & Cooling Project](#)

[Combined Cooling, Heating & Power Project](#)

For more information on how to use the RETScreen Combined Heat & Power Project Model, refer to the CHP Model Flow Chart.

**Note:** At this point the user should complete the *Load & Network* worksheet.

## Proposed case system characteristics

The model can evaluate heating, cooling and/or power projects consisting of various types of equipment as selected by the user in the *Equipment Selection* and the *Energy Model* worksheets. System designs can consist of base load, intermediate load, peak load and/or back-up system, depending on the application (e.g. heating).

The proposed case system characteristics section, depending of the proposed project type selected, is divided into three sub-sections: Power, Heating and Cooling. Only the relevant sections are displayed.

## Power

The proposed case power system analysed can include four main components as follows:

1. Base load power system, designed to operate under the "Operating strategy" selected in the *Equipment Selection* worksheet;
2. Intermediate load power system, designed to operate under the "Operating strategy" selected in the *Equipment Selection* worksheet. The base load power system is assumed to operate at full power capacity output when there is a base and an intermediate load power system;
3. Peak load power system, typically designed to meet only a small portion of the annual electricity demand that occurs during peak periods; and/or,
4. Back-up power system (optional), which is used in case of interruption of the other systems.

If the load is connected to the electricity grid, the grid can act as a peak and back-up power system.

See the following figures:

[Power System Load Definition - Base & Peak Load](#)

[Power System Load Definition - Base, Intermediate & Peak Load](#)

## Base load power system

The user enters the information about the base load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Type

The user selects the base load power system type in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Operating strategy

The user selects the operating strategy in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

If there is a base and an intermediate load power system, the base load power system operating strategy is assumed to be "Full power capacity output."

## Capacity

The user enters the capacity of the base load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the base load power system capacity over the proposed case power system peak load is calculated.

## Electricity delivered to load

The model calculates the electricity delivered to the load by the base load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the electricity delivered to the load by the base load power system over the proposed case power system energy demand is also calculated.

## Electricity exported to grid

The model calculates the electricity exported to the grid by the base load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Intermediate load power system

The user enters the information about the intermediate load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Type

The user selects the intermediate load power system type in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Operating strategy

The user selects the operating strategy in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Capacity

The user enters the capacity of the intermediate load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the intermediate load power system capacity over the proposed case power system peak load is calculated.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load by the intermediate load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the electricity delivered to the load by the intermediate load power system over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid by the intermediate load power system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## **Peak load power system**

The peak load power system is designed to meet the remaining electricity demand not met by the base load and/or the intermediate load power systems, either due to insufficient installed capacity or to cover scheduled shutdowns.

### **Type**

The user selects the peak load power system type considered from the drop-down list. Selecting "Not required" will hide the entire peak load power system section. However, if "Not required" is selected and the Suggested capacity by the model is greater than 0, this section will not hide and the calculations made by the model will not be accurate.

### **Fuel type**

The user selects the fuel type for the peak load power system from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet, the relevant heating value will be used for the calculations.

### **Fuel rate**

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the peak load power system.

## Suggested capacity

The model calculates the suggested capacity of the peak load power system. This value is calculated by subtracting the base load power system capacity (and the intermediate load power system capacity if included) from the proposed case power system peak load calculated in the *Load & Network* worksheet.

Note that if the Availability of the base load and/or intermediate load power systems are less than 100% (or 8,760 hours), then the capacity of these power systems will be added to the suggested capacity for the peak load power system.

## Capacity

The user enters the capacity of the peak load power system. If the capacity entered is below the model's suggested capacity of the peak load power system, then it is assumed that the system cannot meet the peak power load at design conditions and the calculations made by the model will not be accurate. The "System design graph" can be used as a guide.

The percentage of the peak load power system capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Electricity delivered to load

The model calculates the electricity delivered to the load by the peak load power system.

The percentage of the electricity delivered to the load by the peak load power system over the proposed case power system energy demand is also calculated.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Heat rate

The user enters the heat rate of the peak load power system. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity. This value is another way of entering the electricity generation efficiency and is common practice in industry.

The following figures provide average heat rates at International Standards Organization (ISO) standard conditions of 15°C (59°F), 1 atmosphere (101.3 kPa) and 60% relative humidity, typically used by manufacturers. The heat rates are typically quoted in lower heating value. The figures show the heat rates based on natural gas for higher heating value (HHV) and lower heating value (LHV). The heat rate normally varies over the operating range of the equipment and this should be considered if the equipment is not operated at maximum output for most of the year.

See one of the following figures:

[CHP Plant Heat rate & Heat Recovery Efficiency Calculation](#)

[Typical Heat Rates for Reciprocating Engines - LHV \(< 6MW\)](#)

[Typical Heat Rates for Reciprocating Engines - HHV \(< 6MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(>= 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \(>= 50 MW\)](#)

## Back-up power system (optional)

The back-up power system is designed to meet the electricity demand in case of failure by the base load, intermediate load and/or peak load power systems. This is an optional equipment and its use will depend on how critical the electrical loads are, and whether or not the peak load power system is sufficient to provide all the back-up power.

## Type

The user enters optional back-up power system type considered (if required).

## Capacity

The user enters the capacity of the optional back-up power system.

Back-up power system might be part of a system. A common "rule-of-thumb" is that each power plant should have back-up capability equal to the largest system. For example, a back-up generator might be utilised in the case of an unexpected system shutdown. The back-up power system capacity can be calculated as the largest capacity by comparing the sizes of the base load, intermediate load and the peak load power systems. In some cases a designer may choose not to include a back-up system, rather relying only on the peak load power system.

This entry does not impact the energy calculations, it is only used in the *Cost Analysis* worksheet.

## Heating

The proposed case heating system analysed can include five main components as follows:

1. Base load heating system, which could supply heat from a boiler, furnace, etc., or heat recovered from power generation equipment or from a process. Typically this is the primary heating system designed to meet the majority of the annual base load heating demand;
2. Intermediate load heating system, which could supply heat from a boiler, etc., or heat recovered from power generation equipment or from a process;
3. Intermediate load heating system #2, which is only available if the system includes base and intermediate load power systems. Typically this is the secondary heating system designed to meet most of the remaining heating demand not met by the base and intermediate load heating systems;
4. Peak load heating system, typically designed to meet only a small portion of the annual heating demand that occurs during peak periods; and/or,
5. Back-up heating system (optional), which is used in case of interruption of the other systems.

See the following figures:

[Heating System Load Definition - Base & Peak Load](#)

[Heating System Load Definition - Base, Intermediate & Peak Load](#)

[Heating System Load Definition - Base, Intermediate, Intermediate #2 & Peak Load](#)

## Base load heating system

The user enters the information about the base load heating system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet. When the proposed project is Combined heating & power or Combined cooling, heating & power, the base load heating is assumed by the model to be provided by the base load power system via waste heat recovery.

### Type

The user selects the base load heating system type in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

### Capacity

The user enters the capacity of the base load heating system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the base load heating system capacity over the proposed case heating system peak load is calculated.

## Heating delivered

The model calculates the heating delivered by the base load heating system.

The percentage of the heating delivered by the base load heating system over the proposed case heating system energy demand is also calculated.

## Intermediate load heating system

The user enters the information about the intermediate load heating system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

If no intermediate load power system has been specified, the user can enter an intermediate heating load system in the *Energy Model* worksheet.

### Type

The user selects the type of the intermediate load heating system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

If no intermediate load power system has been specified, the user can select the type of the intermediate heating load system in the *Energy Model* worksheet.

## Capacity

The user enters the capacity of the intermediate load heating system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

If no intermediate load power system has been specified, the user can enter the capacity of the intermediate heating load system in the *Energy Model* worksheet.

The percentage of the intermediate load heating system capacity over the proposed case heating system peak load is calculated.

## Heating delivered

The model calculates the heating delivered by the intermediate load heating system.

The percentage of the heating delivered by the intermediate load heating system over the proposed case heating system energy demand is also calculated.

## Intermediate load heating system [#2]

The intermediate load heating system (#2) is designed to meet most of the remaining heating demand not met by the base (and intermediate load heating system, if applicable). The intermediate load heating system (#2) is particularly useful when the heat recovered from the power equipment does not meet a reasonable portion of the total heating energy demand.

## Type

The user selects the type of the intermediate load heating system (#2) considered from the drop-down list. Selecting "Not required" will hide the entire peak load heating system section.

## Fuel type

The user selects the fuel type for the intermediate load heating system (#2) from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet, the relevant heating value will be used for the calculations.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the fuel type of the fuel consumed by the intermediate load heating system (#2).

## Capacity

The user enters the capacity of the intermediate load heating system (#2). The "System design graph" can be used as a guide.

The percentage of the intermediate load heating system (#2) capacity over the proposed case heating system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Heating delivered

The model calculates the heating delivered by the intermediate load heating system (#2).

The percentage of the heating delivered by the intermediate load heating system (#2) over the proposed case heating system energy demand is also calculated.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Seasonal efficiency

The user enters the seasonal efficiency of the intermediate load heating system (#2). This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for heating systems range from 50% for a standard boiler or furnace (with pilot light) to 350% for a ground-source heat pump. Typical values of heating system efficiency are presented in the [Typical Seasonal Efficiencies of Heating Systems](#) table. The first 3 listed are based on HHV natural gas fuel.

## Peak load heating system

The peak load heating system is designed to meet the remaining heating demand not met by the base load, the intermediate load and/or the intermediate load #2 heating system, either due to insufficient installed capacity or to cover scheduled shutdowns.

### Type

The user selects the type of the peak load heating system considered from the drop-down list. Selecting "Not required" will hide the entire peak load heating system section. However, if "Not required" is selected and the Suggested capacity by the model is greater than 0, the calculations made by the model will not be accurate.

### Fuel type

The user selects the fuel type for the peak load heating system from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet, the relevant heating value will be used for the calculations.

### Fuel rate

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the peak load heating system.

### Suggested capacity

The model calculates the suggested capacity of the peak load heating system. This value is calculated by subtracting the base load heating system capacity (as well as the intermediate load heating system capacity and the intermediate load heating system #2 capacity if required) from the proposed case heating system peak load calculated in the *Load & Network* worksheet.

### Capacity

The user enters the capacity of the peak load heating system. If the capacity entered is below the model's suggested capacity of the peak load heating system, then it is assumed that the system cannot meet the peak heating load at design conditions and the calculations made by the model will not be accurate. Note that the "System design graph" can be used as a guide.

The percentage of the peak load heating system capacity over the proposed case heating system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Heating delivered

The model calculates the heating delivered by the peak load heating system.

The percentage of the heating delivered by the peak load heating system over the proposed case heating system energy demand is also calculated.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Seasonal efficiency

The user enters the seasonal efficiency of the peak load heating system. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for heating systems range from 50% for a standard boiler or furnace (with pilot light) to 350% for a ground-source heat pump. Typical values of heating system efficiency are presented in the [Typical Seasonal Efficiencies of Heating Systems](#) table. The first 3 listed are based on HHV natural gas fuel.

## Back-up heating system (optional)

The back-up heating system is designed to meet the heating demand in case of failure by the base load, intermediate load, intermediate load #2 and/or peak load heating systems. This is an optional equipment and its use will depend on how critical the heating loads are, and whether or not the peak load heating system is sufficient to provide all the back-up heating.

## Type

The user enters optional back-up heating system type considered (if required).

## Capacity

The user enters the capacity of the optional back-up heating system.

Back-up heating system might be part of a system. A common "rule-of-thumb" is that each heating plant should have back-up capability equal to the largest system. For example, a back-up heating system might be utilised in the case of a heating system shutdown or during an interruption in the fuel supply. The back-up heating system capacity can be calculated as the largest capacity by comparing the sizes of the base load, intermediate load, intermediate load #2 and the peak load heating systems.

The use of a back-up heating system depends on the "design philosophy" of the user. The back-up heating system provides greater security, but at a higher cost in new systems. For example, used oil boiler will often suffice as a back-up system. In other cases a designer may choose not to include a back-up system, rather relying only on the peak load heating system.

This entry does not impact the energy calculations, it is only used in the *Cost Analysis* worksheet.

## Cooling

The proposed case cooling system analysed can include three main components as follows:

1. Base load cooling system, designed to meet the majority of annual base load cooling demand;
2. Peak load cooling system, typically designed to meet only a small portion of the annual cooling demand that occurs during peak periods; and/or,
3. Back-up cooling system (optional), which is used in case of interruption of the other systems.

See the following figure:

[Cooling System Load Definition](#)

## Base load cooling system

The user enters the information about the base load cooling system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Type

The user selects the base load cooling system type in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Fuel source/Fuel type

The user selects the base load cooling system fuel source or fuel type in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Capacity

The user enters the capacity of the base load cooling system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the base load cooling system capacity over the proposed case cooling system peak load is calculated.

## Cooling delivered

The model calculates the cooling delivered by the base load cooling system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the cooling delivered by the base load cooling system over the proposed case cooling system energy demand is also calculated.

## Peak load cooling system

The user enters the information about the peak load cooling system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Type

The user selects the peak load cooling system type in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Fuel source/Fuel type

The user selects the peak load cooling system fuel source or fuel type in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Capacity

The user enters the capacity of the peak load cooling system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the peak load cooling system capacity over the proposed case cooling system peak load is calculated.

## Cooling delivered

The model calculates the cooling delivered by the peak load cooling system in the *Equipment Selection* worksheet and it is copied automatically to the *Energy Model* worksheet.

The percentage of the cooling delivered by the peak load cooling system over the proposed case cooling system energy demand is also calculated.

## Back-up cooling system (optional)

The back-up cooling system is designed to meet the cooling demand in case of failure by the base load and/or peak load cooling systems. This is an optional equipment and its use will depend on how critical the cooling loads are, and whether or not the peak load cooling system is sufficient to provide all the back-up cooling.

## Type

The user enters optional back-up cooling system type considered (if required).

## Capacity

The user enters the capacity of the optional back-up cooling system.

Back-up cooling system might be part of a system. Back-up cooling system is used if the loss of cooling will have a significant impact (e.g. industrial process, computer equipment, etc.). For example, a back-up cooling system might be utilised in the case of a cooling system shutdown or during maintenance of the other systems.

## System design graph

The System design graph summarises essential design information for the user. The stacked bar graph on the left shows the percentage of the installed capacity (kW) for each of the systems (base load, intermediate load (#2) and peak load) over the System peak load as calculated in the *Load & Network* worksheet. The stacked bar graph can exceed 100% to allow the system to be oversized. The stacked bar graph on the right shows the

percentage of energy delivered (MWh) by each system over the System energy demand as calculated in the *Load & Network* worksheet. This stacked bar graph cannot exceed 100%.

## **Proposed case system summary**

This section summarises the fuel types used, the estimated fuel consumption, the installed capacity and the energy delivered for the different power, heating and/or cooling systems in order to meet the system peak load and energy demand, as calculated in the *Energy Model*, *Load & Network* and *Equipment Selection* worksheets. These values are copied automatically to the *Cost Analysis*, *GHG Analysis* and/or *Financial Summary* worksheets.

The user also selects, by ticking the box, which system or fuel might be able to take advantage of clean energy production credits. This information will be used in the *Financial Summary* calculations.

## Load & Network Design

As part of the RETScreen Clean Energy Project Analysis Software, the *Load & Network Design* worksheet is used to estimate the heating, cooling and/or power loads for the base case and proposed case systems. This worksheet can also be used to prepare a preliminary design and cost estimate for the district heating and/or cooling networks.

### Heating project

#### Site conditions

#### Nearest location for weather data

The user enters the weather station location with the most representative weather conditions for the project. This is for reference purposes only. The user can consult the RETScreen Online Weather Database for more information.

#### Heating design temperature

The user enters the heating design temperature in Celsius degrees, which represents the minimum temperature that has been measured for a frequency level of at least 1% over the year, for a specific area [ASHRAE, 1997]. The heating design temperature is used to determine the heating demand. The user can consult the RETScreen Online Weather Database for more information.

Typical values for heating design temperature range from approximately -40 to 15°C.

If the user selects imperial units at the top of the *Energy Model* worksheet, °F equivalent values will also be displayed.

**Note:** The heating design temperature values found in the RETScreen Online Weather Database were calculated based on hourly data for 12 months of the year. The user might want to overwrite this value depending on local conditions. For example, where temperatures are measured at airports, the heating design temperature could be 1 to 2°C warmer in core areas of large cities.

The user should be aware that if they choose to modify the heating design temperature, the monthly degree-days and the heating loads might have to be adjusted accordingly.

#### Annual heating degree-days below 18°C

The model calculates the total annual heating degree-days below 18°C (65°F) by summing the monthly degree-days entered by the user. Degree-days for a given day represent the number of Celsius degrees that the mean temperature is above or below a

given base. Thus, heating degree-days are the number of degrees below 18°C. The user can consult the RETScreen Online Weather Database for more information.

If the user selects imperial units at the top of the *Energy Model* worksheet, °F equivalent values will also be displayed.

## Domestic hot water heating base demand

The user enters the estimated domestic hot water (DHW) heating base demand as a percentage of the total heating needs (excluding process heating).

In cold climates, typical values for domestic hot water heating base demand range from 0 to 25%. As an example, a hospital will probably use 25% of its heating energy to heat domestic hot water while a typical office building might use only 10% of its heating energy to heat domestic hot water. If no domestic hot water heating is required, the user enters 0. Selecting process heating only (without space heating) for "Base case heating system" will hide this cell and the Equivalent degree-days for DHW heating cell.

## Equivalent degree-days for DHW heating

The model calculates the equivalent degree-days for domestic hot water (DHW) heating. While building heating is often calculated from climatic normals, which are expressed in degree-days, the domestic hot water heating load is often expressed in degree-days/day.

Typical values for equivalent degree-days for DHW heating range from 0 to 10 degree-days/day. A low hot water heating requirement is equivalent to 2 degree-days/day while a high hot water heating requirement (e.g. hospital) is equivalent to 6 to 10 degree-days/day. Selecting process heating only (without space heating) for "Base case heating system" will hide this cell and the Domestic hot water heating base demand cell.

## Equivalent full load hours

The model calculates the equivalent full load hours, which is defined as the annual total heating demand divided by the total peak heating load for a specific location. This value is expressed in hours and is equivalent to the number of hours that a heating system sized exactly for the peak heating load would operate at rated capacity to meet the annual total heating demand. Typical values for the equivalent full load hours range from 1,500 to 4,200 hours for space heating. The upper range increases if the system has a high domestic hot water heating load or process heating load.

## Monthly inputs

The user enters the monthly degree-days below 18°C (65°F). The monthly degree-days are the sum of the degree-days for each day of the month. Degree-days for a given day represent the number of Celsius degrees that the mean temperature is above or below a

given base. Thus, heating degree-days are the number of degrees below 18°C. The user can consult the RETScreen Online Weather Database for more information.

If the user selects imperial units at the top of the *Energy Model* worksheet, °F equivalent values will also be displayed.

## Base case heating system

The user selects the heating load type from the drop-down list.

## Technical note on heating network design

The purpose of this technical note is to provide the user with a sample design of a district heating network used within the RETScreen model. The example described below refers to the values presented in the [Base case heating system](#) section example and the [Proposed case district heating network](#) section example.

In a state-of-the-art district heating system, thermal energy, in the form of hot water, is distributed from the central heating plant and/or power plant (with waste heat recovery) to the individual buildings. The thermal energy is distributed using networks of insulated underground arterial pipeline (main distribution line) and branch pipelines (secondary distribution lines).

The network can either be designed as a branched system, as shown in the [Community System Building Cluster Layout](#), or as a looped system.

This figure shows how the different building clusters are connected to the main distribution line (i.e. section 1, 2, etc.). Note that the office building (cluster 4) and the apartment building (cluster 5) are not put in the same building cluster as they have different heating loads. If they are put together the secondary pipe size will be incorrect. The [Community System Base Case Heating System and Heating Load](#) table provides a summary of the heating loads and pipe lengths for the building clusters shown in the [Community System Building Cluster Layout](#).

## Heated floor area for/per building [zone/cluster]

### Heated floor area for building

The user enters the total heated floor space for the building.

For process heating only, this value is entered for reference purposes only.

## Heated floor area per building zone

The user enters the total heated floor space per building zone. A building zone is any number of similar sections of a building connected to a single point of the distribution system.

**Note:** When the user enters 0 or leaves the heated floor area per building zone cell blank, the remaining cells of the column in this section are hidden. For process heating only, this value is entered for reference purposes only, but it has to be entered for each building zone considered in order to enter inputs in the remaining cells of the column.

## Heated floor area per building cluster

The user enters the total heated floor space per building cluster. A building cluster is any number of similar buildings connected to a single point of the distribution system. The user obtains this value for each of the buildings included in the heating system and summarises the values to enter the cluster total heated floor area (see Technical note on heating network design ).

**Note:** When the user enters 0 or leaves the heated floor area per building cluster cell blank, the remaining cells of the column in this section are hidden. For process heating only, this value is entered for reference purposes only, but it has to be entered for each building cluster considered in order to enter inputs in the remaining cells of the column.

## Number of buildings in building cluster

The user enters the number of buildings in each building cluster.

## Fuel type

The user selects the fuel type for the base case heating system from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet, the relevant heating value will be used for the calculations.

## Seasonal efficiency

The user enters the seasonal efficiency of the base case heating system. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for heating systems range from 50% for a standard boiler or furnace (with pilot light) to 350% for a ground-source heat pump. Typical values of heating system efficiency are presented in the

[Typical Seasonal Efficiencies of Heating Systems](#) table. The first 3 listed are based on HHV natural gas fuel.

## Heating load calculation

### Heating load for building [zone/cluster]

The user enters the heating load for the building, the building zone or the building cluster. If this value is not known (e.g. from fuel bill), the user can use the "Tools, Goal Seek..." function in Excel to easily calculate this value.

The user can also refer to the [Building Heating Load Chart](#) [CET, 1997] to estimate the heating load per unit of heated floor area. This value depends on the heating design temperature for the specific location and on the building insulation efficiency. Typical values for heating load range from 40 to 120 W/m<sup>2</sup>.

### Peak process heating load

The user enters the peak process heating load for the building, the building zone or the building cluster. This value depends on the process type and size used in the building, but it is assumed to be weather independent. If the process heating load (or a portion of it) is weather dependent (e.g. lumber drying kiln), it can be entered as part of the heating load for building, building zone or building cluster.

### Process heating load characteristics

The user selects the process heating load characteristics from the drop-down list.

The "Detailed" option allows the user to enter the percentage of time the process is operating on a monthly basis in the "Base case load characteristics" section located at the bottom of this worksheet. If the "Standard" option is selected, the process load is assumed to be the same for each month of the year and is calculated based on the peak process heating load and the equivalent full load hours for the process heating load.

### Equivalent full load hours - process heating

The equivalent full load hours for the process heating load is defined as the annual process heating demand divided by the peak process heating load. This value is expressed in hours and is equivalent to the number of hours that a heating system sized exactly for the peak process heating load would operate at rated capacity to meet the annual process heating demand.

If the "Standard" option for the process heating load characteristics is selected, the user enters the equivalent full load hours for the process heating load. If the "Detailed" option for the process heating load characteristics is selected, the user has to enter the percentage

of time the process is operating on a monthly basis in the "Base case load characteristics" section located at the bottom of this worksheet, and the model calculates the equivalent full load hours for the process heating load.

Typical values for equivalent full load hours for process heating load range from 2,000 to 8,500 hours for a process that is weather independent and operates 100% of the time, and 200 to 2,000 hours for a process that is only operating part of the year.

## **Space heating demand**

The model calculates the annual space heating demand for the building, the building zone or the building cluster, which is the amount of energy required to heat the space (including domestic hot water).

## **Process heating demand**

The model calculates the annual process heating demand for the building, the building zone or the building cluster, which is the amount of energy required for process heating.

## **Total heating demand**

The model calculates the annual total heating demand for the building, the building zone or the building cluster. This is the amount of energy required from the base case heating system for space heating (including domestic hot water) and/or for process heating.

This value is copied automatically in the *Financial Summary* worksheet.

## **Total peak heating load**

The model calculates the annual total peak heating load for the building, the building zone or the building cluster. This is the instantaneous heat required from the base case heating system to meet the largest space heating load (including domestic hot water) and/or process heating load. It typically coincides with the coldest day of the year for space heating applications.

This value is copied automatically to the *Financial Summary* worksheet.

## **Fuel consumption - unit**

The model displays the unit used for the fuel type selected for each building zone or building cluster.

## Fuel consumption - annual

The model calculates the annual fuel consumption for the building, the building zone or the building cluster.

## Fuel rate - unit

The model displays the unit used for the fuel type selected for each building zone or building cluster.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the base case heating system.

## Fuel cost

The model calculates the fuel cost for the base case heating system.

This value is copied automatically to the *Financial Summary* worksheet.

## Proposed case energy efficiency measures

### End-use energy efficiency measures

The user enters the percent of the base case heating system's total peak heating load that is reduced as a result of implementing the proposed case end-use energy efficiency measures. This value is used to calculate the heating system average load in the "Proposed case load characteristics" section at the bottom of this worksheet, as well as the net peak heating load and the net heating demand for the proposed case system. Typical values range from 0 to 25% depending on the measures implemented.

**Note:** These proposed case end-use energy efficiency measures are in addition to the improvements in energy efficiency that result from implementing the proposed case system, as calculated in the other worksheets. For example, as part of implementing a new cooling, heating and/or power system, the user might also want to implement other measures, such as improved building insulation, that reduce the load that the new proposed case system will have to meet.

### Net peak heating load

The model calculates the annual net peak heating load for the building, the building zone or the building cluster. This is the instantaneous heat required from the proposed case heating system to meet the largest space heating load (including domestic hot water)

and/or process heating load after the implementation of the proposed case end-use energy efficiency measures. It typically coincides with the coldest day of the year for space heating applications.

## **Net heating demand**

The model calculates the annual net heating demand for the building, the building zone or the building cluster. This is the amount of energy required from the proposed case heating system for space heating (including domestic hot water) and/or for process heating after the implementation of the proposed case end-use energy efficiency measures.

## **Proposed case district heating network**

This section is used to prepare a preliminary design and cost estimate for the proposed case district heating network.

As an example, Small-commercial heating systems usually use 32 mm to 150 mm (1 ½" to 6") diameter treated plastic or steel-in-plastic insulated pipes for heat distribution. These pipes have proven to be economical to purchase, install, and maintain, but require water temperatures of less than 130°C (95°C for plastic pipes). The pipe diameter varies depending on the heating load of the system. When pipe length is used in this section it refers to trench length (with two pipes).

The heat losses for a district heating system vary depending on many factors. For example, an area with snow cover for a long period has fewer losses than an area with similar temperatures and no snow cover. In the RETScreen model, heat losses have not been included as a separate line item. The annual heat losses for a modern district heating system are in the range of 2 to 3% of all energy delivered. These numbers change if the pipe length is short and energy delivered is high.

As an example, the heat loss is approximately 58 W/m for a two-pipe system of a DN125 pipes using an average annual supply temperature of 100°C and an average annual return temperature of 50°C. The capacity is 3,400 kW for a DN125 pipe assuming a temperature difference of 45°C. Additional information may be obtained from the District Heating Handbook [Randløv, 1997].

## **Heating pipe design criteria**

### **Design supply temperature**

The user enters the design supply temperature for the district heating network. Typically plastic pipes are smaller than DN100 (100 mm or 4") and have a maximum temperature rating of 95°C; steel pipes are typically rated up to 130°C. If a mixed (plastic and steel) system is designed the rating for the plastic pipes governs the maximum water

temperature allowable. A minimum design supply temperature of 70°C is typically required for supplying heat to domestic hot water.

Refer to the [Typical District Heating Supply and Return Temperatures](#) graph for more information. Medium Temperature (MT) supply is typical for steel pipe systems. Low Temperature (LT) supply is typical for plastic pipe or mixed type systems. High temperature district heating systems are very rare and typically use supply temperatures that are well above temperatures shown in the graph, i.e. about 150°C.

## Design return temperature

The user enters the design return temperature for the district heating network. A low return temperature is desirable. Lower return temperatures make it possible to reduce pipe sizes and achieve higher efficiencies for waste heat recovery. For older buildings, the winter return temperature is likely to be around 75°C. For new systems designed to minimise the return temperature, 55°C can be achieved.

Refer to the [Typical District Heating Supply and Return Temperatures](#) graph for more information. Medium Temperature (MT) return is typical for district heating systems with old and new buildings. Low Temperature (LT) return represents a system with buildings specifically designed for district heating and optimisation of the return temperature. High temperature district heating systems are very rare.

## Differential temperature

The model calculates the differential temperature from the difference between design supply and design return temperatures. This value is used to calculate the size of the district heating pipes.

## Main heating distribution line

The main heating distribution line is the part of the district heating pipe system that connects several buildings, or clusters of buildings, to the heating plant and/or power plant (with waste heat recovery). The first section exiting the plant typically has the largest pipe diameter as it has to serve all the buildings. The pipe diameter is reduced as the load decreases farther away from the plant. The type of pipe can change from steel to plastic if the system is designed as a low temperature supply system (i.e. below 95°C).

**Note:** If the system consists of only one building connected to the plant, this pipe is considered to be a secondary line.

## Main pipe network oversizing

The user enters a pipe network oversizing factor. The pipes are then automatically sized for a load that is increased by the oversizing factor entered by the user. Pipe oversizing is used if it is expected that the system load will increase in the future.

For example, if a community studied requires a 500 kW heating system, but there is a plan to add additional housing that would require an additional load of 50 kW, an oversizing factor of 10% would ensure that the new housing can be connected at a later date. The oversizing factor is also used to test how much extra load the selected system can accommodate. This is achieved by changing the factor until the pipe size is increased. If the pipe sizes change when the oversizing factor is 15% this indicates that the selected system can handle 15% more load without having to change the size of the pipes.

## Pipe sections

The user indicates by selecting from the drop-down list whether or not a building cluster is connected to a section of the main distribution line. (The length refers to trench length with two pipes.) The user also specifies the length of each section of the main distribution line. The model then calculates the total load connected to the section and selects the pipe size using the oversizing factor. For more information, see example in the *Technical note on heating network design*.

The selection of pipe size for this model uses a simplified method. The pipe sizing criteria used allows a pressure drop for the maximum flow between 1 to 2 millibar/meter. The maximum velocity in larger pipes is maximised to 3 m/s. Before construction, it is necessary to verify that the selected pipe system will be able to withstand all relevant actions and fulfil the safety and functional requirements during its entire service life. The final pipe size needs to be verified using detailed calculations including pipe length and factor in the number of valves, connection points, elbows, etc.

## Total pipe length for main distribution line

The model calculates the total pipe length for the main heating distribution network. The length refers to trench length with two pipes.

## Secondary heating distribution lines

The secondary distribution lines are the parts of the district heating pipe system that connect individual buildings to the main distribution line. If the system consists only of one building connected to the plant, this pipe is considered a secondary line.

## Secondary pipe network oversizing

The user enters a pipe network oversizing factor. The pipes are then automatically sized for a load that is increased by the oversizing factor entered by the user. Pipe oversizing is used if it is expected that the system load will increase in the future.

For example, if a community studied requires a 500 kW heating system, but there is a plan to add additional housing that would require an additional load of 50 kW, an oversizing factor of 10% would ensure that the new housing can be connected at a later date. The oversizing factor is also used to test how much extra load the selected system can accommodate. This is achieved by changing the factor until the pipe size is increased. If the pipe sizes change when the oversizing factor is 15% this indicates that the selected system can handle 15% more load without having to change the size of the pipes.

Secondary network pipes are not oversized if, for example, the new buildings that are intended to be connected in the future will be independent of the existing secondary lines.

## Length of pipe section

The user enters the length of each building cluster section of the secondary distribution line. In a cluster of buildings of the same size, the user should insert the total length of pipe used to connect to the main distribution line. The length refers to trench length with two pipes. For more information, see the *Technical note on heating network design*.

## Pipe size

The model calculates the pipe size for each building load of the building cluster. Note that the pipe size is selected using the oversizing factor.

The selection of pipe size for this model uses a simplified method. The pipe sizing criteria used allows a pressure drop for the maximum flow between 1 to 2 millibar/meter. The maximum velocity in larger pipes is maximised to 3 m/s. Before construction, it is necessary to verify that the selected pipe system will be able to withstand all relevant actions and fulfil the safety and functional requirements during its entire service life. The final pipe size needs to be verified using detailed calculations including pipe length and factor in the number of valves, connection points, elbows, etc.

## District heating network cost

### Total pipe length

The model calculates the total pipe length as the sum of the total pipe length for the main heating distribution line and the total length of pipe section for the secondary heating distribution lines.

## Costing method

The user selects the type of costing method from the drop-down list. If the "Formula" costing method is selected, the model calculates the costs according to built-in formulas. If the "Detailed" costing method is selected, the user enters the Energy Transfer Station (ETS) and secondary distribution pipes costs per building cluster and the main distribution line pipe cost by pipe size categories.

The costs calculated by the "Formula" costing method are based on typical Canadian project costs as of January 2005. The user can adjust these costs to local conditions using the cost factors and the exchange rate in the cells below.

## Energy transfer station(s) connection type

The user selects the Energy Transfer Station (ETS) connection type from the drop-down list. If "Direct" connection type is selected, the model sets the costs for energy transfer station to 75% of "Indirect" connection type. If the "Detailed" costing method is selected, the user enters these costs.

The building's heating system is normally connected indirectly to the district heating system via energy transfer stations located in the basement or where a boiler would normally be located. Direct systems connect the district heating system directly to the building's heating system; however, there is still a cost associated to the connection of the system.

## Energy transfer station(s) cost factor

If the user selects the "Formula" costing method, then an energy transfer station(s) cost factor can be entered. This factor is used to modify the built-in formula to compensate for local variations in construction costs, inflation, etc.

## Main distribution line pipe cost factor

If the user selects the "Formula" costing method, then a main distribution line pipe cost factor can be entered. This factor is used to modify the built-in formula to compensate for local variations in construction costs, inflation, etc.

## Secondary distribution line pipe cost factor

If the user selects the "Formula" costing method, the secondary distribution line pipe cost factor can be entered. This factor is used to modify the built-in formula to compensate for local variations in construction costs, inflation, etc.

## Exchange rate

The user enters the exchange rate to convert the calculated Canadian dollar costs into the currency in which the project costs are reported as selected at the top of the *Energy Model* worksheet. The rate entered must be the value of one Canadian dollar expressed in the currency in which the project costs are reported.

## Energy transfer station(s) cost

If the user selects the "Formula" costing method, then the model calculates the energy transfer station(s) cost for all the buildings in each cluster using the [Typical Costs for Indirect Heating Energy Transfer Station\(s\)](#) graph. The cost for a direct connected energy transfer station is calculated to be 75% of the cost of an indirect energy transfer station. If the "Detailed" costing method is selected, then the user enters the energy transfer station(s) cost per building cluster. The model then calculates the total costs for all building clusters.

The costs shown for the energy transfer station include supply and installation in a new building. If the building needs to be converted from steam or electric baseboard heating, the costs are substantially higher and should be confirmed by a local contractor. It should be noted that building owners sometimes choose to remove existing boilers and domestic hot water storage tanks to gain valuable floor space.

Each energy transfer station consists of prefabricated heat exchanger units for space heating, domestic hot water heating and process heating. The energy transfer station is provided with the necessary control equipment as well as all the internal piping. The energy transfer station is designed for ease of connection to the building's internal heating and hot water system.

Domestic hot water tanks and boilers are typically replaced with only a heat exchanger. Where the domestic hot water consumption is large, storage tanks can be used.

Typically, each building includes an energy meter. These meters record district heating water flow through the energy transfer station. By measuring the temperature difference of incoming and return water temperature, the energy usage is calculated.

Prefabricated energy transfer stations with heat exchanger units for both heating and domestic hot water are available for single-family residences and small multi-family residences. They consist of brazed plate or "shell and tube" heat exchangers for both heating and domestic hot water, a circulation pump, an expansion tank, self-actuating control valves and an energy meter.

For larger buildings, the energy transfer station will be site assembled but will consist of the equipment with the same functions as for smaller buildings.

## Secondary distribution line pipe cost

If the user selects the "Formula" costing method, then the secondary distribution line pipe costs for all pipes connecting each cluster to the main distribution pipe are calculated by the model using the [Typical Costs for Heating Distribution Line Pipes](#) graph. If the "Detailed" costing method is selected, then the user enters the secondary distribution pipes cost per building cluster. The model then calculates the total cost for all building clusters.

The costs shown are for the supply and installation of the supply and return pipes (i.e. 2 pipes) per meter of trench. The cost per meter is for two pre-insulated district heating type pipes, in a trench approximately 600 mm deep. It also includes the cost for the replacement of existing sidewalks. Rocky terrain or installations in areas that have many old utility services (e.g. telephone, electricity, sewage, water, etc.) could increase the calculated cost substantially.

Typical secondary distribution line pipe costs can be broken down as follows: 45% for material, 45% for installation and 10% for associated distribution pump system.

## Total building cluster connection cost

The model calculates the total building cluster connection cost based on the ETS and secondary pipes costs per building cluster and for all the building clusters.

## Summary of main distribution line pipe size

The model summarises the pipe sizes specified in the main distribution line sizing section.

## Summary of main distribution line pipe length

The model calculates the total length of the main pipe for each pipe diameter.

## Summary of main distribution line pipe cost

If the user selects the "Formula" costing method, then the model calculates the main distribution line pipe cost by pipe size categories using the [Typical Costs for Heating Distribution Line Pipes](#) graph. If the "Detailed" costing method is selected, then the user enters the main distribution line pipe cost by pipe size categories. The model then calculates the total cost for all the main distribution line.

The costs shown are for the supply and installation of the supply and return pipes (i.e. 2 pipes) per meter of trench. The cost per meter is for two pre-insulated district heating type pipes, in a trench approximately 600 mm deep. It also includes the cost for the replacement of existing sidewalks. Rocky terrain or installations in areas that have many

old utility services (e.g. telephone, electricity, sewage, water, etc.) could increase the calculated cost substantially.

Typical main distribution line pipe costs can be broken down as follows: 45% for material, 45% for installation and 10% for associated distribution pump system.

## **Total district heating network cost**

The model calculates the total district heating network cost, which includes the total cost of secondary and main distribution pipes and the total cost of the energy transfer station(s).

## **Cooling project**

### **Site conditions**

#### **Nearest location for weather data**

The user enters the weather station location with the most representative weather conditions for the project. This is for reference purposes only. The user can consult the RETScreen Online Weather Database for more information.

#### **Cooling design temperature**

The user enters the cooling design temperature in Celsius degrees, which represents the maximum temperature that has been measured for a frequency level of at least 1% over the year, for a specific area [ASHRAE, 1997]. The cooling design temperature is used to determine the cooling demand. The user can consult the RETScreen Online Weather Database for more information.

Typical values for cooling design temperature range from approximately 10 to 47°C.

If the user selects imperial units at the top of the *Energy Model* worksheet, °F equivalent values will also be displayed.

**Note:** The cooling design temperature values found in the RETScreen Online Weather Database were calculated based on hourly data for 12 months of the year. The user might want to overwrite this value depending on local conditions. For example, where temperatures are measured at airports, the cooling design temperature could be 1 to 2°C warmer in core areas of large cities.

The user should be aware that if they choose to modify the cooling design temperature, the monthly degree-days and the cooling loads might have to be adjusted accordingly.

## Annual cooling degree-days above 10°C

The model calculates the total annual cooling degree-days above 10°C (50°F) by summing the monthly degree-days entered by the user. Degree-days for a given day represent the number of Celsius degrees that the mean temperature is above or below a given base. Thus, cooling degree-days are the number of degrees above 10°C. The user can consult the RETScreen Online Weather Database for more information.

If the user selects imperial units at the top of the *Energy Model* worksheet, °F equivalent values will also be displayed.

## Non-weather dependent cooling

The user enters the estimated non-weather dependent cooling demand as a percentage of the total cooling needs (excluding process cooling). Non-weather dependent loads can be cold storage for food or cooling for computer server rooms.

Typical values for base load cooling range from 5 to 30%. If no non-weather dependent cooling is required, the user enters 0. Selecting process cooling only (without space cooling) for "Base case cooling system" will hide this cell.

## Equivalent full load hours

The model calculates the equivalent full load hours, which is defined as the annual total cooling demand divided by the total peak cooling load for a specific location. This value is expressed in hours and is equivalent to the number of hours that a cooling system sized exactly for the peak cooling load would operate at rated capacity to meet the annual total cooling demand. Typical values for the equivalent full load hours range from 1,000 to 4,000 hours for space cooling. The upper range increases if the system has a high base load cooling or process cooling load.

## Monthly inputs

The user enters the monthly degree-days above 10°C (50°F). The monthly degree-days are the sum of the degree-days for each day of the month. Degree-days for a given day represent the number of Celsius degrees that the mean temperature is above or below a given base. Thus, cooling degree-days are the number of degrees above 10°C. The user can consult the RETScreen Online Weather Database for more information.

If the user selects imperial units at the top of the *Energy Model* worksheet, °F equivalent values will also be displayed.

## Base case cooling system

The user selects the cooling load type from the drop-down list.

## Technical note on cooling network design

The purpose of this technical note is to provide the user with a sample design of a district cooling network used within the RETScreen model. The example described below refers to the values presented in the [Base case cooling system](#) section example and the [Proposed case district cooling network](#) section example.

In a state-of-the-art district cooling system, thermal energy, in the form of cold water (ice slurry or brine solution), is distributed from the central cooling plant to the individual buildings. The thermal energy is distributed using networks of uninsulated or insulated underground arterial pipeline (main distribution line) and branch pipelines (secondary distribution lines).

The network can either be designed as a branched system, as shown in the [Community System Building Cluster Layout](#), or as a looped system.

This figure shows how the different building clusters are connected to the main distribution line (i.e. section 1, 2, etc.). Note that the office building (cluster 4) and the apartment building (cluster 5) are not put in the same building cluster as they have different cooling loads. If they are put together the secondary pipe size will be incorrect. The [Community System Base Case Cooling System and Cooling Load](#) table provides a summary of the cooling loads and pipe lengths for the building clusters shown in the [Community System Building Cluster Layout](#).

### Cooled floor area for/per building [zone/cluster]

#### Cooled floor area for building

The user enters the total cooled floor space for the building.

For process cooling only, this value is entered for reference purposes only.

#### Cooled floor area per building zone

The user enters the total cooled floor space per building zone. A building zone is any number of similar sections of a building connected to a single point of the distribution system.

**Note:** When the user enters 0 or leaves the cooled floor area per building zone cell blank, the remaining cells of the column in this section are hidden. For process cooling only, this value is entered for reference purposes only, but it has to be entered for each building zone considered in order to enter inputs in the remaining cells of the column.

## Cooled floor area per building cluster

The user enters the total cooled floor space per building cluster. A building cluster is any number of similar buildings connected to a single point of the distribution system. The user obtains this value for each of the buildings included in the cooling system and summarises the values to enter the cluster total cooled floor area (see Technical note on cooling network design ).

**Note:** When the user enters 0 or leaves the cooled floor area per building cluster cell blank, the remaining cells of the column in this section are hidden. For process cooling only, this value is entered for reference purposes only, but it has to be entered for each building cluster considered in order to enter inputs in the remaining cells of the column.

## Number of buildings in building cluster

The user enters the number of buildings in each building cluster.

## Fuel type

The user selects the fuel type for the base case cooling system from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet, the relevant heating value will be used for the calculations.

## Seasonal efficiency

The user enters the seasonal efficiency of the base case cooling system. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for cooling systems range from 20% for steam jet refrigeration to 700% for compressors. Typical values of cooling system efficiency are presented in the [Typical Seasonal Efficiencies of Cooling Systems](#) table.

## Cooling load calculation

### Cooling load for building [zone/cluster]

The user enters the cooling load for the building, the building zone or the building cluster. If this value is not known (e.g. from fuel bill), the user can use the "Tools, Goal Seek..." function in Excel to easily calculate this value.

The user can also refer to the [Building Cooling Load Chart](#) to estimate the cooling load per unit of cooled floor area. This value depends on the cooling design temperature for the specific location and on the building insulation efficiency. Typical values for cooling load range from 20 to 50 W/m<sup>2</sup>.

## Peak process cooling load

The user enters the peak process cooling load for the building, the building zone or the building cluster. This value depends on the process type and size used in the building, but it is assumed to be weather independent. If the process cooling load (or a portion of it) is weather dependent (e.g. cold storage), it can be entered as part of the cooling load for building, building zone or building cluster.

## Process cooling load characteristics

The user selects the process cooling load characteristics from the drop-down list.

The "Detailed" option allows the user to enter the percentage of time the process is operating on a monthly basis in the "Base case load characteristics" section located at the bottom of this worksheet. If the "Standard" option is selected, the process load is assumed to be the same for each month of the year and is calculated based on the peak process cooling load and the equivalent full load hours for the process cooling load.

## Equivalent full load hours - process cooling

The equivalent full load hours for the process cooling load is defined as the annual process cooling demand divided by the peak process cooling load. This value is expressed in hours and is equivalent to the number of hours that a cooling system sized exactly for the peak process cooling load would operate at rated capacity to meet the annual process cooling demand.

If the "Standard" option for the process cooling load characteristics is selected, the user enters the equivalent full load hours for the process cooling load. If the "Detailed" option for the process cooling load characteristics is selected, the user has to enter the percentage of time the process is operating on a monthly basis in the "Base case load characteristics" section located at the bottom of this worksheet, and the model calculates the equivalent full load hours for the process cooling load.

Typical values for equivalent full load hours for the process cooling load range from 2,000 to 8,500 hours for a process that is weather independent and operates 100% of the time and range from 200 to 2,000 hours for a process that is only operating part of the year.

## Space cooling demand

The model calculates the annual space cooling demand for the building, the building zone or the building cluster, which is the amount of energy required to cool the space (including base load cooling).

## Process cooling demand

The model calculates the annual process cooling demand for the building, the building zone or the building cluster, which is the amount of energy required for process cooling.

## Total cooling demand

The model calculates the annual total cooling demand for the building, the building zone or the building cluster. This is the amount of energy required from the base case cooling system for space cooling (including base load cooling) and/or for process cooling.

This value is copied automatically in the *Financial Summary* worksheet.

## Total peak cooling load

The model calculates the annual total peak cooling load for the building, the building zone or the building cluster. This is the instantaneous cooling required from the base case cooling system to meet the largest space cooling load (including base load cooling) and/or process cooling load. It typically coincides with the warmest day of the year for space cooling applications.

This value is copied automatically in the *Financial Summary* worksheet.

## Fuel consumption - unit

The model displays the unit used for the fuel type selected for each building zone or building cluster.

## Fuel consumption - annual

The model calculates the annual fuel consumption for the building, the building zone or the building cluster.

## Fuel rate - unit

The model displays the unit used for the fuel type selected for each building zone or building cluster.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the base case cooling system.

## Fuel cost

The model calculates the fuel cost for the base case cooling system.

This value is copied automatically in the *Financial Summary* worksheet.

## Proposed case energy efficiency measures

### End-use energy efficiency measures

The user enters the percent of the base case cooling system's total peak cooling load that is reduced as a result of implementing the proposed case end-use energy efficiency measures. This value is used to calculate the cooling system load in the "Proposed case load characteristics" section located at the bottom of this worksheet, as well as the net peak cooling load and the net cooling demand for the proposed case system. Typical values range from 0 to 25% depending on the measures implemented.

**Note:** These proposed case end-use energy efficiency measures are in addition to the improvements in energy efficiency that result from implementing the proposed case system, as calculated in the other worksheets. For example, as part of implementing a new cooling, heating and/or power system, the user might also want to implement other measures, such as improved building insulation, that reduce the load that the new proposed case system will have to meet.

### Net peak cooling load

The model calculates the annual net peak cooling load for the building, the building zone or the building cluster. This is the instantaneous cooling required from the proposed case cooling system to meet the largest space cooling load (including base load cooling) and/or process cooling load after the implementation of the proposed case end-use energy efficiency measures. It typically coincides with the warmest day of the year for space cooling applications.

### Net cooling demand

The model calculates the annual total net cooling demand for the building, the building zone or the building cluster. This is the amount of energy required from the proposed case cooling system for space cooling (including base load cooling) and/or for process

cooling after the implementation of the proposed case end-use energy efficiency measures.

## **Proposed case district cooling network**

This section is used to prepare a preliminary design and cost estimate for the proposed case district cooling network.

Steel pipes used for district cooling are typically externally coated to prevent external corrosion. Typical coating materials are bituminous, epoxy or urethane. For some soil conditions cathodic protection is added.

Typically the pipes are not insulated due to the small temperature difference between the soil and the water. District cooling pipes can also be installed without expansion loops or devices. A building cooling system design pressure is normally between 10 and 15 bar. If a building is directly connected to the distribution system the operating pressure in the system needs be able to supply the static pressure for the building and being within the maximum allowed building pressure.

The pipe diameter varies depending on the cooling load of the system. When pipe length is used in this section it refers to trench length (with two pipes).

The heat gains for a district cooling system vary depending on many factors such as soil temperature and level moisture content. In the RETScreen model, heat gains have not been included as a separate line item. The annual heat gains for a modern district cooling system are in the range of 2 to 3% of all energy delivered. These numbers change if the pipe length is short and energy delivered is high.

## **Cooling pipe design criteria**

### **Design supply temperature**

The user enters the design supply temperature for the district cooling network. Refer to [Typical District Cooling Supply and Return Temperatures](#) graph for more information.

### **Design return temperature**

The user enters the design return temperature for the district cooling network. A high return temperature is desirable. The design return temperature is typically about 12°C. Refer to [Typical District Cooling Supply and Return Temperatures](#) graph for more information.

## Differential temperature

The model calculates the differential temperature from the difference between design supply and design return temperatures. This value is used to calculate the size of the district cooling pipes.

## Main cooling distribution line

The main cooling distribution line is the part of the district cooling pipe system that connects several buildings, or clusters of buildings, to the cooling plant. The first section exiting the plant typically has the largest pipe diameter as it has to serve all the buildings. The pipe diameter is reduced as the load decreases farther away from the plant.

**Note:** If the system consists of only one building connected to the plant, this pipe is considered to be a secondary line.

## Main pipe network oversizing

The user enters a pipe network oversizing factor. The pipes are then automatically sized for a load that is increased by the oversizing factor entered by the user. Pipe oversizing is used if it is expected that the system load will increase in the future.

For example, if a community studied requires a 500 kW cooling system, but there is a plan to add additional housing that would require an additional load of 50 kW, an oversizing factor of 10% would ensure that the new housing can be connected at a later date. The oversizing factor is also used to test how much extra load the selected system can accommodate. This is achieved by changing the factor until the pipe size is increased. If the pipe sizes change when the oversizing factor is 15% this indicates that the selected system can handle 15% more load without having to change the size of the pipes.

## Pipe sections

The user indicates by selecting from the drop-down list whether or not a building cluster is connected to a section of the main distribution line. The user also specifies the length of each section of the main distribution line. (The length refers to trench length with two pipes.) The model then calculates the total load connected to the section and selects the pipe size using the oversizing factor. For more information, see example in the *Technical note on cooling network design*.

The selection of pipe size for this model uses a simplified method. The pipe sizing criteria used allows a pressure drop for the maximum flow between 1 to 2 millibar/meter. The maximum velocity in larger pipes is maximised to 3 m/s. Before construction, it is necessary to verify that the selected pipe system will be able to withstand all relevant actions and fulfil the safety and functional requirements during its entire service life. The

final pipe size needs to be verified using detailed calculations including pipe length and factor in the number of valves, connection points, elbows, etc.

## **Total pipe length for main distribution line**

The model calculates the total pipe length for the main cooling distribution network. The length refers to trench length with two pipes.

## **Secondary cooling distribution lines**

The secondary distribution lines are the parts of the district cooling pipe system that connect individual buildings to the main distribution line. If the system consists only of one building connected to the plant, this pipe is considered a secondary line.

## **Secondary pipe network oversizing**

The user enters a pipe network oversizing factor. The pipes are then automatically sized for a load that is increased by the oversizing factor entered by the user. Pipe oversizing is used if it is expected that the system load will increase in the future.

For example, if a community studied requires a 500 kW cooling system, but there is a plan to add additional housing that would require an additional load of 50 kW, an oversizing factor of 10% would ensure that the new housing can be connected at a later date. The oversizing factor is also used to test how much extra load the selected system can accommodate. This is achieved by changing the factor until the pipe size is increased. If the pipe sizes change when the oversizing factor is 15% this indicates that the selected system can handle 15% more load without having to change the size of the pipes.

Secondary network pipes are not oversized if, for example, the new buildings that are intended to be connected in the future will be independent of the existing secondary lines.

## **Length of pipe section**

The user enters the length of each building cluster section of the secondary distribution line. In a cluster of buildings of the same size, the user should insert the total length of pipe used to connect to the main distribution line. The length refers to trench length with two pipes. For more information, see the *Technical note on cooling network design*.

## **Pipe size**

The model calculates the pipe size for each building load of the building cluster. Note that the pipe size is selected using the oversizing factor.

The selection of pipe size for this model uses a simplified method. The pipe sizing criteria used allows a pressure drop for the maximum flow between 1 to 2 millibar/meter.

The maximum velocity in larger pipes is maximised to 3 m/s. Before construction, it is necessary to verify that the selected pipe system will be able to withstand all relevant actions and fulfil the safety and functional requirements during its entire service life. The final pipe size needs to be verified using detailed calculations including pipe length and factor in the number of valves, connection points, elbows, etc.

## **District cooling network cost**

### **Total pipe length**

The model calculates the total pipe length as the sum of the total pipe length for the main cooling distribution line and the total length of pipe section for the secondary cooling distribution lines.

### **Costing method**

The user selects the type of costing method from the drop-down list. If the "Formula" costing method is selected, the model calculates the costs according to built-in formulas. If the "Detailed" costing method is selected, the user enters the Energy Transfer Station (ETS) and secondary distribution pipes costs per building cluster and the main distribution line pipe cost by pipe size categories.

The costs calculated by the "Formula" costing method are based on typical Canadian project costs as of January 2005. The user can adjust these costs to local conditions using the cost factors and the exchange rate in the cells below.

### **Energy transfer station(s) connection type**

The user selects the Energy Transfer Station (ETS) connection type from the drop-down list. If "Direct" connection type is selected, the model sets the costs for energy transfer station to 75% of "Indirect" connection type. If the "Detailed" costing method is selected, the user enters these costs.

The building's cooling system is normally connected indirectly to the district cooling system via energy transfer stations located in the basement or where a chiller would normally be located. Direct systems connect the district cooling system directly to the building's cooling system; however, there is still a cost associated to the connection of the system.

### **Energy transfer station(s) cost factor**

If the user selects the "Formula" costing method, then an energy transfer station(s) cost factor can be entered. This factor is used to modify the built-in formula to compensate for local variations in construction costs, inflation, etc.

## Main distribution line pipe cost factor

If the user selects the "Formula" costing method, then a main distribution line pipe cost factor can be entered. This factor is used to modify the built-in formula to compensate for local variations in construction costs, inflation, etc.

## Secondary distribution line pipe cost factor

If the user selects the "Formula" costing method, the secondary distribution line pipe cost factor can be entered. This factor is used to modify the built-in formula to compensate for local variations in construction costs, inflation, etc.

## Exchange rate

The user enters the exchange rate to convert the calculated Canadian dollar costs into the currency in which the project costs are reported as selected at the top of the *Energy Model* worksheet. The rate entered must be the value of one Canadian dollar expressed in the currency in which the project costs are reported.

## Energy transfer station(s) cost

If the user selects the "Formula" costing method, then the model calculates the energy transfer station(s) cost for all the buildings in each cluster using the [Typical Costs for Indirect Cooling Energy Transfer Station\(s\)](#) graph. The cost for a direct connected energy transfer station is calculated to be 75% of the cost of an indirect energy transfer station. If the "Detailed" costing method is selected, then the user enters the energy transfer station(s) cost per building cluster. The model then calculates the total costs for all building clusters.

The costs shown for the energy transfer station(s) include supply and installation in a new building. It should be noted that building owners sometimes choose to remove existing chillers to gain valuable floor space.

Each energy transfer station consists of prefabricated heat exchanger unit. The energy transfer station is provided with the necessary control equipment as well as all the internal piping. The energy transfer station is designed for ease of connection to the building's internal cooling system.

Typically, each building includes an energy meter. These meters record district cooling water flow through the energy transfer station. By measuring the temperature difference of incoming and return water temperature, the energy usage is calculated.

Prefabricated energy transfer stations with heat exchanger unit are available for smaller buildings. They consist of brazed plate or "shell and tube" heat exchangers for a circulation pump, an expansion tank, self-actuating control valves and an energy meter.

For larger buildings, the energy transfer station will be site assembled but will consist of the equipment with the same functions as for smaller buildings.

## **Secondary distribution line pipe cost**

If the user selects the "Formula" costing method, then the secondary distribution line pipe costs for all pipes connecting each cluster to the main distribution pipe are calculated by the model using the [Typical Costs for Cooling Distribution Line Pipes](#) graph. If the "Detailed" costing method is selected, then the user enters the secondary distribution pipes cost per building cluster. The model then calculates the total costs for all building clusters.

The costs shown are for the supply and installation of the supply and return pipes (i.e. 2 pipes) per meter of trench. The cost per meter is for two pre-insulated district heating type pipes, in a trench approximately 600 mm deep. It also includes the cost for the replacement of existing sidewalks. Rocky terrain or installations in areas that have many old utility services (e.g. telephone, electricity, sewage, water, etc.) could increase the calculated cost substantially.

Typical secondary distribution line pipe costs can be broken down as follows: 45% for material, 45% for installation and 10% for associated distribution pump system.

## **Total building cluster connection cost**

The model calculates the total building cluster connection cost based on the ETS and secondary distribution pipes costs per building cluster and for all building clusters.

## **Summary of main distribution line pipe size**

The model summarises the pipe sizes specified in the main distribution line sizing section.

## **Summary of main distribution line pipe length**

The model calculates the total length of the main pipe for each pipe diameter.

## **Summary of main distribution line pipe cost**

If the user selects the "Formula" costing method, then the model calculates the main distribution line pipe cost by pipe size categories using the [Typical Costs for Cooling Distribution Line Pipes](#) graph. If the "Detailed" costing method is selected, then the user enters the main distribution line pipe cost by pipe size categories. The model then calculates the total cost for all the main distribution line.

The costs shown are for the supply and installation of the supply and return pipes (i.e. 2 pipes) per meter of trench. The cost per meter is for two pre-insulated district heating type pipes, in a trench approximately 600 mm deep. It also includes the cost for the replacement of existing sidewalks. Rocky terrain or installations in areas that have many old utility services (e.g. telephone, electricity, sewage, water, etc.) could increase the calculated cost substantially.

Typical main distribution line pipe costs can be broken down as follows: 45% for material, 45% for installation and 10% for associated distribution pump system.

## **Total district cooling network cost**

The model calculates the total district cooling network cost, which includes the total cost of secondary and main distribution pipes and the total cost of the energy transfer station(s).

## **Power project**

### **Base case power system**

In this section, the user provides information about the base case power system. The user enters the power gross average load on a monthly basis and, in the case of central-grid and isolated-grid systems, the electricity rate for the base case power system, in the "Base case load characteristics" section.

### **Grid type**

The user selects the grid type for the base case power system from the drop-down list.

### **Peak load - isolated grid**

The user enters the peak load of the isolated-grid for reference purposes only.

### **Minimum load - isolated-grid**

The user enters the minimum load of the isolated-grid. This value is used to evaluate if electricity can be exported to the grid by the proposed case power system. Electricity can not be exported to the grid if the proposed case power system capacity exceeds the minimum load of the isolated-grid.

### **Type**

The user enters the off-grid power system type considered for reference purposes only.

## Fuel type

The user selects the fuel type for the base case power system from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet the relevant heating value will be used for the calculations.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the base case power system.

## Capacity

The user enters the capacity of the base case power system for reference purposes only.

## Heat rate

The user enters the heat rate of the base case power system. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity. This value is another way of entering the electricity generation efficiency and is common practice in industry.

The following figures provide average heat rates at International Standards Organization (ISO) standard conditions of 15°C (59°F), 1 atmosphere (101.3 kPa) and 60% relative humidity, typically used by manufacturers. The heat rates are typically quoted in lower heating value. The figures show the heat rates based on natural gas for higher heating value (HHV) and lower heating value (LHV). The heat rate normally varies over the operating range of the equipment and this should be considered if the equipment is not operated at maximum output for most of the year.

See one of the following figures:

[CHP Plant Heat rate & Heat Recovery Efficiency Calculation](#)

[Typical Heat Rates for Reciprocating Engines - LHV \(< 6MW\)](#)

[Typical Heat Rates for Reciprocating Engines - HHV \(< 6MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(>= 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \(>= 50 MW\)](#)

## Annual O&M cost

The user enters the annual operating and maintenance (O&M) cost for the base case power system (e.g. lubricants, plant staff, etc.)

## Electricity rate - base case

The model calculates the average electricity rate for the base case power system.

Note that this does not include the installed cost of equipment, etc. Those costs would be treated as "Credits" in the *Cost Analysis* worksheet, if the proposed case power system is able to completely displace the need for the base case power system.

## Total electricity cost

The model calculates the total electricity cost based on the electricity demand and the electricity rate for the base case power system.

## Base case load characteristics

This section summarises the monthly loads and the annual peak load for the base case power, cooling and/or heating systems.

## Power gross average load

The user enters the gross monthly average power load for the base case power system. If the base case system includes heating and/or cooling with electricity, the electricity required for heating and/or cooling should be included in the power gross average load on a monthly basis. A "Check value" warning will appear if the value is too low - i.e. the "Power net average load" should be equal or greater than zero. This can occur when electricity is used for heating and/or cooling in the base case, as these loads are broken out separately.

**Note:** This column is only visible if the proposed project includes power.

## Power net average load

The model calculates the net monthly average power load for the base case power system by subtracting the electricity used for heating and/or cooling from the power gross average load on a monthly basis.

**Note:** This column is only visible if the proposed project includes power.

## Cooling % time process operating

The user enters the cooling % time process operating on a monthly basis. If the process operates 24 hours/day 7 days/week (100% of the time) during a month, the user enters 100%. If the process does not operate during a month, the user enters 0%.

**Note:** This column is only visible if "Detailed" is selected for "Process cooling load characteristics."

## Cooling average load

The model calculates the monthly average cooling load for the base case cooling system based on monthly weather inputs, non-weather dependant cooling, cooling load for building, building zone or building cluster, peak process cooling load and, if detailed process cooling load is selected, the cooling % time process operating. When "Standard" process cooling load characteristics is selected, the process load is assumed to be the same for each month of the year. A period for peak load is created to take into account weather dependent loads that occur during extreme temperatures.

**Note:** This column is only visible if the proposed project includes cooling.

## Heating % time process operating

The user enters the heating % time process operating on a monthly basis. If the process operates 24 hours/day 7 days/week (100% of the time) during a month, the user enters 100%. If the process does not operate during a month, the user enters 0%.

**Note:** This column is only visible if "Detailed" is selected for "Process heating load characteristics."

## Heating average load

The model calculates the monthly average heating load for the base case heating system based on monthly weather inputs, domestic hot water heating base demand, heating load for building, building zone or building cluster, peak process heating load and, if detailed process heating load is selected, the heating % time process operating. When "Standard" process heating load characteristics is selected, the process load is assumed to be the same for each month of the year. A period for peak load is created to take into account weather dependent loads that occur during extreme temperatures.

**Note:** This column is only visible if the proposed project includes heating.

## **System peak electricity load over max monthly average**

The user enters the system peak electricity load over maximum monthly average load for the base case power system, which represents the percentage that the peak electricity load exceeds the maximum monthly average power load over the twelve-month period.

## **Peak load - annual**

The model calculates the annual peak load.

## **Electricity demand**

The model calculates annual electricity demand.

## **Electricity rate - base case**

The user enters the average electricity rate for the base case power system.

## **Total electricity cost**

The model calculates the total electricity cost based on the electricity demand and the electricity rate for the base case power system.

## **Base case system load characteristics graph**

The base case system load characteristics graph shows the base case average load profile for the power, cooling and/or heating systems on a monthly basis.

## **Proposed case energy efficiency measures**

### **End-use energy efficiency measures**

The user enters the percent of the base case power system's annual peak load (i.e. power net average load) that is reduced as a result of implementing the proposed case end-use energy efficiency measures. This value is used to calculate the power net average load in the "Proposed case load characteristics" section, the net peak electricity load and the net electricity demand for the proposed case system. Typical values range from 0 to 25% depending on the measures implemented.

**Note:** These proposed case end-use energy efficiency measures are in addition to the improvements in energy efficiency that result from implementing the proposed case system, as calculated in the other worksheets. For example, as part of implementing a new cooling, heating and/or power system, the user might also

want to implement other measures, such as improved lighting fixtures, that reduce the load that the new proposed case system will have to meet.

## **Net peak electricity load**

The model calculates the annual net peak electricity load, which is the amount of power load required to meet the largest electricity load (excluding electricity used for heating and/or cooling) after the proposed case end-use implementation of energy efficiency measures.

## **Net electricity demand**

The model calculates the annual net electricity demand, which is the amount of energy required to run all the electricity loads (excluding electricity used for heating and/or cooling) after the implementation of the proposed case end-use energy efficiency measures.

## **Proposed case load characteristics**

This section summarises the monthly loads and the annual peak load for the proposed case power, cooling and/or heating systems. These loads are calculated with respect to the base case system and the proposed case end-use energy efficiency measures and the type of cooling system equipment selected in the *Equipment Selection* worksheet.

## **Power net average load**

The model calculates the net monthly average power load for the proposed case power system by multiplying the base case power system net average power load on a monthly basis by the proposed case end-use energy efficiency measures for power.

## **Power for cooling**

The model calculates the monthly average power load required by the cooling system equipment selected in the *Equipment Selection* worksheet.

## **Power system load**

The model calculates the monthly average power system load for the proposed case power system by adding the proposed case power net average load and power for cooling load on a monthly basis.

## **Cooling system load**

The model calculates the monthly average cooling system load for the proposed case cooling system by multiplying the base case cooling system average cooling load on a monthly basis by the proposed case end-use energy efficiency measures for cooling.

## **Heating net average load**

The model calculates the net monthly average heating load for the proposed case heating system by multiplying the base case heating system average heating load on a monthly basis by the end-use energy efficiency measures for heating.

## **Heat for cooling**

The model calculates the monthly average heat load required by the cooling system equipment selected in the *Equipment Selection* worksheet.

## **Heating system load**

The model calculates the monthly average heating system load for the proposed case heating system by adding the proposed case heating net average load and heat for cooling load on a monthly basis.

## **Peak load - annual**

The model calculates the annual peak load.

## **Proposed case system load characteristics graph**

The proposed case system load characteristics graph shows the proposed case average load profile for the power, cooling and/or heating systems on a monthly basis.

## **Proposed case load and demand**

The model summarises the proposed case load and demand for the power, heating and/or cooling systems.

## **System peak load**

The model calculates the proposed case system's peak heating, cooling and/or power system peak loads.

## System energy demand

The model calculates the proposed case system's heating, cooling and/or power system energy demands.

**Note:** At this point the user should complete the *Equipment Selection* worksheet.

## Equipment Selection

As part of the RETScreen Clean Energy Project Analysis Software, the *Equipment Selection* worksheet is used to select the equipment for the proposed case system. This worksheet is also used to select the operating strategy used for the selected power generation equipment.

### Show alternative units

In the *Equipment Selection* worksheet, both metric and imperial units can be shown simultaneously by ticking the "Show alternative units" check box at the top the worksheet. The values calculated in the units selected in the *Energy Model* worksheet are displayed in the main column and the values calculated in the alternative units are displayed in the column to the right.

### Proposed case cooling system

In this section, the user enters the information about the proposed case base load and/or peak load cooling systems.

See the following figure:

[Cooling System Load Definition](#)

### Proposed case system load characteristics graph

The proposed case system load characteristics graph shows the proposed case average load profile for the power, cooling and/or heating systems on a monthly basis.

### Base load cooling system

#### Type

The user selects the type of base load cooling system considered from the drop-down list.

Cooling is typically provided by compressors, heat pumps, absorption chillers, desiccant chillers or via free cooling. Compressors are normally centrifugal, reciprocating, screw or scroll type and are typically driven by electricity. If the proposed project includes power, the model automatically selects the power system as the compressor fuel source. Otherwise, the user selects the fuel type. Heat pumps are often air-source or ground-source type and are typically driven by electricity. If the proposed project includes power, the model automatically selects the power system as the heat pump fuel source. Otherwise, the user selects the fuel type. Absorption and desiccant chillers are typically driven by heat. If the proposed project includes heating, the model automatically selects

the heating system as the absorption or desiccant fuel source. Otherwise, the user selects the fuel type. For free cooling, the model automatically sets the fuel source to free cooling.

See one of the following figures:

[Compressor Cooling System Schematic](#)

[Absorption Cooling System Schematic](#)

[Desiccant Cooling System Schematic](#)

## Fuel source

The model automatically selects the base load cooling system fuel source. For compressors, if the proposed project includes power, the model automatically selects the power system as the fuel source. For heat pumps, if the proposed project includes power, the model automatically selects the power system as the fuel source. For absorption and desiccant chillers, if the proposed project includes heating, the model automatically selects the heating system as the fuel source. For free cooling, the model automatically sets the fuel source to free cooling.

Note that the "Proposed case system load characteristics graph" can be used as a guide.

## Fuel type

The user selects the base load cooling system fuel type from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet the relevant heating value will be used for the calculations.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the base load cooling system.

## Capacity

The user enters the capacity of the base load cooling system. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the base load cooling system capacity over the proposed case cooling system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Seasonal efficiency

The user enters the seasonal efficiency of the base load cooling system. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for cooling systems range from 20% for steam jet refrigeration to 700% for compressors. Typical values of cooling system efficiency are presented in the [Typical Seasonal Efficiencies of Cooling Systems](#) table.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Cooling delivered

The model calculates cooling delivered by the base load cooling system.

The percentage of the cooling delivered by the base load cooling system over the proposed case cooling system energy demand is also calculated.

## Peak load cooling system

The peak load cooling system is designed to meet the remaining cooling demand not met by the base load cooling system, either due to insufficient installed capacity or to cover scheduled shutdowns.

## Type

The user selects the type of peak load cooling system considered from the drop-down list. Selecting "Not required" will hide the entire peak load cooling system section. However, if "Not required" is selected and the Suggested capacity by the model is greater than 0, this section will not hide and the calculations made by the model will not be accurate.

## Fuel source

The model automatically selects the peak load cooling system fuel source. For compressors, if the proposed project includes power, the model automatically selects the power system as the fuel source. For heat pumps, if the proposed project includes power, the model automatically selects the power system as the fuel source. For absorption and desiccant chillers, if the proposed project includes heating, the model automatically selects the heating system as the fuel source. For free cooling, the model automatically sets the fuel source to free cooling.

Note that the "Proposed case system load characteristics graph" can be used as a guide.

## Fuel type

The user selects the fuel type for the peak load cooling system from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet the relevant heating value will be used for the calculations.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the peak load cooling system.

## Suggested capacity

The model calculates the suggested capacity of the peak load cooling system. This value is calculated by subtracting the base load cooling system capacity from the proposed case cooling system peak load calculated in the *Load & Network* worksheet.

## Capacity

The user enters the capacity of the peak load cooling system. If the capacity entered is below the model's suggested capacity of the peak load cooling system, then it is assumed that the system cannot meet the peak cooling load at design conditions and the calculations made by the model will not be accurate. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the peak load cooling system capacity over the proposed case cooling system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Seasonal efficiency

The user enters the seasonal efficiency of the peak load cooling system. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for cooling systems range from 20% for steam jet refrigeration to 700% for compressors. Typical values of cooling system efficiency are presented in the [Typical Seasonal Efficiencies of Cooling Systems](#) table.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Cooling delivered

The model calculates the cooling delivered by the peak load cooling system.

The percentage of the cooling delivered by the peak load cooling system over the proposed case cooling system energy demand is also calculated.

## Proposed case heating system

In this section, the user enters the information about the proposed case base load and/or intermediate load heating systems.

See one of the following figures:

[Heating System Load Definition - Base & Peak Load](#)

[Heating System Load Definition - Base, Intermediate & Peak Load](#)

## System selection

The user selects if the proposed case heating system includes a base load system or a combined base load and intermediate load system.

When "Base & intermediate load system" is selected, the model assumes that the base load system is operating 100% of the time and that the amount of energy available from the base load system will be used before energy is supplied by the intermediate and/or peak load systems.

See one of the following figures:

[Heating System Load Definition - Base & Peak Load](#)

[Heating System Load Definition - Base, Intermediate & Peak Load](#)

## **Base load heating system**

## **Intermediate load heating system**

### **Type**

The user selects the power system type considered from the drop-down list.

### **Biomass system, Boiler**

### **Capacity**

The user enters the capacity of the heating system. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the heating system capacity over the proposed case heating system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

### **Heating delivered**

The model calculates the heating delivered by the heating system.

The percentage of the heating delivered by the heating system over the proposed case heating system energy demand is also calculated.

### **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Seasonal efficiency

The user enters the seasonal efficiency of the heating system. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for heating systems range from 50% for a standard boiler or furnace (with pilot light) to 350% for a ground-source heat pump. Typical values of heating system efficiency are presented in the [Typical Seasonal Efficiencies of Heating Systems](#) table. The first 3 listed are based on HHV natural gas fuel.

## Boiler type

The user selects the boiler type considered from the drop-down list.

## Operating pressure

The user enters the operating pressure of the steam boiler.

## Saturation temperature

The model calculates the steam saturation temperature. The saturation temperature is the boiling point at the selected steam (operating) pressure.

## Superheated temperature

The user enters the superheated temperature of the steam. If superheated steam is not required, the user enters the saturation temperature calculated by the model.

Superheated steam is defined as steam heated to a temperature higher than the saturation temperature while maintaining the saturation pressure. It cannot exist in contact with water, nor contain water, and resembles a perfect gas. Superheated steam might be called surcharged steam, anhydrous steam or steam gas. Superheating of the steam also means that smaller size pipes can be used for the steam distribution system.

## **Return temperature**

The user enters the return temperature (or feedwater temperature) for the steam boiler.

The return temperature is typically around 110°C.

## **Steam flow**

The model calculates the steam flow based on the capacity, the superheated temperature and return temperature. This value is another way to express the capacity.

Typically, part of the steam flow is lost in the deaerator or to blowdown. The amount of blowdown ranges from 2 to 10% and varies depending on type of blowdown system used (automatic or manual) and the quality of condensate return and of the water treatment system.

## **Fuel required**

The model calculates the fuel required per hour based on the capacity and seasonal efficiency.

## **Furnace, Heater, Heat pump, Other**

### **Capacity**

The user enters the capacity of the heating system. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the heating system capacity over the proposed case heating system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

### **Heating delivered**

The model calculates the heating delivered by the heating system.

The percentage of the heating delivered by the heating system over the proposed case heating system energy demand is also calculated.

### **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Seasonal efficiency

The user enters the seasonal efficiency of the heating system. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for heating systems range from 50% for a standard boiler or furnace (with pilot light) to 350% for a ground-source heat pump. Typical values of heating system efficiency are presented in the [Typical Seasonal Efficiencies of Heating Systems](#) table. The first 3 listed are based on HHV natural gas fuel.

## Fuel required

The model calculates the fuel required per hour based on the capacity and seasonal efficiency.

## Fuel selection method

The user selects the fuel selection method from the drop-down list.

## Single fuel

Selecting "Single fuel" allows the user to select one fuel from the fuel type list.

## Fuel type

The user selects the fuel type for the system from the drop-down list. Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet the relevant heating value will be used for the calculations.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the type of fuel consumed by the system.

## Multiple fuels - monthly

Selecting "Multiple fuels - monthly" allows the user to select up to 3 different fuel types from the fuel type list. The user assigns the 3 fuel types to the twelve months of the year.

### Fuel type

The user selects a fuel type from the drop-down list for "Fuel type #1," "Fuel type #2" and/or "Fuel type #3." Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet the relevant heating value will be used for the calculations.

The model calculates the fuel consumption on a monthly basis. In the monthly fuel type column, the user assigns the 3 fuel types to the twelve months of the year by referring to "Fuel type #1," "Fuel type #2" and/or "Fuel type #3."

### Fuel mix

The model calculates the fuel mix based on the monthly fuel consumption for each fuel type selected.

### Fuel consumption - unit

The model displays the unit used for the fuel types selected.

### Fuel consumption

The model calculates the annual fuel consumption for the fuel types selected.

### Fuel rate - unit

The model displays the unit used for the fuel types selected.

### Fuel rate

The user enters the fuel rate (price per unit fuel) for the fuel types.

### Fuel cost

The model calculates the annual fuel cost for the fuel types by multiplying the fuel rate by the annual fuel consumption. The total cost for the entire fuel mix is also calculated.

## Multiple fuels - percentage

Selecting "Multiple fuels - percentage" allows the user to select up to 3 different fuel types from the fuel type list. The user then enters the fuel mix (%) for the 3 fuel types.

## **Fuel type**

The user selects a fuel type from the drop-down list for "Fuel type #1," "Fuel type #2" and/or "Fuel type #3." Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet the relevant heating value will be used for the calculations.

## **Fuel mix**

The user enters the fuel mix (%) for each fuel type selected. Note that the user should verify that the sum of all fuel listed in the fuel mix column equals 100%.

## **Fuel consumption - unit**

The model displays the unit used for the fuel types selected.

## **Fuel consumption**

The model calculates the annual fuel consumption for the fuel types selected.

## **Fuel rate - unit**

The model displays the unit used for the fuel types selected.

## **Fuel rate**

The user enters the fuel rate (price per unit fuel) for the fuel types.

## Fuel cost

The model calculates the annual fuel cost for the fuel types by multiplying the fuel rate by the annual fuel consumption. The total cost for the entire fuel mix is also calculated.

## Proposed case power system

In this section, the user enters the information about the proposed case base load and/or intermediate load power systems.

See one of the following figures:

[Power System Load Definition - Base & Peak Load](#)

[Power System Load Definition - Base, Intermediate & Peak Load](#)

## System selection

The user selects if the proposed case power system includes a base load system or a combined base and intermediate load system.

When "Base & intermediate load system" is selected, the model assumes that the base load system operates at full power capacity output and that the amount of energy available from the base load system will be used before energy is supplied by the intermediate and/or peak load systems. The intermediate load power system then operates under the "Operating strategy selected in the "Operating strategy" section.

See one of the following figures:

[Power System Load Definition - Base & Peak Load](#)

[Power System Load Definition - Base, Intermediate & Peak Load](#)

## Base load power system

## Intermediate load power system

### Type

The user selects the power system type considered from the drop-down list.

### Availability

The user enters the availability of the power system in either hours, or percent of hours, per year. This value is used to calculate the electricity delivered to load and electricity exported to grid, to calculate the suggested capacity for the peak load power system.

Typical values for availability for a new power system range from 8,000 (91.3%) to 8,400 hours (95.9%) per year. Used and older equipment might have less availability.

## Reciprocating engine

Reciprocating engines produce electricity for the power load using a generator. In addition to producing electricity, useful heat can be recovered from the exhaust gas using a heat recovery steam generator (HRSG), or heat recovery system for hot water. Heat can also be recovered from the lubricating oil cooler, the jacket water cooler and/or the charge air cooler, and this recovered "waste" heat can be provided to a heating load. Refer to the [Reciprocating Engine Schematic](#) for more information.

## Power capacity

The user enters the power capacity. Typical values for reciprocating engine power capacity are presented in the [Typical Reciprocating Engine Power Capacity](#) table. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Minimum capacity

The user enters the minimum power capacity that the power equipment can operate at, as a percentage of the "Power capacity" entered above. This value is compared with the monthly "Power net average load" for the proposed case system, as calculated in the *Load & Network* worksheet. If the minimum capacity exceeds the power net average load for any months, the user should adjust this value until the minimum capacity is always maintained. One way to do this is to have several smaller units, with the same total power capacity combined, running in parallel.

Typical minimum capacity for reciprocating engines is 25%.

## Electricity delivered to load

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## Electricity exported to grid

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Heat rate

The user enters the heat rate of the power system. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity. This value is another way of entering the electricity generation efficiency and is common practice in industry.

The following figures provide average heat rates at International Standards Organization (ISO) standard conditions of 15°C (59°F), 1 atmosphere (101.3 kPa) and 60% relative humidity, typically used by manufacturers. The heat rates are typically quoted in lower heating value. The figures show the heat rates based on natural gas for higher heating value (HHV) and lower heating value (LHV). The heat rate normally varies over the operating range of the equipment and this should be considered if the equipment is not operated at maximum output for most of the year. The heat rate for gas turbines varies also depending on the location (i.e. altitude, humidity and temperature).

See one of the following figures:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation](#)

[Typical Heat Rates for Gas Turbines - LHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(>= 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \( \$\geq 50\$  MW\)](#)

[Heat Rate Correction Factor - Altitude](#)

[Heat Rate Correction Factor - Specific Humidity](#)

[Heat Rate Correction Factor - Ambient Temperature](#)

## Heat recovery efficiency

The user enters the heat recovery efficiency of the heat recovery steam generator (HRSG) or heat recovery system for hot water. If the power equipment temperature is too low, only part of the heat produced can be recovered.

Typical values for heat recovery efficiency range from 50 to 80%. For a low temperature heating load, the higher value can be used and for high temperature heating load, the lower value is more suitable. If the heat recovery system is for hot water, the heat recovery efficiency is typically higher than if it is for steam.

See the following figure:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation](#)

## Fuel required

The model calculates the fuel required per hour based on the power capacity and heat rate.

## Heating capacity

The model calculates the heating capacity of the power equipment based on the power capacity, the heat rate and the heat recovery efficiency.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## Gas turbine

Gas turbines produce electricity for the power load using a generator. In addition to producing electricity, useful heat can be recovered from the exhaust gas using a heat recovery steam generator (HRSG), or heat recovery system for hot water, and this recovered "waste" heat can be provided to a heating load. Refer to the [Gas Turbine Schematic](#) for more information.

## **Power capacity**

The user enters the power capacity. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## **Minimum capacity**

The user enters the minimum power capacity that the power equipment can operate at, as a percentage of the "Power capacity" entered above. This value is compared with the monthly "Power net average load" for the proposed case system, as calculated in the *Load & Network* worksheet. If the minimum capacity exceeds the power net average load for any months, the user should adjust this value until the minimum capacity is always maintained. One way to do this is to have several smaller units, with the same total power capacity combined, running in parallel.

Typical minimum capacity for gas turbines is 40%.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Model**

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Heat rate

The user enters the heat rate of the power system. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity. This value is another way of entering the electricity generation efficiency and is common practice in industry.

The following figures provide average heat rates at International Standards Organization (ISO) standard conditions of 15°C (59°F), 1 atmosphere (101.3 kPa) and 60% relative humidity, typically used by manufacturers. The heat rates are typically quoted in lower heating value. The figures show the heat rates based on natural gas for higher heating value (HHV) and lower heating value (LHV). The heat rate normally varies over the operating range of the equipment and this should be considered if the equipment is not operated at maximum output for most of the year. The heat rate for gas turbines varies also depending on the location (i.e. altitude, humidity and temperature).

See one of the following figures:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation](#)

[Typical Heat Rates for Gas Turbines - LHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(50 to 300 MW\)](#)

[Heat Rate Correction Factor - Altitude](#)

[Heat Rate Correction Factor - Specific Humidity](#)

[Heat Rate Correction Factor - Ambient Temperature](#)

## Heat recovery efficiency

The user enters the heat recovery efficiency of the heat recovery steam generator (HRSG) or heat recovery system for hot water. If the power equipment temperature is too low, only part of the heat produced can be recovered.

Typical values for heat recovery efficiency range from 50 to 80%. For a low temperature heating load, the higher value can be used and for high temperature heating load, the lower value is more suitable. If the heat recovery system is for hot water, the heat recovery efficiency is typically higher than if it is for steam.

## Fuel required

The model calculates the fuel required per hour based on the power capacity and heat rate.

## Heating capacity

The model calculates the heating capacity of the power equipment based on the power capacity, the heat rate and the heat recovery efficiency.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## Gas turbine - combined cycle

Gas turbine - combined cycle (GTCC) power systems produce electricity for the power load using a gas turbine and a generator, as well as a steam turbine and generator using heat recovered from the gas turbine's exhaust gas (using a heat recovery steam generator - HRSG). Heat can be recovered from the steam turbine (ST) extraction port and back pressure port for the heating load. Refer to the [Gas Turbine - Combined Cycle Schematic](#) for more information.

## Power capacity (GT)

The user enters the power capacity of the gas turbine (GT). The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity (GT) over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Minimum capacity

The user enters the minimum power capacity that the power equipment can operate at, as a percentage of the "Power capacity" entered above. This value is compared with the monthly "Power net average load" for the proposed case system, as calculated in the *Load & Network* worksheet. If the minimum capacity exceeds the power net average load for any months, the user should adjust this value until the minimum capacity is always maintained. One way to do this is to have several smaller units, with the same total power capacity combined, running in parallel.

Typical minimum capacity for gas turbines is 40%.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Heat rate

The user enters the heat rate of the power system. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity. This value is another way of entering the electricity generation efficiency and is common practice in industry.

The following figures provide average heat rates at International Standards Organization (ISO) standard conditions of 15°C (59°F), 1 atmosphere (101.3 kPa) and 60% relative humidity, typically used by manufacturers. The heat rates are typically quoted in lower heating value. The figures show the heat rates based on natural gas for higher heating value (HHV) and lower heating value (LHV). The heat rate normally varies over the operating range of the equipment and this should be considered if the equipment is not operated at maximum output for most of the year. The heat rate for gas turbines varies also depending on the location (i.e. altitude, humidity and temperature).

See one of the following figures:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation](#)

[Typical Heat Rates for Gas Turbines - LHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(< 5 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(5 to 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - LHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - HHV \(50 to 300 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \(< 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - LHV \(>= 50 MW\)](#)

[Typical Heat Rates for Gas Turbines - Combined Cycle - HHV \(>= 50 MW\)](#)

[Heat Rate Correction Factor - Altitude](#)

[Heat Rate Correction Factor - Specific Humidity](#)

[Heat Rate Correction Factor - Ambient Temperature](#)

## Heat recovery efficiency

The user enters the heat recovery efficiency of the heat recovery steam generator (HRSG). If the gas turbine temperature is too low, only part of the heat produced can be recovered.

Typical values for heat recovery efficiency range from 50 to 80%. For a low temperature heating load, the higher value can be used and for high temperature heating load, the lower value is more suitable. If the heat recovery system is for hot water, the heat recovery efficiency is typically higher than if it is for steam.

See the following figure:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation](#)

## Fuel required

The model calculates the fuel required per hour based on the power capacity and heat rate.

## Heating capacity

The model calculates the heating capacity of the gas turbine based on the power capacity (GT), the heat rate and the heat recovery efficiency.

The heating capacity is the useful thermal output produced by the gas turbine that can be recovered for the steam turbine.

## Duct firing

The user indicates by selecting from the drop-down list whether or not duct firing is used.

The exhaust from a gas turbine contains large amounts of excess air, with oxygen content close to fresh air. The exhaust can be utilised as preheated combustion air for duct firing, thus increasing the heating capacity at the input of the steam turbine. Also, duct firing may be used in the case of gas turbine shutdown or in the case of temporary heating load swings.

The model assumes that the fuel type used for duct firing is the same as for the gas turbine.

## Duct firing heating capacity

The user enters the duct firing heating capacity, which represents the burner capacity. The efficiency of the burners used for duct firing is about 100%.

## Heating capacity after duct firing

The model calculates the heating capacity after duct firing, which is the amount of heat available in the duct for the heat recovery steam generator (HRSG) after the duct firing.

## Steam turbine

Gas turbine - combined cycle (GTCC) power systems produce electricity for the power load using a gas turbine and a generator, as well as a steam turbine and generator using heat recovered from the gas turbine's exhaust gas (using a heat recovery steam generator - HRSG). Heat can be recovered from the steam turbine (ST) extraction port and back pressure port for the heating load. Refer to the [Gas Turbine - Combined Cycle Schematic](#) for more information.

## Operating pressure

The user enters the operating pressure of the steam turbine. Refer to the [Typical Steam Turbine Pressures and Temperatures](#) table for information.

## Saturation temperature

The model calculates the steam saturation temperature. The saturation temperature is the boiling point at the selected steam (operating) pressure.

## Superheated temperature

The user enters the superheated temperature of the steam. If superheated steam is not required, the user enters the saturation temperature calculated by the model.

Superheated steam is defined as steam heated to a temperature higher than the saturation temperature while maintaining the saturation pressure. It cannot exist in contact with water, nor contain water, and resembles a perfect gas. Superheated steam might be called surcharged steam, anhydrous steam or steam gas. It increases the steam turbine efficiency. Superheating of the steam also means that smaller size pipes can be used for the steam distribution system.

## Steam flow

The model calculates the steam flow based on the heating capacity (after duct firing, if applicable) and the temperature at the back pressure port. This value is another way to express the steam turbine capacity.

Typical values for steam flow range from 1,000 kg/h (150 kW) to 2,500,000 kg/h (1,000 MW).

## Enthalpy

The model calculates the enthalpy of the steam at the input of the steam turbine. Enthalpy is a general measure of the heat content of a substance.

## Entropy

The model calculates the entropy of the steam at the input of the steam turbine. Entropy is a general measure of the thermodynamic potential of a system.

## Extraction port

The user indicates by selecting from the drop-down list whether or not an extraction port is included.

Extraction ports are used to provide heat to a heating load at a higher grade than available from the back pressure port.

## Maximum extraction

The user enters the maximum extraction as a percentage of the steam flow. The maximum allowable steam extraction varies depending on the equipment manufacturer and model.

## Extraction

The model calculates the amount of steam that can be extracted based on the maximum extraction and the steam flow.

## Extraction pressure

The user enters the steam turbine extraction pressure. The higher the extraction pressure is, the higher the heating capacity is at the extraction port and the lower the power capacity is, and vice-versa.

## Temperature

The model calculates the temperature of the extracted steam, which is the saturation temperature at the extraction pressure.

## Mixture quality

The model calculates steam moisture mixture quality at the output of the extraction port. If the mixture quality is below 1.0 the steam contains water (i.e. the steam is wet).

Typically, a steam turbine requires a minimum mixture quality in the range of 0.90 to 0.95. If the mixture quality is too low, there could be erosion of the steam turbine blades due to the collision of the water droplets and the turbine blades, thus increasing the cost of maintenance of the power system. Increasing the extraction pressure increases the mixture quality. If the extraction pressure cannot be increased, more than one steam turbine has to be used in conjunction with a reheater or a moisture separator. This will help reduce ongoing maintenance costs, but will increase the initial cost of equipment.

## **Enthalpy**

The model calculates the enthalpy of the steam at the output of the extraction port. Enthalpy is a general measure of the heat content of a substance.

## **Theoretical steam rate (TSR)**

The model calculates the theoretical steam rate (TSR) of the extracted steam, which represents the theoretical amount of steam necessary to produce 1 kWh of power.

## **Back pressure**

The user enters the steam turbine back pressure or exhaust pressure. The higher the back pressure is, the higher the heating capacity is at the back pressure port and the lower the power capacity is, and vice-versa.

## **Temperature**

The model calculates the temperature of the steam at the back pressure port, which is the saturation temperature at the back pressure.

## **Mixture quality**

The model calculates steam moisture mixture quality at the output of the back pressure port. If the mixture quality is below 1.0 the steam contains water (i.e. the steam is wet).

Typically, a steam turbine requires a minimum mixture quality in the range of 0.90 to 0.95. If the mixture quality is too low, there could be erosion of the steam turbine blades due to the collision of the water droplets and the turbine blades, thus increasing the cost of maintenance of the power system. Increasing the back pressure increases the mixture quality. If the back pressure cannot be increased, more than one steam turbine has to be used in conjunction with a reheater or a moisture separator. This will help reduce ongoing maintenance costs, but will increase the initial cost of equipment.

## Enthalpy

The model calculates the enthalpy of the steam at the output of the back pressure port. Enthalpy is a general measure of the heat content of a substance.

## Theoretical steam rate (TSR)

The model calculates the theoretical steam rate (TSR) of the back pressure steam, which represents the theoretical amount of steam necessary to produce 1 kWh of power.

## Steam turbine (ST) efficiency

The user enters the steam turbine (ST) efficiency. This value includes the losses in the steam turbine for auxiliary power and system losses.

Typical values for steam turbine efficiency range from 70 to 80%. Large steam turbines typically have higher efficiencies than small steam turbines. The turbine efficiency varies depending on the back pressure and the difference between the superheated and saturated temperature.

See one of the following figures:

[Typical Steam Turbine Efficiency](#)

[Steam Turbine Efficiency Correction Factor - Back Pressure](#)

[Steam Turbine Efficiency Correction Factor - Initial Superheat](#)

## Actual steam rate (ASR)

The model calculates the actual steam rate (ASR) for the steam turbine based on the steam flow, maximum extraction, turbine efficiency and the theoretical steam rates at the extraction port and back pressure port. This value is the actual amount of steam necessary to produce 1 kWh of power.

## Summary

This section summarises the power and heating capacities, with and without extraction. It also provides the electricity delivered to the load and exported to the grid depending on the operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## Power capacity (ST) - with extraction

The model calculates the power capacity of the steam turbine (ST) with extraction.

The percentage of the power capacity (ST) with extraction over the proposed case power system peak load is also calculated.

## **Total power capacity (GTCC) - with extraction**

The model calculates the total power capacity with extraction for the gas turbine - combined cycle (GTCC) power system, by adding the gas turbine power capacity (GT) to the steam turbine power capacity (ST) with extraction.

The percentage of the total power capacity (GTCC) with extraction over the total power system peak load is also calculated.

## **Power capacity (ST) [- without extraction]**

The model calculates the power capacity of the steam turbine (ST) without extraction.

The percentage of the power capacity (ST) without extraction over the proposed case power system peak load is also calculated.

## **Total power capacity (GTCC) [- without extraction]**

The model calculates the total power capacity without extraction for the gas turbine - combined cycle (GTCC) power system, by adding the gas turbine power capacity (GT) to the steam turbine power capacity (ST) without extraction.

The percentage of the total power capacity (GTCC) without extraction over the total power system peak load is also calculated.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## **Return temperature**

The user enters the return temperature (or feedwater temperature) for the steam turbine, which is the temperature of the condensed steam at the back pressure and extraction port.

The return temperature is typically around 110°C.

## Heating capacity - without extraction

The model calculates the heating capacity without extraction based on the steam flow, pressure and temperature at the back pressure port and return temperature.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## Heating capacity [- with extraction]

The model calculates the heating capacity with extraction (if an extraction port is included) based on the steam flow, maximum extraction, pressure and temperature at the extraction port, pressure and temperature at the back pressure port and return temperature.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## Steam turbine

Steam turbines produce electricity for the power load using a generator. Heat can be recovered from the extraction port and back pressure port for the heating load. Refer to the [Steam Turbine Schematic](#) for more information.

## Steam flow

The user enters the steam flow available at the inlet of the steam turbine. Typical values for steam flow range from 1,000 kg/h (150 kW) to 2,500,000 kg/h (1,000 MW).

## Operating pressure

The user enters the operating pressure of the steam turbine. Refer to the [Typical Steam Turbine Pressures and Temperatures](#) table for information.

## Saturation temperature

The model calculates the steam saturation temperature. The saturation temperature is the boiling point at the selected steam (operating) pressure.

## **Superheated temperature**

The user enters the superheated temperature of the steam. If superheated steam is not required, the user enters the saturation temperature calculated by the model.

Superheated steam is defined as steam heated to a temperature higher than the saturation temperature while maintaining the saturation pressure. It cannot exist in contact with water, nor contain water, and resembles a perfect gas. Superheated steam might be called surcharged steam, anhydrous steam or steam gas. It increases the steam turbine efficiency. Superheating of the steam also means that smaller size pipes can be used for the steam distribution system.

## **Enthalpy**

The model calculates the enthalpy of the steam at the input of the steam turbine. Enthalpy is a general measure of the heat content of a substance.

## **Entropy**

The model calculates the entropy of the steam at the input of the steam turbine. Entropy is a general measure of the thermodynamic potential of a system.

## **Extraction port**

The user indicates by selecting from the drop-down list whether or not an extraction port is included.

Extraction ports are used to provide heat to a heating load at a higher grade than available from the back pressure port.

## **Maximum extraction**

The user enters the maximum extraction as a percentage of the steam flow. The maximum allowable steam extraction varies depending on the equipment manufacturer and model.

## **Extraction**

The model calculates the amount of steam that can be extracted based on the maximum extraction and the steam flow.

## **Extraction pressure**

The user enters the steam turbine extraction pressure. The higher the extraction pressure is, the higher the heating capacity is at the extraction port and the lower the power capacity is, and vice-versa.

## **Temperature**

The model calculates the temperature of the extracted steam, which is the saturation temperature at the extraction pressure.

## **Mixture quality**

The model calculates steam moisture mixture quality at the output of the extraction port. If the mixture quality is below 1.0 the steam contains water (i.e. the steam is wet).

Typically, a steam turbine requires a minimum mixture quality in the range of 0.90 to 0.95. If the mixture quality is too low, there could be erosion of the steam turbine blades due to the collision of the water droplets and the turbine blades, thus increasing the cost of maintenance of the power system. Increasing the extraction pressure increases the mixture quality. If the extraction pressure cannot be increased, more than one steam turbine has to be used in conjunction with a reheater or a moisture separator. This will help reduce ongoing maintenance costs, but will increase the initial cost of equipment.

## **Enthalpy**

The model calculates the enthalpy of the steam at the output of the extraction port. Enthalpy is a general measure of the heat content of a substance.

## **Theoretical steam rate (TSR)**

The model calculates the theoretical steam rate (TSR) of the extracted steam, which represents the theoretical amount of steam necessary to produce 1 kWh of power.

## **Back pressure**

The user enters the steam turbine back pressure or exhaust pressure. The higher the back pressure is, the higher the heating capacity is at the back pressure port and the lower the power capacity is, and vice-versa.

## **Temperature**

The model calculates the temperature of the steam at the back pressure port, which is the saturation temperature at the back pressure.

## Mixture quality

The model calculates steam moisture mixture quality at the output of the back pressure port. If the mixture quality is below 1.0 the steam contains water (i.e. the steam is wet).

Typically, a steam turbine requires a minimum mixture quality in the range of 0.90 to 0.95. If the mixture quality is too low, there could be erosion of the steam turbine blades due to the collision of the water droplets and the turbine blades, thus increasing the cost of maintenance of the power system. Increasing the back pressure increases the mixture quality. If the back pressure cannot be increased, more than one steam turbine has to be used in conjunction with a reheater or a moisture separator. This will help reduce ongoing maintenance costs, but will increase the initial cost of equipment.

## Enthalpy

The model calculates the enthalpy of the steam at the output of the back pressure port. Enthalpy is a general measure of the heat content of a substance.

## Theoretical steam rate (TSR)

The model calculates the theoretical steam rate (TSR) of the back pressure steam, which represents the theoretical amount of steam necessary to produce 1 kWh of power.

## Steam turbine (ST) efficiency

The user enters the steam turbine (ST) efficiency. This value includes the losses in the steam turbine for auxiliary power and system losses.

Typical values for steam turbine efficiency range from 70 to 80%. Large steam turbines typically have higher efficiencies than small steam turbines. The turbine efficiency varies depending on the back pressure and the difference between the superheated and saturated temperature.

See one of the following figures:

[Typical Steam Turbine Efficiency](#)

[Steam Turbine Efficiency Correction Factor - Back Pressure](#)

[Steam Turbine Efficiency Correction Factor - Initial Superheat](#)

## Actual steam rate (ASR)

The model calculates the actual steam rate (ASR) for the steam turbine based on the steam flow, maximum extraction, turbine efficiency and the theoretical steam rates at the extraction port and back pressure port. This value is the actual amount of steam necessary to produce 1 kWh of power.

## Summary

This section summarises the power and heating capacities, with and without extraction. It also provides the electricity delivered to the load and exported to the grid depending on the operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

### Power capacity - with extraction

The model calculates the power capacity of the steam turbine with extraction.

The percentage of the power capacity with extraction over the proposed case power system peak load is also calculated.

### Power capacity [- without extraction]

The model calculates the power capacity of the steam turbine without extraction.

The percentage of the power capacity without extraction over the proposed case power system peak load is also calculated.

### Minimum capacity

The user enters the minimum power capacity that the power equipment can operate at, as a percentage of the "Power capacity" entered above. This value is compared with the monthly "Power net average load" for the proposed case system, as calculated in the *Load & Network* worksheet. If the minimum capacity exceeds the power net average load for any months, the user should adjust this value until the minimum capacity is always maintained. One way to do this is to have several smaller units, with the same total power capacity combined, running in parallel.

Typical minimum capacity for steam turbines is 40%.

### Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

### Model and capacity

The user enters the name of the equipment model for reference purposes only. The user can also enter the equipment power capacity for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## **Seasonal efficiency**

The user enters the seasonal efficiency of the steam boiler. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. In other words, the "steady-state efficiency" is for full load conditions while the "seasonal efficiency" takes into consideration the lower efficiency part load conditions that occur during the year. Typical values for seasonal efficiency for steam turbine boilers range from 75 to 85% (based on HHV natural gas fuel).

## **Return temperature**

The user enters the return temperature (or feedwater temperature) for the steam turbine, which is the temperature of the condensed steam at the back pressure and extraction port.

The return temperature is typically around 110°C.

## **Fuel required**

The model calculates the fuel required per hour based on the return temperature, the steam flow, the superheated temperature and the seasonal efficiency.

## **Heating capacity - without extraction**

The model calculates the heating capacity without extraction based on the steam flow, pressure and temperature at the back pressure port and return temperature.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the

heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## **Heating capacity [- with extraction]**

The model calculates the heating capacity with extraction (if an extraction port is included) based on the steam flow, maximum extraction, pressure and temperature at the extraction port, pressure and temperature at the back pressure port and return temperature.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## **Geothermal system**

Geothermal systems produce electricity for the power load using the natural heat of the earth. The model assumes that there is no waste heat recovered for CHP applications.

## **Steam flow**

The user enters the steam flow available at the inlet of the steam turbine. Typical values for steam flow range from 1,000 kg/h (150 kW) to 2,500,000 kg/h (1,000 MW).

## **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Model and capacity**

The user enters the name of the equipment model for reference purposes only. The user can also enter the equipment power capacity for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Operating pressure**

The user enters the operating pressure of the steam turbine. Refer to the [Typical Steam Turbine Pressures and Temperature](#) table for information.

## Saturation temperature

The model calculates the steam saturation temperature. The saturation temperature is the boiling point at the selected steam (operating) pressure.

## Steam temperature

The user enters the steam temperature, which represents the temperature at which the steam is extracted from the earth.

## Back pressure

The user enters the steam turbine back pressure or exhaust pressure.

## Steam turbine (ST) efficiency

The user enters the steam turbine (ST) efficiency. This value includes the losses in the steam turbine for auxiliary power and system losses.

Typical values for steam turbine efficiency range from 70 to 80%. Large steam turbines typically have higher efficiencies than small steam turbines.

See one of the following figures:

[Typical Steam Turbine Efficiency](#)

[Steam Turbine Efficiency Correction Factor - Back Pressure](#)

[Steam Turbine Efficiency Correction Factor - Initial Superheat](#)

## Actual steam rate (ASR)

The model calculates the actual steam rate (ASR) for the geothermal system based on the steam flow, steam temperature, back pressure and turbine efficiency. This value represents the actual amount of steam necessary to produce 1 kWh of power.

## Minimum capacity

The user enters the minimum power capacity that the power equipment can operate at, as a percentage of the "Power capacity" entered above. This value is compared with the monthly "Power net average load" for the proposed case system, as calculated in the *Load & Network* worksheet. If the minimum capacity exceeds the power net average load for any months, the user should adjust this value until the minimum capacity is always maintained. One way to do this is to have several smaller units, with the same total power capacity combined, running in parallel.

Typical minimum capacity for steam turbines is 40%.

## **Power capacity**

The model calculates the power capacity.

The percentage of the power capacity over the proposed case power system peak load is also calculated.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## **Fuel cell**

Fuel cells produce electricity for the power load using an electrochemical process. Heat can be recovered from the chemical exothermic reaction. Refer to the Fuel Cell Schematic and Fuel Cell Characteristics table for more information.

## **Power capacity**

The user enters the power capacity. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## **Minimum capacity**

The user enters the minimum power capacity that the power equipment can operate at, as a percentage of the "Power capacity" entered above. This value is compared with the monthly "Power net average load" for the proposed case system, as calculated in the *Load & Network* worksheet. If the minimum capacity exceeds the power net average load

for any months, the user should adjust this value until the minimum capacity is always maintained. One way to do this is to have several smaller units, with the same total power capacity combined, running in parallel.

Typical minimum capacity for fuel cells is 25% for power capacity over 10 kW and 35% for power capacity less than 10 kW.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Model**

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Heat rate**

The user enters the heat rate of the power system. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity. This value is another way of entering the electricity generation efficiency and is common practice in industry.

The following figures provide average heat rates at International Standards Organization (ISO) standard conditions of 15°C (59°F), 1 atmosphere (101.3 kPa) and 60% relative humidity, typically used by manufacturers. The heat rates are typically quoted in lower heating value. The figures show the heat rates based on natural gas for higher heating value (HHV) and lower heating value (LHV). The heat rate normally varies over the

operating range of the equipment and this should be considered if the equipment is not operated at maximum output for most of the year.

See one of the following figures:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation Fuel Cell Characteristics](#)

## Heat recovery efficiency

The user enters the heat recovery efficiency of the heat recovery system. If the power equipment temperature is too low, only part of the heat produced can be recovered.

Typical values for fuel cell heat recovery efficiency range from 0 to 30%.

See one of the following figures:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation Fuel Cell Characteristics](#)

## Fuel required

The model calculates the fuel required per hour based on the power capacity and heat rate.

## Heating capacity

The model calculates the heating capacity of the power equipment based on the power capacity, the heat rate and the heat recovery efficiency.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## Wind turbine

Wind turbines produce electricity for the power load using the kinetic energy from the wind. The model assumes that there is no waste heat recovered for CHP applications.

## Power capacity

The user enters the power capacity. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Model**

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Capacity factor**

The user enters the capacity factor, which represents the ratio of the average power produced by the wind plant over a year to its rated power capacity. Typical values for wind plant capacity factor range from 20 to 40%. The lower end of the range is representative of older technologies installed in average wind regimes while the higher end of the range represents the latest wind turbines installed in good wind regimes.

The user can refer to the RETScreen International Wind Energy Project Model to calculate this value.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid based on the Operating strategy elected in the "Operating strategy" section at the bottom of this worksheet.

## Hydro turbine

Hydro turbines produce electricity for the power load using the potential and kinetic energy from the falling/flowing water. The model assumes that there is no waste heat recovered for CHP applications.

## Power capacity

The user enters the power capacity. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Capacity factor

The user enters the capacity factor, which represents the ratio of the average power produced by the hydro plant over a year to its rated power capacity. Typical values for hydro plant capacity factor range from 40 to 95%.

The user can refer to the RETScreen International Small Hydro Project Model to calculate this value.

## Electricity delivered to load

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## Electricity exported to grid

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## Photovoltaic module

Photovoltaic (PV) modules produce electricity for the power load using the photons from the sun. The model assumes that there is no waste heat recovered for CHP applications.

## Power capacity

The user enters the power capacity. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Manufacturer

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Model

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## Capacity factor

The user enters the capacity factor, which represents the ratio of the average power produced by the photovoltaic system over a year to its rated power capacity. Typical values for photovoltaic system capacity factor range from 15 to 20%.

The user can refer to the RETScreen International Photovoltaic Project Model (version 3.0 or higher) to calculate this value.

## Electricity delivered to load

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## Electricity exported to grid

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## Other

In this section, the user enters information about other types of power systems not listed in the "Type" drop-down list. The "Other" option can be used to evaluate new power generation technologies.

## Description

The user enters the description of the power system for reference purposes only.

## Power capacity

The user enters the power capacity. The "System design graph" displayed in the *Energy Model* worksheet can be used as a guide.

The percentage of the power capacity over the proposed case power system peak load is calculated.

The user can consult the RETScreen Online Product Database for more information.

## Minimum capacity

The user enters the minimum power capacity that the power equipment can operate at, as a percentage of the "Power capacity" entered above. This value is compared with the monthly "Power net average load" for the proposed case system, as calculated in the *Load & Network* worksheet. If the minimum capacity exceeds the power net average load for any months, the user should adjust this value until the minimum capacity is always maintained. One way to do this is to have several smaller units, with the same total power capacity combined, running in parallel.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

The percentage of the electricity delivered to the load over the proposed case power system energy demand is also calculated.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid based on the Operating strategy selected in the "Operating strategy" section at the bottom of this worksheet.

## **Manufacturer**

The user enters the name of the equipment manufacturer for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Model**

The user enters the name of the equipment model for reference purposes only.

The user can consult the RETScreen Online Product Database for more information.

## **Heat rate**

The user enters the heat rate of the power system. The heat rate is the amount of energy input (in kJ or Btu) from the fuel required to produce 1 kWh of electricity. This value is another way of entering the electricity generation efficiency and is common practice in industry.

The heat rates are typically quoted in lower heating value. The heat rate normally varies over the operating range of the equipment and this should be considered if the equipment is not operated at maximum output for most of the year.

See the following figure:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation](#)

## Heat recovery efficiency

The user enters the heat recovery efficiency of the heat recovery system. If the power equipment temperature is too low, only part of the heat produced can be recovered. See the following figure:

[CHP Plant Heat Rate & Heat Recovery Efficiency Calculation](#)

## Fuel required

The model calculates the fuel required per hour based on the power capacity and heat rate.

## Heating capacity

The model calculates the heating capacity of the power equipment based on the power capacity, the heat rate and the heat recovery efficiency.

The heating capacity is the useful heat produced by the power equipment that can be recovered for the heating load. If the proposed project does not include heating or if the heating load is lower than the heating capacity, this heat has to be removed (i.e. the power equipment has to be cooled down).

## Operating strategy

The operating strategy section is used to help determine the optimal operating strategy for the selected power system. Note that this method is only an indicator of the profitability of the selected system.

The values calculated for the selected operating strategy in the *Equipment Selection* worksheet are displayed in bold and are copied automatically to the *Energy Model* worksheet.

## Fuel rate - base case heating system

The model calculates the fuel rate (price per MWh of fuel) for the base case heating system based on values entered in the *Load & Network* worksheet.

## Electricity rate - base case

The model calculates the electricity rate for the base case system based on values entered in the *Load & Network* worksheet.

## **Fuel rate - proposed case power system**

The model calculates the fuel rate (price per unit fuel) for the proposed case power system (either base load or intermediate load) based on the fuel rate entered in the fuel selection method section above.

## **Electricity export rate**

The user enters the electricity export rate, which is the rate paid by the electric utility or another customer. If there is no electricity exported to the grid then the user does not have to enter this value, or can simply enter a value of 0.

## **Electricity rate - proposed case**

The user enters the electricity rate for the proposed case system, which represents the rate paid for electricity delivered by the utility after the implementation of the proposed project. The electricity rate might increase after the implementation of the proposed project since utilities will often give lower rates to large users who have higher electricity demand.

## **Electricity delivered to load**

The model calculates the electricity delivered to the load for the different operating strategies.

## **Electricity exported to grid**

The model calculates the electricity exported to the grid (or to another customer) for the different operating strategies.

## **Remaining electricity required**

The model calculates the remaining electricity required for the different operating strategies. This value represents the electricity that has to be provided by the peak load power system (which can include grid electricity), as defined in the *Energy Model* worksheet.

## **Heat recovered**

The model calculates the heat recovered from the power system for the heating load for the different operating strategies.

## Remaining heat required

The model calculates the remaining heat required for the different operating strategies. This value represents the heat that has to be provided by the intermediate load (#2) and/or the peak load heating systems, as defined in the *Energy Model* worksheet.

## Power system fuel

The model calculates the power system fuel consumed for the different operating strategies.

## Operating profit (loss)

The model calculates the operating profit (loss) for the different operating strategies. This value represents the operating profit or loss to operate the selected power system based on the operating strategy selected. This calculation does not include costs related to initial costs, operation and maintenance, financing, etc.

## Efficiency

The model calculates the efficiency (%) for the different operating strategies, which represents the ratio of useful energy (electricity delivered to load, electricity exported to grid and heat recovered) to the energy input (power system fuel). The user can also select the efficiency in kJ/kWh units from the drop-down list. In this case, the efficiency is expressed as the amount of energy input (in kJ) from the fuel required to produce 1 kWh of useful energy.

See the following figure:

[Efficiency Calculation](#)

## Select base load power system

When there is a base and an intermediate load power system, the user selects the power system that will act as the base load system, from the drop-down list. The model then recalculates the values in the "Base load power system" and "Intermediate load power system" sections and operating strategy table.

See the following figure:

[Power System Load Definition - Base, Intermediate & Peak Load](#)

## Select operating strategy

The user selects the operating strategy from the drop-down list. For "Full power capacity output," the model assumes that the system is operating at full capacity 100% of the time. For "Power load following," the model assumes that the system is operating at a capacity to match the power load. For "Heating load following," the model assumes that the system is operating at a capacity to match the heating load.

The values calculated for the selected operating strategy in the *Equipment Selection* worksheet are displayed in bold and are copied automatically to the *Energy Model* worksheet.

See one of the following figures:

[Full Power Capacity Output](#)

[Power Load Following](#)

[Heating Load Following](#)

## Cost Analysis<sup>1</sup>

As part of the RETScreen Clean Energy Project Analysis Software, the *Cost Analysis* worksheet is used to help the user estimate costs (and credits) associated with the proposed case project. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

The most cost effective installations of combined cooling, heating and/or power (CHP) systems normally occur in new construction. The second most cost effective installation is likely for retrofit situations when there are plans to either repair or upgrade an existing system. However, it is certainly possible that high cooling, heating and/or electricity costs, or financial incentives could make the CHP system financially attractive, even in retrofit situations that do not meet the above criteria. Many times the availability of a low cost fuel will make the CHP project financially attractive.

While preparing the cost analysis for the proposed case CHP project, it is important to consider that some items should be "credited" for material and labour costs that would have been spent on a "conventional" or base case system had the CHP project not been considered. The user determines which initial cost items that should be credited. It is possible that engineering and design and other development costs could also be credited as some of the time required for these items would have to be incurred for the base case system. A "Custom" input cell is provided to allow project decision-makers to keep track of these items when preparing the project cost analysis. These "credits" can have a significant impact on the financial viability of the proposed case system.

## Settings

### Pre-feasibility or Feasibility analysis

The user selects the type of analysis by clicking on the appropriate radio button. For a "Pre-feasibility analysis," less detailed and lower accuracy information is typically required while for a "Feasibility analysis," more detailed and higher accuracy information is usually required.

To put this in context, when funding and financing organisations are presented with a request to fund an energy project, some of the first questions they will likely ask are "how accurate is the estimate, what are the possibilities for cost over-runs and how does it compare financially with other options?" These are very difficult to answer with any degree of confidence, since whoever prepared the estimate would have been faced with

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<sup>1</sup> A reminder to the user that the typical values for cost items mentioned in the manual are for a 2005 baseline year in Canadian dollars. Some of this data may be time sensitive so the user should verify current values where appropriate. (The approximate exchange rate from Canadian dollars to United States dollars was 1 CAD = 0.81 USD and to the Euro was 1 CAD = 0.62 EUR as of January 1, 2005).

two conflicting requirements:

- Keep the project development costs low in case funding cannot be secured, or in case the project proves to be uneconomic when compared with other energy options.
- Spend additional money and time on engineering to more clearly delineate potential project costs and to more precisely estimate the amount of energy produced or energy saved.

To overcome, to some extent, such conflicts, the usual procedure is to advance the project through the following four stages:

- Pre-feasibility analysis
- Feasibility analysis
- Development (including financing) and engineering
- Construction and commissioning

Each stage could represent an increase of a magnitude or so in expenditure and a halving of the uncertainty in the project cost-estimate. This process is illustrated, for hydro projects, in the [Accuracy of Project Cost Estimates](#) figure [Gordon, 1989].

At the completion of each step, a "go or no go" decision is usually made by the project proponent as to whether to proceed to the next step of the development process. High quality, but low-cost, pre-feasibility and feasibility studies are critical to helping the project proponent "screen out" projects that do not make financial sense, as well as to help focus development and engineering efforts prior to construction. The RETScreen Clean Energy Project Analysis Software can be used to prepare both the initial pre-feasibility analysis and the more detailed feasibility analysis.

## **Cost reference or Second currency**

The user selects the type of reference that will be used as a guide to help estimate the costs for the proposed case project by clicking on the appropriate radio button. Note that this selection is for reference purposes only, and does not affect the calculations made in this or other worksheets.

If the user selects "Cost reference," the user can choose the cost reference from the drop-down list that appears in the next column. This feature allows the user to change the information in the "Quantity range" and "Unit cost range" columns, thus allowing the user to create a custom cost reference database. If the user selects "Second currency," two additional input cells appear in the next column: "Second currency" and "Rate: 1st currency/2nd currency." In addition, the "Quantity range" and "Unit cost

range" columns change to "% Foreign" and "Foreign amount," respectively. This option allows the user to assign a portion of a project cost item in a second currency, to account for those costs that must be paid for in a currency other than the currency in which the project costs are reported.

## **Cost reference**

The user selects the cost reference from the drop-down list.

If the user selects "Canada - 2005," the range of values reported in the "Quantity range" and "Unit cost range" columns are for a 2005 baseline year, for projects in Canada and in Canadian dollars.

If the user selects "None," the information presented in the "Quantity range" and "Unit cost range" columns hides. The user might choose this option, for example, to minimise the amount of information printed in the final report.

If the user selects "Custom 1" (or any of the other 5 selections), the user may manually enter quantity and cost information that is specific to the region in which the project is located and/or for a different cost base year. This selection thus allows the user to customise the information in the "Quantity range" and "Unit cost range" columns. The user can also overwrite "Custom 1" to enter a specific name (e.g. Japan - 2005) for a new set of unit cost and quantity ranges in the cell next to the drop-down list. The user may also evaluate a single project using different quantity and cost ranges; selecting a new range reference ("Custom 1" to "Custom 5") enables the user to keep track of different cost scenarios. Hence the user may retain a record of up to 5 different quantities and cost ranges that can be used in future RETScreen analyses and thus create a localised cost reference database.

## **Second currency**

The user selects the second currency; this is the currency in which a portion of a project cost item will be paid for in the second currency specified by the user. This second unit of currency is displayed in the "Foreign amount" column.

If the user selects "\$," the unit of currency shown in the "Foreign amount" column is "\$."

Selecting "User-defined" allows the user to specify the currency manually by entering a name or symbol in the additional input cell that appears just below the Second currency switch cell. The currency may be expressed using a maximum of three characters (\$US, £, ¥, etc.). To facilitate the presentation of monetary data, this selection may also be used to reduce the monetary data by a factor (e.g. \$ reduced by a factor of a thousand, hence k\$ 1,000 instead of \$ 1,000,000).

If "None" is selected, no unit of currency is shown in the "Foreign amount" column. The user may also select a country to obtain the International Standard Organisation

(ISO) three-letter country currency code. For example, if Afghanistan is selected from the Second currency switch drop-down list, the unit of currency shown in the "Foreign amount" column is "AFA." The first two letters of the country currency code refer to the name of the country (AF for Afghanistan), and the third letter to the name of the currency (A for Afghani).

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings of the sheet. The user can then increase the zoom to see those symbols correctly. Usually, symbols will be fully visible on printing even if not fully appearing on the screen display.

## **Rate: 1st currency/2nd currency**

The user enters the exchange rate between the currency selected in "Currency" (at the top of the *Energy Model* worksheet) and the currency selected in "Second currency" (selected at the top right of the *Cost Analysis* worksheet). The exchange rate is used to calculate the values in the "Foreign amount" column.

For example, the user selects the Afghanistan currency (AFA) as the currency in which the monetary data of the project is reported (i.e. selection made in "Currency" input cell on *Energy Model* worksheet) - this is the 1st currency. The user then selects United States currency (USD) from the "Second currency" input cell on the *Cost Analysis* worksheet - this is the 2nd currency. The user then enters the exchange rate in the "Rate: AFA/USD" input cell i.e. the amount of AFA needed to purchase 1 USD. Using this feature the user can then specify what portion (in the "% Foreign" column) of a project cost item's costs will be paid for in USD.

## **Symbol**

The user enters the currency manually when selecting "User-defined" as the Second currency. The currency may be expressed using a maximum of three characters (\$US, £, ¥, etc.). To facilitate the presentation of monetary data, this selection may also be used to reduce the monetary data by a factor (e.g. \$ reduced by a factor of a thousand, hence k\$ 1,000 instead of \$ 1,000,000).

## **% Foreign**

The user enters the percentage of an item's costs that will be paid for in the second currency. The second currency is selected by the user in the "Second currency" cell.

## **Foreign amount**

The model calculates (for reference purposes only) the amount of an item's costs that will be paid for in the second currency. This value is based on the exchange rate and the

percentage of an item's cost that will be paid for in the second currency, as specified by the user.

## **Initial costs (credits)**

The initial costs associated with the implementation of the project are detailed below. The major categories include costs for preparing a feasibility study, performing the project development functions, completing the necessary engineering, purchasing and installing the energy (power, heating and/or cooling) equipment, construction of the balance of system and costs for any other miscellaneous items.

## **Feasibility study**

Once a potential cost-effective proposed case project has been identified through the RETScreen pre-feasibility analysis process, a more detailed feasibility analysis study is often required. This is particularly the case for large projects. Feasibility studies typically include such items as a site investigation, a resource assessment, an environmental assessment, a preliminary project design, a detailed cost estimate, a GHG baseline study and a monitoring plan and a final report. Feasibility study project management and travel costs are also normally incurred. These costs are detailed below.

Feasibility studies typically cost about 5% of the total project cost. For small projects, the cost of the more detailed feasibility study, relative to the cost of the proposed case project might not be justified. In this case the project proponent might choose to go directly to the engineering stage (combining some steps from the feasibility and development stages).

**Note:** The RETScreen Clean Energy Project Analysis Software can also be used to help prepare the Feasibility Study as well.

## **Site investigation**

A site investigation is normally required for CHP projects, especially with ones that include district heating and/or cooling. The site visit involves a brief survey of all major buildings under consideration. In small district energy systems (less than 1,000 kW), the user would likely look for clusters of oil or electricity heated and/or cooled buildings with a distance not exceeding 500 metres. Typical major buildings heated and/or cooled with oil or electricity include schools, hospital/health clinics, churches, senior's apartments, service garages and community offices. For larger systems, customers can be many kilometres away from the central plant.

The identification of the most promising buildings or clusters is generally followed by a detailed site and building or clusters analysis. The analysis includes: measurement of the distance between the various buildings; determination of the fuel consumption for each building; measurement of the building areas and insulation levels; study and

documentation of the existing building cooling, heating and/or power systems and locations, including notes on any attributes or problems for conversion to a CHP plant; selection of a possible site for the CHP plant; preparation of a layout of approach roads and a plant yard for outdoor storage of fuel resource. Site visit time includes the time required to arrange meetings, survey the site, obtain the necessary information and any travel time (but not travel expenses - see "Travel & accommodation".) Preliminary data gathering, which should build upon the initial pre-feasibility analysis data, should be conducted prior to, and during, the site visit.

The time required for a site survey, detailed building and site analysis varies according to the number of buildings involved and the complexity of the existing system. Obtaining fuel consumption data can sometimes add to the time required. The cost of a site visit is influenced by the planned duration and travel time to and from the site. The time required to gather the data prior to the site visit and during the site visit typically falls between 1 and 5 person-days. The average per daily fees of the personnel making the visit(s) will range from \$300 to \$1,000, depending on their experience.

## **Resource assessment**

The user must carefully consider the energy resource to ensure that there is a sufficient local resource to meet the projects energy requirements in an environmentally appropriate and financially viable manner. For example, biomass projects are not considered "renewable energy" unless the biomass is harvested in a sustainable manner.

The time required to carry out a brief resource assessment is typically 1 to 5 person-days, depending on the extent of the field survey and the amount of data collection and analysis involved. Typical rates range from \$300 to \$1,000. This assessment can usually be combined with the site investigation. The costs of charter flights might need to be added if an aerial survey is required (add to "Travel & accommodation").

## **Environmental assessment**

An environmental assessment is an essential part of the feasibility study work. While CHP projects can usually be developed in an environmentally acceptable manner (projects can often be designed to enhance environmental conditions), work is required to study the potential environmental impacts of any proposed case project. At the feasibility study stage, the objective of the environmental assessment is to determine if there is any major environmental impact that could prevent the implementation of a project. Noise and visual impacts as well as potential impact on the flora and fauna must be addressed.

The time required to consult with the different stakeholders, gather and process relevant data and possibly visit the site and local communities typically falls between 1 and 8 person-days. The average per daily fees of the personnel making the assessment will range from \$300 to \$1,000, depending on their experience.

## **Preliminary design**

A preliminary design is required in order to determine the optimum plant capacity, the size and layout of the structures and equipment, and the estimated construction quantities necessary for the detailed cost estimate. As with site investigations, the scope of this task is often reduced for small projects in order to reduce costs. Consequently, additional contingencies should be allowed to account for the resulting additional risk of cost overruns during construction.

The cost of the preliminary design is calculated based on an estimate of the time required by an expert to complete the necessary work. The cost of professional services required to complete a preliminary design will range between \$300 and \$1,000 per person-day. As with site investigations, the time required to complete the preliminary design will depend, to a large extent on the size of the project and corresponding acceptable level of risk. The number of person-days required can range between 2 and 20.

## **Detailed cost estimate**

The detailed cost estimate for the proposed case project is based on the results of the preliminary design and other investigations carried out during the feasibility study. The cost of preparing the detailed cost estimate is calculated based on an estimate of the time required by an expert to complete the necessary work. Engineering services for completing a CHP project detailed cost estimate will range between \$300 and \$1,000 per person-day. The number of person-days required to complete the cost estimate will range between 3 and 100 depending on the size of the project and acceptable level of risk.

## **GHG baseline study & monitoring plan**

In order for the greenhouse gas (GHG) emissions reductions generated from a project to be recognized and sold on domestic or international carbon markets, several project documents need to be developed, the key elements of which are a GHG baseline study and a Monitoring Plan (MP). A GHG baseline study identifies and justifies a credible project baseline based on the review of relevant information such as grid expansion plans, dispatch models, fuel use on the margin, current fuel consumption patterns and emissions factors. The GHG baseline study sets a project boundary and identifies all sources of GHG emissions that would have occurred under the baseline scenario, i.e. the scenario most likely to have occurred if the project were not implemented. A Monitoring Plan identifies the data that needs to be collected in order to monitor and verify the emissions reductions resulting from the project and describes a methodology for quantifying these reductions as measured against the project baseline.

An outside consultant or team is often called in to develop the baseline study and monitoring plan. However, as more project examples become available and standardised methodologies are accepted, these studies may be more easily carried out by project proponents. Costs will depend on the complexity of the baseline, the size of the project

and the availability of sectoral or regional baselines and standardised monitoring methodologies. Costs for developing baseline studies and monitoring plans for large projects have ranged from \$US 30,000- \$US 40,000 according to analysis by the Prototype Carbon Fund (PCF).

Requirements for Clean Development Mechanism (CDM) projects are generally more stringent than for Joint Implementation (JI) or other projects. For example, CDM projects must also be monitored for their contribution to sustainable development of the host country. The rules governing baselines and monitoring for CDM can be found at [UNFCCC's CDM Website](#). Note that for small-scale CDM projects (capacity of 15 MW, or energy savings of 15 GWh, or less), it might not be necessary to carry out a full baseline study as simplified baselines and monitoring methodologies are available.

**Note:** The optional *GHG Analysis* worksheet in RETScreen can be used to help prepare the baseline study.

## Report preparation

A summary report should be prepared. It will describe the feasibility study, its findings and recommendations. The written report will contain data summaries, charts, tables and illustrations that clearly describe the proposed project. This report should be in sufficient detail regarding costs, performance and risks to enable project investors and other decision makers to evaluate the merits of the project.

The cost of the report preparation is calculated based on an estimate of the time required by an expert to complete the necessary work. Preparing a feasibility study report will involve between 2 and 15 person-days at a rate of between \$300 and \$1,000 per person-day.

## Project management

The project management cost item should cover the estimated costs of managing all phases of the feasibility study for the project, including the time required for stakeholder consultations. Consultations with the stakeholders in a given project are called for in order to build support and collaboration toward the project, and to identify any opposition at the earliest stage of development.

The cost of the management of the feasibility study is calculated based on an estimate of the time required by an expert to complete the necessary work. It will involve between 2 and 8 person-days at a rate of between \$300 and \$1,000 per person-day. In addition, the time required to present the project to the stakeholders should not exceed an additional 3 person-days (travel time must also be added).

## Travel & accommodation

This cost item includes all travel related costs (excluding time) required to prepare all sections of the feasibility study by the various members of the feasibility study team. These expenses include such things as airfare, car rental, lodging and per diem rates for each trip required.

In the case of isolated areas, rates for air travel will vary markedly. Airfares are typically twice those for similar distances in populated areas. Since travel is a large component of the cost of doing work in isolated areas and the range of cost so variable, it is advised to contact a travel agent with experience in arranging such travel. Accommodation rates are typically twice the going rate for modest accommodation in populated areas. Typical rates for modest hotel rooms can range from \$180 to \$250 per day in the more isolated areas.

## Custom

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## Development

Once the proposed case project has been identified through the feasibility study to be desirable to implement, project development activities follow. For some projects, the feasibility study, development and engineering activities might proceed in parallel, depending on the risk and return acceptable to the project proponent.

For CHP projects with district heating and/or cooling, there are a number of possible project developers. Currently, a common approach is for the client to be the building owner with the developer being the local fuel and/or main equipment supplier who provides complete design/build services. General contractors may also be the developer, purchasing the fuel and/or cooling, heating and/or power systems on behalf of the building owner. It is also possible that an Energy Services Company (ESCO) or the local

community utility or public works department could be the project developer, where they purchase the fuel and/or CHP system and sell the energy to local building owners. Estimating the costs of the development phase depends on the particular development arrangement established. Project development activities typically includes cost for such items as contract negotiations, permits & approvals, site survey & land rights, GHG validation & registration, project financing, legal & accounting, project development management and travel costs. These costs are detailed below.

## **Contract negotiations**

If there is a decision to proceed with the project based on a positive result of the feasibility study, the project proponent will need to establish a fiscal operating arrangement and negotiate a contract with one or more appropriate project stakeholders.

For power projects, the Power Purchase Agreement (PPA) is one of the first required steps of the project development stage for non-utility generators. A PPA negotiation will be required if the project is to be owned privately, rather than by a utility, and will also involve legal and other professional advice (e.g. finance, accounting). The scope of the work involved in the PPA negotiation will depend on whether or not conditions for the sale of power already exist (e.g. utility policy to purchase private power).

The cost of contract negotiations for the proposed case project is calculated based on an estimate of the time required by experts to complete the necessary work. The number of person-days required can range between 0 and 30 person-days or more depending on the complexity of the contract. The cost of professional services required for the negotiation of a contract will range between \$300 and \$1,500 per person-day.

## **Permits & approvals**

A number of permits & approvals might be required for the construction of the project. These include environmental approvals (e.g. federal/national or state/provincial/regional), authorisations regarding the use of land (e.g. state/provincial/regional or local), air traffic (e.g. federal/national), building permits (e.g. state/provincial/regional or local), use of water resource (e.g. state/provincial/regional), use of navigable waters (e.g. federal/national) and operating agreements (e.g. state/provincial/regional or local). Other agencies include local building and electrical inspectors, boiler inspectors, fire safety inspectors, forestry (fuel supply) and an emissions regulating authority. For a large project, environmental approvals are likely to be the longest and most costly authorisations to obtain.

The cost of acquiring the necessary permits and approvals is calculated based on an estimate of the time required by an expert to complete the necessary work. For CHP projects it can involve between 0 and 400 person-days, depending on the scale, location and complexity of the project. Rates of between \$300 and \$1,000 per day are common.

The time required depends on the number of agencies involved and what is specifically required to meet their rules and regulations. The user can also add to the number of days, or unit costs, an amount to cover the actual permit itself. Permit fees are usually minor relative to the total project cost.

## Site survey & land rights

The requirement to survey the site will depend in large part on the status of the site ownership, zoning and site use planning, location, size and possible legal and insurance issues. Land rights are required for the land on which the proposed case project is located, including the service road, transmission and collection lines, substation and O&M building. Right-of-way might be granted for the access road, electric lines and the district heating and/or cooling network, if applicable. The land required for the project infrastructure might be leased or purchased.

Typically, the costs to survey one simple lot of 1 to 10 hectares are of the order of \$750. As an example, a 40 MW biomass fired CHP plant will typically require 2 to 5 hectares, whereas a single small packaged gas turbine less than 100 kW (micro-turbine) will likely require less than 20 m<sup>2</sup>. The cost may vary if travel and accommodation costs are billed by a surveyor. Depending upon the CHP project size a site survey can take approximately 0 to 5 days to complete at a daily rate of \$400 to \$1,000 per day. The user enters the total estimated cost of purchasing the required land that cannot be leased or used under a right-of-way agreement. The cost should include an allowance for legal fees. Note that the estimated cost of negotiating any land lease and rights-of-way agreements should be included under the "Permits & approvals" section described above.

## GHG validation & registration

Greenhouse gas (GHG) projects might need to be validated by an independent third party organisation to ensure that the project design documents, including the GHG baseline study and Monitoring Plan, meet the prescribed requirements. Validation includes the confirmation that the emission reductions claimed by the project developer are considered realistic. GHG projects must then be registered through an accredited organisation.

Validation is necessary for Clean Development Mechanism (CDM) projects and must be carried out by an operational entity that has been certified by the United Nations Framework Convention on Climate Change (UNFCCC). See [UNFCCC's CDM Website](#) for further details. For other projects, third party validation may provide investors with increased confidence that the estimated emissions reductions will be achieved.

The cost of validation will vary according to the size of the project. For the validation of CDM projects, a prescribed rate of \$US 400/day has been set for the staff of designated operational entities or \$US 1,200/day for a team of three. The Prototype Carbon Fund (PCF) estimates the cost of validation of large projects at \$US 30,000.

CDM projects will also require a registration fee to be paid to the UNFCCC for administration. Registration fees for CDM projects are scaled according to the size of the project as presented in the Registration Fees for CDM Projects table.

## **Project financing**

The time and effort required to arrange project financing will vary depending upon the project developer and client relationship. In most cases, where the client is the building owner and the developer is the product supplier, the project financing costs attributable to the project are minimal. The building owner will usually finance the project out of capital or O&M budgets and the product supplier will provide in-kind support as required to help arrange the client project financing. In the case of an ESCO, independent power producer or local utility developed project much more effort will likely be required to arrange financing, negotiate an energy services contract with the building owner, purchase power agreement with the utility or other customers and prepare legal documents.

The cost of financing will be comprised of the effort required by experts to make the arrangements, identify investors and solicit funds. Typical rates for such work are set at a percentage of the financed amount and may include a fixed commencement fee.

The cost of project financing is calculated based on an estimate of the services required to secure both debt and equity commitments. Acquiring the necessary project financing will involve between 3 and 100 person-days at a rate of between \$500 and \$1,500 per person-day depending on the complexity of the proposed financing structure. As a rule-of-thumb, the cost of acquiring the necessary project financing should be about 1.5% of the total project cost.

## **Legal & accounting**

Legal and accounting support will be required at different points throughout the development stages of the project. This cost item allows the user to account for legal and accounting services not included as part of other development cost items such as for establishing a company to develop the project, to prepare monthly and annual financial statements, for project accounting, etc. The requirement for legal support will depend on the arrangements for financing, ownership, insurance, assumption of liability and complexity of contracts and agreements.

The cost of legal and accounting support is calculated based on an estimate of the time required by experts to provide these services throughout the development of the project. Legal and accounting support will involve between 3 and 100 person-days at a rate of between \$300 and \$1,500 per person-day depending on the complexity and size of the project.

## Project management

The project management cost item should cover the estimated expenses of managing all phases of the development of the project (excluding construction supervision). Public relations are also included as part of the project management cost item. Public relations can be an important element for successful project implementation.

The elapsed time for the development of a CHP project can be up to 2 years or more. The project management time (not including the time to manage the feasibility study) will involve between 0.2 and 4 person-years at a rate of between \$150,000 and \$200,000 per person-year, depending on the scale of the project. A reasonable estimate for project management is 10% of the cost of the total development activities. However, the investment in public relations will depend on the level of local support deemed necessary to achieve a successful implementation of the project. For a large project involving many stakeholders, and requiring an extensive number of permits and approvals, additional public relations related project management costs of up to \$150,000 per year is not unusual.

## Travel & accommodation

A number of field visits and other trips will be required during the development phase (primarily for meetings). This cost item includes all travel related costs (excluding time) required to develop the project.

## Custom

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## Engineering

The engineering phase includes costs for the proposed case project site & building design, mechanical design, electrical design, civil design, tenders & contracting, and

construction supervision. These costs are detailed below.

If the project is awarded on a design/build basis, then all of these costs would be included in prices provided by the equipment supplier or contractor responsible for the project. If the project is awarded by tender based on specifications prepared by a consultant, then there will be engineering charges from the consultant overseeing the project and perhaps the equipment supplier.

## **Site & building design**

Site layout includes selecting the site for the CHP plant; selecting of the building or cluster of buildings to be heated and/or cooled by the district heating and/or cooling system; determining where approach roads should go for site access and determining the boundaries of the plant yard. For example, the buildings used to house small-commercial biomass heating equipment and to provide fuel storage are usually similar to a heated garage. The buildings must have a concrete floor and the walls of the fuel storage reserve must be strong enough to permit the use of a front-end loader. The building for a large CHP plant is similar to an industrial building.

Carrying out a site layout and building design involves typically 2 to 4 person-days for a small plant and up to 100 person-days for a large plant. Variables include site restrictions, type of delivery vehicles to be used and the turning space required and space needed to store and handle fuel. Rates of \$300 to \$1,000 per person-day are common.

## **Mechanical design**

The principal mechanical engineering tasks will be associated with design and planning of the assembly and installation of equipment. The cost of the mechanical engineering should be based on an estimate of the time required by experts to complete the necessary work. It can involve between 20 and 10,000 person-days at a rate of between \$300 and \$1,000.

As an example, a typical CHP plant producing in the 20 MW scale range will require approximately 2,000 person-days while a small heating plant might require a much lower effort of approximately 20 person-days.

## **Electrical design**

The principal electrical engineering tasks will be associated with design and planning of construction of the control and electrical protection systems and the electrical interconnection with the existing electrical grid. For instance, the interconnection study will address all safety aspects related to the addition of a new production source on the grid, as well as analyse the impact with respect to the quality of the power delivered. The level of effort will be influenced by the availability of appropriate design information from the equipment supplier and interconnection requirements from the utility.

The cost of the electrical engineering should be based on an estimate of the time required by experts to complete the necessary work. It can involve between 5 and 300 person-days at a rate of between \$300 and \$1,000, depending upon the scale and complexity of the project.

As an example, CHP plants in the 50 to 100 MW scale range will be at the high end of this range while a small system might require a much lower effort of approximately 5 to 15 person-days.

## **Civil design**

The principal civil engineering tasks will be associated with design and planning of construction of the buildings, foundations, access roads and other on ground systems. The level of effort will be influenced by the availability of approved design information from the suppliers and site specific information regarding access, soil conditions, surface drainage and other physical conditions.

The cost of the civil engineering should be based on an estimate of the time required by experts to complete the necessary work. It can involve between 5 and 300 person-days at a rate of between \$300 and \$1,000, depending upon the scale and complexity of the project.

As an example, CHP plants in the 30 MW scale range will be at the high end of this range while a small system might require a much lower effort of approximately 5 to 20 person-days.

## **Tenders & contracting**

Upon completion of the various engineering tasks, tender documents usually are prepared for the purpose of selecting contractors to undertake the work. Once tenders are released, the contracting process is required to both negotiate and establish contracts for the completion of the project.

The cost of the tendering and contracting process should be based on an estimate of the time required by professionals to complete the necessary work. It can involve between 5 and 300 person-days, depending on the complexity of the project at a rate of between \$300 and \$1,000.

As an example, CHP plants in the 30 MW range will be at the high end of this range while a small system may require a much lower effort of approximately 5 to 20 person-days.

## Construction supervision

The construction supervision cost item summarises the estimated costs associated with ensuring that the project is constructed as designed. Construction supervision is provided either by the consultant overseeing the project or by the equipment supplier, or the project manager. Construction supervision involves full time presence at the job site to inspect the installation.

Construction supervision will involve between 0 to 2 person-years at a rate of between \$150,000 and \$200,000 per person-year depending on the duration of the project construction schedule. For example, the installation of a packaged gas turbine in the 60 kW range (micro-turbine) should not require more than 0.02 person-year ( $\approx$  7 days) of supervision. Travel time to the site for construction supervision is in addition to the range given. Travels costs should be included in the "Development" section.

## Custom

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## Power system

The power system, as defined here, includes the base load, intermediate load, peak load and/or back-up power equipment, and the associated road construction, transmission line, substation and power related energy efficiency measures costs. The user can refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required. These costs are detailed below.

## Power equipment

The user enters the installed cost per unit capacity for the proposed case power equipment. The capacity (in kW) is copied automatically from the *Energy Model* worksheet to the *Cost Analysis* worksheet. This value includes both equipment and

installation costs. Typically, due to economies-of-scale, the larger the capacity, the lower the installed cost per unit capacity. The user can refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

See one of the following figures:

[Typical Installed Cost Range - Power Equipment](#)

[Reciprocating Engine Installed Cost Examples](#)

[Gas Turbine Installed Cost Examples \(<5MW\)](#)

[Gas Turbine Installed Cost Examples \(5 to 50MW\)](#)

[Gas Turbine Installed Cost Examples \(50 to 300MW\)](#)

[Steam Turbine Installed Cost Examples](#)

[Fuel Cell Installed Cost Examples](#)

## Road construction

An access road for construction and an on-going service road is normally required for a medium to large-scale power project. These requirements will depend on the site selection and the nature of the terrain. There might be seasonal limitations both for construction activity and for use of roads to transport equipment. At some project sites there might be no need for road construction even if the site selected is not on existing routes. The location of existing roads is a consideration during site selection.

Cost for road construction typically ranges from \$0 to \$80,000 per km, but can be as high as \$500,000 per km if river crossings are required. The length of the road required comprises the length of the access road to the site and the length of the service road on the site. The anticipated length of the required access and service roads can be determined by topographic maps.

## Transmission line

The transmission line cost is site specific and depends on the type, length, voltage and location of the line and the installed capacity of the power plant being developed. The [Estimated Transmission Line Costs](#) table provides an indication of the approximate costs involved, assuming reasonable access. These costs are representative of aerial lines and should be adjusted based on site conditions. Underground lines are normally used to connect the system within an urban area. Their cost can be 2 to 4 times higher than an equivalent aerial line.

The user enters the length of the transmission line and the cost per unit of length. In areas of permafrost, special soil conditions can increase the cost of line extension significantly. Advice from an expert specialising in local transmission line design or construction might be required in order to estimate this cost.

## Substation

The substation cost is site specific and depends mainly on the voltage and the installed capacity of the power plant being developed. Auxiliary electrical equipment might also include such items as dump loads and heaters, banks of capacitors, monitoring equipment and integrated or SCADA type control systems. The [Estimated Substation Costs](#) table provides an indication of the approximate costs involved, assuming reasonable access.

The user calculates the total cost based on the substations and other auxiliary electrical equipment. For smaller scale projects near to the electric distribution grid, substation costs will likely be lower than presented in the table.

## Energy efficiency measures

The user enters the total installed cost for any additional power related energy efficiency measures for the project. This value includes both equipment and installation costs.

As an example, in Canada, implementing power related energy efficiency measures to reduce the base case power system's annual peak load by 10 to 20% typically costs \$1/m<sup>2</sup> to \$10/m<sup>2</sup> depending on the measures implemented.

## Custom

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## Heating system

The heating system, as defined here, includes the base load, intermediate load, intermediate load #2, peak load and/or back-up heating equipment. It also includes the heat distribution system components such as distribution piping and trenching, and any building interconnection plumbing required. In addition, the cost for any heating system related energy efficiency measures is also included. The user may refer to the RETScreen

Online Product Database for supplier contact information in order to obtain prices or other information required. These costs are detailed below.

## Heating equipment

The user enters the installed cost per unit capacity for the proposed case heating equipment. The capacity (in kW or million Btu/h) is copied automatically from the *Energy Model* worksheet to the *Cost Analysis* worksheet. This value includes both equipment and installation costs. Typically, due to economies-of-scale, the larger the capacity, the lower the installed cost per unit capacity. The user can refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

See the following figure:

[Typical Installed Cost Range - Heating Equipment](#)

## Energy transfer station(s)

The number of buildings and cost of the energy transfer station(s) is copied automatically from the *Load & Network* worksheet.

## Main heating distribution line pipe

The total length and cost of the main system piping is copied automatically from the *Load & Network* worksheet.

## Secondary heating distribution line pipe

The total length and cost of the secondary distribution line pipe is copied automatically from the *Load & Network* worksheet.

## Energy efficiency measures

The user enters the total installed cost for any additional heating related energy efficiency measures for the project. This value includes both equipment and installation costs.

As an example, in Canada, implementing heating related energy efficiency measures to reduce the base case heating system's total peak heating load by 20 to 30% typically costs \$10/m<sup>2</sup> to \$35/m<sup>2</sup> depending on the measures implemented.

## Custom

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## Cooling system

The cooling system, as defined here, includes the base load, peak load and back-up cooling equipment. It also includes the cooling distribution system components such as distribution piping and trenching, and any building interconnection plumbing required. In addition, the cost for any cooling system related energy efficiency measures is also included. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required. These costs are detailed below.

## Cooling equipment

The user enters the installed cost per unit capacity for the proposed case cooling equipment. The capacity (in kW, million Btu/h or RT) is copied automatically from the *Energy Model* worksheet to the *Cost Analysis* worksheet. This value includes both equipment and installation costs. Typically, due to economies-of-scale, the larger the capacity, the lower the installed cost per unit capacity. The user can refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

See the following figure:

[Typical Installed Cost Range - Cooling Equipment](#)

## Energy transfer station(s)

The number of buildings and cost of the energy transfer station(s) is copied automatically from the *Load & Network* worksheet.

## Main cooling distribution line pipe

The total length and cost of the main system piping is copied automatically from the *Load & Network* worksheet.

## Secondary cooling distribution line pipe

The total length and cost of the secondary distribution line pipe is copied automatically from the *Load & Network* worksheet.

## Energy efficiency measures

The user enters the total installed cost for any additional cooling related energy efficiency measures for the project. This value includes both equipment and installation costs.

As an example, in Canada, implementing cooling related energy efficiency measures to reduce the base case cooling system's total peak cooling load by 10 to 20% typically costs \$5/m<sup>2</sup> to \$15/m<sup>2</sup> depending on the measures implemented.

## Custom

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category.

A cost item may be entered in the grey input cell by overwriting the word "Custom." The user then selects "cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may also be entered in the grey input cell. The user then selects "credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

## Balance of system & miscellaneous

The balance of system & miscellaneous costs for the proposed case project typically includes a number of items such as specific project costs (i.e. LFG collection system, fuel handling system or custom), building & yard construction, spare parts, transportation, training & commissioning, contingencies and interest during construction. These costs are detailed below.

## Specific project costs

The user selects the specific project costs to be entered from the drop-down list.

## LFG collection system

In this section, the user enters specific project costs related to the landfill gas (LFG) collection system. The user should also refer to the "Landfill gas" tool on the *Tools* worksheet.

**Note:** Much of the text on landfill gas is adapted from the *Handbook for the Preparation of Landfill Gas to Energy Projects in Latin America and the Caribbean*, prepared Conestoga-Rovers & Associates (Waterloo, Ontario, Canada) on behalf of The World Bank. Conestoga Rovers & Associates also helped CETC-Varenes develop the Landfill gas tool within RETScreen.

## LFG collection field

The user enters the cost for the landfill gas (LFG) collection field.

A network of vertical LFG extraction wells and/or horizontal LFG collection trenches are installed into the waste to collect the LFG. Vertical wells are typically installed in a landfill once filling operations have been completed. Horizontal LFG collection trenches are typically used to collect gas while the site is still active.

The costs to install vertical wells can vary dramatically as a function of local costs for materials such as aggregate, pipe and grout; contractor availability; available equipment types and capacities; and the specific characteristics of the well design. [The World Bank, 2004]

As an example, for 100 to 150 mm diameter wells, typical costs for vertical wells range from \$225/vertical metre to \$375/vertical metre for depths below 15 m and from \$300/vertical metre to \$525/vertical metre for depths between 15 and 30 m. For 900 mm diameter wells, typical costs are greater than \$750/vertical metre, and are not normally considered to be cost effective.

## LFG collection piping

The user enters the cost for the landfill gas (LFG) collection piping. This includes small diameter (minimum 100 mm), short laterals connecting the wells/trenches, subheaders which connect the laterals and headers connecting the subheaders to the extraction plant.

The relative costs of the piping systems to collect and transport the LFG to the facility can vary substantively based on site specific conditions and the applicable design basis.

The costs for small diameter above ground piping can be less than \$45/metre but larger diameter buried piping can cost up to, and more than, \$300/metre. The cost is highly influenced by factors such as the nature of the design (e.g., above or below grade), the need to remove and relocate any waste, the need to add fill or grade areas of the cap and perimeter areas, the extent and number of condensate removal traps, the cost of petroleum and associated products and the availability and costs for suitable construction contractors [The World Bank, 2004].

## **LFG condensate drop-out system**

The user enters the cost for the landfill gas (LFG) condensate drop-out system. LFG is extremely moist and therefore produces a lot of condensate within the LFG collection wells and piping. It is important that all the pipes are designed with minimum slopes so that condensate does not remain within the piping, but flows towards a nearby drain or sump. Improper drainage of the condensate can lead to blockages in the pipe, which can disable large parts of the LFG collection system limiting the amount of LFG that can be collected [The World Bank, 2004].

## **LFG blower system & miscellaneous**

The user enters the cost for the landfill gas (LFG) blower system and miscellaneous items. The blower system includes all components that are used to generate and apply the vacuum to collect the LFG and supply it for its subsequent end use, such as valves and controls as required for safe operation (e.g., a flame arrestor), condensate pumping or storage, LFG flow metering and recording and blowers or compressors to meet capacity requirements.

The costs of the blower systems are a function of many factors and can only be assigned based on the specific requirements for the overall system. As a rough estimate, the cost for a blower system for a flaring application can range from \$37 to \$75 per m<sup>3</sup>/hour of LFG. If the LFG will be used as a fuel in an energy project, the cost range for the blower system can increase by a factor from 2 to 5, or more, depending upon the fuel supply requirements [The World Bank, 2004].

## **LFG flare**

The user enters the cost for the landfill gas (LFG) flare. There are 2 basic flare designs; the enclosed drum flare and the waste gas flare that simply ignites the methane without any extensive combustion controls. This second type of flare is in common use in many jurisdictions, but it is not typically deemed acceptable if there is any intent to qualify for Certified Emissions Reductions (CERs). As a rough estimate, a waste gas flare capable of combusting 1,000 m<sup>3</sup>/hour of LFG would cost in the range of \$75,000 to \$150,000 depending upon the peripheral controls and safety features required. By comparison, an enclosed drum flare with a similar capacity will have a cost range of about twice that of the waste gas flare [The World Bank, 2004].

## Custom

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category.

A cost item may be entered in the grey input cell by overwriting the word "Custom." The user then selects "cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may also be entered in the grey input cell. The user then selects "credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

## Fuel handling system

In this section, the user enters specific costs related to the fuel handling system.

## Delivery equipment

The user enters the cost of the fuel delivery equipment. Delivery options depend on type of fuel. For solid fuel, it can include trucks, a weight scale, a truck unloading system, a front-end loader, etc. For gas and liquid fuels, it can include a transfer station, etc.

## Preparation equipment

The user enters the cost of the fuel preparation equipment. For solid fuel like biomass, it can include a chipper for oversized pieces, as well as sorting and screening equipment. For liquid fuels, it can include filters, heating equipment, etc. For gas fuels, it might include dryers, or cleaning equipment for the gas.

## Storage equipment

The user enters the cost of the fuel storage equipment. For gas and liquid fuels, it can include storage tanks. Solid fuels can be stored outdoors or indoors. The cost can include structures, with or without moving floors, cranes, etc. The storage bin can also have discharge and mixing systems.

## Distribution equipment

The user enters the cost of the fuel distribution equipment. For gas and liquid fuels, it can include pumps, compressors, pressure reducing systems, pipes, etc. For solid fuels, it includes different conveyer systems such as chains, augers, bucket elevators and blow systems. For solid fuels, it is also common to have smaller fuel storage close to the combustion equipment (surge or metering bins).

## Custom

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category.

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A credit item may also be entered in the grey input cell. The user then selects "credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

## Building & yard construction

The user enters the building & yard construction cost per unit area. The user should obtain an estimate from local building contractors as this item can represent a significant amount of the total project costs. Other uses for the building (e.g. workshop, lumber drying kiln, etc.) should also be considered. Existing buildings should be used if possible to help avoid this cost.

The length of approach roads and the area of the yard vary depending on the particular site, the volume of fuel that is to be stored in the yard and the delivery vehicles that are to be used. The roads and yards must permit vehicles to manoeuvre and back up without difficulty. Making them too small could cause a lot of problems.

The cost of approach roads and yard construction vary significantly, depending on the required road and yard area, the soil material and the proximity of gravel pits. In some cases, additional land might need to be purchased for the yard and building construction. If this is the case, add the land costs to the yard construction costs. If land is to be leased, include the lease cost under "Land lease" in the "Annual costs" section.

## Spare parts

Spare parts necessary for the proposed case project should be included in the project costs. The after purchase price will most often be significantly higher. The extent of the inventory required will depend on the reliability of the system, warranty, complexity of equipment at the site, transportation difficulty and availability of off-the-shelf components. The cost of spare parts should normally be part of the purchase price request to the manufacturer. The user can refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

The cost allocated to spare parts is best described as a percentage of the total system costs (power, heating, cooling and/or balance of system and miscellaneous). For large CHP projects, operating in normal conditions, an inventory of spare parts representing at the most 3% of the total equipment cost should suffice.

## Transportation

Transportation costs for equipment and construction materials will vary widely depending upon the mode of transport available and the location of the project site. In many instances the cost will depend on distance and be based on a volume/weight formula. Costs to handle the material at the receiving end should be considered. In isolated areas, bulk shipments may be received only once a year. Logistical control is extremely important here. Shipping costs should be obtained from shipping agents when the scope of the project, equipment and materials are determined. Note that the transportation cost might be included in the equipment cost entered above. The user can

refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

## **Training & commissioning**

The costs associated with the training of equipment operators and maintenance personnel will depend on the size, complexity and remoteness of the project. For isolated areas, there will be a greater need for local trained technicians in order to avoid lengthy repair delays.

For a CHP plant, a crew of about 20 persons may be required to operate the plant. For small packaged gas turbines (micro-turbines), one operator/maintenance technician can perform regular operation and maintenance tasks. However, some of the periodic repairs will require specialised labour. Training costs include professional fees. Any travel expenses can be entered in "Travel & accommodation" under the "Development" section.

Training will involve between 2 and 10 people for 1 to 20 days at a rate of between \$300 and \$1,000 per person-day depending on the size of the project.

Commissioning is the last activity of the construction phase. It consists of operating all the equipment to detect and fix any malfunctions, and ensure that the plant function as guaranteed. Commissioning normally involves the monitoring of the equipment performance over a set period of time under typical operating conditions. The cost associated with the commissioning of the CHP project will depend on the technology, size and number of systems and on the skills and experience of the O&M staff. It could also depend on the climatic conditions to the extent that a sustained period of peak heating and/or cooling load is required to demonstrate and prove the adequate performance of the equipment.

Commissioning will involve between 1 and 8 people for 1 to 30 days at a rate of between \$300 and \$1,000 per person-day depending on the size of the project.

## **Contingencies**

The allowance made for contingency costs depends on the level of accuracy of the cost estimates. Contingencies are estimated based on a user-selected percentage of the sub-total of all project costs excluding interest during construction. Note that contingencies are incremental in the sense that they are derived from project costs including any credits.

The allowance for contingency items should be based on the level of accuracy associated with the RETScreen Pre-feasibility or Feasibility estimate of the project costs. Typically, a "Pre-feasibility" level cost analysis should be accurate within + or - 40 to 50% and a "Feasibility" level cost analysis should be accurate within + or - 15 to 25%. However, this accuracy will depend on the expertise of the study team, the scale of the project being considered, the level of effort put forward to complete the pre-feasibility or feasibility study and the availability of accurate information. It is certainly possible that the

RETScreen user experienced with project development could estimate costs in the range of 5 to 40% of the total initial project costs.

## **Interest during construction**

Interest during construction (short-term construction financing) will vary depending on the duration of construction and the cost of money. Although the construction of a CHP project can take up to two years, normally not more than 12 months are required between building or infrastructure construction, delivery of the equipment (one of the most important cost items) and commissioning of the system. The user enters the interest rate (%) and the length of construction in months.

The interest during construction is then calculated assuming the average debt over the project length in months is 50% of the subtotal of all project costs. For example, if \$1 million worth of equipment must be financed over 12 months at an annual rate of 10 %, the user should enter 10 % as the interest rate during construction, the calculated interest cost during construction is:  $\$1,000,000 \times 50\% \times 12 \text{ months} / 12 \text{ months/year} \times 10\%/\text{year} = \$50,000$

The cost of interest during construction can vary between 3 and 15% of the project costs.

## **Annual costs (credits)**

There will be a number of annual costs associated with the operation of a proposed case project. These could include land lease, property taxes, insurance premium, parts & labour, GHG monitoring & verification, community benefits, and general & administrative expenses. In addition, costs for contingencies and fuel consumption will also be incurred. These costs are detailed below.

## **O&M**

### **Land lease**

The user enters the applicable annual land lease costs. If the land is not purchased, it is necessary to negotiate the use of the land where the project is being implemented. In some cases an agreement might be established that a clean energy project is a desirable use of the land and that no land use expenses will be charged to the project developer. As an example, this may be the case on government owned land. However, in most cases the landowner requires compensation for use of the land over a fixed period of time.

### **Property taxes**

This cost item summarises the annual costs of property taxes and is often calculated as a percentage of the total estimated initial costs. Property taxes might be levied on the proposed case project, depending upon the jurisdiction. Applicable property taxes have to

be estimated on a site-by-site basis and will depend on the property value of the project and/or the revenue generated by the project.

## **Insurance premium**

This cost item summarises the annual costs of insurance premium costs and is often calculated as a percentage of the total estimated initial costs. As a minimum, insurance is required for public liability, property damage, and equipment failure and business interruption. The annual costs for insurance can be significant for an energy project and should be estimated by contacting an insurance broker.

## **Parts & labour**

The parts & labour cost item summarises the cost of spare parts and annual labour required for routine and emergency maintenance and operation of the proposed project. It also includes the transmission line and the district heating and/or cooling network maintenance (if this cost is covered by the project owner). Operation includes monitoring, regular inspection of the equipment (including routine lubrication and adjustments), snow, ice and dirt removal, scheduled maintenance (internal inspection and maintenance), etc.

The maintenance of transmission lines associated with a power project will involve periodic clearing of trees (where present) and replacement of parts (e.g. poles, conductor, insulators) that become damaged due to lightning, impact, etc. The annual cost of transmission line maintenance is often estimated based on the capital cost of the transmission line and substation. Annual costs normally range between 3 and 6% of capital costs depending on the location and communication equipment required (i.e. ease of access, presence of trees, VHF radio network, etc.).

For CHP projects, the cost for parts and labour is typically best expressed as a percentage of the total initial cost and represents around 5% of the initial costs. It can also be expressed in terms of \$/kWh of electricity generated and range between \$0.005/kWh and \$0.015/kWh depending on complexity and staffing requirements. The parts and labour costs can sometimes be governed by local regulations stipulating high staffing requirements for the plant and smaller plants can have very high annual cost compared to the project cost.

Labour costs in isolated areas are typically twice the rate found in most urban locations. Productivity is often less as resources are limited and an annual allowance should be made for travel, room and board costs associated with annual maintenance. The costs proposed should thus be adjusted accordingly if appropriate.

## GHG monitoring & verification

Greenhouse gas (GHG) monitoring is generally carried out by project proponents in accordance with the data requirements and methods laid out in the Monitoring Plan. If additional data needs to be collected in order to estimate GHG emissions, the cost of collecting that data and quantifying emissions reductions should be estimated. Note that in the case of Clean Development Mechanism (CDM) projects sustainable development indicators will also need to be monitored. For small-scale CDM projects (capacity of 15 MW, or energy savings of 15 GWh, or less), monitoring requirements will be simplified, and therefore the estimated costs should be reduced. (See UNFCCC's CDM Website for details on monitoring requirements for CDM projects.)

Most GHG projects will also require third party verification of emissions reductions on an annual or periodic basis. For Joint Implementation (JI) projects, verification results in an independent confirmation of the actual emissions reductions the project has achieved and the quantification of Emissions Reduction Units (ERUs).

For CDM projects, emissions reductions must be verified and certified by a designated operational entity before Certified Emissions Reductions (CERs) are issued. A prescribed rate of \$US 400/day has been set for the staff of designated operational entities or \$US 1,200/day for a team of three. For CDM projects, an administration and adaptation fee will be charged by the United Nations Framework Convention on Climate Change (UNFCCC). Some host countries may also require a percentage of the value of CERs to be paid as an administration fee (note this percentage can be entered and accounted for on the *GHG Analysis* worksheet).

It may be decided to bundle and incur GHG monitoring and verification on a periodic (e.g. every two years) rather than on an annual basis, especially for smaller projects. In this case, the user should use the Periodic Costs section at the bottom of the *Cost Analysis* worksheet to do so, and set the same to "0" in the Annual O&M Costs section.

## Community benefits

In order to ensure the acceptance of the proposed case project within a community, it is common in large projects to reserve a small portion of the O&M budget to fund an initiative that will benefit the community. This could take the form of a donation to support a public awareness centre for the plant, donations to charitable organisations, a grant to support cultural or sporting events, scholarships, training sessions, environmental protection, etc.

## General & administrative

Annual general & administrative costs include the costs of bookkeeping, preparation of annual statements, bank charges, communication, etc. General and administrative costs are project specific and depend on the nature of the business enterprise (e.g. privately-

owned with a simple power purchase agreement or utility/publicly owned with individual customers).

General and administrative costs can range between 1 to 20% of the annual costs (excluding custom costs and contingencies).

## **O&M (Custom)**

This input cell is provided to allow the user to enter a cost or credit item that is not included in the information provided in the above cost category.

A cost item may be entered in the grey input cell by overwriting the word "O&M." The user then selects "cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may also be entered in the grey input cell. The user then selects "credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

## **Contingencies**

A contingency allowance should be included to account for unforeseen annual expenses and will depend on the level of accuracy of the operation and maintenance cost estimate section. This is especially true in the case of project in isolated areas. It is common to carry a contingency allowance for at least the replacement of the most expensive component subject to catastrophic failure. The contingency allowance is calculated based on an estimated percentage of the other operation and maintenance costs. It typically ranges from 10 to 20% of these costs.

## **Fuel**

The fuel consumption (quantity) and fuel rate (unit cost) are calculated in the *Energy Model, Load & Network* and *Equipment Selection* worksheets and these values are automatically copied to the *Cost Analysis* worksheet. If the same fuel is used for different types of equipment, the model will display this fuel type only once in the *Cost Analysis* worksheet and the total fuel consumption and fuel cost will be calculated by the model. "Electricity" fuel refers to energy supplied by the electricity grid for the proposed case system.

## Periodic costs (credits)

This section is provided to allow the user to specify the periodic costs associated with the operation of the system over the project life. Grey input cells are provided to allow the user to enter the name of a periodic cost and periodic credit item.

A periodic cost represents recurrent costs that must be incurred at regular intervals to maintain the project in working condition. A periodic cost item is entered in the grey input cell. The user then selects "cost" from the drop-down list in the unit column. The interval (in years) over which the periodic cost is incurred is entered in the Year column. The amount of the cost incurred at each interval is entered in the unit cost column.

The project may also be credited for periodic costs that would have been incurred over the project life of the base case, or conventional, energy system. The periodic credit item is entered in the grey input cell. The user then selects "credit" from the drop-down list in the unit column. The interval (in years) over which the periodic credit is incurred is entered in the year column. The amount of the credit incurred at each interval is entered in the unit cost column. Note that the credit item is expressed as a negative value in the "Amount" column.

## End of project life

The user enters the value of the project at the end of its life. This amount is also commonly referred to as the salvage value (or disposal value). If the salvage value of the project at the end of its life is positive, then the user selects "credit" from the drop-down list in the unit column in order to express this item as a negative value. However, if the costs of remediation or decommissioning that must be incurred at the end of the project life exceed the salvage value, then the user must select "cost" from the drop-down list.

**Note:** At this point, the user should go to the optional *GHG Analysis* worksheet.

## Financial Summary

As part of the RETScreen Clean Energy Project Analysis Software, a *Financial Summary* worksheet is provided for each project evaluated. This financial analysis worksheet contains seven sections: **Annual fuel cost summary**, **Financial parameters**, **Annual income**, **Project costs and savings/income summary**, **Financial viability**, **Yearly cash flows** and **Cumulative cash flows graph**.

One of the primary benefits of using the RETScreen software is that it **facilitates the project evaluation process for decision-makers**. The *Financial Summary* worksheet, with its financial parameters input items (e.g. discount rate, debt ratio, etc.), and its calculated financial viability output items (e.g. IRR, simple payback, NPV etc.), allows the project decision-maker to consider various financial parameters with relative ease. A description of these items, including comments regarding their relevance to the preliminary feasibility analysis, is included below.

### Annual fuel cost summary

This section summarises the base case system peak load, energy demand, end-use energy rate and fuel cost as entered and/or calculated in the *Load & Network* worksheet.

This section also summarises the proposed case system capacity, energy delivered, end-use energy rate and fuel cost as entered and/or calculated in the *Energy Model* and *Equipment Selection* worksheets.

The total fuel cost for the base case and proposed case systems is also calculated.

### Financial parameters

The items entered here are used to perform calculations in this *Financial Summary* worksheet. Values for each parameter will depend on the perspective of the user (e.g. utility vs. independent power producer).

#### General

##### Fuel cost escalation rate

The user enters the fuel cost escalation rate (%), which is the projected annual average rate of increase in base case and proposed case fuel costs over the life of the project. This permits the user to apply rates of inflation to fuel costs, which might be different from general inflation. For example, in North America, long-term fuel cost escalation rates range anywhere from 0 to 5% with 2 to 3% being the most common values.

## **Inflation rate**

The user enters the inflation rate (%), which is the projected annual average rate of inflation over the life of the project. For example, inflation for the next 25 years in North America is currently forecasted to range between 2 and 3%.

## **Discount rate**

The user enters the discount rate (%), which is the rate used to discount future cash flows in order to obtain their present value. The rate generally viewed as being most appropriate is an organisation's weighted average cost of capital. An organisation's cost of capital is not simply the interest rate that it must pay for long-term debt. Rather, cost of capital is a broad concept involving a blending of the costs of all sources of investment funds, both debt and equity. The discount rate used to assess the financial viability of a given project is sometimes called the "hurdle rate," the "cut-off rate," or the "required rate of return." The model uses the discount rate to calculate the annual life cycle savings. For example, North American electric utilities currently use discount rates ranging anywhere from 3 to 18% with 6 to 11% being the most common values.

## **Project life**

The user enters the project life (year), which is the duration over which the financial viability of the project is evaluated. Depending on circumstances, it can correspond to the life expectancy of the energy equipment, the term of the debt, or the duration of a power purchase agreement. The model can analyse project life's up to 50 years.

## **Finance**

### **Incentives and grants**

The user enters the financial incentive; this is any contribution, grant, subsidy, etc. that is paid for the initial cost (excluding credits) of the project. In the model, the incentive is deemed not to be refundable and is treated as income during the development/construction year, year 0, for income tax purposes.

The incentives and grants is transferred to the Projects costs and savings/income summary section.

### **Debt ratio**

The user enters the debt ratio (%), which is the ratio of debt over the sum of the debt and the equity of a project. The debt ratio reflects the financial leverage created for a project; the higher the debt ratio, the larger the financial leverage. The model uses the debt ratio to calculate the equity investment that is required to finance the project. For example,

debt ratios typically range anywhere from 0 to 90% with 50 to 90% being the most common.

## **Debt**

The model calculates the project debt, which is the portion of the total investment required to implement the project and that is financed by a loan. The project debt leads to the calculation of the debt payments and the net present value. It is calculated using the total initial costs and the equity.

## **Equity**

The model calculates the project equity, which is the portion of the total investment required to finance the project that is funded directly by the project owner(s). The project equity is deemed to be disbursed at the end of year 0, i.e. the development/construction year. It is calculated using the total initial costs and the debt ratio.

## **Debt interest rate**

The user enters the debt interest rate (%), which is the annual rate of interest paid to the debt holder at the end of each year of the term of the debt. The model uses the debt interest rate to calculate the debt payments. For example, at a minimum the debt interest rate will correspond to the yield of government bonds with the same term as the debt term. A premium is normally added to this rate (the "spread") to reflect the perceived risk of the project.

## **Debt term**

The user enters the debt term (year), which is the number of years over which the debt is repaid. The debt term is either equal to, or shorter than the project life. Generally, the longer the term, the more the financial viability of an energy project improves. The model uses the debt term in the calculation of the debt payments and the yearly cash flows. The term of the debt normally falls within a 1 to 25 year range. It should not exceed the estimated project life.

## **Debt payments**

The model calculates the annual debt payments, which is the sum of the principal and interest paid yearly to service the debt. Whereas debt payments are constant over the debt term, the principal portion increases and the interest portion decreases with time. In that respect, it is similar to the yearly annuity paid to reimburse the mortgage of a house. Debt payments are calculated using the debt interest rate, the debt term and the debt.

The annual debt payments is transferred to the Projects costs and savings/income summary section.

## Income tax analysis

The user indicates by ticking the box whether or not income tax should be factored into the financial analysis. If the user ticks the box, certain input fields will be added to allow the user to customize the income tax analysis according to the specific circumstances of the project. In some situations, the after-tax return of a project can be more attractive than its pre-tax return.

The income tax analysis allows the model to calculate after-tax cash flows and after-tax financial indicators. In all cases, the model assumes a single income tax rate valid throughout the project life and applied to net income. Note that the analysis is based, among others, on net initial and annual costs, i.e. any credits entered in the *Cost Analysis* worksheet for these two categories are not treated separately. This leads to a reasonably accurate tax analysis unless the initial and/or annual credits are of the same order of magnitude as the corresponding costs and fall under a different depreciation schedule for tax purposes.

## Effective income tax rate

The user enters the effective income tax rate (%), which is the effective equivalent rate at which the net income and/or savings derived from the project are taxed. For example, in most jurisdictions, this would correspond to the combined federal, provincial/state and/or local income tax rates for businesses. Net taxable income is derived from the project cash inflows and outflows assuming that all revenues and expenses are paid at the end of the year in which they are earned or incurred.

The effective income tax rate is assumed to be constant throughout the project life. Note that sales tax should be considered in the "Initial Costs" section of the *Cost Analysis* worksheet and that property tax should be considered in the "Annual Costs" section.

## Loss carryforward?

The user indicates by selecting from the drop-down list whether or not losses are carried forward, i.e. whether or not a loss (a negative taxable income) in a given year can be used to lower taxes owed in that same year or can be deferred to offset profits from future years. If the user selects "Yes," losses are carried forward and applied against taxable income and/or savings in the following years, thereby reducing the income tax owed up to the accumulated losses, years after the losses occur. If the user selects "No," losses are not carried forward but rather lost and thereby never used to offset any other year taxable income. If the user selects "Flow-through," losses are not carried forward but rather used in the year in which they occur and applied against profits from sources other than the project (or qualify and generate a refundable tax credit), thereby reducing the income tax owed in the years in which losses occur.

Whether losses must be carried forward or not will depend on the tax laws in the jurisdiction in which the project is located. The "Flow-through" situation is typically the most advantageous for the project owner and can contribute to make profitable a project which would not appear financially attractive on a pre-tax basis.

The model does not allow losses to be carried backward and does not set a limit on the number of years for carryforwards.

## **Depreciation method**

The user selects the depreciation method from three options in the drop-down list: "None," "Declining balance" and "Straight-line." This selection of the yearly depreciation of assets is used in the model in the calculation of income taxes and after-tax financial indicators. The user should select the method accepted by the tax departments in the jurisdiction of the project. The difference between the "End of project life" value and its undepreciated capital costs at the end of the project life is treated as an income if positive and as a loss if negative.

When "None" is selected, the model assumes that the project is fully capitalised at inception, is not depreciated through the years and therefore maintains its undepreciated value throughout its life.

When "Declining balance" is selected, the model assumes that the capitalised costs of the project, as specified by the depreciation tax basis, are depreciated at the depreciation rate. The portion of initial costs not capitalised is deemed to be expensed during the year of construction, i.e. year 0.

When "Straight-line" is selected, the model assumes that the capitalised costs of the project, as specified by the depreciation tax basis, are depreciated with a constant rate over the depreciation period. The portion of initial costs not capitalised is deemed to be expensed during the year of construction, i.e. year 0.

For both declining balance and straight-line depreciation, the model assumes that the full depreciation allowed for a given year is always taken. Also, the model does not incorporate the half-year rule used in some countries and according to which depreciation is calculated over only half of the capitalised cost during the first year of operation of the equipment.

## **Depreciation tax basis**

The user enters the depreciation tax basis (%), which is used to specify which portion of the initial costs are capitalised and can be depreciated for tax purposes. The remaining portion is deemed to be fully expensed during the year of construction (year 0).

For example, if a project costs \$20,000 to evaluate (feasibility study) and develop, and \$80,000 to design (engineering), build, install and commission, the user could enter 80%

as the depreciation tax basis in order to depreciate only the engineering, energy system, balance of system and miscellaneous costs while the feasibility and development costs would be fully expensed during year 0.

## **Depreciation rate**

The user enters the depreciation rate (%), which is the rate at which the undepreciated capital cost of the project is depreciated each year. The depreciation rate can vary widely according to the class of assets considered and the jurisdiction in which the project is located.

## **Depreciation period**

The user enters the depreciation period (year), which is the period over which the project capital costs are depreciated using a constant rate. The depreciation period can vary widely according to the class of assets considered and the jurisdiction in which the project is located.

## **Tax holiday available?**

The user indicates by selecting from the drop-down list whether or not the project can benefit from a tax holiday. If the user selects "Yes," the tax holiday applies starting in the first year of operation, year 1, up to the tax holiday duration. The income tax calculation for the development/construction year, year 0, is not affected.

## **Tax holiday duration**

The user enters the tax holiday duration (year), which is the number of years over which the tax holiday applies, starting in the first year of operation, year 1. For example, in India, certain renewable energy projects are given a five-year tax holiday.

## **Annual income**

### **Customer premium income (rebate)**

The user indicates by ticking the box whether or not customer premium income (or rebate) is applicable. If the user ticks the box, certain input fields will be added to allow the user to customise the customer premium income (rebate) analysis according to the specific circumstances of the project.

### **Electricity premium (rebate)**

The user enters the annual electricity premium or rebate (negative value) as a percentage of the base case power system annual fuel cost. This permits the user to apply rates that

are either higher or lower than what is paid for electricity in the base case. By selecting a positive value (premium), it means that the end-user is willing to pay more for electricity delivered by the proposed case power system (e.g. "Green Power Premium"). By entering a negative value (rebate), it means that the electricity is "sold" for less than the base case electricity cost.

## **Electricity premium income (rebate)**

The model calculates the electricity premium income or rebate. This value is calculated by multiplying the base case power system fuel cost by the electricity premium or rebate. The annual value of the electricity premium income (rebate) is escalated at the fuel cost escalation rate.

## **Heating premium (rebate)**

The user enters the annual heating premium or rebate (negative value) as a percentage of the base case heating system annual fuel cost. This permits the user to apply rates that are either higher or lower than what is paid for heating in the base case. By selecting a positive value (premium), it means that the end-user is willing to pay more for heating delivered by the proposed case heating system. For example, the proposed case heating system could be built by an Energy Services Company (ESCO) and the existing heating system can be disconnected and no future maintenance or operating costs will be required by the end-use customer (e.g. building owner). By entering a negative value (rebate), it means that heating is "sold" for less than the base case fuel cost.

## **Heating premium income (rebate)**

The model calculates the heating premium income or rebate. This value is calculated by multiplying the base case heating system fuel cost by the heating premium or rebate. The annual value of the heating premium income (rebate) is escalated at the fuel cost escalation rate.

## **Cooling premium (rebate)**

The user enters the annual cooling premium or rebate (negative value) as a percentage of the base case cooling system annual fuel cost. This permits the user to apply rates that are either higher or lower than what is paid for cooling in the base case. By selecting a positive value (premium), it means that the end-user is willing to pay more for cooling delivered by the proposed case cooling system. For example, the proposed case cooling system could be built by an Energy System Company (ESCO) and the existing cooling system can be disconnected and no future maintenance or operating costs will be required by the end-use customer (e.g. building owner). By entering a negative value (rebate), it means that cooling is "sold" for less than the base case fuel cost.

## Cooling premium income (rebate)

The model calculates the cooling premium income or rebate. This value is calculated by multiplying the base case cooling system fuel cost by the cooling premium or rebate. The annual value of the cooling premium income (rebate) is escalated at the fuel cost escalation rate.

## Customer premium income (rebate)

The model calculates the total annual customer premium income (or rebate). This value is transferred to the Project costs and savings/income summary section.

## Electricity export income

If there is electricity exported to the grid by the proposed case power system, certain input fields will be added to allow the user to customise the electricity export income analysis according to the specific circumstances of the project. Note that if there is no electricity exported to the grid then the user can not use this option

## Electricity exported to grid

The model calculates the electricity exported to the grid. This value is calculated in the *Equipment Selection* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

## Electricity export rate

The user enters the electricity export rate for the proposed case power system in the *Equipment Selection* worksheet, and it is copied automatically to the *Financial Summary* worksheet. This value is assumed to be representative of year 0, i.e. the development year prior to the first year of operation (year 1).

## Electricity export income

The model calculates the annual electricity export income. This value is calculated by multiplying the electricity exported to grid by the electricity export rate. The annual value of the electricity export income is escalated at the electricity export escalation rate.

The annual electricity export income is transferred to the Project costs and savings/income summary section.

## Electricity export escalation rate

The user enters the electricity export escalation rate (%), which is the projected annual average rate of increase in electricity export rate over the life of the project. This permits the user to apply rates of inflation to the value of electricity export rate, which might be different from general inflation.

## Clean Energy (CE) production income

The user indicates by ticking the box whether or not Clean Energy (CE) production income is applicable. If the user ticks the box, certain input fields will be added to allow the user to customise the CE production income analysis according to the specific circumstances of the project. Note that if the user did not select at the bottom of the *Energy Model* worksheet any fuels or systems that can benefit from a CE production credit, then the user can not use this option.

## CE production

The model calculates the annual Clean Energy (CE) production. The user selects which fuel or system can benefit from a clean energy production credit in the Proposed case system summary section at the bottom of the *Energy Model* worksheet.

## CE production credit rate

The user enters the Clean Energy (CE) production credit rate. This value typically represents the amount that can be credited to the project in exchange of the production generated by the clean energy delivered by the proposed case system. It is used in conjunction with the clean energy production to calculate the annual CE production income.

CE production credits are most common for electricity generation from clean energy projects. For example, it is possible to receive a tax credit of 1.5 ¢/kWh in the USA for electricity produced from wind, biomass or chicken manure power projects. Whether or not a given project would qualify to receive such payments depends on the rules of the specific programs in the jurisdiction in which the system is installed.

This value is assumed to be representative of year 0, i.e. the development year prior to the first year of operation (year 1). The model escalates the CE production credit rate yearly according to the CE production credit escalation rate starting from year 1 and throughout the CE production credit duration.

## CE production income

The model calculates the annual Clean Energy (CE) production income. This value is calculated by multiplying the CE production and the CE production credit rate. The

annual value of CE production income is escalated at the CE production credit escalation rate.

The annual CE production income is transferred to the Project costs and savings/income summary section.

## **CE production credit duration**

The user enters the Clean Energy (CE) production credit duration (year). This value typically represents the number of years for which the project receives a CE production credit.

## **CE production credit escalation rate**

The user enters the Clean Energy (CE) production credit escalation rate (%), which is the projected annual average rate of increase in the CE production credit rate over the life of the project. This allows the user to apply rates of inflation to the value of CE production credit rate, which might be different from general inflation.

## **GHG reduction income**

The user indicates by ticking the box whether or not greenhouse gas (GHG) reduction income is applicable. If the user ticks the box, certain input fields will be added to allow the user to customise the GHG reduction income analysis according to the specific circumstances of the project. Note that if the user did not select to perform the "GHG Analysis" in the *GHG Analysis* worksheet, then the user can not use this option.

## **Net GHG reduction - yr 1 to x (1st period)**

The model calculates the net annual average GHG reduction, in equivalent tonnes of CO<sub>2</sub> per year (t<sub>CO2</sub>/yr), resulting from the implementation of the proposed case system instead of the base case, or baseline, system for the years preceding the change in baseline emission factor for the base case electricity system. This value is calculated in the *GHG Analysis* worksheet and it is copied automatically to the *Financial Summary* worksheet.

## **Net GHG reduction [- yr x+1 and beyond (2nd period)]**

The model calculates the annual net GHG reduction in equivalent tonnes of CO<sub>2</sub> per year (t<sub>CO2</sub>/yr) resulting from the implementation of the proposed case system instead of the base case, or baseline, system. This value is calculated in the *GHG Analysis* worksheet, and it is copied automatically to the *Financial Summary* worksheet. For projects in which a change in baseline emission factor for the base case electricity system has been selected in the *GHG Analysis* worksheet, the model indicates the net annual GHG emission reduction for the years following the change.

## Net GHG reduction - project life

The model calculates the cumulative net GHG reduction for the duration of the project life, in equivalent tonnes of CO<sub>2</sub> (tCO<sub>2</sub>), resulting from the implementation of the proposed case system instead of the base case, or baseline, system. This value is calculated by multiplying the appropriate annual net GHG reduction by the project life.

## GHG reduction credit rate

The user enters the GHG reduction credit per equivalent tonne of CO<sub>2</sub> (tCO<sub>2</sub>). It is used in conjunction with the net GHG reduction to calculate the annual GHG reduction income.

Preliminary estimates predict the market price of GHG reduction credit rates will range from \$US 4 to \$US 95 per tonne of CO<sub>2</sub>, with \$5 to \$8 per tonne being the most likely range [Sandor, 1999]. As of 2003, the global market price has typically been in the range of \$US 3 to \$US 5 per tonne of CO<sub>2</sub>.

The value entered is assumed to be representative of year 0, i.e. the development year prior to the first year of operation (year 1). The model escalates the GHG reduction credit rate yearly according to the GHG reduction credit escalation rate starting from year 1 and throughout the GHG reduction credit duration.

## GHG reduction income

The model calculates the annual GHG reduction income which represents the income generated by the sale or exchange of the GHG reductions. It is calculated from the annual net GHG reduction and the GHG reduction credit rate. The annual value of GHG reduction income is escalated at the GHG reduction credit escalation rate.

The annual GHG reduction income is transferred to the Project costs and savings/income summary section.

## GHG reduction credit duration

The user enters the GHG reduction credit duration (year). This value typically represents the number of years for which the project receives GHG reduction credits. It is used to determine the GHG reduction income over the project life.

For Clean Development Mechanism (CDM) projects, two options are currently available for the length of the crediting period (i) a fixed crediting period of 10 years or (ii) a renewable crediting period of 7 years that can be renewed twice (for a maximum credit duration of 21 years). If a crediting period of 10 years is selected, once the project has been validated and registered, Certified Emission Reductions (CERs) can be certified and issued for the 10 years of the project without revisiting the baseline. However, in the case

of a renewable 7-year crediting period, the project will have to be validated after each 7-year period in order to receive CERs for the subsequent 7 years.

Thus in selecting a crediting period, the benefits of the potentially longer crediting period of the renewable crediting period (e.g. up to 21 years) must be weighed against the additional transaction costs of re-validating the project after each 7-year period, and the risk of the project potentially not meeting validation requirements at that time.

## Net GHG reduction - credit duration

The model calculates the cumulative net GHG reduction, in equivalent tonnes of CO<sub>2</sub> (t<sub>CO2</sub>), resulting from the implementation of the proposed case system instead of the base case, or baseline, system for the GHG credit duration. This value is calculated by multiplying the appropriate annual net GHG reduction by the GHG reduction credit duration.

## GHG reduction credit escalation rate

The user enters the GHG reduction credit escalation rate (%), which is the projected annual average rate of increase in the GHG reduction credit rate over the project life. This allows the user to apply rates of inflation to the value of GHG reduction credit rates, which might be different from general inflation.

## Project costs and savings/income summary

Many of the summary items here are calculated and/or entered in the *Cost Analysis* worksheet and transferred to the *Financial Summary* worksheet. The remainder are calculated and/or entered in other parts of the *Financial Summary* worksheet.

## Initial costs

The total initial costs represent the total investment that must be made to bring a project on line, before it begins to generate savings and/or income. The total initial costs are the sum of the estimated feasibility study, development, engineering, power system, heating system, cooling system and balance of system & miscellaneous costs and are inputs in the calculation of the simple payback, the net present value and the project equity and debt.

It is important to note that the range of possible costs listed throughout RETScreen **do not include sales taxes**. In a number of jurisdictions, clean energy project costs are often exempt from sales taxes. Users will have to consider these costs for their region when preparing their evaluations. For example, if in a particular region sales tax is applicable to the cost of an energy project then the user must add the amount of sales tax to the cost of the project chosen from the proposed range of values.

## Feasibility study

The feasibility study item represents the sum of the costs incurred to assess the feasibility of a project. It is net of any "credits" for not having to develop the base case project. Considerable detail is provided in the *Cost Analysis* worksheet for estimating the sub-costs for feasibility studies. This is done because it will help the project proponent better estimate the costs of the next investment required, which is the investment in a feasibility study. However for smaller projects, a RETScreen pre-feasibility analysis may be sufficient to move to the development and engineering phase or to construction.

**Note:** The RETScreen Clean Energy Project Analysis Software can also be used to help prepare the Feasibility Study as well.

## Development

The development item typically represents the sum of the costs incurred to bring a project to the detailed design and construction stage, once its feasibility has been proven. It is net of any "credits" for not having to develop the base case project.

## Engineering

The engineering item typically represents the sum of the costs of the design activities required to go from the development stage to the construction stage of a project. It is net of any "credits" for not having to develop the base case project.

## Power system

The power system item typically represents the sum of the purchase and installation costs of the power equipment, less any "credits" for not having to purchase or install base case equipment.

## Heating system

The heating system item typically represents the sum of the purchase and installation costs of the heating equipment, less any "credits" for not having to purchase or install base case equipment.

## Cooling system

The cooling system item typically represents the sum of the purchase and installation costs of the cooling equipment, less any "credits" for not having to purchase or install base case equipment.

## **Balance of system & miscellaneous**

The balance of system & miscellaneous item represents the sum of the purchase, construction and installation costs of all the elements of the energy system other than the equipment costs less any "credits" for not having to purchase or install base case equipment. It also includes all the costs not considered in any of the other initial costs categories that are required to bring a project to the operational stage.

## **Incentives and grants**

The financial incentive entered by the user in the financial parameters section is transferred here. This is any contribution, grant, subsidy, etc. that is paid for the initial cost (excluding credits) of the project. In the model, the incentive is deemed not to be refundable and is treated as income during the development/construction year, year 0, for income tax purposes.

## **Annual costs and debt payments**

The total annual costs are calculated by the model and represent the yearly costs incurred to operate, maintain and finance the project. It is the sum of the O&M, fuel cost for the proposed case system and debt payments. Note that the total annual costs include the reimbursement of the "principal" portion of the debt which is not, strictly speaking, a cost but rather an outflow of cash. These costs are described briefly below.

### **O&M**

The operation and maintenance (O&M) costs are the sum of the annual costs that must be incurred to operate and maintain the energy system, in excess of the O&M cost required by the base case system. The model uses the O&M cost to calculate the total annual costs and the yearly cash flows.

### **Fuel cost - Proposed case**

The model calculates the total fuel cost for the proposed case power, heating and/or cooling systems. The annual value of fuel cost for the proposed case is escalated at the fuel cost escalation rate.

### **Debt payments - debt term**

The model calculates the debt payments, which is the sum of the principal and interest paid yearly to service the debt. Whereas debt payments are constant over the debt term, the principal portion increases and the interest portion decreases with time. In that respect, it is similar to the yearly annuity paid to reimburse the mortgage of a house. Debt payments are calculated using the debt interest rate, the debt term and the debt.

## Periodic costs (credits)

The periodic costs and periodic credits are entered by the user in the *Cost Analysis* worksheet and are transferred here.

The model escalates the periodic costs and credits yearly according to the inflation rate starting from year 1 and throughout the project life. From an income tax perspective, periodic costs and credits are treated as operating expenses rather than capital investments and are therefore fully expensed in the year they are incurred.

## End of project life - cost/credit

The value of the project at the end of its life is entered by the user in the *Cost Analysis* worksheet and it is transferred here. This amount is also commonly referred to as the salvage value (or disposal value).

The salvage value entered is assumed to be representative of year 0, i.e. the development/construction year prior to the first year of operation (year 1). The model escalates the salvage value yearly according to inflation rate starting from year 1 and up to the end of the project life (i.e. the schedule year reported in the model).

For tax purposes, the difference between the project salvage value and its undepreciated capital costs at the end of the project life is treated as income if positive and as a loss if negative.

## Annual savings and income

The total annual savings and income represents the annual savings and/or income realised due to the implementation of the proposed case system.

## Fuel cost - Base case

The model calculates the total fuel cost for the base case power, heating and/or cooling systems. The annual value of fuel cost for the base case is escalated at the fuel cost escalation rate.

## Customer premium income (rebate)

The model calculates the customer premium income (rebate). This value is calculated by multiplying the base case power, heating and cooling systems fuel costs by the electricity, heating and/or cooling premium income or rebate. The annual values of the electricity, heating and/or cooling premium income (rebate) are escalated at the fuel cost escalation rate.

## **Electricity export income**

The model calculates the electricity export income. This value is calculated by multiplying the electricity exported to grid by the electricity export rate. The annual value of the electricity export income is escalated at the electricity export escalation rate.

## **CE production income - duration**

The model calculates the annual CE production income. This value is calculated by multiplying the CE production and the CE production credit rate. The annual value of CE production income is escalated at the CE production credit escalation rate.

## **GHG reduction income - duration**

The model calculates the annual GHG reduction income, which represents the income generated by the sale or exchange of the GHG reduction. This value is calculated from the annual net GHG reduction and the GHG reduction credit rate. The yearly value of GHG reduction income is escalated at the GHG credit escalation rate.

## **Financial viability**

The results provide the planner decision-maker with various financial indicators for the proposed project.

## **Pre-tax Internal Rate of Return - equity**

The model calculates the pre-tax internal rate of return on equity (%), which represents the true interest yield provided by the project equity over its life before income tax. It is calculated using the pre-tax yearly cash flows and the project life. It is also referred to as the return on equity (ROE) or return on investment (ROI) or the time-adjusted rate of return. It is calculated by finding the discount rate that causes the net present value of the equity to be equal to zero. Hence, it is not necessary to establish the discount rate of an organisation to use this indicator. An organisation interested in a project can compare the internal rate of return to its required rate of return (often, the cost of capital). The IRR is calculated on a nominal basis, that is including inflation.

If the internal rate of return is equal to or greater than the required rate of return of the organisation, then the project will likely be considered financially acceptable (assuming equal risk). If it is less than the required rate of return, the project is typically rejected. An organisation may have multiple required rates of return that will vary according to the perceived risk of the projects. The most obvious advantage of using the internal rate of return indicator to evaluate a project is that the outcome does not depend on a discount rate that is specific to a given organisation. Instead, the IRR obtained is specific to the project and applies to all investors in the project.

## Pre-tax Internal Rate of Return - assets

The model calculates the pre-tax internal rate of return on assets (%), which represents the true interest yield provided by the project assets over its life before income tax. It is calculated using the pre-tax yearly cash flows and the project life. It is also referred to as the return on assets (ROA). It is calculated by finding the discount rate that causes the net present value of the assets to be equal to zero. Hence, it is not necessary to establish the discount rate of an organisation to use this indicator. An organisation interested in a project can compare the internal rate of return to its required rate of return (often, the cost of capital). The IRR is calculated on a nominal basis, that is including inflation.

## After-tax Internal Rate of Return - equity

The model calculates the after-tax internal rate of return on equity (%), which represents the true interest yield provided by the project equity over its life after income tax. It is calculated using the after-tax yearly cash flows and the project life.

## After-tax Internal Rate of Return - assets

The model calculates the after-tax internal rate of return on assets (%), which represents the true interest yield provided by the project assets over its life after income tax. It is calculated using the after-tax yearly cash flows and the project life.

## Simple payback

The model calculates the simple payback (year), which represents the length of time that it takes for a proposed project to recoup its own initial cost, out of the income or savings it generates. The basic premise of the simple payback method is that the more quickly the cost of an investment can be recovered, the more desirable is the investment. For example, in the case of the implementation of an energy project, a negative payback period would be an indication that the annual costs incurred are higher than the annual savings generated.

The simple payback method is not a measure of how profitable one project is compared to another. Rather, it is a measure of time in the sense that it indicates how many years are required to recover the investment for one project compared to another. **The simple payback should not be used as the primary indicator to evaluate a project.** It is useful, however, as a secondary indicator to indicate the level of risk of an investment. A further criticism of the simple payback method is that it does not consider the time value of money, nor the impact of inflation on the costs.

On the other hand, the payback period is often of great importance to individuals or small firms that may be cash poor. When a firm is cash poor, a project with a short payback period, but a low rate of return, might be preferred over another project with a high rate of return, but a long payback period. The reason is that the organisation might simply

need a faster repayment of its cash investment. The model uses the total initial costs, the total annual costs (excluding debt payments) and the total annual savings and income to calculate the simple payback. The calculation is based on pre-tax amounts and includes any initial cost incentives and grants.

## **Equity payback**

The model calculates the equity payback, which represents the length of time that it takes for the owner of a project to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback considers project cash flows from its inception as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. The model uses the year number and the cumulative after-tax cash flows in order to calculate this value.

Note that equity payback was referred to "Year-to-positive cash flow" in previous RETScreen models.

## **Net Present Value (NPV)**

The model calculates the Net Present Value (NPV) of the project, which is the value of all future cash flows, discounted at the discount rate, in today's currency. NPV is related to the internal rate of return (IRR). NPV is thus calculated at a time 0 corresponding to the junction of the end of year 0 and the beginning of year 1. Under the NPV method, the present value of all cash inflows is compared against the present value of all cash outflows associated with an investment project. The difference between the present value of these cash flows, called the NPV, determines whether or not the project is generally a financially acceptable investment. Positive NPV values are an indicator of a potentially feasible project. In using the net present value method, it is necessary to choose a rate for discounting cash flows to present value. As a practical matter, organisations put much time and study into the choice of a discount rate. The model calculates the NPV using the cumulative after-tax cash flows. In cases where the user has selected not to conduct a tax analysis, the NPV calculated will be that of the pre-tax cash flows.

## **Annual life cycle savings**

The model calculates the annual life cycle savings which is the levelized nominal yearly savings having exactly the same life and net present value as the project. The annual life cycle savings are calculated using the net present value, the discount rate and the project life.

## **Benefit-Cost (B-C) ratio**

The model calculates the net Benefit-Cost (B-C) ratio, which is the ratio of the net benefits to costs of the project. Net benefits represent the present value of annual income and savings less annual costs, while the cost is defined as the project equity.

Ratios greater than 1 are indicative of profitable projects. The net benefit-cost ratio, similar to the profitability index, leads to the same conclusion as the net present value indicator.

## **Debt service coverage**

The model calculates the debt service coverage for each year of the project and reports the lowest ratio encountered throughout the term of debt. The debt service coverage is the ratio of the operating benefits of the project over the debt payments. This value reflects the capacity of the project to generate the cash liquidity required to meet the debt payments. It is calculated by dividing net operation income and savings (net cash flows before depreciation, debt payments and income taxes) by debt payments (principal and interest).

The debt service coverage is a ratio used extensively by the potential lenders for a project to judge financial risk. The model assumes that the cumulative cash flows are used to finance a sufficient debt service reserve before any distributions to the shareholders.

## **GHG reduction cost**

The model calculates the GHG reduction cost. The GHG reduction cost is calculated by dividing the annual life cycle savings of the project by the net GHG reduction per year, averaged over the project life. For projects with a net increase in GHG emission, the GHG reduction cost is irrelevant and hence not calculated. In order to calculate the true economic (not financial) cost of GHG reductions, a number of other parameters, such as the GHG credits transaction fee, GHG reduction credit rate, debt ratio, etc. should be set to 0. In addition "Income tax analysis" should not be selected and other taxes should also be set to 0.

## **Yearly cash flows**

### **Pre-tax**

The model calculates the net pre-tax cash flows, which are the yearly net flows of cash for the project before income tax. It represents the estimated sum of cash that will be paid or received each year during the entire life of the project. Note that the equity is assumed to occur at the end of year 0 and that year 1 is the first year of operation of the project. Annual costs and savings/income given in the *Financial Summary* worksheet, which reflect amounts valid for year 0, are thus escalated one year in order to determine the actual costs and savings/income incurred during the first year of operation (i.e. year 1).

### **After-tax**

The model calculates the net after-tax cash flows, which are the yearly net flows of cash for the project after income tax. It represents the estimated sum of cash that will be paid

or received each year during the entire life of the project. Note that the equity is assumed to occur at the end of year 0 and that year 1 is the first year of operation of the project. Annual costs and savings/income given in the *Financial Summary* worksheet, which reflect amounts valid for year 0, are thus escalated one year in order to determine the actual costs and savings/income incurred during the first year of operation (i.e. year 1).

## **Cumulative**

The model calculates the cumulative cash flows, which represent the net after-tax flows accumulated from year 0. It uses the net flows to calculate the cumulative flows.

## **Cumulative cash flows graph**

The cumulative cash flows are plotted versus time in the cash flows graph. These cash flows over the project life are calculated in the model and reported in the yearly cash flows table.

## **Blank Worksheets (3)**

These worksheets are provided to allow the user to prepare a customised RETScreen project analysis. For example, the worksheets can be used to enter more details about the project, to prepare graphs, to perform a more detailed sensitivity analysis and to create a custom database. The user may also use these worksheets to develop a companion model to RETScreen.

## Greenhouse Gas (GHG) Emission Reduction Analysis

As part of the RETScreen Clean Energy Project Analysis Software, a *GHG Analysis* worksheet is provided to help the user estimate the greenhouse gas emission reduction (mitigation) potential of the proposed project. This GHG emission reduction analysis worksheet contains five main sections: **Settings**, **Base case electricity system (Baseline)**, **Base case system GHG summary (Baseline)**, **Proposed case system GHG summary (Project)** and **GHG emission reduction summary**. The settings section is used to indicate whether or not the optional GHG Analysis worksheet is used and to select the preferred type of analysis. It also provides GHG global warming potential factors. The Base case electricity system and Base case system GHG summary sections provide a description of the emission profile of the baseline system. The Proposed case system GHG summary section provides a description of the emission profile of the proposed project. The GHG emission reduction summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections. Results are calculated as equivalent tonnes of CO<sub>2</sub> avoided per annum. This is an optional analysis - inputs entered in this worksheet will not affect results reported in other worksheets, except for the GHG related items that appear in the *Financial Summary* and *Sensitivity* worksheets.

Greenhouse gases include water vapour, carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), ozone (O<sub>3</sub>) and several classes of halo carbons (that is, chemicals that contain carbon together with fluorine, chlorine and bromine). Greenhouse gases allow solar radiation to enter the Earth's atmosphere, but prevent the infrared radiation emitted by the Earth's surface from escaping. Instead, this outgoing radiation is absorbed by the greenhouse gases and then partially re-emitted as thermal radiation back to Earth, warming the surface. Greenhouse gases that are most relevant to energy project analysis are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O); these gases are considered in the RETScreen GHG emission reduction analysis.

RETScreen has been improved to better take into account the emerging rules for carbon finance under the **Kyoto Protocol**, in collaboration with the United Nations Environment Programme (UNEP) and the Prototype Carbon Fund (PCF) at The World Bank. The Kyoto Protocol is the protocol to the United Nations Framework Convention on Climate Change (UNFCCC) that was adopted in 1997 in Kyoto at the third Conference of the Parties (COP 3). The Kyoto Protocol commits industrialised countries (defined as Annex I countries) to legally binding greenhouse gas (GHG) reduction targets during the period between 2008 and 2012. These commitments are on average 5% below 1990 emissions levels.

The *GHG Analysis* worksheet of each Workbook file has been developed with a similar framework so as to simplify the task of the user in analysing the viability of different projects. Hence, the description of each parameter is common for most of the items appearing in the worksheet. RETScreen allows the user to evaluate proposed projects in both domestic and international markets, including projects that fall under the Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI). The

online manual provides information and Website links related to the rules and guidelines that have been developed for CDM and JI projects, in particular those regarding baselines, and the transaction costs associated with these projects. Based on user inputs, RETScreen estimates the quantity of credits that the project may generate and includes the value of these credits in the financial analysis of the project.

One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers. The *GHG Analysis* worksheet, with its emission related input items (e.g. fuel mix) and its calculated emission factor output items (e.g. GHG emission factor), allows the decision-maker to consider various emission parameters with relative ease. However, the user should be aware that this ease of use may give a project developer a too optimistic and simplified view of what is required in setting a baseline for a proposed project. As such, it is suggested that the user **take a conservative approach in calculating the baseline emission factor for the project**, particularly at the pre-feasibility analysis stage. In order to determine the net benefits of obtaining carbon finance for the project, the user can evaluate the project twice, once including the value of the carbon credits and the associated transaction costs and once without, and then compare the results.

The procedure to follow is presented in the RETScreen [GHG Analysis Worksheet Flow Chart](#).

## Settings

### GHG analysis

The user indicates, by ticking the box, whether or not the optional *GHG Analysis* worksheet is used to conduct an analysis of GHG emission reduction.

If the user ticks the box, the user should complete the *GHG Analysis* worksheet. Certain input fields will be added to the *Financial Summary* worksheet in order to calculate the GHG reduction income.

If the user does not tick the box, the user should then go directly to the *Financial Summary* worksheet.

### Simplified, Standard or Custom analysis

The user selects the type of analysis from the three options: "Simplified analysis," "Standard analysis" and "Custom analysis." Standard analysis uses many pre-defined parameters in the calculations whereas the Custom analysis requires that the user enter these parameters.

The user will typically select Simplified analysis if electricity generation emission factors are already known. GHG emissions factors for electricity generation for some

jurisdictions might be calculated on an aggregate basis to help simplify the preparation of GHG calculations. This simplified method for calculating the baseline for a project can reduce the time and costs associated with establishing the baseline for the project, but in most cases will reduce the accuracy of the baseline calculations.

RETScreen includes electricity generation GHG emission factors for a number of countries.

## Potential CDM project

The Kyoto Protocol has established three mechanisms: the **Clean Development Mechanism (CDM)**, **Joint Implementation (JI)**, and **Emissions Trading**, that allow Parties to pursue opportunities to cut emissions, or enhance carbon sinks, abroad. The cost of curbing emissions varies considerably from region to region and therefore makes economic sense to cut emissions, where it is cheapest to do so, given that the impact on the atmosphere is the same.

The user indicates, by ticking the box, whether or not the project is to be evaluated as a potential CDM project. The user should tick the box if the **project is located in a developing country** and it has good potential to **meet the requirements for CDM projects**. These requirements are described in brief below and covered in detail at the [UNFCCC's CDM Website](#). The user should not tick the box for any other domestic or international GHG reduction projects, including ones that might qualify for Joint Implementation. JI requirements are also described in brief below.

If the user ticks the box, RETScreen automatically assesses, by checking values calculated on other RETScreen worksheets, whether or not the project can be considered as a **small-scale CDM project** (i.e. the capacity of a renewable energy system does not exceed 15 MW or the aggregate energy savings by an energy efficiency improvement project does not exceed the equivalent of 15 GWh per year). If the project fits within the criteria for small-scale CDM projects, then the user may be able to take advantage of the simplified baseline methods and other rules and procedures for small-scale CDM projects.

The basic concept of the [Clean Development Mechanism](#) is that industrialised countries (or companies) invest in GHG emission-reduction projects in developing countries and gain credits from these projects that they can then apply to their own GHG reduction commitments as agreed to under the Kyoto Protocol.

Article 12 of the Kyoto Protocol defines the goals of the CDM as:

- to assist developing countries in achieving sustainable development, and in contributing to the ultimate objective of the Convention; and
- to assist industrialised countries in meeting their quantified emission reduction commitments.

The Kyoto Protocol also proscribes that emissions reductions will only be certified if:

- the CDM project has the approval of the host country;
- the project produces real, measurable and long-term GHG benefits; and
- the reductions in emissions are additional to any that would occur in the absence of the certified project activity.

Under the Kyoto Protocol an Executive Board (EB) has been established to oversee and monitor the CDM. The Executive Board is responsible for accrediting Designated Operational Entities (DOE) that validate CDM projects and verify and certify emissions reductions. Credits generated and certified from CDM projects are known as "Certified Emissions Reductions," or CERs. A CER is equal to one metric tonne of carbon dioxide (CO<sub>2</sub>) equivalent and must be certified by a Designated Operational Entity.

In November 2001, at COP 7 in Marrakech, Morocco, the parties reached an agreement on the legal text needed to implement the Kyoto Protocol. A key outcome of Marrakech was agreement on the basic rules and regulations governing the CDM. These rules are covered in a section of the Marrakech Accord known as "Modalities and Procedures for a Clean Development Mechanism." Specific issues agreed to in Marrakech include the baseline approaches that will be permitted for CDM projects, the procedures for approving baseline methodologies, and the format of the [Project Design Document \(PDD\)](#). Marrakech also allowed for simplified procedures for small-scale projects and identified the types of projects that could be considered small scale.

All CDM projects must be "additional to any that would occur in the absence of the proposed project activity" in order to be eligible for credits. This qualification is called "**additionality**." All CDM projects, therefore, require the estimation or measurement of "baseline" emissions - those that would have occurred without the project - and actual emissions that occur after a project has been implemented. Guidelines are available at the [UNFCCC's CDM Website](#) on how to demonstrate additionality.

A **baseline approach** is the basis for defining a baseline methodology. The Conference of the Parties has agreed to the following three approaches for CDM project activities.

1. Existing actual or historical emissions, as applicable.
2. Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment.
3. The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category.

The RETScreen *GHG Analysis* worksheet can be used for each of these approaches.

Note that although the Executive Board has approved these three baseline approaches, they are simply guidelines. In order to register a CDM project the baseline must be developed using an approved methodology.

A **baseline methodology** is an application of one of the allowable baseline approaches, as defined to an individual project activity, reflecting aspects such as sector and region. Baseline methodologies for CDM projects must be approved by the Executive Board. If project proponents wish to use a new methodology they may submit it for approval. Details of approved methodologies are provided at the [UNFCCC's CDM Website](#).

**Joint Implementation (JI)** projects, on the other hand, occur in Annex 1 countries, that is, countries that have agreed to emissions targets under the Kyoto Protocol. Like the CDM, the basic concept of JI is that industrialised countries (or companies) invest in GHG emission-reduction projects in other Annex 1 countries where reductions are cheaper than in their own country and gain credits from these projects that can then be applied to their own GHG reduction commitments as agreed to under Kyoto. In practice, Joint Implementation projects are more likely to take place in Economies-In-Transition or EITs, where there tends to be more scope for cutting emissions at lower costs.

Joint Implementation projects must have the approval of all Parties involved, and must lead to emission reductions or removals that are additional to any that would have occurred without the project. An ERU is an Emission Reduction Unit generated from a JI project. An ERU is equal to one metric tonne of carbon dioxide (CO<sub>2</sub>) equivalent. Projects starting from the year 2000 that meet the above rules may be listed as Joint Implementation projects. However, ERUs may only be issued after 2008.<sup>1</sup>

## Simplified baseline methods possible

RETScreen automatically assesses, by checking values calculated on other RETScreen worksheets, whether or not the project can be considered as a **small-scale CDM project** (i.e. the capacity of a renewable energy system does not exceed 15 MW or the aggregate energy savings by an energy efficiency improvement project does not exceed the equivalent of 15 GWh per year). Note that this option will automatically be hidden in RETScreen for non-CDM projects, or for potential CDM projects that exceed the small-scale CDM project size limits.

Simplified rules and procedures are available for small-scale CDM projects if it can be demonstrated that one of the barriers identified by the UNFCCC has been overcome in order to implement the project. These simplifications will allow the use of standardized baselines, streamlined monitoring procedures, a simpler Project Design Document, and

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<sup>1</sup> Portions of this text were adapted from the UNFCCC's document, *Guide to the Climate Convention and its Kyoto Protocol*, available at [UNFCCC's Website](#).

reduced registration fees - all of which reduce transaction costs so that small-scale projects can offer CERs at more competitive prices.

The RETScreen *GHG Analysis* worksheet can be used to calculate the baseline for a small-scale CDM project directly in conjunction with Appendix B of the document "[Simplified modalities and procedures for small-scale CDM project activities](#)," which is available at the [UNFCCC's CDM Website](#). This appendix contains indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories, including recommendations for determining the project boundary, leakage, baseline and monitoring. Note that small-scale CDM projects should not be debundled components of larger project activities, as described in Appendix C.

In accordance with the simplified modalities and procedures for small-scale CDM project activities, a simplified baseline and monitoring methodology listed in the appendix may be used for a small-scale CDM project activity if project participants are able to demonstrate to a designated operational entity that the project activity would otherwise not be implemented due to the existence of one or more barrier(s) listed below.

- a) Investment barrier: a financially more viable alternative to the project activity would have led to higher emissions.
- b) Technological barrier: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions.
- c) Barrier due to prevailing practice: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions.
- d) Other barriers: without the project activity, for another specific reason identified by the participant, such as institutional barriers or limited information, managerial resources, organisational capacity, financial resources, or capacity to absorb new technologies, emissions would have been higher.

As an example of how RETScreen can be used with Appendix B of the document "Simplified modalities and procedures for small-scale CDM project activities," under paragraph 28 of this document concerning a system where all fossil fuel fired generating units use fuel oil or diesel fuel, the baseline is the annual kWh generated by the renewable unit times an emission coefficient for a modern diesel generating unit of the relevant capacity operating at optimal load as given in the [Emission Factors for Diesel Generator Systems](#) table.<sup>2</sup>

In this example, the user would select "Simplified analysis" at the top of the RETScreen

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<sup>2</sup> Portions of this text were adapted from Appendix B of the document, *Simplified modalities and procedures for small-scale CDM project activities*, available at the [UNFCCC's CDM Website](#).

*GHG Analysis Worksheet* and enter "other" as the fuel type under the Base case electricity system (Baseline) section, and then enter the appropriate GHG emission factor as selected from the table. Note that the UNFCCC used RETScreen to help calculate the emission factors at different load levels for the table.

## **Global warming potential of GHG**

The model indicates the global warming potential of methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). If the user selects the custom type of analysis, different values from the default values provided may be entered by the user. Researchers have assigned Global Warming Potentials (GWPs) to greenhouse gases to allow for comparisons of their relative heat-trapping effect. The higher the global warming potential of a gas the greater the contribution to the greenhouse effect. For example nitrous oxide is 310 times more effective than carbon dioxide at trapping heat in the atmosphere.

GWPs of gases are defined as a unit multiple of that given to carbon dioxide (CO<sub>2</sub>), which is assigned a reference value of 1 (i.e., the GWP of CO<sub>2</sub> is 1 and the GWP of N<sub>2</sub>O is 310). The default values are those defined by the Revised Intergovernmental Panel on Climate Change (IPCC) Guidelines for Greenhouse Gas Inventories, 1996.

## **Base case electricity system (Baseline)**

To perform the RETScreen GHG emission reduction analysis for the project, the user needs to define the baseline (also called base case or reference case) electricity system.

The user selects the type of analysis from the three options: "Simplified analysis," "Standard analysis" and "Custom analysis." Standard analysis uses many pre-defined parameters in the calculations whereas the Custom analysis requires that the user enter these parameters. The user selects the type of analysis in the "Settings" section at the top of the GHG Analysis worksheet.

The user will typically select Simplified analysis if electricity generation emission factors are already known. GHG emissions factors for electricity generation for some jurisdictions might be calculated on an aggregate basis to help simplify the preparation of GHG calculations. This simplified method for calculating the baseline for a project can reduce the time and costs associated with establishing the baseline for the project, but in most cases will reduce the accuracy of the baseline calculations.

RETScreen includes electricity generation GHG emission factors for a number of countries.

As an alternative, a more detailed standard analysis can be prepared. For example, for central-grid electricity projects in North America, it is often reasonable to assume that a combined-cycle natural gas power plant is the baseline or proxy plant. In this case the user needs only to select "Natural gas" as the fuel type with a 100% fuel mix and use the

default "T&D losses" of 8%. For the case of an isolated-grid application, a diesel genset would likely be the "proxy" power plant with "Diesel (#2 oil)" chosen as the fuel type. For off-grid applications, the fuel type is defined in the *Load & Network* worksheet.

It is also possible to define the grid and the mix of the different power plants with their respective fuels, fuel mix and different T&D losses (e.g. distributed generators such as photovoltaics will have lower T&D losses). This information is usually available through the local electric utility, the utility regulator and/or through government. For example, the United States Environmental Protection Agency (US-EPA) provides "The Emissions & Generation Resource Integrated Database" called E-GRID. This is a database featuring environmental characteristics of electric power generation in the US, including fuel mix. This database is available free of charge at the [E-GRID Website](#).

To illustrate this alternative analysis method, for a grid-connected project based in Nova Scotia, Canada, the provincial government might determine the baseline to be the weighted average of the current electricity generation mix. This can be calculated by simply entering the current fuel mix into the grid along with the appropriate emissions coefficient. For this example and with information provided by Natural Resources Canada, the user would select the following fuel types and associated fuel mix: coal with 78% of the fuel mix, large hydro with 9%, #6 oil with 5%, natural gas with 5% and biomass with 3% of the fuel mix and T&D losses of 8% for all fuel types. Note that this methodology can be used for small-scale CDM renewable energy projects that are connected to a grid that includes generating units other than diesel or fuel oil.

Some users may prefer to perform a much more detailed analysis of the GHG reduction potential of the project (e.g. an economist working for a public utility commission). The model allows for a more detailed analysis regarding electricity generation efficiency and T&D losses, and using the custom analysis, the user can prepare an even more detailed analysis regarding emission factors, etc.

If the user has access to dispatch information from the local utility, the Base case electricity system table can be used to model the marginal fuel use on the grid, which may more accurately represent the fuels and the emissions that are being displaced by the proposed project. For example, if dispatch information shows that the fuel used on the margin is natural gas 85% of the time and fuel oil 15% of the time, the user would enter these details into the base case table along with the corresponding GHG coefficients. The resulting baseline is often referred to as the "operating margin."

Another baseline option, referred to as the "build margin" can be calculated by modeling recent capacity additions, for example, the 5 most recent plants that have been added to the grid. The build margin can be modeled in the base case table by entering recent capacity additions along with their relative generating capacities (scaled to total 100%) and appropriate GHG coefficients.

It is suggested that the user take a conservative approach in calculating the baseline emission factor for the project, particularly at the pre-feasibility analysis stage.

## Country - region

The user selects the country - region from the drop-down list.

RETScreen includes electricity generation GHG emission factors for a number of countries and sub-regions for the year 2002 for all countries, and 2000 for Canadian provinces. Transmission and Distribution (T&D) losses are not included in these factors. T&D losses are added separately by the user [GHG Protocol Initiative, 2004], [International Energy Agency, 2002] and the [United Nations Framework Convention on Climate Change, 2004].

Note that GHG emission factors will vary year to year and from fuel to fuel. The user should use more recent information if readily available. However, in the absence of other data, this country - region information provides a reasonable first estimate.

## Fuel type

*(Standard or Custom analysis)*

The user selects the fuel type from the drop-down list. The RETScreen software can model the GHG emissions of any electricity supply system. The fuel type is the fuel(s) or power plant(s) which will be displaced by the proposed project. If the user selects one of the fuel types from the drop-down list, default emission factor and fuel conversion efficiency values will be inserted into the row inputs of the table.

If a specific fuel type is not included in the drop-down list, the user may choose "User-defined." For Custom analyses, the user enters values for the remainder of the row inputs. For standard analyses, the user enters the factors in the *Tools* worksheet.

## Fuel type

*(Simplified analysis)*

The user selects the fuel type from the drop-down list. RETScreen includes electricity generation GHG emission factors for a number of countries and sub-regions. "All types" refers to all fuels on the grid. The user can also select Natural gas, Coal, Oil (#6) or Other, depending on the type of fuel(s) displaced by the proposed case power system.

## Fuel mix

The user enters the fuel mix (%) of the base case electricity system for each fuel type. Units are given as percentages of total electricity supplied. Note that the user should verify that the sum of all fuel types listed in the fuel mix column equals 100%.

## **CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors**

*(Custom analysis)*

The user enters the CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors for the different fuel types. They represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants. For grid-connected projects, the user should enter factors representative of large generating plants. On the electricity mix row at the bottom of the table, the model calculates the equivalent emission factors for the global electricity mix and per unit of electricity delivered. The electricity mix factors thus account for a weighted average of the electricity generation efficiencies and T&D losses of the different fuel types.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ). For the global electricity mix shown on the bottom row of the table, units are given in kilograms of gas emitted per gigajoule of end-use electricity delivered.

For more information on determining GHG emission factors, see the revised [IPCC Guidelines for National Greenhouse Gas Inventories](#). CO<sub>2</sub> emission factors for many fuels are included on page [1.13 of the IPCC Reference Manual](#). CH<sub>4</sub> and N<sub>2</sub>O emission factors for a number of fuels are included on [pages 1.35 and 1.36 of the IPCC Reference Manual](#). In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

## **CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors**

*(Standard analysis)*

The model provides the CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors which represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants. The default factors provided are those which are representative of large power plants that feed a central electricity grid. On the electricity mix row at the bottom of the table, the model calculates the equivalent emission factors for the total electricity mix and per unit of electricity delivered. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T&D losses of the different fuel types.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ). For the total electricity mix shown on the bottom row of the table, units are given in kilograms of gas emitted per gigajoule of end-use electricity delivered.

For more information on determining GHG emission factors, see the revised [IPCC Guidelines for National Greenhouse Gas Inventories](#). CO<sub>2</sub> emission factors for many fuels are included on page [1.13 of the IPCC Reference Manual](#). CH<sub>4</sub> and N<sub>2</sub>O emission factors for a number of fuels are included on [pages 1.35 and 1.36 of the IPCC Reference](#)

[Manual](#). In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

## Electricity generation efficiency

The user enters the electricity generation efficiency for the selected fuel type. The electricity generation efficiency is the efficiency of energy conversion from primary heat potential to actual power plant output. This value is used to calculate, for each fuel type, the aggregate GHG emission factor and therefore is only relevant for fuel types which actually produce greenhouse gases (i.e. with non-zero CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors).

For example, a typical coal-fired power plant could have an electricity generation efficiency of 35%, which indicates that 35% of the heat content of the coal is transformed into electricity fed to the grid.

Units are given as a percentage of primary heat potential (gigajoules of heat) to actual power plant output (gigajoules of electricity). Fuel types which emit no GHGs (e.g. solar) have a default value of 100%.

## T&D losses

The user enters the transmission and distribution (T&D) losses (%) of the base case electricity system, which includes all energy losses between the power plant and the end-user. This value will vary based on the voltage of transport lines, the distance from the site of energy production to the point of use, peak energy demands, ambient temperature and electricity theft. In addition, T&D system type (e.g. AC vs. DC) and quality may also influence losses. The model calculates the weighted average of the T&D losses of the global electricity mix on the bottom row of the table.

Units are given as a percentage of all electricity losses to electricity generated. As a first estimate, it is reasonable to assume T&D losses of 8 to 10% in modern grids in industrialised countries and 10 to 20% in grids located in developing countries.

## GHG emission factor (excl. T&D)

The user enters the GHG emission factor excluding transmission and distribution (T&D) losses for the base case electricity system specified.

The user can obtain GHG emission factors (excluding T&D losses) by selecting a "country - region" and "fuel type" in the two cells adjacent to the left. If a blank value appears that indicates that no information is available for that selection. The user can override these values by entering a value directly in the cell.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## **GHG emission factor** *(Standard or Custom analysis)*

The model calculates the GHG emission factor for each fuel type considered. Values are calculated based on the individual emission factors, the electricity generation efficiency and the T&D losses. The weighted GHG emission factor for the total electricity mix is calculated on the bottom row of the table.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## **GHG emission factor** *(Simplified analysis)*

The model calculates the GHG emission factor for the electricity system specified. The value is calculated based on the GHG emission factor (excl. T&D) and the T&D losses entered by the user.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## **Baseline changes during project life**

The user indicates, by ticking the box, whether or not the baseline changes during the project life. The project electricity generation baseline might not stay constant throughout the life of the project, due to factors such as changes in regulations in the electricity sectors, the planned addition of new generation units on the grid (e.g. large-scale hydroelectric project), or decommissioning of existing units.

The model allows for one change in the baseline during the project life that the user enters as a percentage increase or decrease in the initial baseline. The baseline emissions will thus be scaled accordingly for the year in which the change occurs as well as each year following the change.

## **Change in GHG emission factor**

The user enters the percentage by which baseline emissions will increase (positive percentage) or decrease (negative percentage) because of the change in the baseline.

For example, if a new hydro plant already under construction will decrease emissions by 10% in year 5, then the user enters negative 10%. The model will then reduce baseline emissions by 10% for year 5 and all subsequent years.

## Year of change

The user enters the year in which the change in the baseline occurs.

For example, if a new hydro plant is scheduled to be added to the electricity grid during the fifth year after this proposed project begins, the user enters 5.

## GHG emission factor year X and beyond

The model calculates the GHG emission factor for the years following the change in baseline. Values are calculated by applying the specified change in emission factor to the weighted GHG emission factor of the electricity mix.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## Reason/event for baseline change

The user enters the reason for the baseline change, i.e. the event that triggers the change in the baseline. This information is given for reference purposes only.

For example, if the addition of a new hydro plant is the reason for the change in the baseline, the user would enter something like "New hydro plant under construction."

## Base case system GHG summary (Baseline)

The base case system, or baseline system, represents the system to which the proposed case system is compared. The base case system is normally referred to as the reference or baseline option in standard economic analysis.

## Fuel type

The user enters the fuel types in the *Load & Network* worksheet (or in the Base case electricity system section for fuel type "electricity") and they are copied automatically to the *GHG Analysis* worksheet. If the same fuel type is used for several building zones or clusters or for both heating and cooling, the model will display this fuel type only once in the *GHG Analysis* worksheet and the total fuel consumption will be calculated by the model.

Note that if electricity is exported to the grid in the proposed case, this electricity is also added to the base case system so that the GHG emissions for this generation are included in the comparison. For projects using landfill gas as a fuel, the GHG emissions from the landfill site or existing flare are also included in the baseline calculations.

## Fuel mix

The fuel mix of the base case system is calculated automatically from the consumption of different fuel types as defined in the *Load & Network* worksheet and in the Operating strategy section in the *Equipment Selection* worksheet, if electricity is exported to the grid.

## CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors

*(Custom analysis)*

The user enters the CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors corresponding to the fuel types. If one of the fuel types is electricity, the emission factor for the base case electricity system is used.

CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of equipment.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised [IPCC Guidelines for National Greenhouse Gas Inventories](#). CO<sub>2</sub> emission factors for many fuels are included on [page 1.13 of the IPCC Reference Manual](#). CH<sub>4</sub> and N<sub>2</sub>O emission factors for a number of fuels are included on [pages 1.35 and 1.36 of the IPCC Reference Manual](#). In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

## CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors

*(Standard analysis)*

The model provides the CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors corresponding to the fuel types. If one of the fuel types is electricity, the emission factor for the base case electricity system is used.

CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of equipment.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised [IPCC Guidelines for National Greenhouse Gas Inventories](#). CO<sub>2</sub> emission factors for many fuels are included on [page 1.13 of the IPCC Reference Manual](#). CH<sub>4</sub> and N<sub>2</sub>O emission

factors for a number of fuels are included on [pages 1.35 and 1.36 of the IPCC Reference Manual](#). In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

## Fuel consumption

The model calculates the total fuel consumption for each fuel type. This value is used in conjunction with the aggregate GHG emission factor to calculate the GHG emissions for each fuel type considered.

**Units switch:** The user can choose to express the fuel consumption in MWh or in GJ.

## GHG emission factor (Standard or Custom analysis)

The model calculates the GHG emission factor each fuel type considered. Values are calculated based on the individual emission factors.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## GHG emission factor (Simplified analysis)

The model calculates the GHG emission factor each fuel type considered.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## GHG emission

The model calculates the GHG emission for the base case system by multiplying the fuel consumption by the GHG emission factor.

Units are given in equivalent tonnes of CO<sub>2</sub> emissions per year (tCO<sub>2</sub>/yr).

## Landfill gas potential

The model calculates the amount of landfill gas flared and the amount of landfill gas emitted based on values entered in the *Tools* worksheet.

## Proposed case system GHG summary (Project)

The proposed case system, or mitigation system, is the proposed project.

The proposed case system is normally referred to as the mitigation option in standard economic analysis.

## Fuel type

The user enters the fuel types in the *Equipment Selection* and *Energy Model* worksheets and they are copied automatically to the *GHG Analysis* worksheet. If the same fuel is used for different types of equipment, the model will display this fuel type only once in the *GHG Analysis* worksheet and the total fuel consumption will be calculated by the model. "Electricity" fuel refers to energy supplied by the electricity grid for the proposed case system.

## Fuel mix

The fuel mix of the proposed case system is calculated automatically from the consumption of different fuel types as defined in the *Equipment Selection* and *Energy Model* worksheets.

## CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors

*(Custom analysis)*

The user enters the CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors corresponding to the fuel types. If one of the fuel types is electricity, the emission factor for the base case electricity system is used.

CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of equipment.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised [IPCC Guidelines for National Greenhouse Gas Inventories](#). CO<sub>2</sub> emission factors for many fuels are included on [page 1.13 of the IPCC Reference Manual](#). CH<sub>4</sub> and N<sub>2</sub>O emission factors for a number of fuels are included on [pages 1.35 and 1.36 of the IPCC Reference Manual](#). In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

## CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors

*(Standard analysis)*

The model provides the CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors corresponding to the fuel types.

CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emission factors represent the mass of greenhouse gas emitted per unit of energy generated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of equipment.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised [IPCC Guidelines for National Greenhouse Gas Inventories](#). CO<sub>2</sub> emission factors for many fuels are included on [page 1.13 of the IPCC Reference Manual](#). CH<sub>4</sub> and N<sub>2</sub>O emission factors for a number of fuels are included on [pages 1.35 and 1.36 of the IPCC Reference Manual](#). In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

## Fuel consumption

The model calculates the total fuel consumption for each fuel type. This value is used in conjunction with the aggregate GHG emission factor to calculate the GHG emissions for each fuel type considered.

**Units switch:** The user can choose to express the fuel consumption in MWh or in GJ.

## GHG emission factor

*(Standard or Custom analysis)*

The model calculates the GHG emission factor for each fuel type considered. Values are calculated based on the individual emission factors.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## GHG emission factor

*(Simplified analysis)*

The model calculates the GHG emission factor for each fuel type considered.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## GHG emission

The model calculates the GHG emission for the proposed case system by multiplying the fuel consumption by the GHG emission factor.

Units are given in equivalent tonnes of CO<sub>2</sub> emissions per year (tCO<sub>2</sub>/yr).

## Landfill gas potential

The model calculates the amount of landfill gas flared based on values entered in the *Tools* worksheet.

## Electricity exported to grid

The electricity exported to the grid is calculated in the *Equipment Selection* worksheet, and it is copied automatically to the *GHG Analysis* worksheet.

This value is multiplied by the Transmission and Distribution (T&D) losses (in %) and by the GHG emission factor for the base case electricity system, to calculate the GHG emissions associated with the T&D losses for the proposed case power system.

## T&D losses

The user enters the transmission and distribution (T&D) losses (%) of the proposed case power system, which includes all energy losses between the power plant and the end-user. This value will vary based on the voltage of transport lines, the distance from the site of energy production to the point of use, peak energy demands, ambient temperature and electricity theft. In addition, T&D system type (e.g. AC vs. DC) and quality may also influence losses.

Units are given as a percentage of all electricity losses to electricity exported to the grid. Electricity delivered to the load within the project is assumed to have no transmission and distribution losses. As a first estimate, it is reasonable to assume T&D losses of 8 to 10% in modern grids in industrialised countries and 10 to 20% in grids located in developing countries.

## GHG emission reduction summary

Based on the GHG emission data entered, the model calculates the annual reduction in GHG emissions when the base case system is displaced with the proposed case system.

If the baseline for electricity production changes during the project life, then the model calculates the annual GHG reduction for both periods of the base case, that is, for the years before the change in baseline and for the years following the change in baseline.

## Years of occurrence

If the user has entered that the project electricity baseline does change, the model indicates the year numbers for the first period GHG emission factors and for the second period GHG emission factors.

## Base case GHG emission

The model transfers the total base case system GHG emission calculated in the base case system GHG summary section. This value represents the amount of GHG emitted for the base case system.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## Proposed case GHG emission

The model transfers the total proposed case system GHG emission calculated in the proposed case system GHG summary section. This value represents the amount of GHG emitted for the proposed case system.

**Units switch:** The user can choose to express the emission factor in kgCO<sub>2</sub>/kWh or in tCO<sub>2</sub>/MWh (which are equivalent).

## Gross annual GHG emission reduction

The model calculates the gross annual reduction in GHG emissions estimated to occur if the proposed project is implemented. The calculation is based on emissions of both the base case and the proposed case systems on an annual basis.

Units are given in equivalent tonnes of CO<sub>2</sub> emissions per year (tCO<sub>2</sub>/yr).

## GHG credits transaction fee

The user enters the percentage of credits that will have to be paid annually as a transaction fee. In order to obtain credits for a GHG project, a portion of the credits might have to be subtracted as a transaction fee, to be paid each year to the crediting agency (e.g. the UNFCCC) and/or the host country.

For CDM projects 2% of the CERs generated by each project will be paid into an *Adaptation fund* to help particularly vulnerable developing countries adapt to climate change. Note that projects in least developed countries are exempt from this part of the levy in order to promote the equitable distribution of projects.

The CDM Executive Board, as well as a number of host countries, also require that they receive a percentage of the credits to help cover their administrative costs (e.g. for project approval etc.). The user might wish to check the [UNFCCC's CDM Website](#) and with the host country's Designated National Authority to find out if they require a percentage of credits to be paid.<sup>3</sup>

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<sup>3</sup> A list of Designated National Authorities is available at the [UNFCCC's CDM Website](#).

The model then reduces the gross annual GHG emission reductions by this percentage to calculate the net annual GHG emission reduction.

## Net annual GHG emission reduction

The model calculates the net annual reduction in GHG emissions estimated to occur if the proposed project is implemented. The calculation is based on the gross annual GHG emission reduction and the GHG credits transaction fee.

Units are given in equivalent tonnes of CO<sub>2</sub> emissions per year (tCO<sub>2</sub>/yr).

The model allows the user to compare the net annual GHG emission reduction with units that are easier to conceptualise (e.g. Cars & light trucks not used), using the drop-down list. These numbers are based on North American energy use patterns.

**Note:** At this point, the user should complete the *Financial Summary* worksheet.

## Sensitivity and Risk Analysis

As part of the RETScreen Clean Energy Project Analysis Software, a *Sensitivity and Risk Analysis* worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This standard sensitivity and risk analysis worksheet contains a settings section and two main sections: **Sensitivity analysis** and **Risk analysis**. Each section provides information on the relationship between the key parameters and the important financial indicators, showing the parameters which have the greatest impact on the financial indicators. The Sensitivity analysis section is intended for general use, while the Risk analysis section, which performs a Monte Carlo simulation, is intended for users with knowledge of statistics.

Both types of analysis are optional. Inputs entered in this worksheet will not affect results in other worksheets.

### Settings

#### Sensitivity analysis

The user indicates, by ticking the box, whether or not the optional sensitivity analysis section is used to conduct a sensitivity analysis of the important financial indicators.

If the user ticks the box, the sensitivity analysis section will open.

#### Risk analysis

The user indicates, by ticking the box, whether or not the optional risk analysis section is used to conduct a risk analysis of the important financial indicators. In the risk analysis section, the impact of each input parameter on a financial indicator is obtained by applying a standardised multiple linear regression on the financial indicator.

If the user ticks the box, the risk analysis section will open.

#### Sensitivity analysis for...

This section presents the results of the sensitivity analysis. Each table shows what happens to the selected financial indicator (e.g. After-tax IRR - equity) when two key parameters (e.g. Initial costs and O&M) are varied by the indicated percentages. The user indicates from the drop-down list, which parameters will be varied together. Parameters are varied using the following fraction of the sensitivity range: -1, -1/2, 0, 1/2, 1. Original values (which appear in the *Financial Summary* worksheet) are in bold in these sensitivity analysis results tables.

Results which indicate an unviable project, as defined by the user Threshold, will appear as orange cells in these sensitivity analysis results tables.

All parameter values used for the calculations are taken from the *Financial Summary* worksheet and all the sensitivity variations are evaluated at the level of that worksheet.

## Perform analysis on

The user selects, from four options in the drop-down list, the financial indicator to be used for the sensitivity analysis. Modifying the selection in this cell will change the results in the worksheet.

## Sensitivity range

The user enters the sensitivity range (%), which defines the maximum percentage variation that will be applied to all the key parameters in the sensitivity analysis results tables. Each parameter is varied by the following fraction of the sensitivity range: -1, -1/2, 0, 1/2, 1.

## Threshold

The user enters the threshold value for the financial indicator selected. The threshold is the value under which (for the "After-tax IRR - equity," "After-tax IRR - assets" and "Net Present Value (NPV)") or over which (for "Equity payback") the user considers that the proposed project is not financially viable. Results which indicate an unviable project, as defined by the user threshold, will appear as orange cells in the sensitivity analysis results tables.

## Risk analysis for...

This section allows the user to perform a risk analysis by specifying the uncertainty associated with a number of key input parameters and to evaluate the impact of this uncertainty on after-tax IRR - equity, after-tax IRR - assets, equity payback or Net Present Value (NPV).

The risk analysis is performed using a Monte Carlo simulation that includes 500 possible combinations of input variables resulting in 500 values of after-tax IRR - equity, after-tax IRR - assets, equity payback or Net Present Value (NPV). The risk analysis allows the user to assess if the variability of the financial indicator is acceptable, or not, by looking at the distribution of the possible outcomes. An unacceptable variability will be an indication of a need to put more effort into reducing the uncertainty associated with the input parameters that were identified as having the greatest impact on the financial indicator.

## Perform analysis on

The user selects, from four options in the drop-down list, the financial indicator to be used for the risk analysis. Modifying the selection in this cell will change the results in the bottom part of the worksheet.

## Initial costs

The total initial cost is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the initial costs range. The range is a percentage corresponding to the uncertainty associated with the estimated initial costs value. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the initial costs could take.

For example, a range of 10% for initial costs of \$30,000,000 means that the initial costs could take any value between \$27,000,000 and \$33,000,000. Since \$30,000,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the initial costs are known exactly by the user (no uncertainty), the user should enter a range of 0%.

## O&M

The annual operating and maintenance (O&M) cost for the project is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the O&M cost range. The range is a percentage corresponding to the uncertainty associated with the estimated O&M cost value. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the O&M cost could take.

For example, a range of 10% for an O&M cost of \$1,000,000 means that the O&M cost could take any value between \$900,000 and \$1,100,000. Since \$1,000,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the O&M cost is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Fuel cost - Proposed case

The annual fuel cost for the proposed case is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the fuel cost range for the proposed case. The range is a percentage corresponding to the uncertainty associated with the estimated fuel cost value for the proposed case. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the fuel cost for the proposed case could take.

For example, a range of 10% for fuel cost for the proposed case of \$300,000 means that the fuel cost for the proposed case could take any value between \$270,000 and \$330,000. Since \$300,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the fuel cost for the proposed case is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Fuel cost - Base case

The annual fuel cost for the base case is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the fuel cost range for the base case. The range is a percentage corresponding to the uncertainty associated with the estimated fuel cost value for the base case. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the fuel cost for the base case could take.

For example, a range of 10% for fuel cost for the base case of \$300,000 means that the fuel cost for the base case could take any value between \$270,000 and \$330,000. Since \$300,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the fuel cost for the base case is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Customer premium income (rebate)

The customer premium income (rebate) is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the customer premium income (rebate) range. The range is a percentage corresponding to the uncertainty associated with the estimated customer premium income (rebate) value. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the customer premium income (rebate) could take.

For example, a range of 10% for customer premium income (rebate) of \$300,000 means that the customer premium income (rebate) could take any value between \$270,000 and \$330,000. Since \$300,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the customer premium income (rebate) is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## **Electricity export rate**

The electricity export rate is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the electricity export rate range. The range is a percentage corresponding to the uncertainty associated with the estimated electricity export rate value. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the electricity export rate could take.

For example, a range of 10% for electricity export rate of \$100/MWh means that the electricity export rate could take any value between \$90/MWh and \$110/MWh. Since \$100/MWh is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the electricity export rate are known exactly by the user (no uncertainty), the user should enter a range of 0%.

## **CE production credit rate**

The CE production credit rate is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the CE production credit rate range. The range is a percentage corresponding to the uncertainty associated with the estimated CE production credit rate value. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the CE production credit rate could take.

For example, a range of 10% for a CE production credit rate of \$0.05/kWh means that the CE production credit rate could take any value between \$0.045/kWh and \$0.055/kWh.

Since \$0.05/kWh is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the CE production credit rate is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## **GHG reduction credit rate**

The GHG reduction credit rate is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the GHG reduction credit rate range. The range is a percentage corresponding to the uncertainty associated with the estimated GHG reduction credit rate value. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the GHG reduction credit rate could take.

For example, a range of 10% for a GHG reduction credit rate of \$5/t<sub>CO2</sub> means that the GHG reduction credit rate could take any value between \$4.5/t<sub>CO2</sub> and \$5.5/t<sub>CO2</sub>. Since \$5/t<sub>CO2</sub> is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the GHG reduction credit rate is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## **Net GHG reduction - credit duration**

The net GHG reduction for the credit duration is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the net GHG reduction range for the credit duration. The range is a percentage corresponding to the uncertainty associated with the estimated net GHG reduction value for the credit duration. The higher the percentage, the greater the uncertainty. The range determines the limits of the interval of possible values that the net GHG reduction for the credit duration could take.

For example, a range of 10% for net GHG reduction for the credit duration of 10,000 equivalent tonnes of CO<sub>2</sub> emissions means that the net GHG reduction for the credit duration could take any value between 9,000 and 11,000 tonnes. Since 10,000 tonnes is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the net GHG reduction for the credit duration is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Debt ratio

The debt ratio is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt ratio range. The range is a percentage corresponding to the uncertainty associated with the estimated debt ratio value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0% and the lowest percentage such that the debt ratio will always fall between 0 and 100%. The range determines the limits of the interval of possible values that the debt ratio could take.

For example, a range of 10% for a debt ratio of 70% means that the debt ratio could take any value between 63 and 77%. Since 70% is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt ratio is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Debt interest rate

The debt interest rate is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt interest rate range. The range is a percentage corresponding to the uncertainty associated with the estimated debt interest rate value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 100%. The range determines the limits of the interval of possible values that the debt interest rate could take.

For example, a range of 10% for a debt interest rate of 20% means that the debt interest rate could take any value between 18 and 22%. Since 20% is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt interest rate is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Debt term

The debt term is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt term range. The range is a percentage corresponding to the uncertainty associated with the estimated debt term value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0% and the lowest percentage such that the debt term will always fall between 1 year and the project life. The range determines the limits of the interval of possible values that the debt term could take.

For example, a range of 10% for a debt term of 20 years means that the debt term could take any value between 18 and 22 years. Since 20 years is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt term is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## **Click here to calculate risk analysis**

The "Click here to calculate risk analysis" button updates the risk analysis calculations using the input parameter ranges specified by the user. Clicking on this button starts a Monte Carlo simulation that uses 500 possible combinations of input variables resulting in 500 values of the selected financial indicator. The impact graph, the median, the minimum and maximum confidence levels, the distribution graph and the bar graph are calculated using these results and updated each time the user clicks on the button "Click here to calculate risk analysis."

The risk analysis calculations can take up to 15 seconds to run depending on the Excel version and the speed of the computer. When the risk analysis is updated, the button disappears.

If the user makes any changes to the input range values, or navigates through any of the other worksheets, the button will reappear and the impact graph, the distribution graph and the bar graph will be crossed out, showing that the risk analysis calculations have to be updated. The user will then have to click on the button to update the risk analysis calculations so that the results reflect the changes.

## **Impact graph**

The impact graph shows the relative contribution of the uncertainty in each key parameter to the variability of the financial indicator. The X axis at the bottom of the graph does not have any units, but rather presents a relative indication of the strength of the contribution of each parameter.

The longer the horizontal bar, for a given input parameter, the greater is the impact of the input parameter on the variability of the financial indicator.

The input parameters are automatically sorted by their impact on the financial indicator.

The input parameter at the top (Y axis) contributes the most to the variability of the financial indicator while the input parameter at the bottom contributes the least. This "tornado graph" will help the user determine which input parameters should be considered for a more detailed analysis, if that is required.

The direction of the horizontal bar (positive or negative) provides an indication of the relationship between the input parameter and the financial indicator. There is a positive relationship between an input parameter and the financial indicator when an increase in the value of that parameter results in an increase in the value of the financial indicator. For example, there is usually a negative relationship between initial costs and the Net Present Value (NPV), since decreasing the initial costs will increase the NPV.

In some cases, there is insufficient data to properly plot the graph. For example, when the equity payback is immediate, the result is the "n/a" symbol, and therefore these values cannot be plotted.

If the user makes any changes to the input range values, or navigates through any of the other worksheets, the "Click here to calculate risk analysis" button will reappear and the impact graph, the distribution graph and the bar graph will be crossed out, showing that the risk analysis calculations have to be updated.

## **Median**

The model calculates the median of the financial indicator. The median of the financial indicator is the 50<sup>th</sup> percentile of the 500 values generated by the Monte Carlo simulation. The median will normally be close to the financial indicator value calculated in the *Financial Summary* worksheet.

## **Level of risk**

The user enters the acceptable level of risk for the financial indicator under consideration.

The level of risk input is used to establish a confidence interval (defined by maximum and minimum limits) within which the financial indicator is expected to fall. The level of risk represents the probability that the financial indicator will fall outside this confidence interval.

The limits of the confidence interval are automatically calculated based on the median and the level of risk, and are shown as "Minimum within level of confidence" and "Maximum within level of confidence."

It is suggested that the user enter a level of risk of 5 or 10%, which are typical values for standard risk analysis.

## Minimum within level of confidence

The model calculates the "Minimum within level of confidence," which is the lower limit of the confidence interval within which the financial indicator likely falls. It is the percentile of the distribution of the financial indicator corresponding to half the level of risk defined by the user. For example, for a "Minimum within level of confidence" value of 15% IRR - equity, a level of risk of 10% means that 5% (half the level of risk) of the possible IRR - equity values are lower than 15%.

## Maximum within level of confidence

The model calculates the "Maximum within level of confidence," which is the upper limit of the confidence interval within which the financial indicator likely falls. It is the percentile of the distribution of the financial indicator corresponding to 100% minus half the level of risk. For example, for a "Maximum within level of confidence" value of 27.5% IRR - equity, a level of risk of 10% means that 95% of the possible IRR - equity values are lower than 27.5%.

## Distribution graph

This histogram provides a distribution of the possible values for the financial indicator resulting from the Monte Carlo simulation. The height of each bar represents the frequency (%) of values that fall in the range defined by the width of each bar. The value corresponding to the middle of each range is plotted on the X axis.

Looking at the distribution of financial indicator, the user is able to rapidly assess its' variability.

In some cases, there is insufficient data to properly plot the graph. For example, when the equity payback is immediate, the result is the "n/a" symbol, and therefore these values cannot be plotted.

If the user makes any changes to the input range values, or navigates through any of the other worksheets, the "Click here to calculate risk analysis" button will reappear and the impact graph, the distribution graph and the bar graph will be crossed out, showing that the risk analysis calculations have to be updated.

## Bar graph

The bar graph summarises the maximum and minimum financial indicator values that can be expected according to the level of risk defined by the user.

If the user makes any changes to the input range values, or navigates through any of the other worksheets, the "Click here to calculate risk analysis" button will reappear and the impact graph, the distribution graph and the bar graph will be crossed out, showing that the risk analysis calculations have to be updated.

## Tools

As part of the RETScreen Clean Energy Project Analysis Software, an optional *Tools* worksheet is provided to help the user calculate a number of different values, such as the amount of methane gas available from a landfill site.

## Settings

The user indicates, by ticking the box, whether or not one or more of the optional *Tools* will be used.

If the user ticks the box, the selected Tool will open.

## User-defined fuel

This tool is used to define the "User-defined fuel" selected by the user from the "Fuel type" list in the *Energy Model, Load & Network, Equipment Selection* and/or *GHG Analysis* worksheets.

## Fuel type

The user enters the name of the fuel for reference purposes only. The user also selects "Energy units" or "Heating value units" whether the fuel is bought in energy units or not.

## Higher heating value (HHV)

The user enters the higher heating value of the fuel.

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.

## Lower heating value (LHV)

The user enters the lower heating value of the fuel.

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.

## Density

The user enters the density for the fuel.

## Fuel consumption - unit

*(Heating value units)*

The model displays the fuel consumption unit.

## Fuel consumption - unit

*(Energy units)*

The user selects the fuel consumption unit.

## Fuel rate - unit

The model displays the fuel rate unit.

## CO<sub>2</sub> emission factor

The user enters the carbon dioxide (CO<sub>2</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

## CH<sub>4</sub> emission factor

The user enters the methane (CH<sub>4</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

## N<sub>2</sub>O emission factor

The user enters the nitrous oxide (N<sub>2</sub>O) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

## User-defined fuel - solid

This tool is used to define the "User-defined fuel - solid" selected by the user from the "Fuel type" list in the *Equipment Selection* worksheet.

## Fuel type

The user enters the name of the fuel for reference purposes only. The user also selects between fossil fuel and biomass.

## Proximate analysis

A proximate analysis describes the volatiles, fixed carbon and ash present in the fuel as a percentage of dry fuel weight. The amount of volatiles and fixed carbon directly affect the heating value of the fuel, flame temperature and the process by which combustion is achieved. The ash content is important in the design of air emission control equipment, combustion system and ash handling system. Typically, the analysis includes hydrogen, carbon, oxygen, nitrogen, sulphur and ash. The amount of sulphur in biomass fuels is typically very low or non-existent.

Analytically derived formulae have been developed for the prediction of the higher heating value of coal and other fossil fuels. Exact calculations are available for all components of biomass fuel, which will oxidize. However, it is very difficult to quantify the contribution of volatiles to the heating value.

## Carbon

The user enters the amount of carbon (C) present in the fuel as a percentage of dry fuel weight. This is used to calculate the heating value of the fuel.

Biomass carbon content typically ranges from 40 to 55%.

## Hydrogen

The user enters the amount of hydrogen (H<sub>2</sub>) present in the fuel as a percentage of dry fuel weight. This is used to calculate the heating value of the fuel.

Biomass hydrogen content typically ranges from 4 to 6%.

## Oxygen

The user enters the amount of oxygen (O<sub>2</sub>) present in the fuel as a percentage of dry fuel weight. This is used to calculate the heating value of the fuel.

Biomass oxygen content typically ranges from 33 to 43%.

## Nitrogen

The user enters the amount of nitrogen ( $N_2$ ) present in the fuel as a percentage of dry fuel weight. This is used to calculate the heating value of the fuel.

Biomass nitrogen content typically ranges from 0 to 4%. Green parts of the tree typically have higher nitrogen content.

## Sulphur

The user enters the amount of sulphur present in the fuel as a percentage of dry fuel weight. This is used to calculate the heating value of the fuel.

Biomass sulphur content typically ranges from 0 to 1%.

## Ash

The user enters the amount of ash present in the fuel as a percentage of dry fuel weight. This is used to calculate the heating value of the fuel.

Biomass ash content typically ranges from 1 to 10%. Some biomass-derived fuels, such as paper mill sludge, can have ash contents greater than 25%.

## Total

The model calculates the total percentage of dry fuel weight of the fuel evaluated. The user should verify that this value equals 100%.

## Higher heating value (HHV)

The model calculates the higher heating value of the fuel using Delong's formula for fossil fuel and a modified Delong formula for biomass fuel.

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.

## Lower heating value (LHV)

The model calculates the lower heating value of the fuel using Delong's formula for fossil fuel and a modified Delong formula for biomass fuel.

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.

## Fuel consumption - unit

The user selects the fuel consumption unit.

## Fuel rate - unit

The model displays the fuel rate unit.

## CO<sub>2</sub> emission factor

The user enters the carbon dioxide (CO<sub>2</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

Note that the model also calculates the CO<sub>2</sub> emission factor based on the proximate analysis and this value is shown to the right of the entry cell. However, for biomass fuels, it is reasonable to assume that this value will be equal to zero for the purpose of preparing a greenhouse gas analysis, since the same amount of CO<sub>2</sub> emitted from the energy utilisation of biomass is used in new biomass growth.

## CH<sub>4</sub> emission factor

The user enters the methane (CH<sub>4</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

## N<sub>2</sub>O emission factor

The user enters the nitrous oxide (N<sub>2</sub>O) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

**Note:** At this point the user should return to the *Equipment Selection* worksheet.

## User-defined fuel - gas

This tool is used to define the "User-defined fuel - gas" selected by the user from the "Fuel type" list in the *Equipment Selection* worksheet.

## Fuel type

The user enters the name of the fuel for reference purposes only.

## Temperature

The user enters the gas reference temperature for the "% Volume" entry method. If "% Weight" entry method is selected, the gas reference temperature will be used to calculate the volume based percentages and the density of the gas at the reference temperature.

The user selects "% Volume" or "% Weight" entry method for the proximate analysis that follows.

## Proximate analysis

A proximate analysis for a gaseous fuel typically includes methane, ethane, propane, carbon monoxide, carbon dioxide, hydrogen sulphide, hydrogen, nitrogen and oxygen.

## Methane

The user enters the amount of methane ( $\text{CH}_4$ ) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Ethane

The user enters the amount of ethane ( $\text{C}_2\text{H}_6$ ) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Propane

The user enters the amount of propane ( $\text{C}_3\text{H}_8$ ) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Carbon monoxide

The user enters the amount of carbon monoxide ( $\text{CO}$ ) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Carbon dioxide

The user enters the amount of carbon dioxide (CO<sub>2</sub>) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Hydrogen sulphide

The user enters the amount of hydrogen sulphide (H<sub>2</sub>S) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Hydrogen

The user enters the amount of hydrogen (H<sub>2</sub>) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Nitrogen

The user enters the amount of nitrogen (N<sub>2</sub>) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Oxygen

The user enters the amount of oxygen (O<sub>2</sub>) present in the fuel as a percentage of volume or weight (depending on entry method selected). This is used to calculate the heating value of the fuel.

## Total

The model calculates the total percentage of volume or weight (depending on entry method selected) of the fuel evaluated. The user should verify that this value equals 100%.

## Higher heating value (HHV)

The model calculates the higher heating value of the fuel using Delong's formula.

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.

## Lower heating value (LHV)

The model calculates the lower heating value of the fuel using Delong's formula.

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.

## Fuel consumption - unit

The user selects the fuel consumption unit.

## Density

The model calculates the density of the fuel at normal pressure (1 atm or 101.3 kPa) and at the reference temperature entered above.

## Fuel rate - unit

The model displays the fuel rate unit.

## CO<sub>2</sub> emission factor

The user enters the carbon dioxide (CO<sub>2</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

Note that the model also calculates the CO<sub>2</sub> emission factor based on the proximate analysis and this value is shown to the right of the entry cell. However, for biogas fuels, it is reasonable to assume that this value will be equal to zero for the purpose of preparing a greenhouse gas analysis, since the same amount of CO<sub>2</sub> emitted from the energy utilisation of biomass is used in new biomass growth.

## CH<sub>4</sub> emission factor

The user enters the methane (CH<sub>4</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

## N<sub>2</sub>O emission factor

The user enters the nitrous oxide (N<sub>2</sub>O) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

**Note:** At this point the user should return to the *Equipment Selection* worksheet.

## Landfill gas

This tool is used to define the "Landfill gas" fuel selected by the user from the "Fuel type" list in the *Equipment Selection* worksheet. The landfill gas (LFG) may be collected from a nearby landfill via an existing LFG collection system at the landfill, or through the construction of a new LFG collection system. The user enters the cost for the new LFG collection system in the *Cost Analysis* worksheet.

Landfill gas is generated by the biological decomposition of wastes placed in a landfill. The composition of landfill gas is highly variable and depends on a number of site-specific conditions including solid waste composition, density, moisture content, and age. The specific composition of landfill gas varies significantly from landfill to landfill and even from place to place within a single landfill. However, landfill gas is typically comprised of methane and carbon dioxide, approximately 50 percent each by volume, with trace quantities of other compounds. Methane is the primary component of landfill gas that contributes to the gas's heating value. The heating value of methane is typically defined on a volume basis.

There are numerous models available for estimating rates of landfill gas generation, however accepted industry standard models are generally first order kinetic models that rely on a number of basic assumptions. These models are used to predict the variation of landfill gas generation rates with time for a typical unit mass of solid waste. This generation rate curve is then applied to records, or projections, of solid waste filling at a site to produce an estimate of the site's landfill gas generation over time.

RETScreen uses the Scholl Canyon Model. This model, with defined default parameters, is the empirical, first-order decay model most widely accepted and used by industry and regulatory agencies, including Environment Canada and the United States Environmental Protection Agency (USEPA). There are many more detailed models available for the estimation of landfill gas generation rates, however, these models require more specific knowledge of the waste quantities, waste composition, and land-filling practices associated with the site than is normally available, especially for older landfill sites where such records were not required. The Scholl Canyon Model is based on the assumption that there is a constant fraction of biodegradable material in the landfill per unit of time, and is an estimate of the generation of methane from this biodegradable material [The World Bank, 2004].

## **Landfill**

### **Year landfill opened**

The user enters the year the landfill opened (or opens) and received (or receives) waste.

### **Final year landfill used**

The user enters the final year that the landfill is used, i.e., the last year that waste is accepted at the landfill.

### **Waste disposal benchmark years**

The user enters the waste disposal benchmark years, based on the years that the most significant changes in the annual waste disposal rate occurred, or are expected to occur. Six waste disposal benchmark years are entered in this row, one each corresponding to an historical or expected annual waste disposal rate. The model pastes the year that the landfill opened and the final year that the landfill is used from two cells above. The user enters years to help identify the four remaining benchmark years.

For example, if a graph of the annual waste disposal rate were to be plotted versus time in years, the user would select those years corresponding to inflection points on the plotted curve. If there are no significant changes in the waste profile, or fewer points of inflection than is required by the model, the user should select years on a regular time interval. The user must enter a year in each column provided, and these years must be entered in chronological order.

### **Waste disposal rate**

The user enters the annual waste disposal rate corresponding to the benchmark year in the row above. The model linearly extrapolates the annual waste disposal rates for all years in between those that are entered.

An annual waste disposal rate must be entered in each entry cell on this row.

### **Total waste in landfill (x years)**

The model calculates the total waste in the landfill over the life of the landfill from values entered by the user above.

## Landfill gas (LFG)

### Lag time before LFG generation

The user enters the length of time in years expected between the time that waste is first placed in the landfill and the time that the initial generation of landfill gas from that waste actually occurs. A typical lag time between the placement of waste and the start of LFG generation is 1 year.

### Methane generation constant (k)

The user enters the methane generation constant,  $k$ , which represents the first-order biodegradation rate at which methane is generated following the placement of biodegradable wastes in the landfill. This constant is influenced by moisture content, the availability of nutrients, pH, and temperature. The moisture content of the waste within a landfill is one of the most important parameters affecting the landfill gas generation rate. Primarily the infiltration of precipitation through the landfill cover, the initial moisture content of the waste, the design of the leachate collection system, and the depth of waste in the site influence the moisture content of waste within a landfill.

Typical values for  $k$  range from 0.02 for dry sites to 0.07 for wet sites. Typical values of  $k$  are presented in the [Range of k Values by Annual Precipitation](#) table.

### Methane by volume of LFG

The user enters the percentage of methane in the landfill gas on a volume basis. This value is used to calculate the Methane generation from waste ( $Lo$ ) value, as well as the landfill gas methane emission factor. It is typical practice to assume that the landfill gas generated consists of 50 % methane and 50 % carbon dioxide by volume.

### Methane generation from waste ( $Lo$ )

The user enters the volume of methane generation from waste ( $Lo$ ) per tonne of waste deposited. The methane generation from waste value represents the total yield of methane that will be produced by the waste deposited.

Also referred to as the "Lo" value, it is dependent on the composition of the waste, in particular, the fraction of organic matter present. The  $Lo$  value is selected based on an estimation of the carbon content of the waste, the biodegradable carbon fraction, and a stoichiometric conversion factor. Typical values for this parameter range from 125 m<sup>3</sup> of methane/tonne of waste for moderately decomposable waste to 310 m<sup>3</sup> of methane/tonne of waste for highly organic decomposable wastes. A default value for  $Lo$  of 170 m<sup>3</sup> of methane/tonne of waste is recommended by the United States Environmental Protection Agency (USEPA) in their New Source Performance Guidelines (NSPS Tier 1 default, 1994), is considered to be a fairly conservative value, which is representative of a

majority of domestic and municipal solid waste landfills in the United States. Selection of a different value for the methane generation from waste (Lo) should be based on the users specific knowledge and experience with the landfill site that is being assessed.

## **Inerts in waste adjustment factor**

The user enters the percentage of inert material in the waste. An inert waste is one that does not contain an appreciable quantity of organic or biodegradable material, e.g., construction and demolition wastes. This adjustment factor is to be distinguished from the Methane generation from waste (Lo) value, which already takes into consideration that a certain portion of municipal domestic solid waste, as well as industrial, commercial and institutional wastes does contain a fraction of inert material. Unless there is a compelling case to the contrary, i.e., a significant, quantifiable portion of landfilled waste falls into the category of inert on a consistent annual basis, the adjustment factor for the known inert waste quantities should be assigned a value of 0.

## **LFG generation - Theoretical**

The model calculates the theoretical volume of landfill gas that can be generated per tonne of waste by dividing the "Methane generation from waste (Lo)" value by the "Methane by volume of LFG" value.

## **LFG collection efficiency**

The user enters the landfill gas collection system efficiency. Typical values range from 60 to 80 % of gas recovered, with 75 % normally assumed in the absence of site-specific data.

## **LFG generation - Potential**

The model calculates the potential volume of landfill gas that can be generated per tonne of waste in the landfill site, collected by the landfill gas collection system and potentially used by the energy project. This is calculated by multiplying the "LFG generation - Theoretical" times "LFG collection efficiency."

## **Heating value of LFG**

The user enters the heating value of the landfill gas. The heating value of the landfill gas is based on the concentration of methane in the landfill gas since methane is the primary component of landfill gas that contributes to the gas's heating value.

Typical landfill gas consists of 50% methane and 50% carbon dioxide and has a heating value of about 18.5 MJ/m<sup>3</sup>.

## **LFG - CH<sub>4</sub> emission factor**

The model calculates the methane (CH<sub>4</sub>) emission factor for the landfill gas generated at the landfill site. This value is used to calculate the base case greenhouse gas (GHG) emissions resulting from the portion of the LFG that is not flared.

## **Energy project**

### **LFG fuel consumption start year**

The user enters the first year that the landfill gas will be used as a fuel for the energy project.

## **Project life**

The user enters the project life in the *Financial Summary* worksheet, and it is copied automatically to the *Tools* worksheet.

## **Units**

The user selects the type of units (energy or volume) from the drop-down list that the results of this sub-section will be displayed in.

## **Fuel required - average**

The model calculates the average landfill gas fuel required per hour by the type of energy equipment entered by the user on the *Equipment Selection* worksheet.

See the following figure:

[Fuel Required - Average](#)

## **LFG fuel potential**

The model calculates the landfill gas fuel potential per hour, up to a maximum amount equal to the "Fuel required - average" as calculated in the cell above.

The percentage of LFG fuel potential over the average fuel required is also calculated.

See the following figure:

[LFG Fuel Potential](#)

## Remaining fuel required

The model calculates the average remaining fuel required per hour by the type of energy equipment entered by the user on the *Equipment Selection* worksheet. This is the amount of fuel required that cannot be met by the landfill site and must come from other sources of fuels (e.g. natural gas).

The percentage of remaining fuel required over the average fuel required is also calculated.

See the following figure:

[Remaining Fuel Required](#)

## Fuel required - annual

The model calculates the annual landfill gas fuel required for the proposed case energy project.

See the following figure:

[Fuel Required - Annual](#)

## LFG fuel potential - annual

The model calculates the annual LFG fuel potential, which is the annual average amount of landfill gas generated from waste in the landfill site, and that is collected by the landfill gas collection system.

See the following figure:

[LFG Fuel Potential - Annual](#)

## Landfill gas generation rate graph

The Landfill gas generation rate graph shows the theoretical and potential landfill gas generation rate of the landfill, as well as the landfill gas fuel required by the energy project, over the lives of both the landfill and the energy project.

## **GHG analysis**

### **LFG system - Base case**

The user selects the type of base case landfill gas collection system from the drop-down list ("Not collected" and "Flared").

### **Percent of LFG flared - Base case**

The user enters the amount of landfill gas flared in the base case scenario. This value is used to calculate the base case GHG emissions from the landfill site.

### **LFG flared - Base case**

The model calculates the annual average amount of landfill gas flared in the base case scenario during the energy project life.

### **LFG flared - Proposed case**

The model calculates the annual average amount of landfill gas flared in the proposed case scenario during the energy project life. This is the annual average amount of landfill gas generated from waste in the landfill site, collected by the landfill gas collection system but not used as fuel by the proposed case energy project, and therefore is instead flared.

### **CO<sub>2</sub> emission factor**

The user enters the carbon dioxide (CO<sub>2</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

For landfill gas fuels, it is reasonable to assume that this value will be equal to zero for the purpose of preparing a greenhouse gas analysis.

### **CH<sub>4</sub> emission factor**

The user enters the methane (CH<sub>4</sub>) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

In the absence of project specific data, a value of 0.0036 for HHV and 0.0040 for LHV provides a reasonable first estimate.

## **N<sub>2</sub>O emission factor**

The user enters the nitrous oxide (N<sub>2</sub>O) emission factor for the fuel. It represents the mass of greenhouse gas emitted per unit of energy generated. Units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ).

In the absence of project specific data, a value of 0.0009 for HHV and 0.0010 for LHV provides a reasonable first estimate.

**Note:** At this point the user should return to the *Equipment Selection* worksheet.

## **As fired fuel**

This tool is used to convert the fuel consumption and fuel rate values for the fuels selected by the user from the "Fuel type" drop-down list in the *Energy Model, Load & Network, Equipment Selection* and/or *GHG Analysis* worksheets, from a "dry basis" to "as fired" values.

## **Fuel type**

The user selects the fuel type(s) from the "Fuel type" drop-down lists in the *Energy Model, Load & Network, Equipment Selection* and/or *GHG Analysis* worksheets, and the fuel type(s) is copied automatically to the *Tools* worksheet.

## **Fuel consumption - unit**

The model displays the unit used for the fuel type(s) selected.

## **Fuel consumption**

The model displays the annual fuel consumption for the fuel type(s) selected. The fuel consumption is on a "dry basis" (i.e. excluding moisture).

## **Fuel rate**

The model displays the fuel rate (price per unit fuel) for the fuel type(s) selected. The fuel rate is on a "dry basis" (i.e. excluding moisture).

## **Fuel cost**

The model displays the annual fuel cost for the fuel type(s) selected.

## Moisture content wet basis

The user enters the % of moisture on wet basis for the fuel type(s).

For wood, typical values for moisture content range from 10 to 50%, with freshly chipped wood ranging from 40 to 55%. Fuels that have moisture content greater than 50 to 55% normally require drying before they can be used as a fuel.

## Fuel consumption - as fired

The model calculates the as fired annual fuel consumption for the fuel type(s) selected.

## Fuel rate - as fired

The model calculates the as fired fuel rate (price per unit fuel) for the fuel type(s) selected.

## Heating value & fuel rate

This tool is used to convert the heating value and fuel rate into alternative units for the fuel selected by the user from the "Fuel type" drop-down list.

## Fuel type

The user selects the fuel type from the drop-down list.

## Heating value

The model displays the heating value for the fuel type selected. A drop-down list is also provided to allow the user to view the heating value in alternative units.

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.

Depending on the selection of "Higher or Lower heating value" at the top of the *Energy Model* worksheet, the relevant heating value will be displayed.

## Fuel rate

The user enters the fuel rate (price per unit fuel) for the fuel type selected, and the model calculates the fuel rate in alternative units.

## Unit conversion

This tool is used to convert one chosen unit to another. The conversion is based on the conversion factors in the table.

### Heat rate

This tool is used to calculate the heat rate, heat recovery efficiency and/or the total system efficiency of a Combined Heat and Power (CHP) plant, using three separate methods that are based on various types of information normally available from product suppliers or system designers.

See one of the following figures:

[CHP Plant Heat Rate and Heat Recovery Calculation Efficiency Calculation](#)

### Power capacity

The user enters the power capacity (electricity generation) of the power equipment.

### Fuel required

In Method 1, the user enters the hourly fuel required by the power equipment. For Method 2 and 3, the model calculates the hourly fuel required based on the system's heat rate.

### Heating capacity

In Method 1 and 2, the user enters the power equipment's heating capacity (i.e. usable thermal output). The heating capacity of the power equipment is used to calculate the heat recovery efficiency. For Method 3, the heating capacity is calculated from the heat recovery efficiency.

<b>Distance</b>			
1 in	=	0,0254 m	(exact)
1 ft	=	0,3048 m	(exact)
1 mi	=	5 280 ft	(exact)
<b>Area</b>			
1 ft <sup>2</sup>	=	0,092903 m <sup>2</sup>	(exact)
1 acre	=	43 560 ft <sup>2</sup>	(exact)
1 mi <sup>2</sup>	=	27 878 400 ft <sup>2</sup>	(exact)
1 ha	=	10 000 m <sup>2</sup>	(exact)
<b>Volume</b>			
1 m <sup>3</sup>	=	1 000 L	(exact)
1 in <sup>3</sup>	=	0,01638 L	(exact)
1 US gal	=	231 in <sup>3</sup>	(exact)
1 imp gal	=	4,54609 L	(exact)
1 ft <sup>3</sup>	=	1,728 in <sup>3</sup>	(exact)
1 barrel	=	42 US gal	(exact)
1 yard <sup>3</sup>	=	27 ft <sup>3</sup>	(exact)
<b>Weight</b>			
1 t	=	1 000 kg	(exact)
1 lb	=	0,4536 kg	(exact)
<b>Pressure</b>			
1 bar	=	100 kPa	(exact)
1 bar	=	14,5038 psia	(exact)
1 atm	=	101,3250 kPa	(exact)
1 atm	=	760,0000 mm Hg (0 °C)	(exact)
1 atm	=	29,9213 in Hg (0 °C)	(exact)
1 atm	=	10,3323 m H <sub>2</sub> O (4 °C)	(exact)
1 atm	=	33,8986 ft H <sub>2</sub> O (4 °C)	(exact)
<b>Temperature</b>			
°C	=	(°F - 32) / 1.8	(exact)
°F	=	°C * 1.8 + 32	(exact)
0 K	=	- 273.15 °C	(exact)
<b>Power (load)</b>			
1 Btu/h	=	0,2931 W	(exact)
1 kW	=	3 600 kJ/h	(exact)
1 hp (electric)	=	746 W	(exact)
1 hp (boiler)	=	9 809,5 W	(exact)
1 RT	=	12 000 Btu/h	(exact)
<b>Energy (demand)</b>			
1 Btu	=	1,0551 kJ	(exact)
1 kcal	=	4,1868 kJ	(exact)
1 kWh	=	3 600 kJ	(exact)
<b>Heating value</b>			
1 MJ/kg	=	429,9226 Btu/lb	(exact)
1 MJ/kg	=	238,8459 kcal/kg	(exact)
<b>Emission factor</b>			
1 kg/GJ	=	0,0036 kg/kWh	(exact)
1 kg/GJ	=	0,0036 t/MWh	(exact)
1 lb/MWh	=	0,1260 kg/GJ	(exact)
1 kg/GJ	=	2,3260 lb/million Btu	(exact)
<b>Load</b>			
1 W/m <sup>2</sup>	=	0,3170 Btu/ft <sup>2</sup>	(exact)
1 W/m <sup>2</sup>	=	37 855,0889 ft <sup>2</sup> /RT	(exact)
1 W/m <sup>2</sup>	=	0,0264 RT/1000 ft <sup>2</sup>	(exact)

Conversion Factors

## Heat rate

In Method 1, the heat rate is calculated from the fuel required divided by the power capacity. For Method 2 and 3, the user enters the heat rate.

## Heat recovery efficiency

In Method 1 and 2, the heat recovery efficiency is calculated from the heating capacity, the power capacity and the fuel required. For Method 3, the user enters the heat recovery efficiency to calculate the heating capacity.

## Efficiency

In Method 1, the model calculates the total system efficiency of a Combined Heat and Power (CHP) plant by dividing the recovered energy from the fuel (for power and heating) by the fuel required.

## Electricity rate - time of use

This tool is used to determine the average electricity rate based on information from a time of use electricity bill.

The user enters values for peak and off peak rates, for two different seasons, and for weekdays or weekends, during the day and/or at night. The user enters the rate structure and estimated average load for the different periods. The model then calculates the total cost of electricity for the year, the annual electricity demand and the average electricity rate for the year. This electricity rate can be used for the base case and/or proposed case system, depending on the project circumstances.

## Begin

The user enters the begin date in day and month (dd/mm) for the first season as defined by the electric utility rate structure. The model then assumes that the remaining days not covered in the first season belong to the second season.

The user then enters the begin time for the various rate periods in this column. The time can be entered using the 24 hour clock or by AM/PM method (14:00 can also be entered as 2 PM).

## End

The user enters the end date in day and month (dd/mm) for the first season as defined by the electric utility rate structure. The model then assumes that the remaining days not covered in the first season belong to the second season.

The user then enters the end time for the various rate periods in this column. The time can be entered using the 24 hour clock or by AM/PM method (14:00 can also be entered as 2 PM).

## **Hours**

The model calculates the number of hours in each rate period.

## **Capacity charge**

The user enters the capacity charge for the various rate periods, for peak rates only.

## **Energy charge**

The user enters the energy charge for the various rate periods.

## **Average load**

The user enters the estimated average load during the various rate periods.

## **Electricity demand - time of use**

The model calculates the estimated electricity demand in for the various rate periods by multiplying the average load for the period by the number of hours for the week.

## **Electricity cost**

The model calculates the estimated electricity cost for the various rate periods on a weekly basis, by multiplying the electricity demand by the energy charge. The capacity charge is calculated separately and included in the annual total electricity cost.

## **Fixed charge - monthly**

The user enters the monthly fixed charge.

## **System peak electricity load over max monthly average**

The user enters the system peak electricity load over maximum monthly average load, which represents the percentage that the peak electricity load exceeds the maximum monthly average load over the twelve-month period.

## **Total electricity cost**

The model calculates the total annual electricity cost.

## **Electricity demand**

The model calculates annual electricity demand.

## **Electricity rate**

The model calculates average electricity rate for the year. This electricity rate can be used for the base case and/or proposed case system, depending on the project circumstances.

## **Electricity rate - monthly**

This tool is used to determine the average electricity rate for the base case power system, based on information from a monthly electricity bill.

The user enters monthly values for electricity demand for up to four different rate periods, the peak load for the month, the monthly fixed charge and the total electricity cost for the month. The model then calculates the average load for each month, the system peak electricity load over maximum monthly average, the annual peak load, the annual electricity demand, and the base case electricity rate. These values can then be used in the "Base case load characteristics" section of the *Load & Network* worksheet to help the user complete the analysis.

## **Rate - kWh**

The user enters the electricity demand per month, for each relevant rate period.

## **Peak load**

The user enters the peak electricity load per month.

## **Fixed charge - monthly**

The user enters the fixed charge per month.

## **Total electricity cost**

The user enters the total electricity cost per month.

## Average load

The model calculates the average electricity load per month by dividing the electricity demand by the number of hours per month. These values can then be used in the "Base case load characteristics" section of the *Load & Network* worksheet, in the "Power gross average load" column, to help the user complete the analysis.

## System peak electricity load over max monthly average

The model calculates the system peak electricity load over maximum monthly average load, which represents the percentage that the peak electricity load exceeds the maximum monthly average load over the twelve-month period. This value can then be used in the "Base case load characteristics" section of the *Load & Network* worksheet to help the user complete the analysis.

## Peak load - annual

The model calculates the annual peak load.

## Electricity demand

The model calculates annual electricity demand.

## Electricity demand difference

The model displays the difference in calculations between annual electricity demand entered by the user from the monthly electricity bills, and the amount calculated by the model using average load and peak load values on a monthly basis. The user should use the "Electricity demand correction factor" in the next cell to make this difference reasonably insignificant (e.g. 1 to 2%).

## Electricity demand correction factor

The user should enter values in an iterative process until the "Electricity demand difference" value calculated in the cell above is reasonably insignificant (e.g. 1 to 2%). The Goal Seek function in Excel cannot be used for this calculation.

## Electricity rate - base case

The model calculates the average electricity rate for the base case power system. This value can then be used in the "Base case load characteristics" section of the *Load & Network* worksheet to help the user complete the analysis.

## Water & steam

This tool is used to calculate the properties of water and steam. These values are calculated using "The International Association for the Properties of Water and Steam, Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam." Entropy and enthalpy, for a fluid stage, are calculated using Equation 7, and for a vapour stage using Equation 15, 18 and 19, both as a function of pressure and temperature. Finally, the saturation temperature is calculated using Equation 31 as a function of pressure.

## Water temperature

The user enters the water temperature and the model calculates the enthalpy at the selected temperature, in kJ/kg.

## Enthalpy difference

The model calculates the enthalpy difference for the two selected vapor states, in kJ/kg.

## Steam pressure

The user enters the steam pressure.

## Saturation temperature

The model calculates the steam saturation temperature. The saturation temperature is the boiling point at the selected steam pressure.

## Steam temperature

The user enters the steam temperature and the model calculates the enthalpy at the selected temperature, in kJ/kg. If superheated steam is not considered enter the saturation temperature.

## GHG equivalence

This tool is used to compare the Net annual GHG emission reduction with units that are easier to conceptualise (e.g. Cars & light trucks not used), using the drop-down list. These numbers are based on North American energy use patterns. The user can compare the "Net annual GHG emission reduction" calculated on the *GHG Analysis* worksheet, which are given in equivalent tonnes of CO<sub>2</sub> emissions per year (tCO<sub>2</sub>/yr) by pasting the value in the cell.

## Custom (1 to 3)

These tools are provided to allow the user to prepare custom tools for RETScreen. Three *Blank Worksheets* are also provided in a similar fashion. These custom tools and blank worksheets can be used, for example, to enter more details about the project, to prepare graphs, to perform a more detailed sensitivity analysis and to create a custom database. The user may also use these custom tools and/or worksheets to develop a companion model to RETScreen.

## Product Data

Some of the product data requirements for the model are provided in the RETScreen Online Product Database. To access the product database specific to the type of system being considered, the user should click on the "blue-underlined" hyperlink next to the entry cell that says "see product database" or "see PDB." The product database provides information on the equipment associated with the project. From the online product database dialogue box the user may obtain product specification and performance data, as well as company contact information.

The product database sorting routine starts by using the system being designed and "Type" selected by the user in the *Energy Model* or *Equipment Selection* worksheet. From the dialogue box the user selects, for example, the Manufacturer, Model and the number of units. The data can be pasted from the dialogue box to the spreadsheets by clicking on the "Paste Data" button. Only data that are in **bold** are pasted to the spreadsheets; all other data are provided for reference purposes only. Data entered using the product database may be **overwritten**; i.e. the user may prefer to use other data and can manually enter values into the spreadsheets. "Other information" such as product fuel type is provided to help the user prepare the study. The product database contains a link to the Websites of some product suppliers. In the case where the Website link cannot be activated the user should try using another browser.

Note that the capacity provided in the product database for some technologies (e.g. reciprocating engines) is an indication only and needs to be verified with the manufacturer for each specific application. Reciprocating engines, for example, are rated for ISO conditions (15°C, 101.3 kPa and 60% relative humidity) and for specific fuels; therefore, the type of fuel used and the site conditions, such as humidity, temperature and altitude will have an effect on the actual capacity. Also, an engine can run at a higher output than rated capacity, but it will have a shorter lifespan and will require more maintenance. For shorter projects, a higher capacity can be entered in the model since the rated capacity typically includes a derating factor.

**Note:** To see all the suppliers listed in the product database and their contact information, the user can open the product database using the icon in the RETScreen menu bar or toolbar.

The product database is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of any commercial product or person. Neither Canada nor its ministers, officers, employees or agents make any warranty in respect to this database or assumes any liability arising out of this database.

Product manufacturers interested in having their products listed in the product database can reach RETScreen® International at:

RETScreen® International  
CANMET Energy Technology Centre - Varennes  
Natural Resources Canada  
1615 Lionel-Boulet, P.O. Box 4800  
Varennes, Quebec, CANADA J3X 1S6  
Tel: +1-450-652-4621  
Fax: +1-450-652-5177  
E-mail: [rets@nrcan.gc.ca](mailto:rets@nrcan.gc.ca)

## Weather Data

This database includes some of the weather data required in the model. To access the weather database the user may refer to "Data & help access." While running the software the user may obtain weather data from **ground monitoring stations** and/or from **NASA's satellite data**. Ground monitoring stations data is obtained by making a selection for a specific location from the online weather database dialogue box. Data sets from NASA are obtained via the "Visit NASA Satellite Data Site" button in the dialogue box.

### Ground monitoring stations data

From the dialogue box, the user selects the Country, then the Sub-region (provinces in Canada, states in the United States of America and n/a in the rest of the countries), and finally a weather station location. The weather station usually corresponds to the name of a city/town within the selected country. In the [Weather Database Map](#), the white dots represent weather stations. From the dialogue box the data can be pasted to the spreadsheets by clicking on the "Paste Data" button. Only data that are in **bold** are pasted to the spreadsheets; all other data are for reference purposes only. Data entered using the online weather database may be **overwritten**; i.e. the user may prefer to use other data and can manually enter values into the spreadsheets. As an alternative the user can use the NASA satellite data, particularly for the case when the project location is not close to the given weather station location.

### NASA global satellite data

A link to the [NASA Surface meteorology and Solar Energy Data Set](#) Website is provided in the online weather database dialogue box. The user is able to select the data required for the model by clicking on a region on the world map illustrated on the NASA Website. The location is narrowed down to a "cell" within a specified latitude and longitude. The user may simply copy and paste this data to the RETScreen spreadsheets or manually enter these values.

NASA and CETC - Varennes are co-operating to facilitate the use of NASA's global satellite solar data with RETScreen and to develop a new global weather database (see [Surface meteorology and Solar Energy Data Set](#) for the tool). This work is sponsored as part of NASA's Earth Science Enterprise Program and is being carried out at the NASA Langley Research Center and at CETC - Varennes. This collaboration provides RETScreen users access (free-of-charge) to satellite data (e.g. the amount of solar energy striking the surface of the earth, global temperatures and wind speeds), simply by clicking on links in either the RETScreen software or the NASA Website. These data had previously only been available from a limited number of ground monitoring stations and are critical for assessing the amount of energy a project is expected to produce. The use of these data results in substantial cost savings for users and increased market opportunities for industry while allowing governments and industry to evaluate regional energy resource potential.

## Cost Data

Typical cost data required to prepare RETScreen studies are provided in the RETScreen Online Cost Database and in the Online Manual. This database is built into the "right-hand column" of the *Cost Analysis* worksheet. Data are provided for Canadian costs with 2005 as a baseline year. The user also has the ability to create a custom cost database.

The user selects the reference (from the *Cost Analysis* worksheet) that will be used as a guideline for the estimation of costs associated with the implementation of the project. This feature allows the user to change the "Quantity range" and the "Unit cost range" columns. The options from the drop down list are: "Canada - 2005," "None" and a selection of 5 user-defined options ("Custom 1," "Custom 2," etc.).

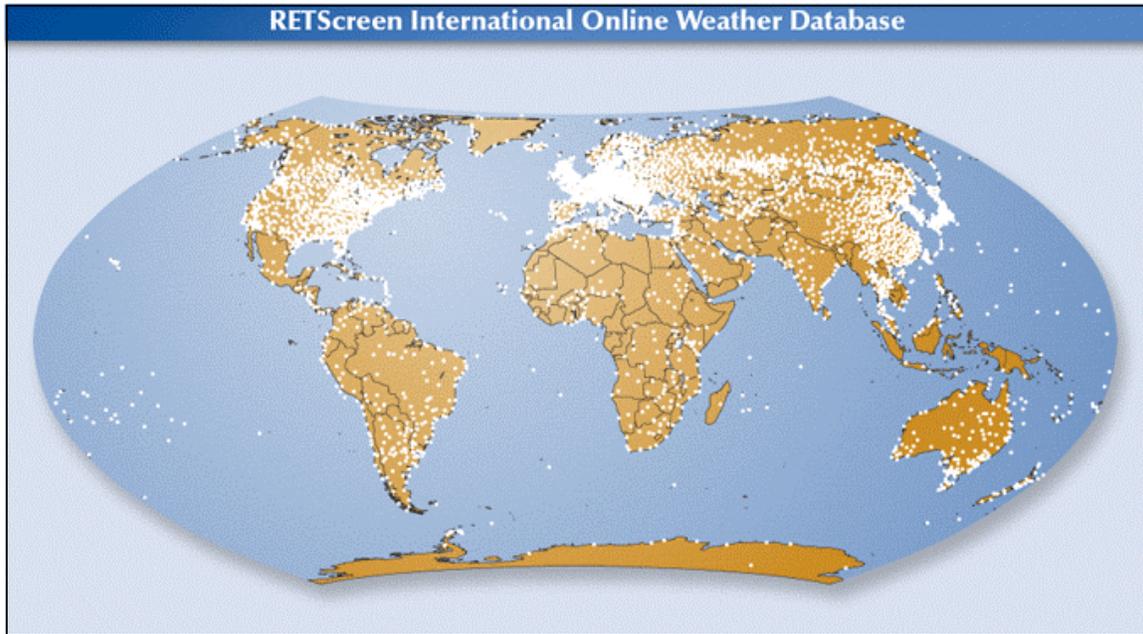
If the user selects "Canada - 2005" the range of values reported in the "Quantity range" and "Unit cost range" columns are for a 2005 baseline year, for projects in Canada and in Canadian dollars.

Selecting "None" hides the information presented in the "Quantity range" and "Unit cost range" columns. The user may choose this option, for example, to minimise the amount of information printed in the final report.

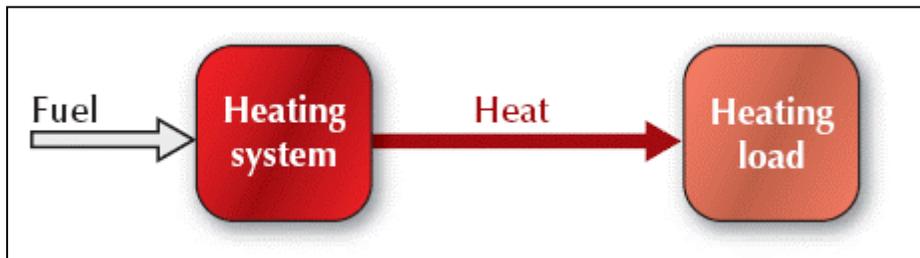
If "Custom 1" (or any of the other 5 selections) is selected, the user may manually enter quantity and cost information that is specific to the region in which the project is located and/or for a different cost base year. This selection thus allows the user to customise the information in the "Quantity range" and "Unit cost range" columns. The user can also overwrite "Custom 1" to enter a specific name (e.g. Japan - 2005) for a new set of unit cost and quantity ranges. The user may also evaluate a single project using different quantity and cost ranges; selecting a new range reference ("Custom 1" to "Custom 5") enables the user to keep track of different cost scenarios. Hence the user may retain a record of up to 5 different quantities and cost ranges that can be used in future RETScreen analyses and thus create a localised cost database.

## Figures & Tables

### Weather Database Map



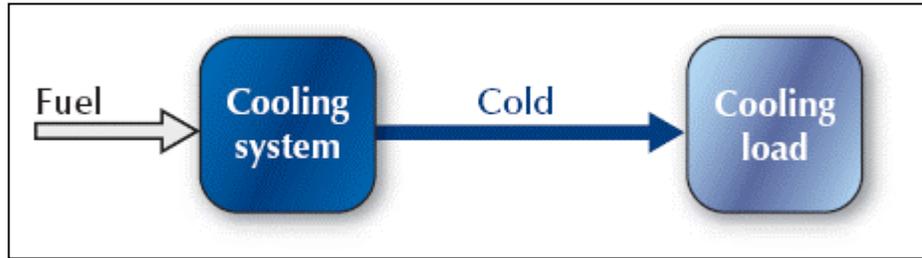
### Heating Only Project



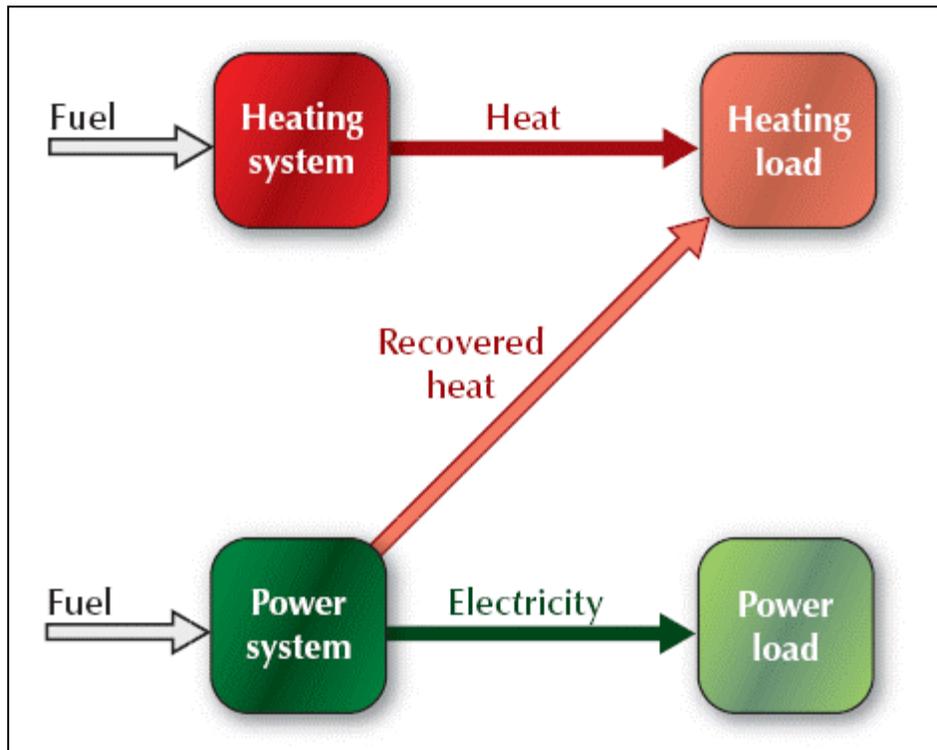
### Power Only Project



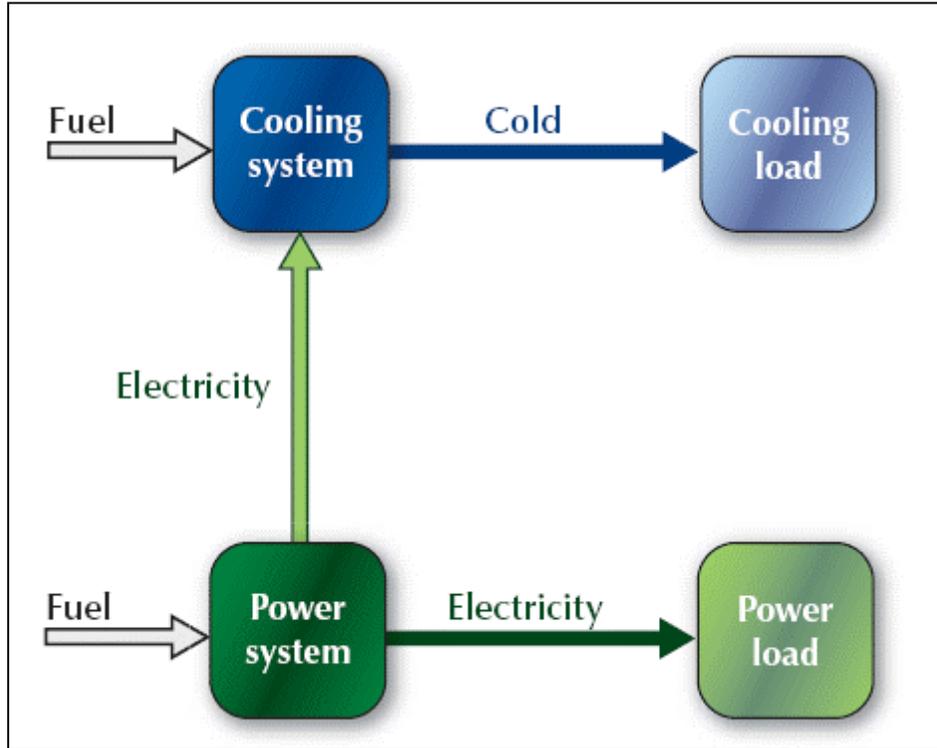
## Cooling Only Project



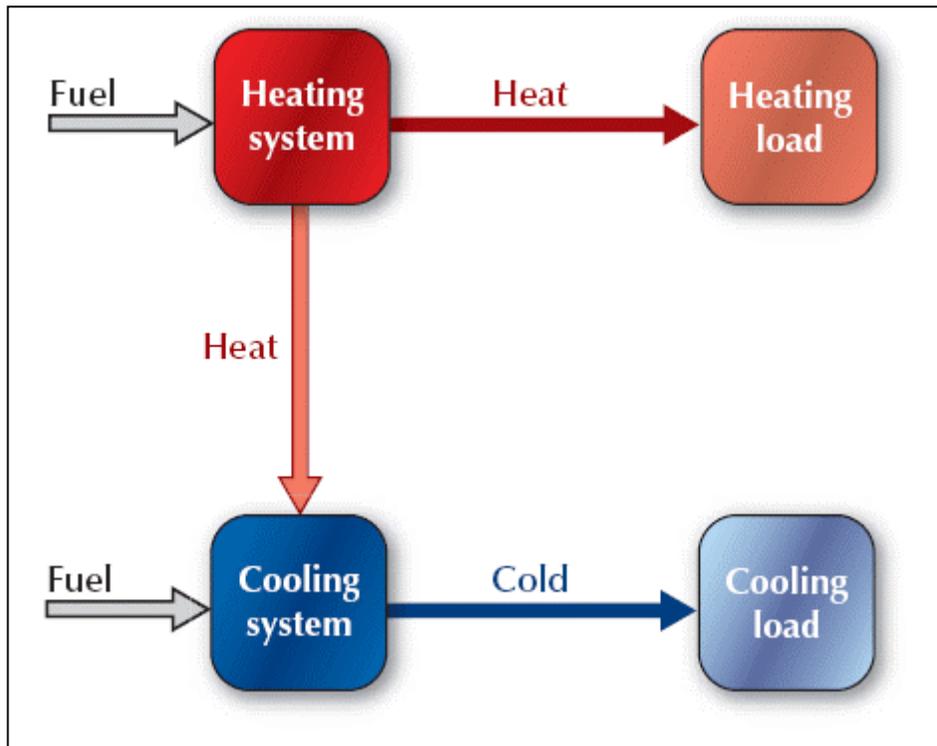
## Combined Heating & Power Project



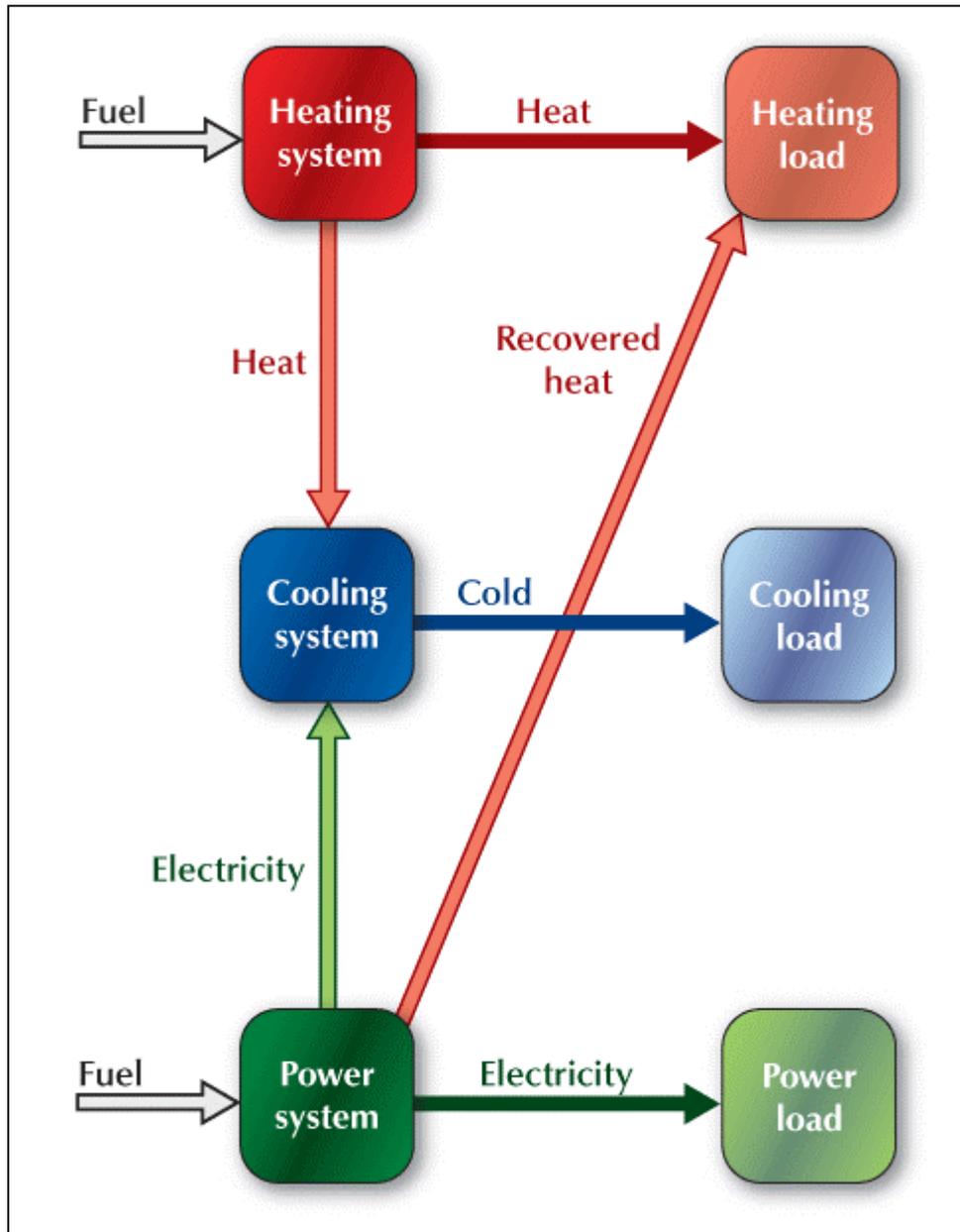
## Combined Cooling & Power Project



## Combined Heating & Cooling Project



## Combined Cooling, Heating & Power Project



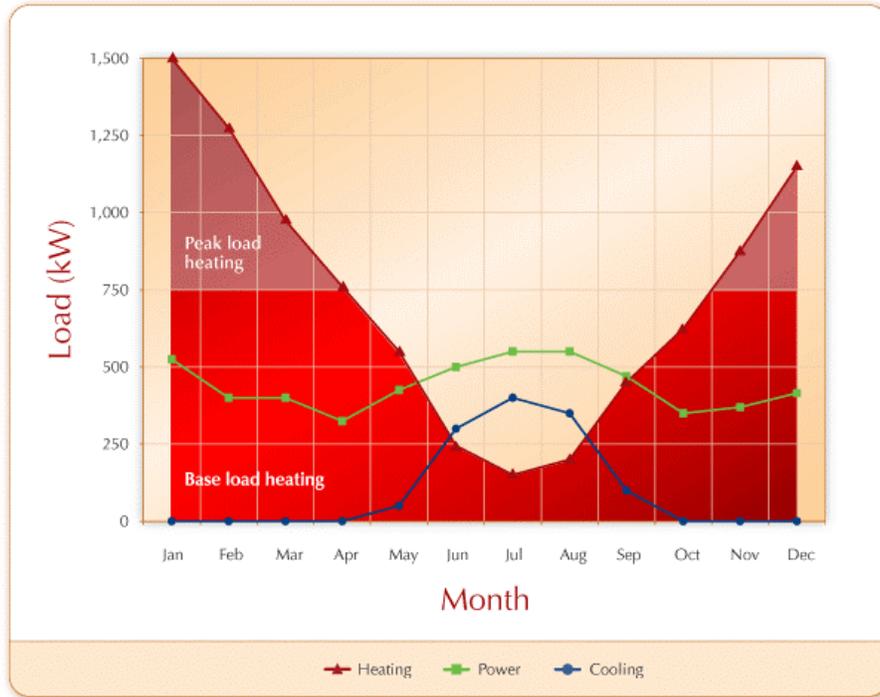
## Power System Load Definition - Base & Peak Load



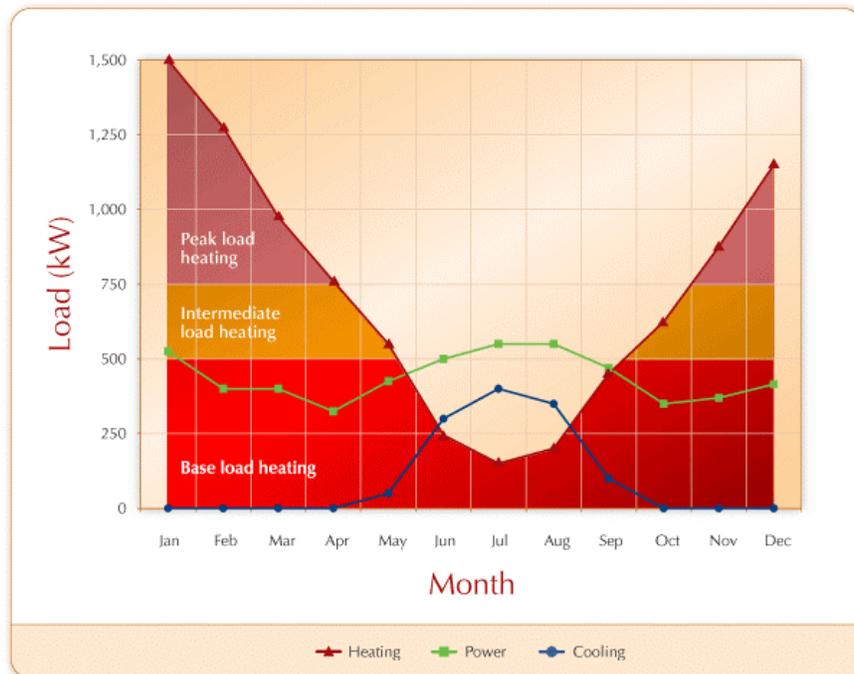
## Power System Load Definition - Base, Intermediate & Peak Load



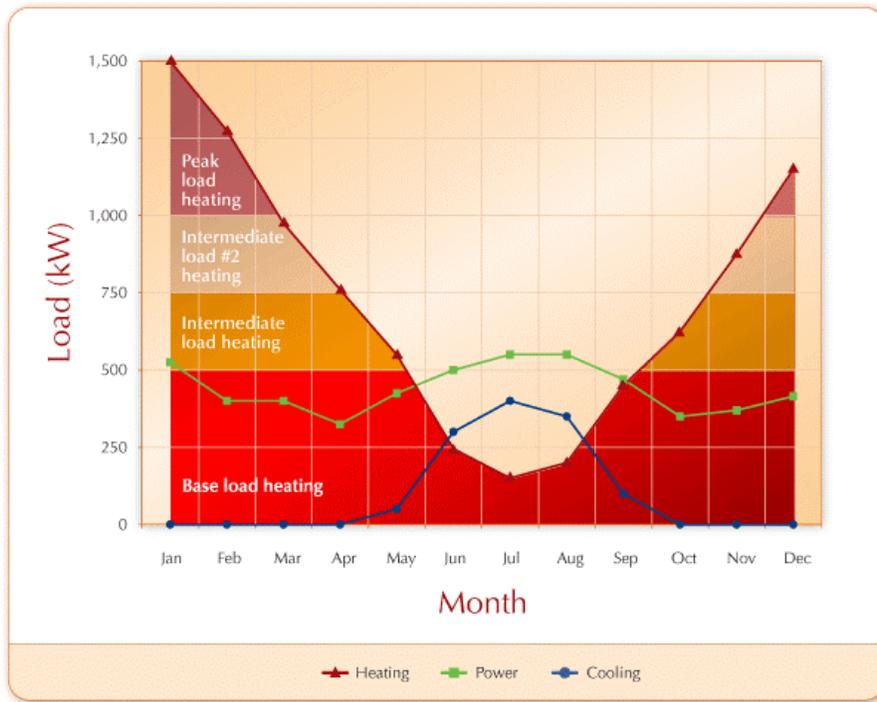
## Heating System Load Definition - Base & Peak Load



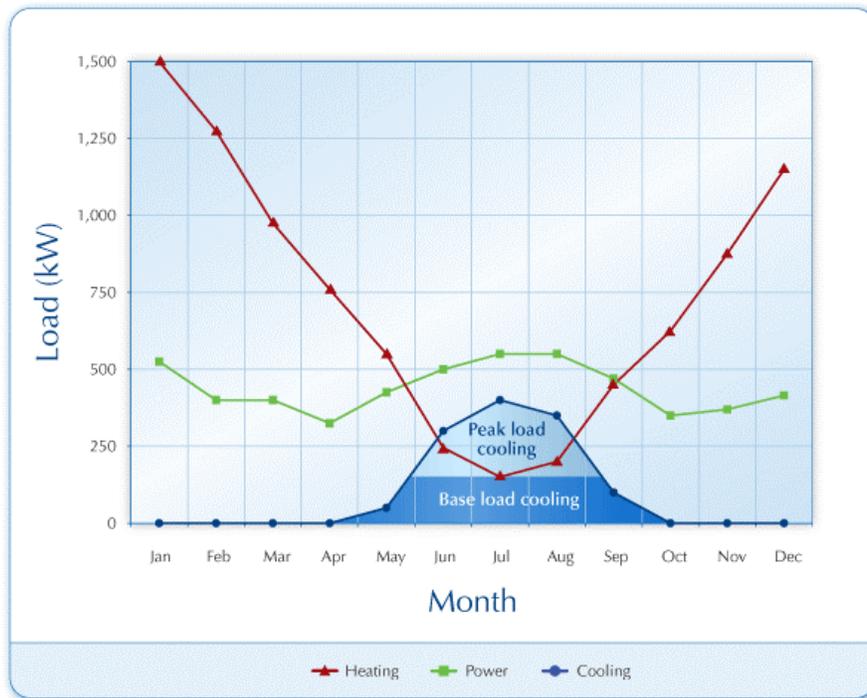
## Heating System Load Definition - Base, Intermediate & Peak Load



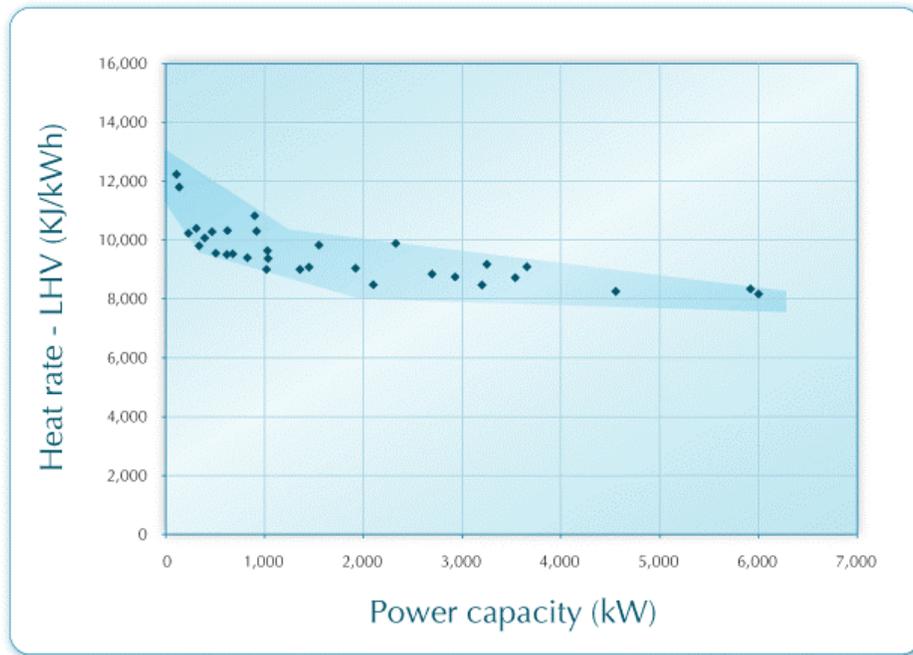
## Heating System Load Definition - Base, Intermediate, Intermediate #2 & Peak Load



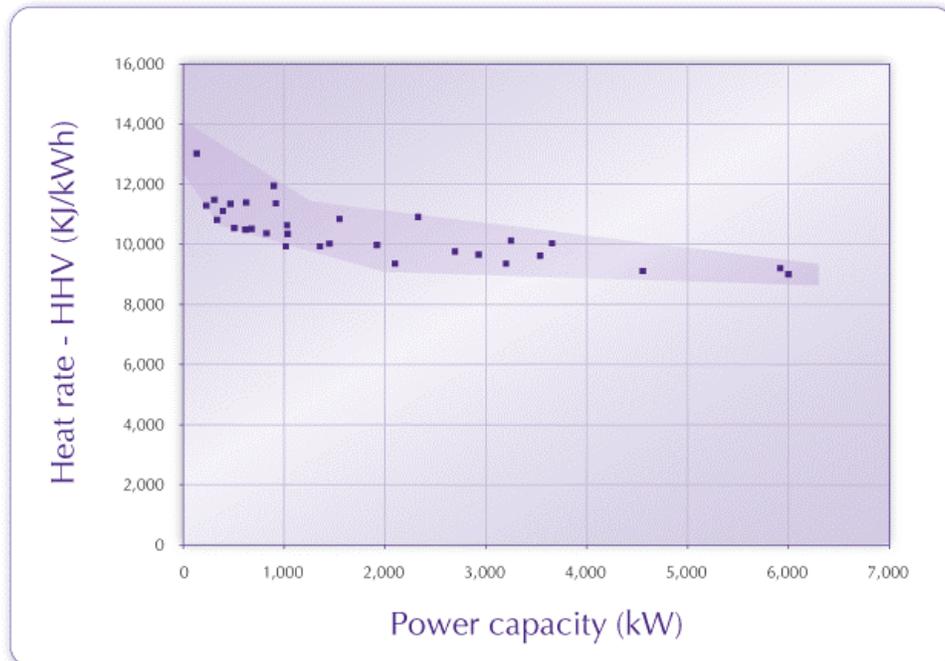
## Cooling System Load Definition



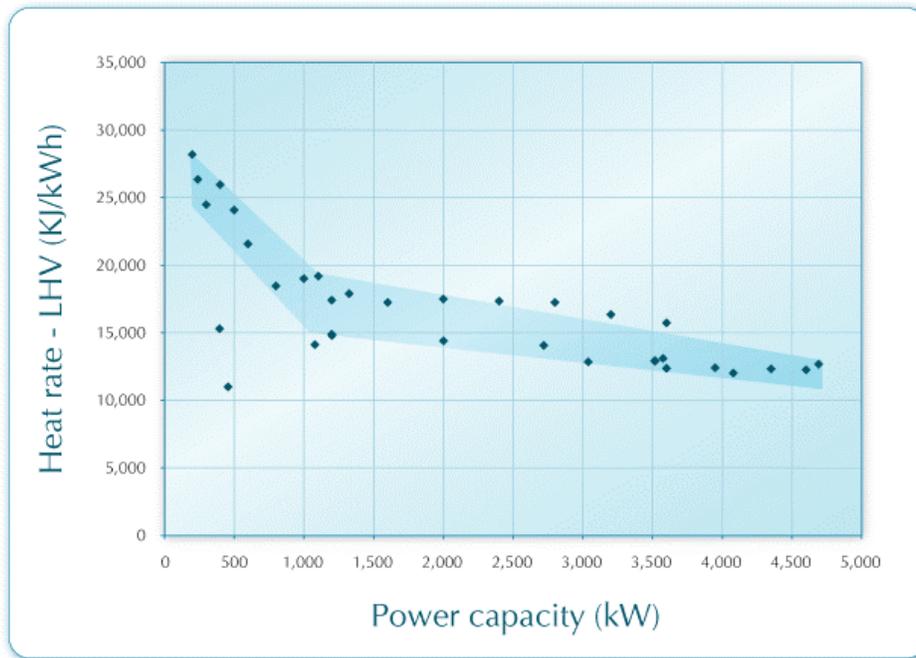
## Typical Heat Rates for Reciprocating Engines - LHV (< 6MW)



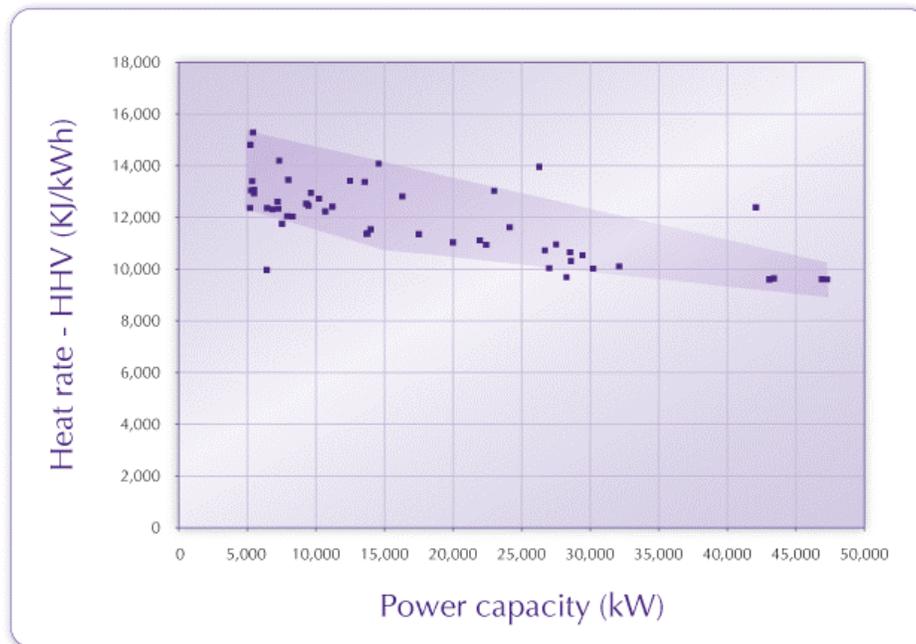
## Typical Heat Rates for Reciprocating Engines - HHV (< 6MW)



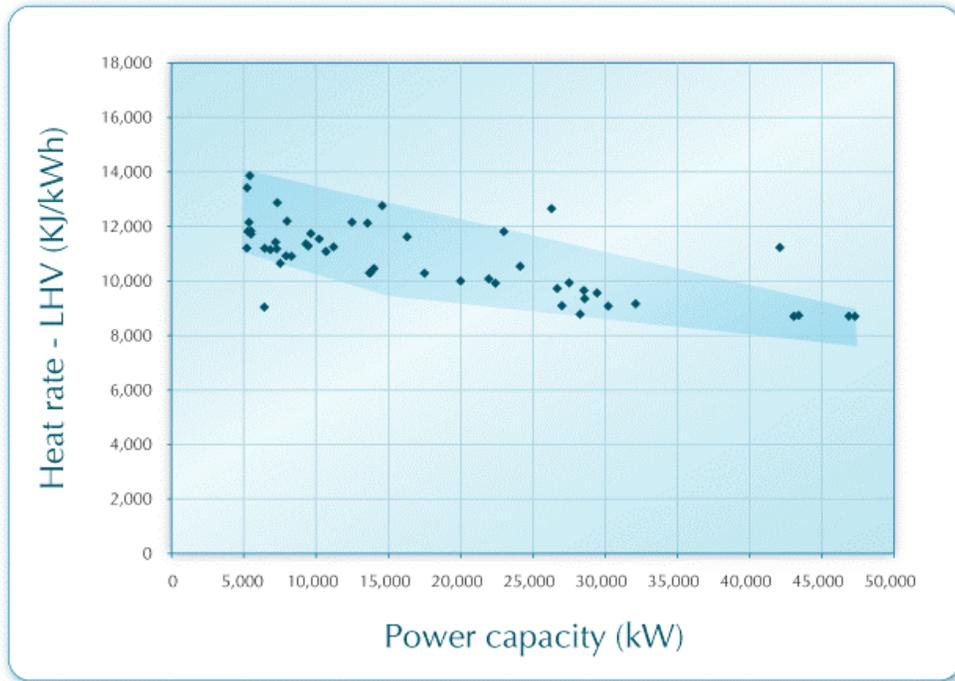
## Typical Heat Rates for Gas Turbines - LHV (< 5 MW)



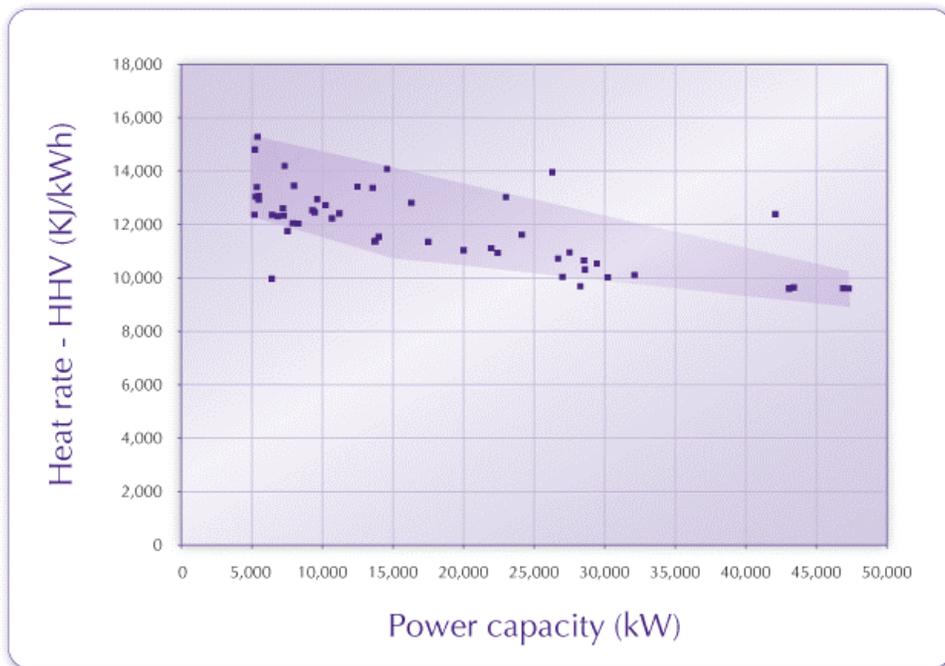
## Typical Heat Rates for Gas Turbines - HHV (< 5 MW)



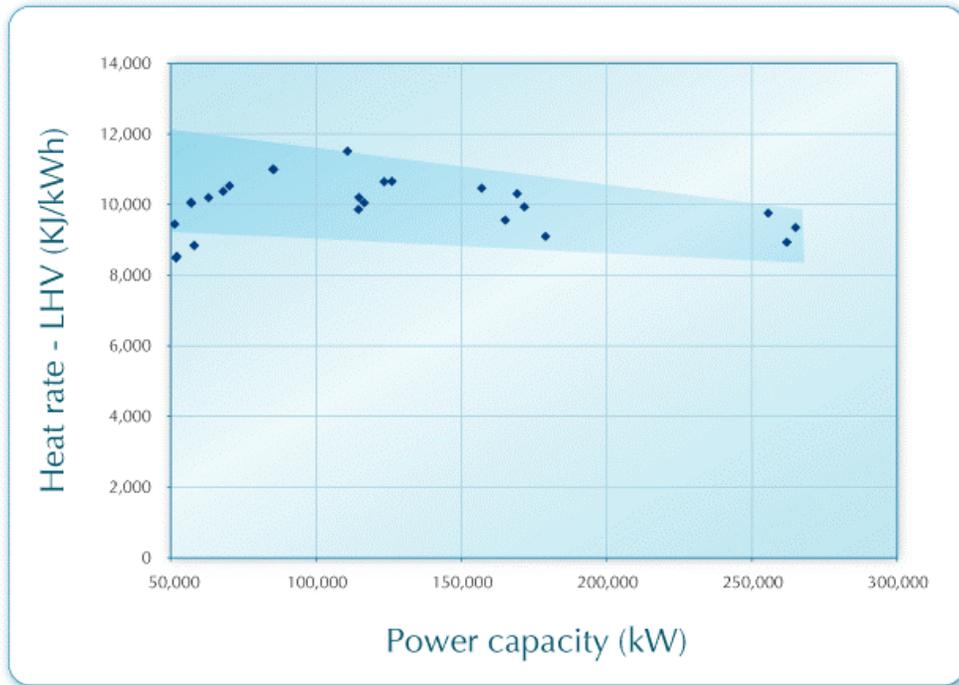
## Typical Heat Rates for Gas Turbines - LHV (5 to 50 MW)



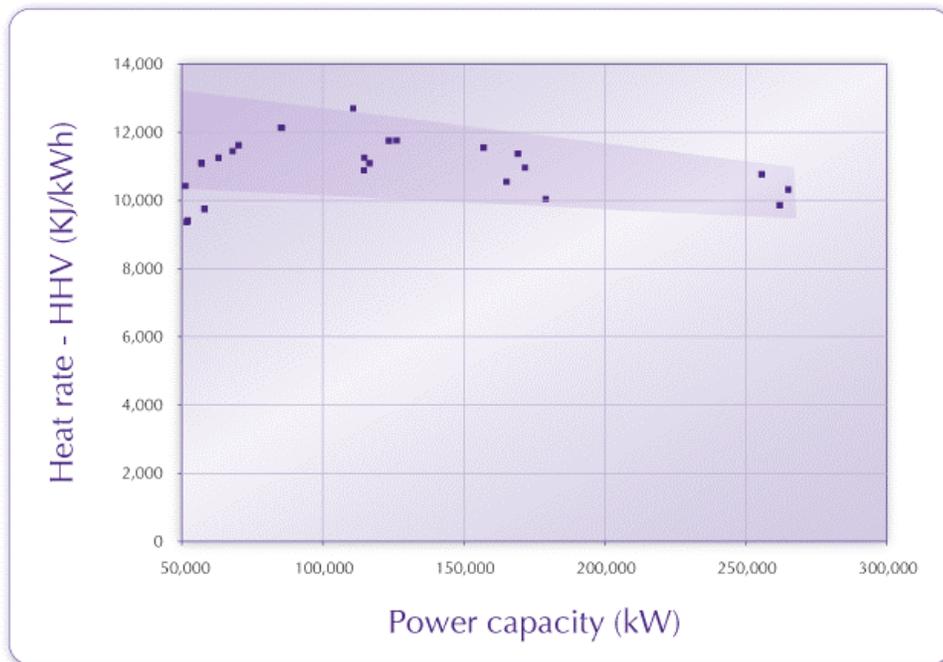
## Typical Heat Rates for Gas Turbines - HHV (5 to 50 MW)



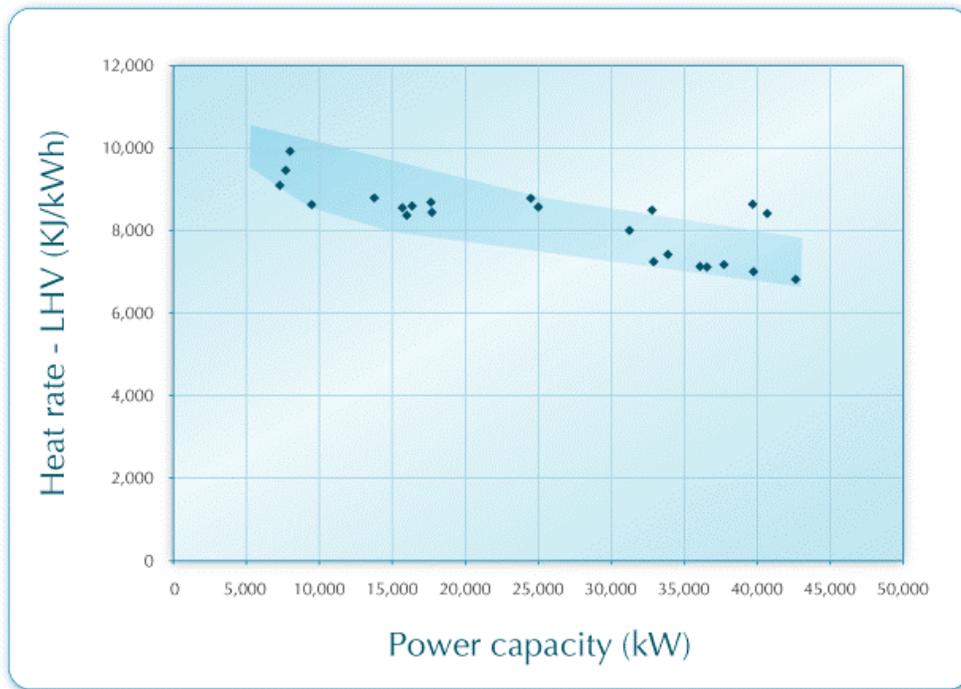
## Typical Heat Rates for Gas Turbines - LHV (50 to 300 MW)



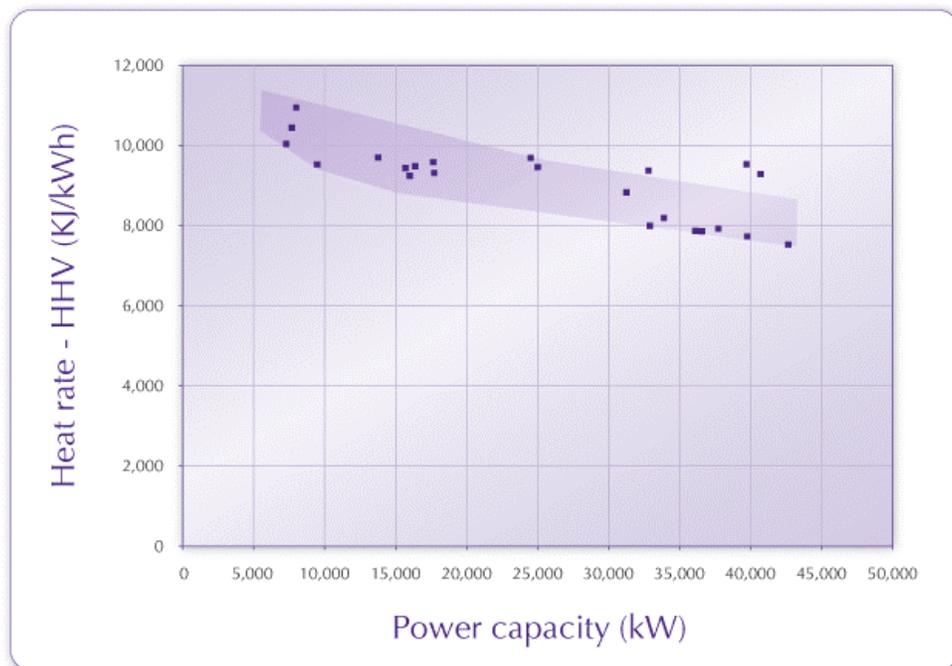
## Typical Heat Rates for Gas Turbines - HHV (50 to 300 MW)



### Typical Heat Rates for Gas Turbines - Combined Cycle - LHV (< 50 MW)



### Typical Heat Rates for Gas Turbines - Combined Cycle - HHV (< 50 MW)





## Fuel Cell Characteristics

Characteristics	System 1	System 2	System 3	System 4	System 5	System 6
Fuel cell type	PAFC <sup>1</sup>	PEMFC <sup>2</sup>	PEMFC <sup>2</sup>	MCFC <sup>3</sup>	MCFC <sup>3</sup>	SOFC <sup>4</sup>
Power capacity (kW)	200	10	200	250	2,000	100
Commercial status in 2002	Com'l	Demo	Demo	Demo	Demo	Demo
Operating temperature (°C)	204	66	66	649	649	954
Fuel required (kW)	557	29	571	580	4,336	222
Heating capacity >65°C (kW)	108	0	0	64	554	29
Heating capacity <65°C (kW)	108	12	211	64	489	26
Heat rate (kJ/kWh)	10,015	10,542	10,278	8,360	7,801	7,991
Heat recovery efficiency >65°C	30.4%	0.0%	0.0%	19.5%	23.7%	24.0%

<sup>1</sup>PAFC: Phosphoric acid fuel cell

Source: Environmental Protection Agency, 2002

<sup>2</sup>PEMFC: Proton exchange membrane fuel cell

<sup>3</sup>MCFC: Molten carbonate fuel cell

<sup>4</sup>SOFC: Solid oxide fuel cell

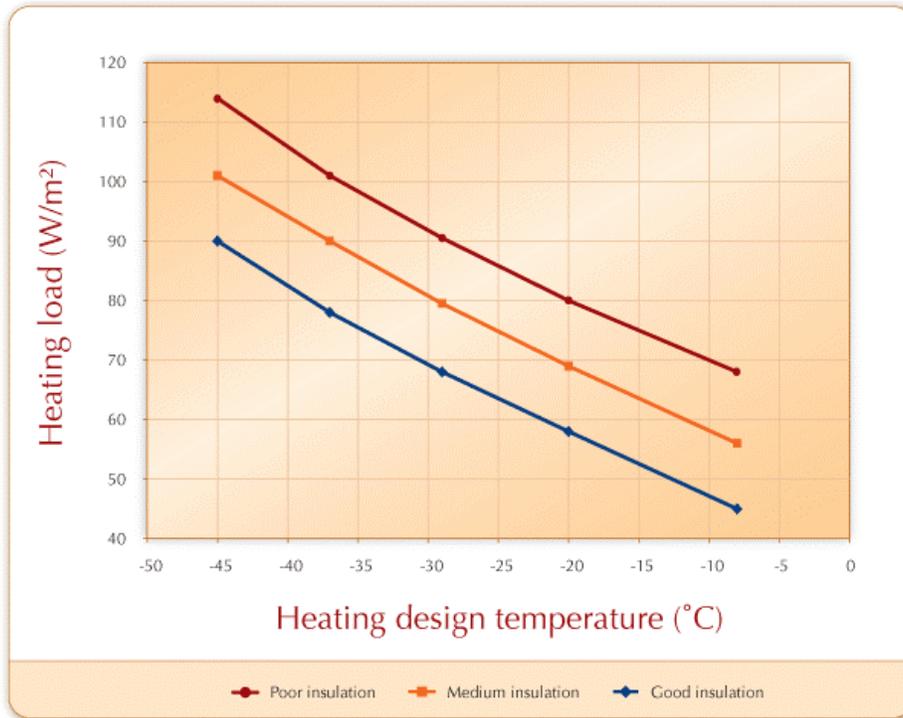
## Typical Seasonal Efficiencies of Heating Systems

Heating system type	Typical annual heating system efficiency
Standard boiler/furnace (with pilot light)	55 to 65%
Mid efficiency boiler/furnace (spark ignition)	65 to 75%
High efficiency or condensing boiler/furnace	75 to 85%
Electric resistance	100%
Heat pump - air-source	130 to 200%
Heat pump - ground source	250 to 350%

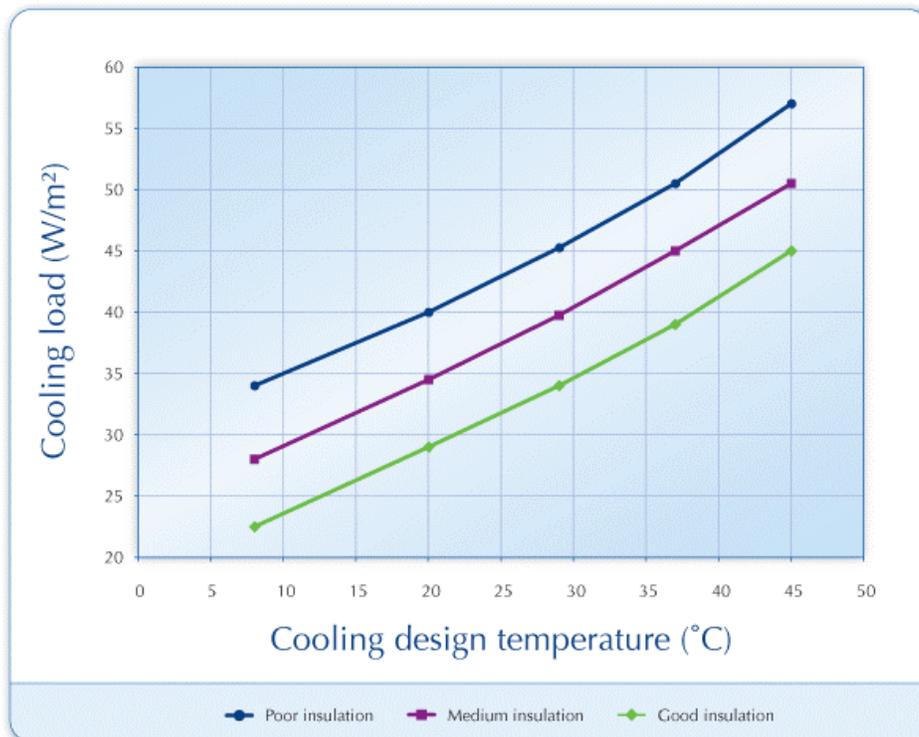
## Typical Seasonal Efficiencies of Cooling Systems

Cooling system type	Typical annual cooling system efficiency
Compressor - centrifugal	500 to 670%
Compressor - reciprocating	380 to 460%
Compressor - screw	410 to 560%
Compressor - scroll	460 to 700%
Heat pump - gas	110%
Heat pump - air-source	130 to 200%
Heat pump - ground-source	300 to 350%
Absorption - single stage	50%
Absorption - two stage	70%
Steam jet refrigeration	20 to 30%

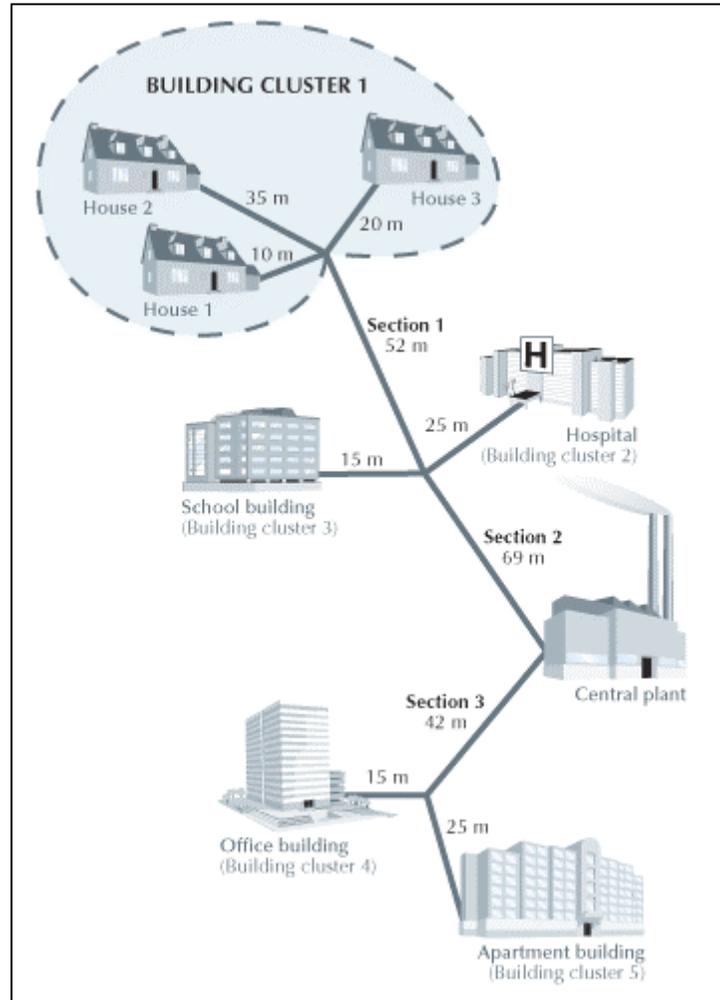
## Building Heating Load Chart



## Building Cooling Load Chart



## Community System Building Cluster Layout



## Base Case Heating System

Heating project		Unit							
<b>Site conditions</b>			<b>Estimate</b>		<b>Notes/Range</b>		<b>Monthly inputs</b>		
Nearest location for weather data		Stockholm			See <a href="#">Weather Database</a>		Month	°C-d	
Heating design temperature	°C	-19.4			-40 to 15 °C		January	<18°C	
Annual heating degree-days below 18°C	°C-d	4,239			Complete <a href="#">Monthly inputs</a>		February	596	
Domestic hot water heating base demand	%	10%			0% to 25%		March	564	
Equivalent degree-days for DHW heating	°C-d/d	1.3			0 to 10 °C-d/d		April	411	
Equivalent full load hours	h	2,278							
<b>Base case heating system</b>			Multiple buildings - space heating						
<a href="#">See technical note on heating network design</a>					<b>Building clusters</b>				
Heated floor area per building cluster	m²	4,650			1	2	3	4	5
Number of buildings in building cluster	building	7			450	900	800	1,000	1,500
Fuel type					3	1	1	1	1
Seasonal efficiency	%	-			Diesel (#2 oil) - L	Diesel (#2 oil) - L	Electricity	Propane - L	User-defined fuel
<b>Heating load calculation</b>					65%	65%	100%	70%	60%
Heating load for building cluster	W/m²	-			70	90	70	65	100
Total heating demand	MWh	873			72	184	128	148	342
Total peak heating load	kW	383.5			31.5	81.0	56.0	65.0	150.0
Fuel consumption - unit		-			L	L	MWh	L	MWh
Fuel consumption - annual		-			10,354	26,624	128	28,655	569
Fuel rate - unit		-			\$/L	\$/L	\$/kWh	\$/L	\$/MWh
Fuel rate		-			0.600	0.600	0.150	0.180	11.000
Fuel cost	\$	52,740			\$	6,212	\$	15,974	\$
<b>Proposed case energy efficiency measures</b>					\$	19,132	\$	5,158	\$
End-use energy efficiency measures	%	0%			0%	0%	0%	0%	0%
Net peak heating load	kW	383.5			31.5	81.0	56.0	65.0	150.0
Net heating demand	MWh	873			72	184	128	148	342



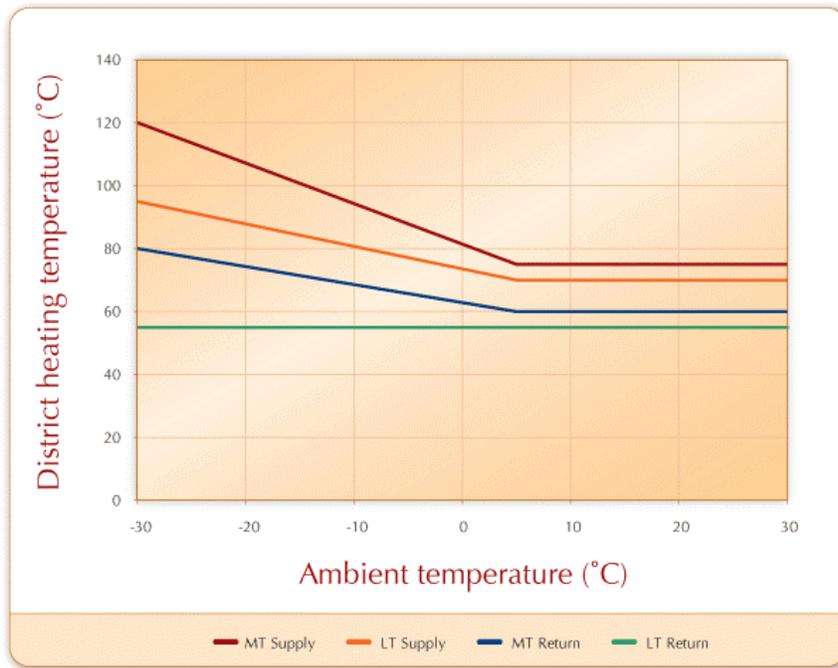
## Community System Base Case Heating System and Heating Load

Building cluster	Heated floor area (m <sup>2</sup> )	Number of buildings	Heating load (W/m <sup>2</sup> )	Seasonal efficiency	Fuel rate	Length of pipe (m)
Building cluster 1	450	3	70	65%	0.6 \$/L	65
<i>House 1</i>	150	1	70	65%	0.6 \$/L	10
<i>House 2</i>	150	1	70	65%	0.6 \$/L	35
<i>House 3</i>	150	1	70	65%	0.6 \$/L	20
Building cluster 2 (Hospital)	900	1	90	65%	0.6 \$/L	25
Building cluster 3 (School building)	800	1	70	100%	0.15 \$/kWh	15
Building cluster 4 (Office building)	1,000	1	65	70%	0.18 \$/L	15
Building cluster 5 (Apartment building)	1,500	1	100	60%	11 \$/MWh	25

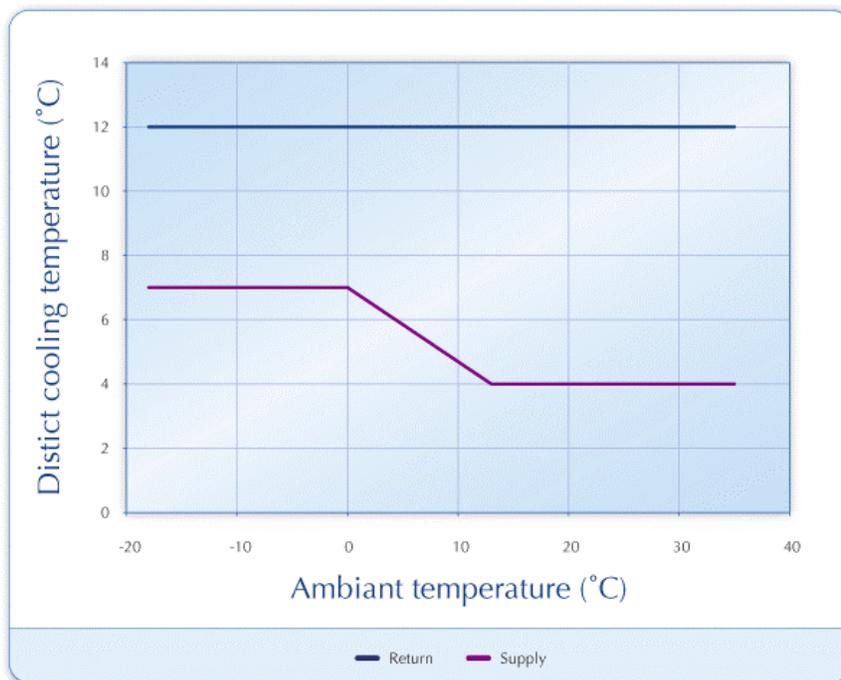
## Community System Base Case Cooling System and Cooling Load

Building cluster	Cooled floor area (m <sup>2</sup> )	Number of buildings	Cooling load (W/m <sup>2</sup> )	Seasonal efficiency	Fuel rate	Length of pipe (m)
Building cluster 1	450	3	20	300%	0.15 \$/kWh	65
<i>House 1</i>	150	1	20	300%	0.15 \$/kWh	10
<i>House 2</i>	150	1	20	300%	0.15 \$/kWh	35
<i>House 3</i>	150	1	20	300%	0.15 \$/kWh	20
Building cluster 2 (Hospital)	900	1	20	300%	0.15 \$/kWh	25
Building cluster 3 (School building)	800	1	20	280%	0.15 \$/kWh	15
Building cluster 4 (Office building)	1,000	1	20	300%	0.15 \$/kWh	15
Building cluster 5 (Apartment building)	1,500	1	25	300%	0.15 \$/kWh	25

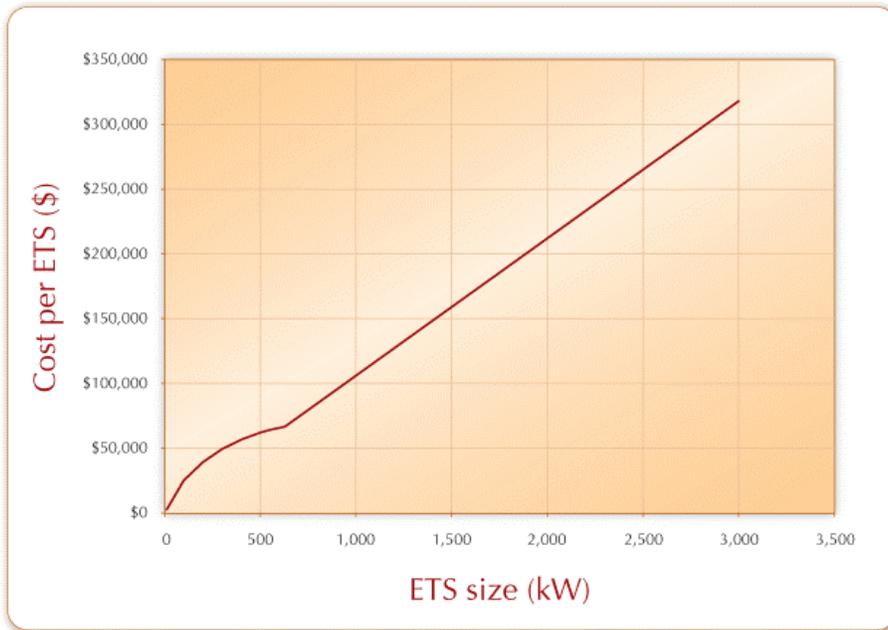
## Typical District Heating Supply and Return Temperatures



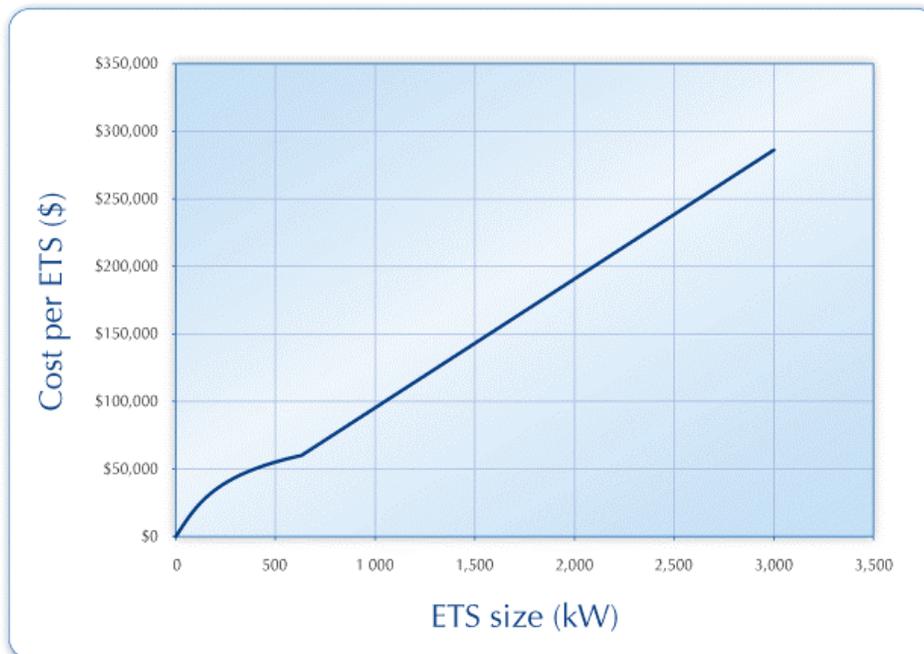
## Typical District Cooling Supply and Return Temperatures



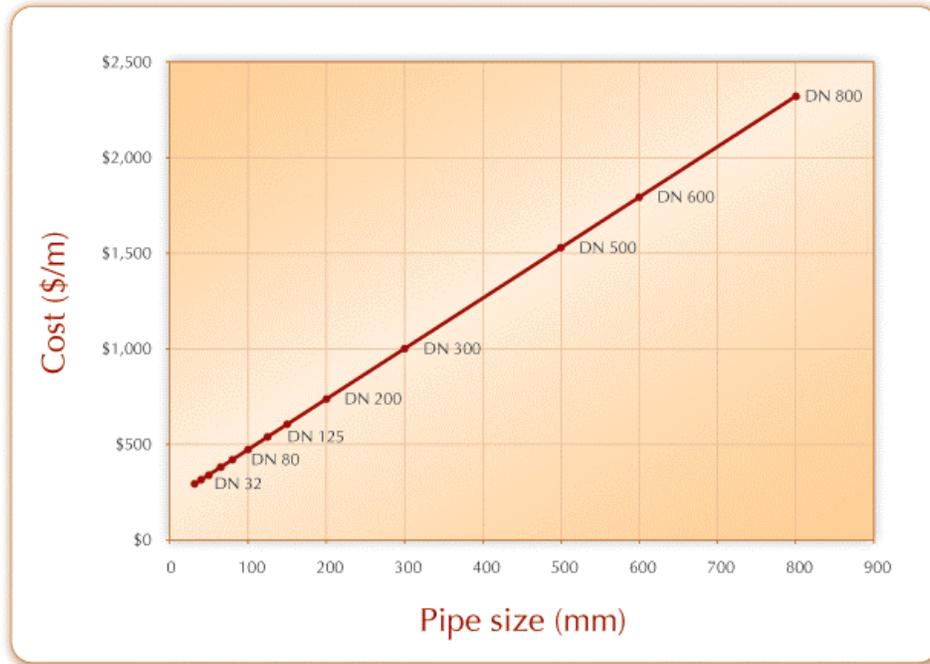
## Typical Costs for Indirect Heating Energy Transfer Station(s)



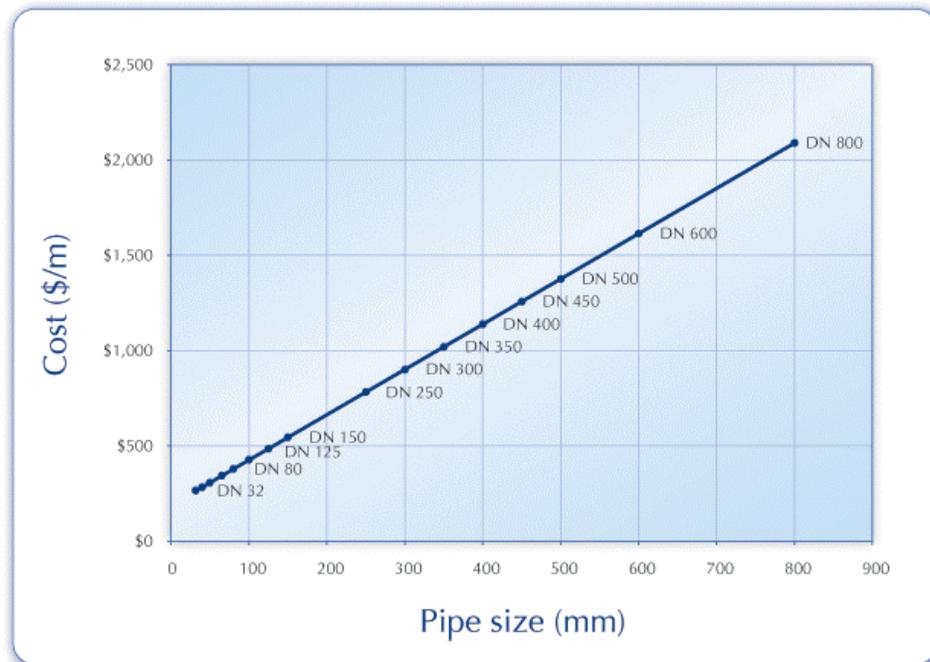
## Typical Costs for Indirect Cooling Energy Transfer Station(s)



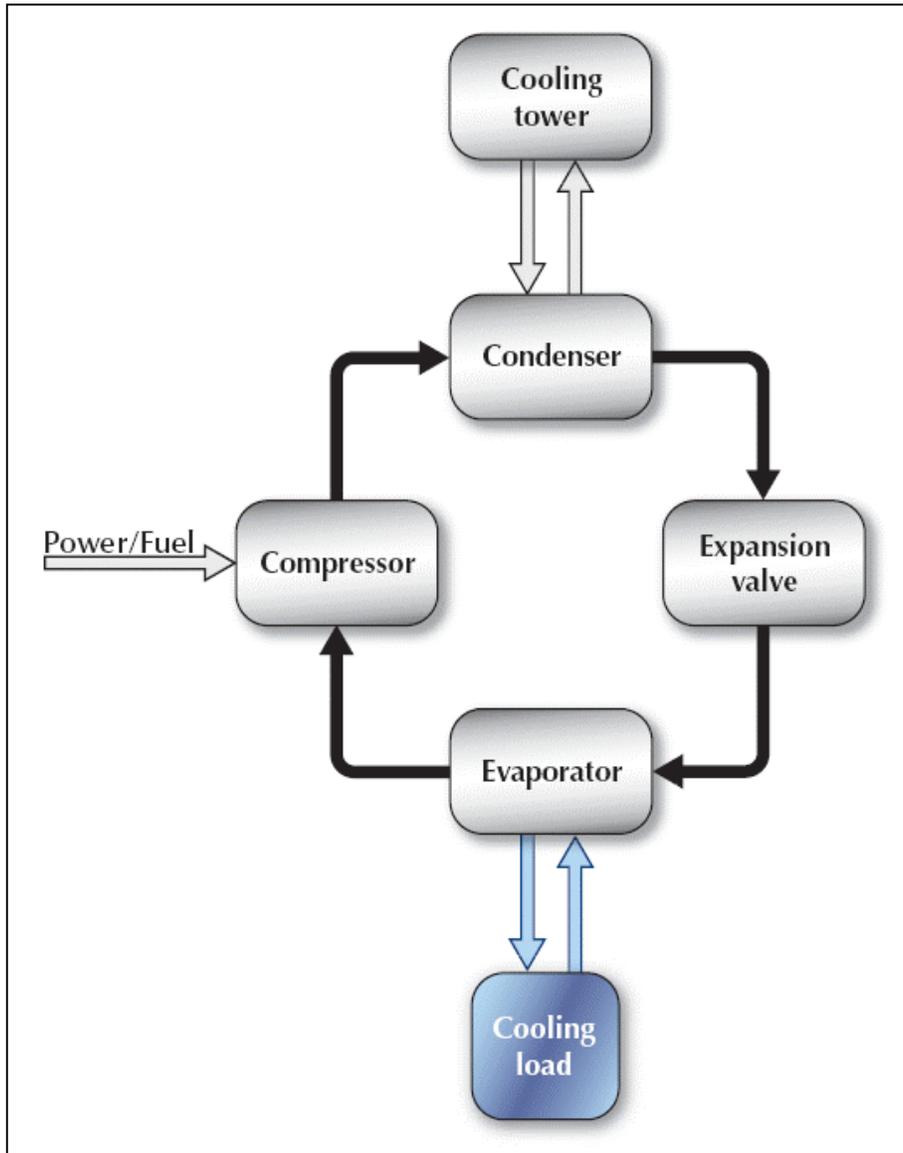
## Typical Costs for Heating Distribution Line Pipes



## Typical Costs for Cooling Distribution Line Pipes

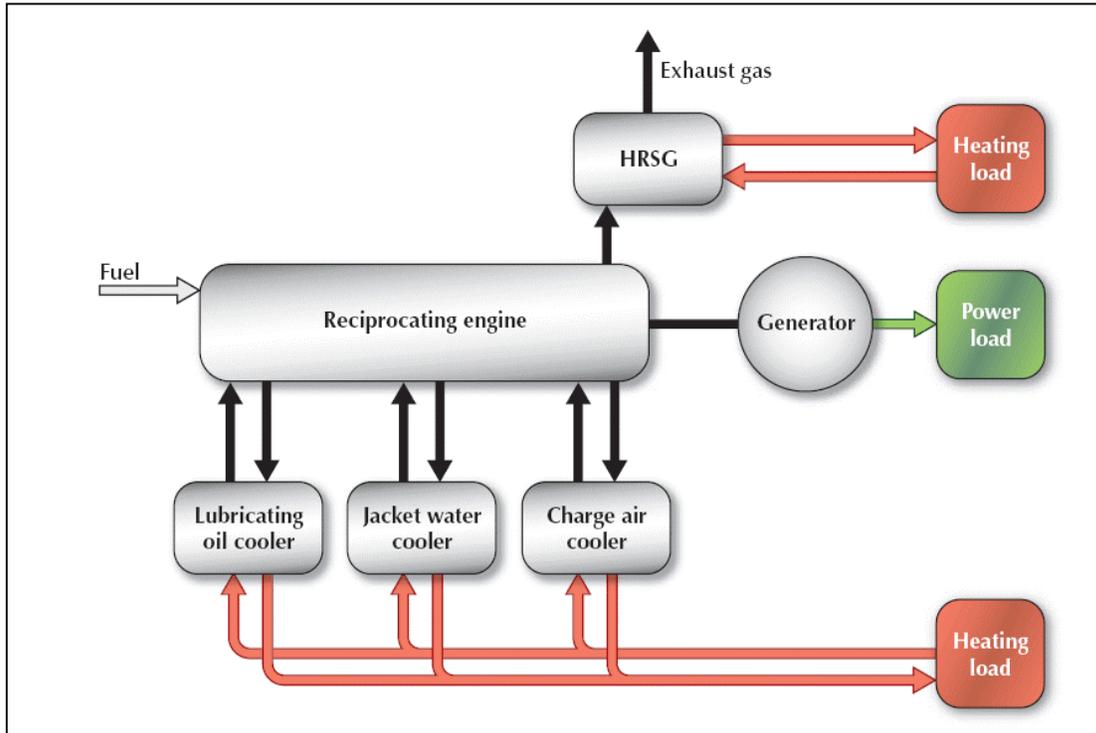


## Compressor Cooling System Schematic

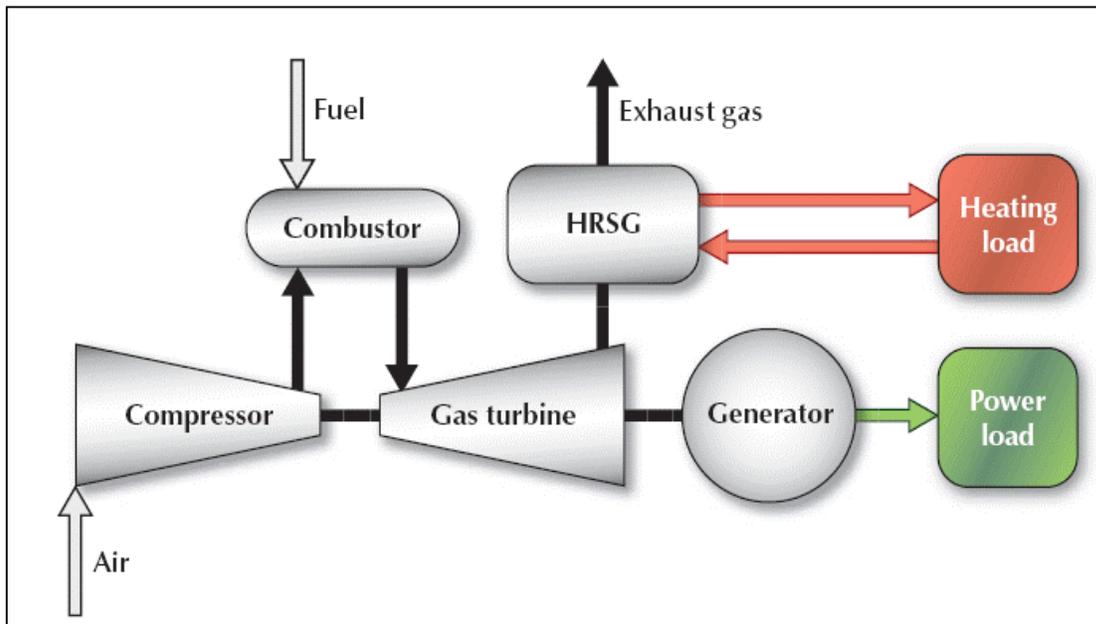




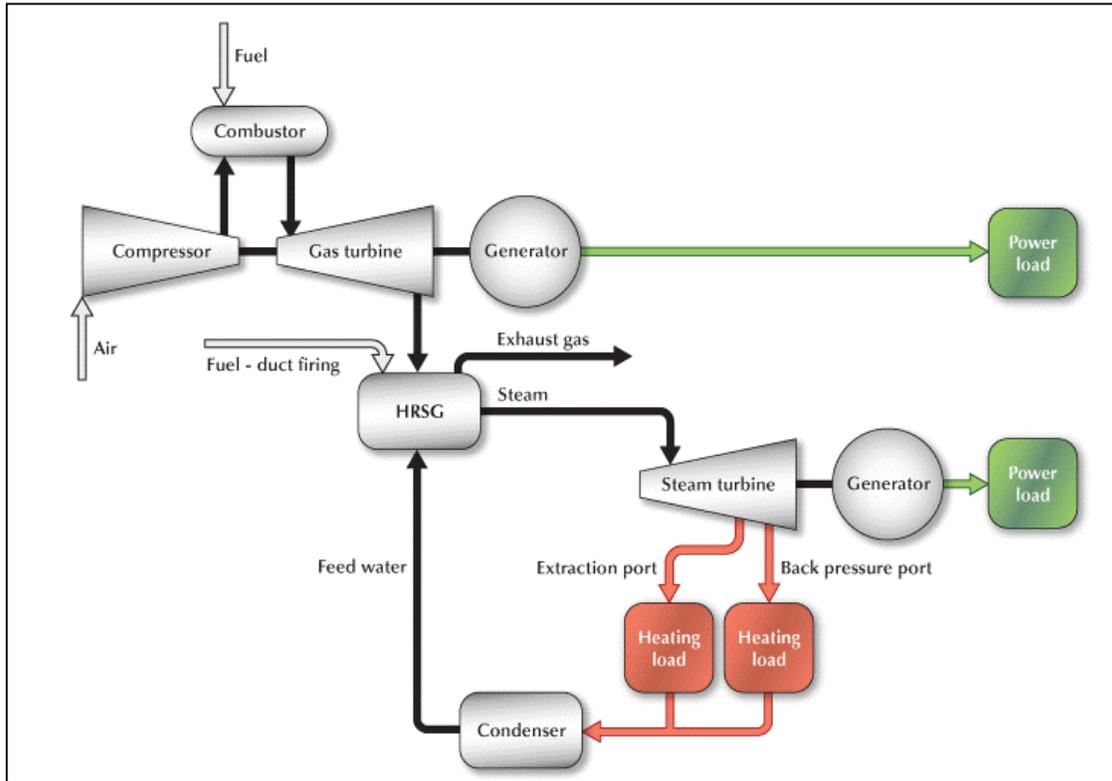
## Reciprocating Engine Schematic



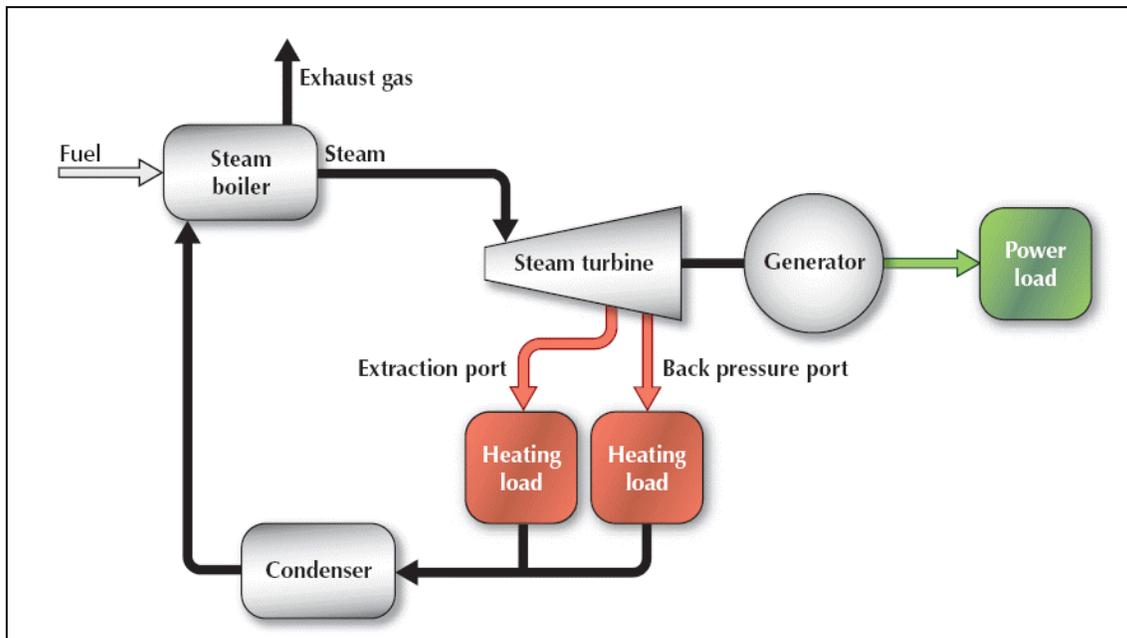
## Gas Turbine Schematic



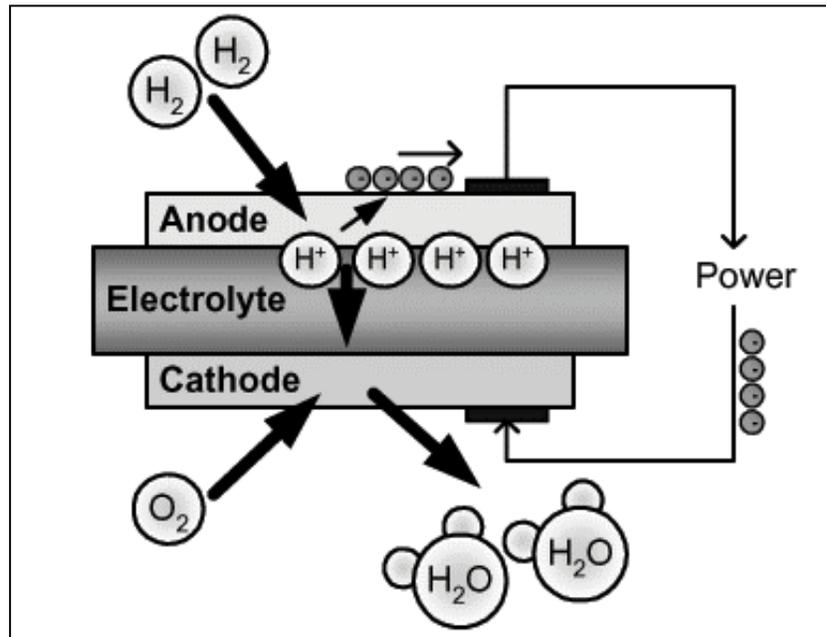
## Gas Turbine - Combined Cycle Schematic



## Steam Turbine Schematic



## Fuel Cell Schematic



## Typical Reciprocating Engine Power Capacity

Type	Power capacity		
	Low speed ( $< 275$ RPM)	Medium speed ( $275 - 1,000$ RPM)	High speed ( $1,000 - 3,600$ RPM)
Rich burn spark ignition	-	-	10 kW - 1.5 MW
Lean burn spark ignition	-	1 - 6 MW	150 kW - 3 MW
Dual fuel	2 - 65 MW	1 - 25 MW	1 MW - 3.5 MW
Diesel/Oil #6	2 - 65 MW	0.5 - 35 MW	10 kW - 3.5 MW

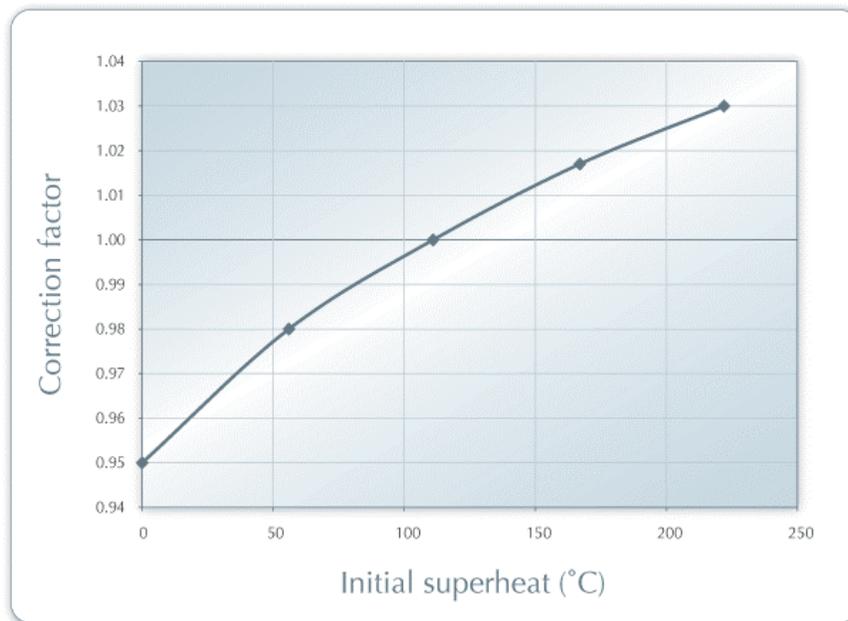
## Typical Steam Turbine Pressures and Temperatures

Type	Power capacity	Operating pressure	Temperature
Steam turbine - low power capacity	0.1 - 2 MW	1,000 - 2,000 kPa (150 - 250 psig)	Saturation
Steam turbine - high power capacity	5 - 300 MW	4,000 - 21,000 kPa (600 - 3,000 psig)	Superheated 330 - 700 °C (625 - 1,300 °F)
Gas turbine - combined cycle	2 - 100 MW	4,000 - 5,600 kPa (600 - 800 psig)	Superheated 400 °C (750 °F)

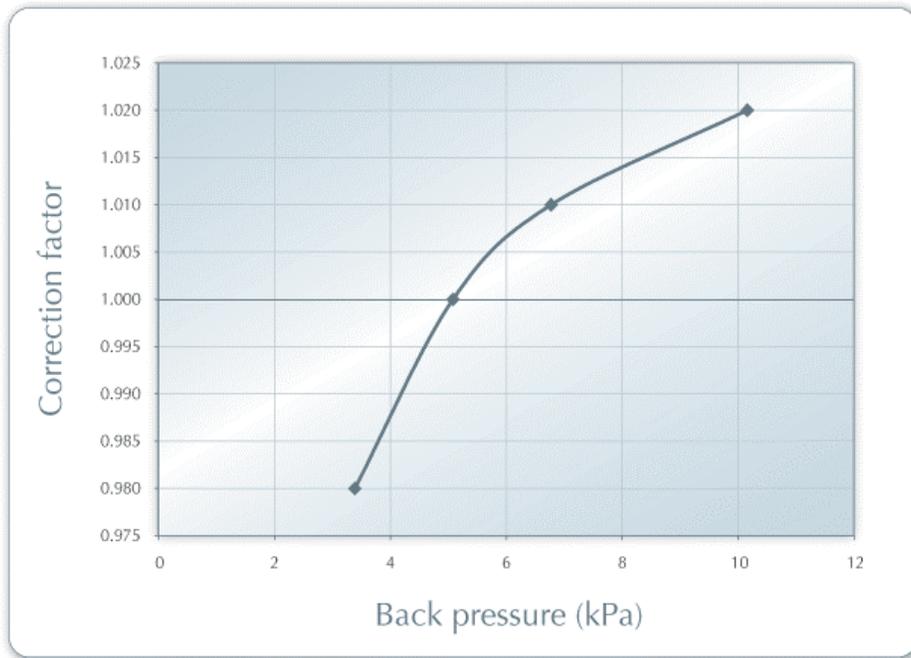
## Typical Steam Turbine Efficiency

Operating pressure	Power capacity				
	5,000 kW	10,000 kW	15,000 kW	20,000 kW	30,000 kW
250 psig (17.2 bar)	74.3%	76.6%	-	-	-
400 psig (27.6 bar)	73.3%	75.7%	76.9%	77.7%	-
600 psig (41.4 bar)	72.0%	74.8%	76.3%	77.2%	77.6%
850 psig (58.6 bar)	-	74.2%	75.8%	76.8%	77.3%
1250 psig (86.2 bar)	-	-	75.4%	76.5%	77.0%

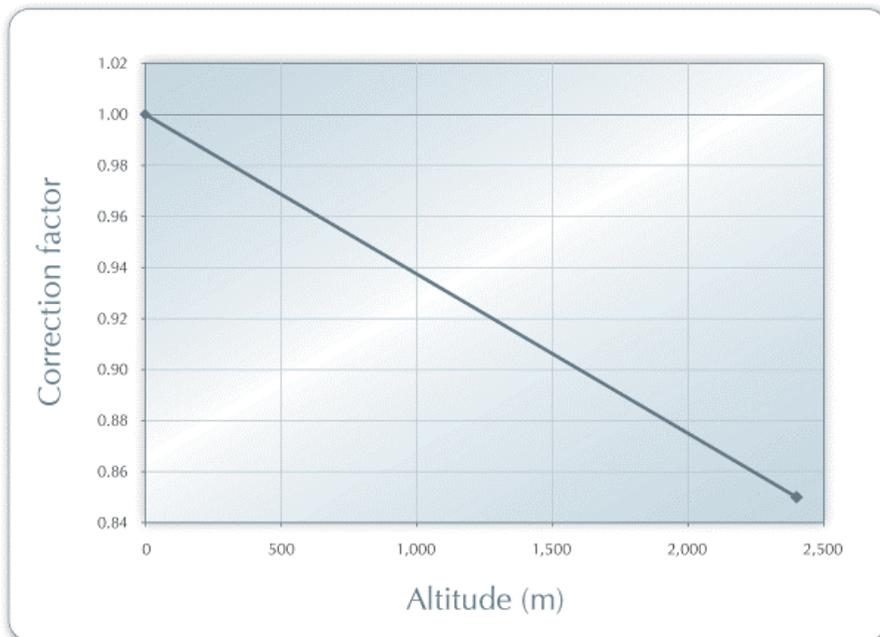
## Steam Turbine Efficiency Correction Factor - Initial Superheat



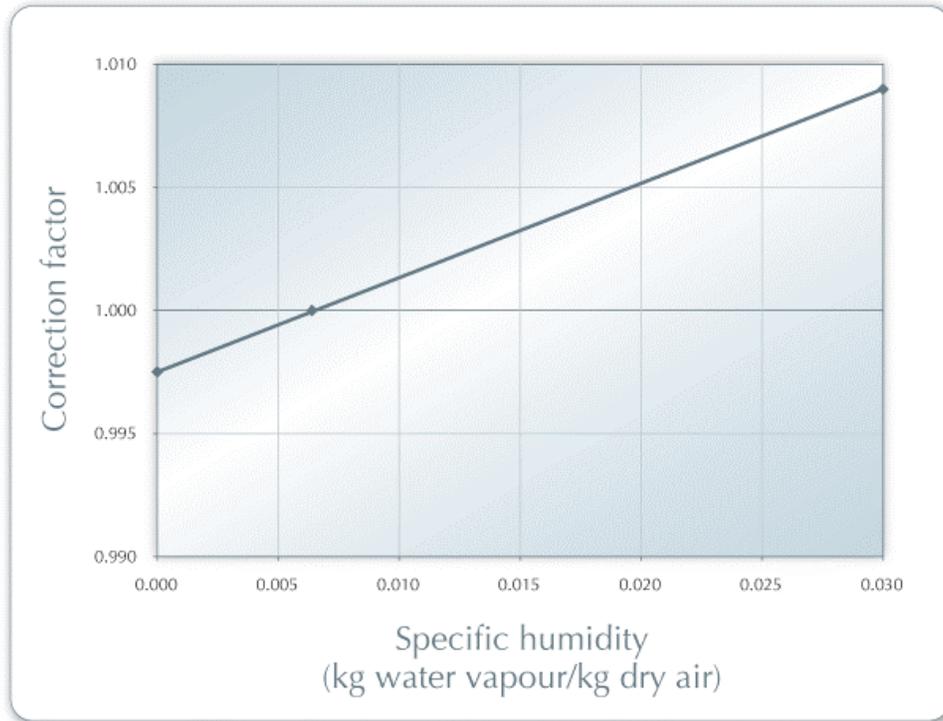
## Steam Turbine Efficiency Correction Factor - Back Pressure



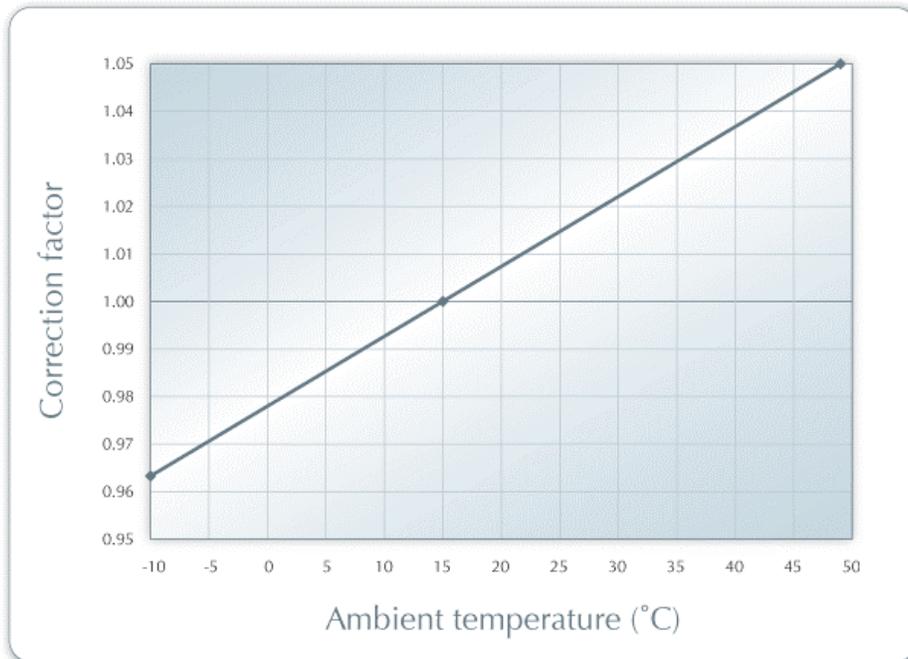
## Heat Rate Correction Factor - Altitude



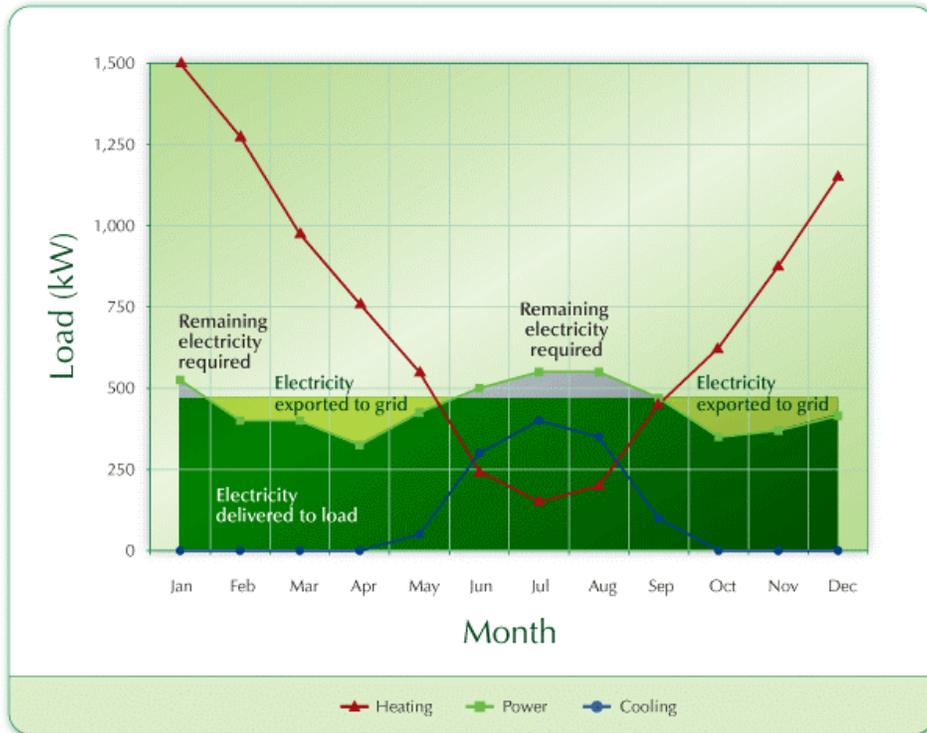
## Heat Rate Correction Factor - Specific Humidity



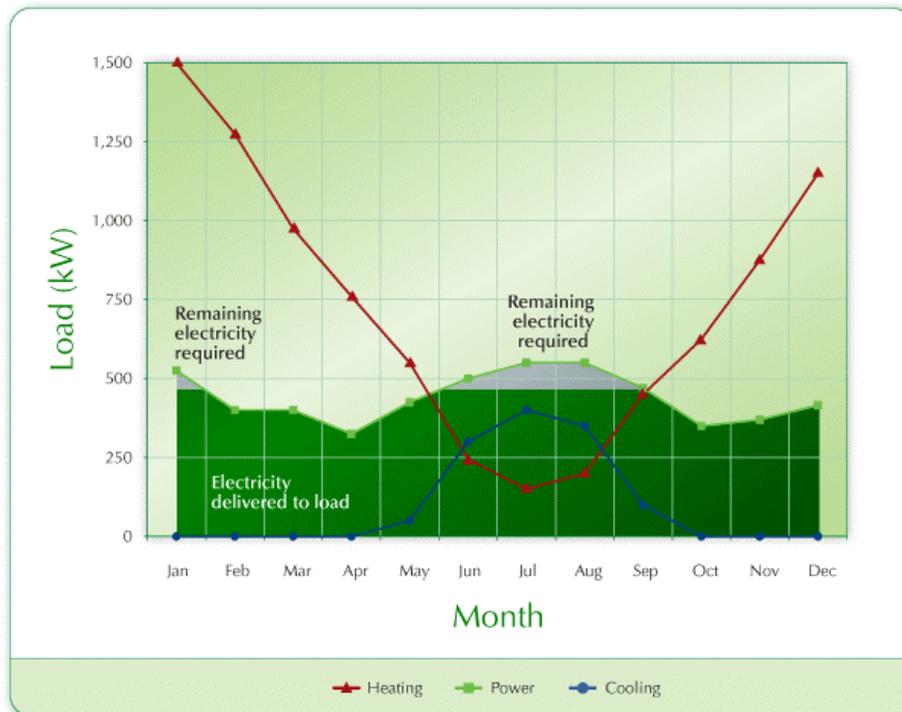
## Heat Rate Correction Factor - Ambient Temperature



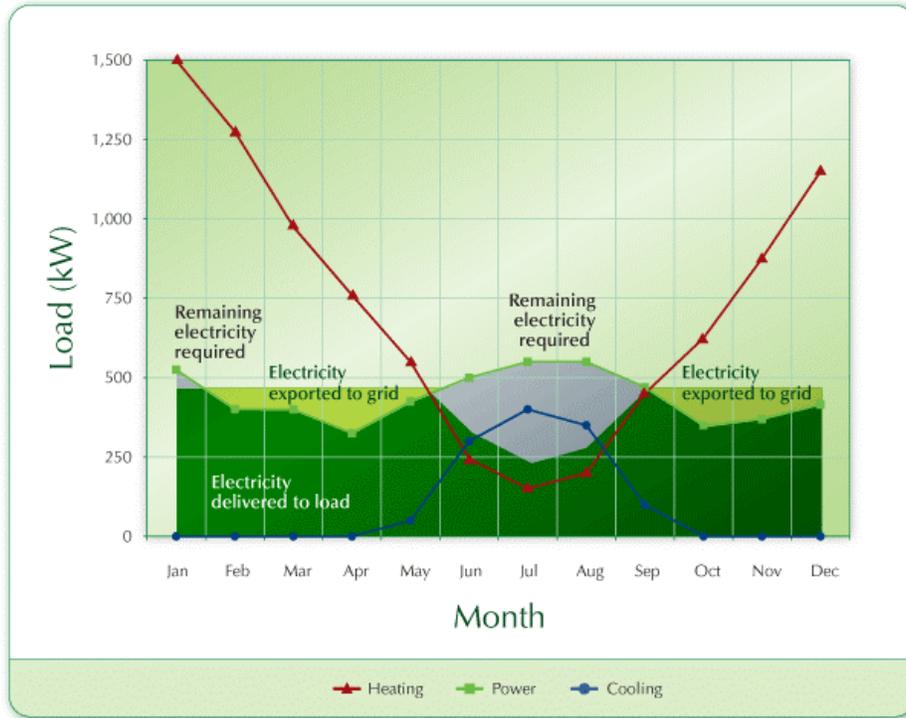
## Full Power Capacity Output



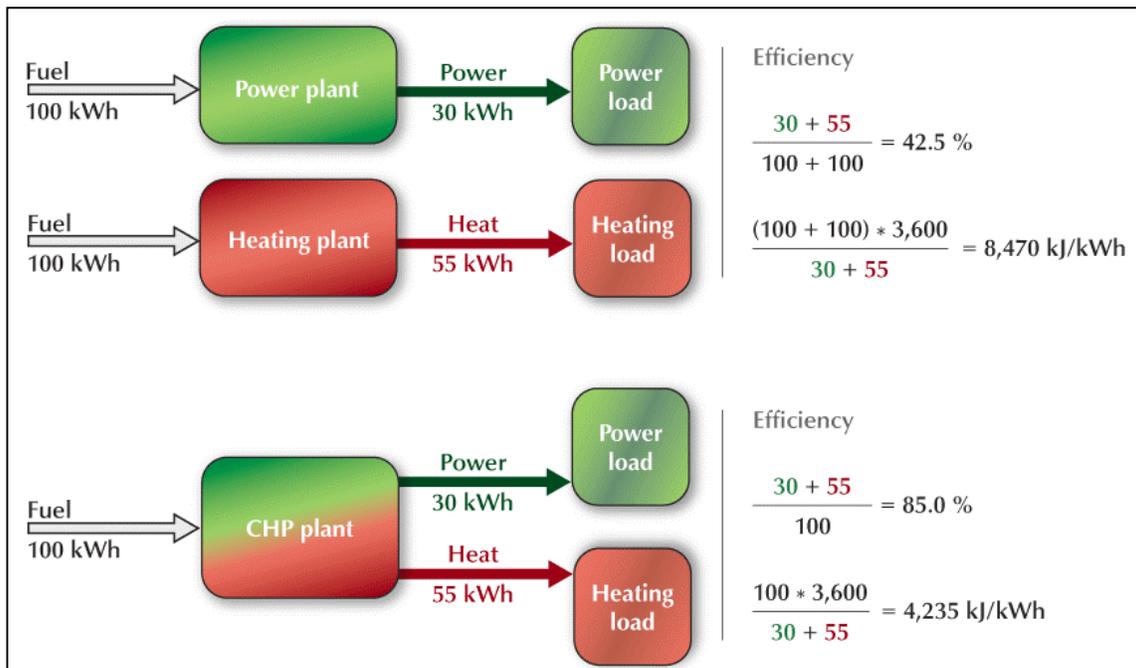
## Power Load Following



## Heating Load Following

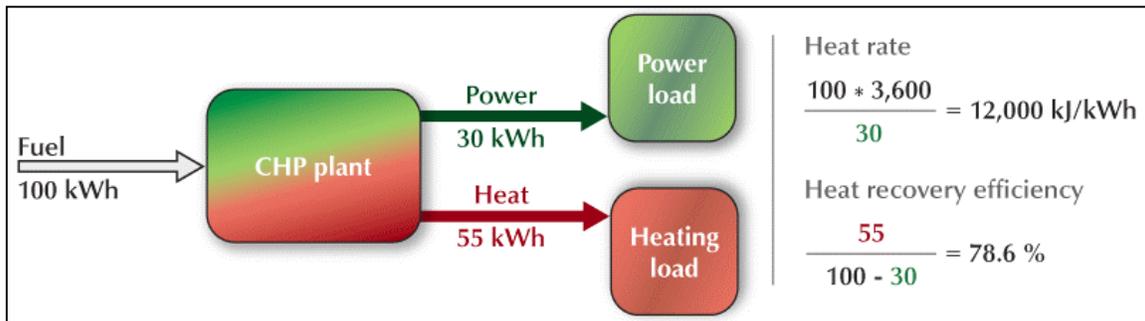


## Efficiency Calculation



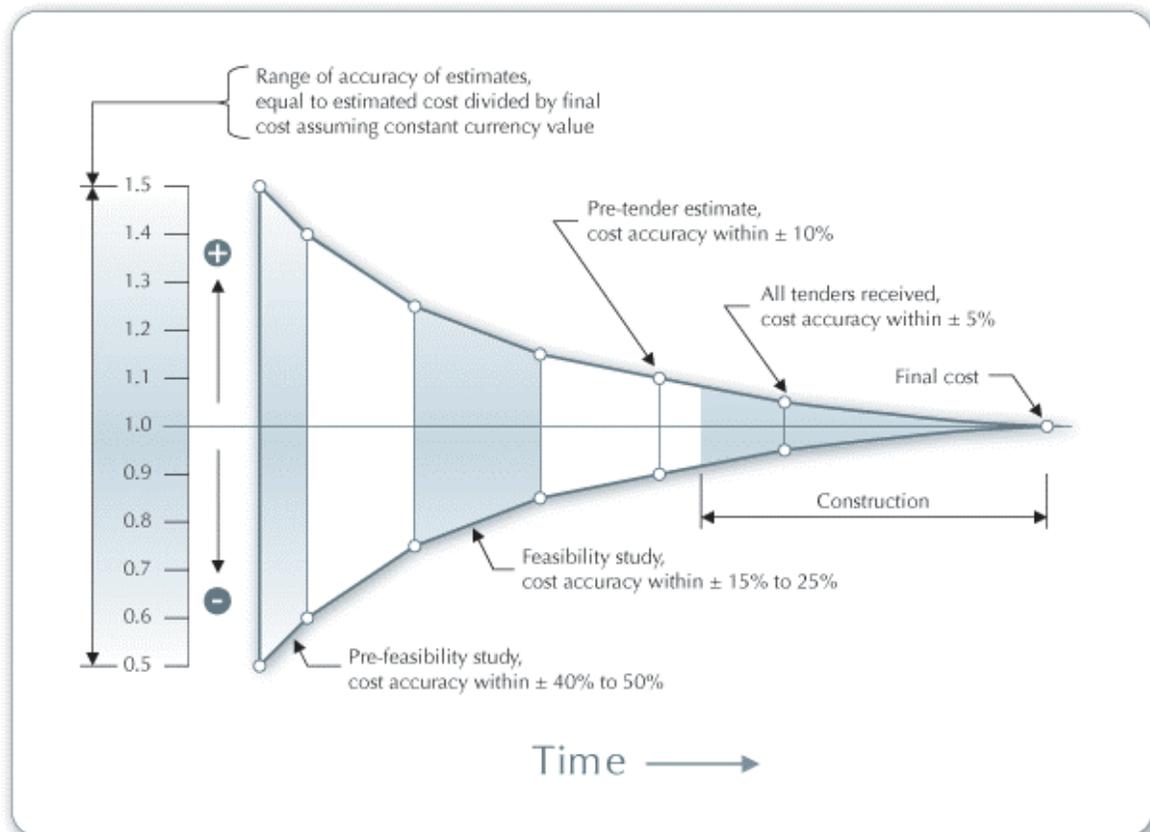
**Note:** To calculate the efficiency in heat rate units (kJ/kWh), the fuel consumption in kWh is multiplied by 3,600 kJ/kWh, and to calculate the efficiency in heat rate units (Btu/kWh), the fuel consumption in kWh is multiplied by 3,412 Btu/kWh.

## CHP Plant Heat Rate & Heat Recovery Efficiency Calculation

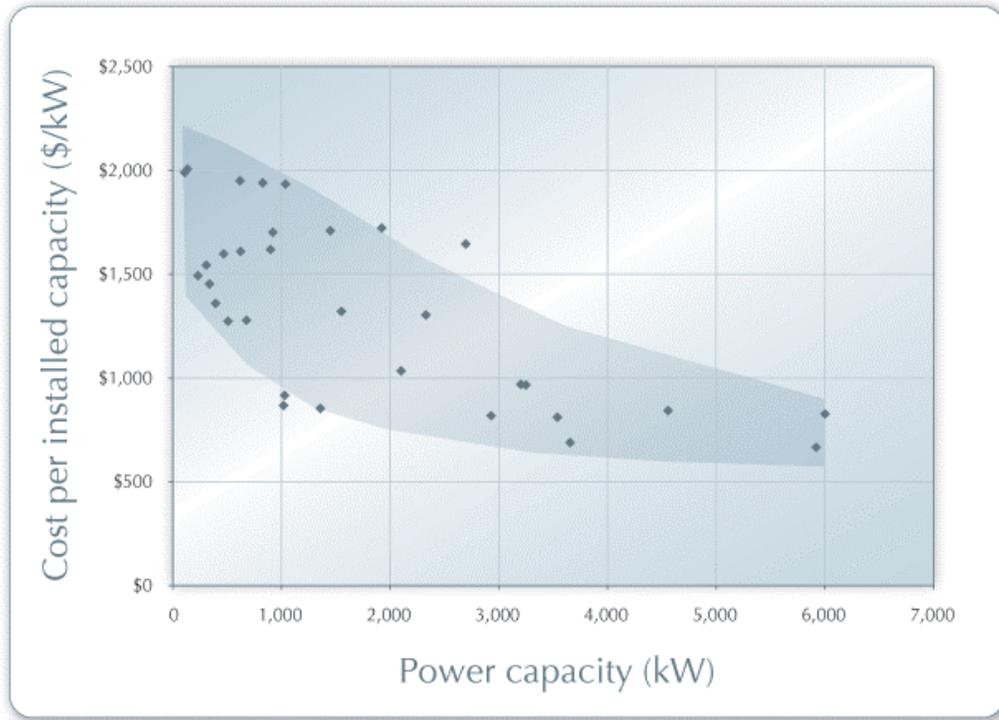


**Note:** To calculate the efficiency in heat rate units (kJ/kWh), the fuel consumption in kWh is multiplied by 3,600 kJ/kWh, and to calculate the efficiency in heat rate units (Btu/kWh), the fuel consumption in kWh is multiplied by 3,412 Btu/kWh.

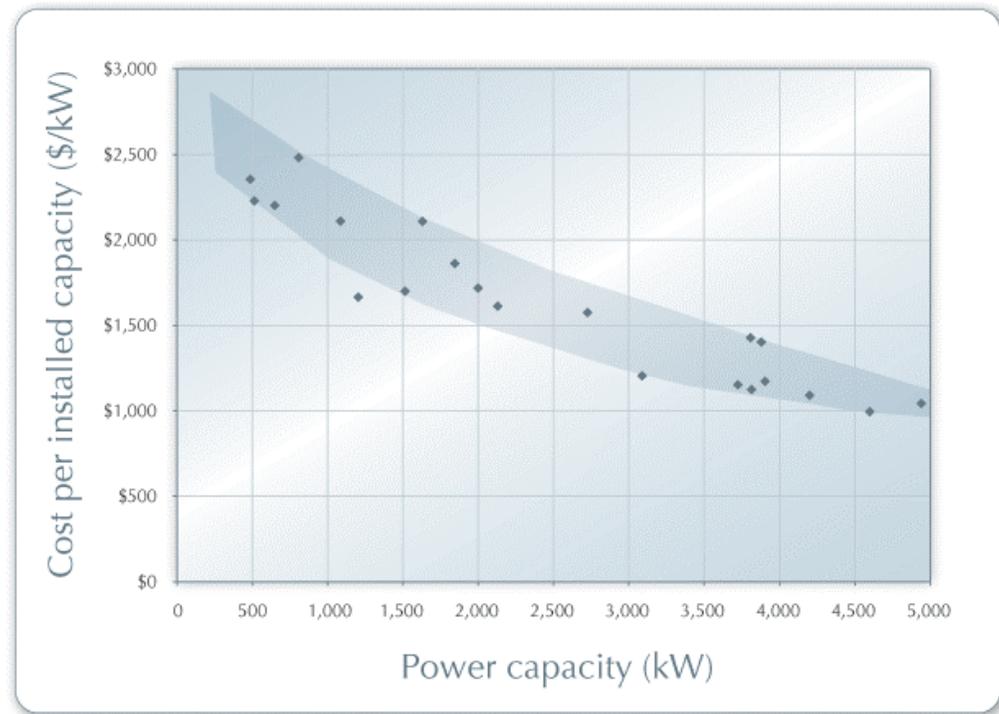
## Accuracy of Project Cost Estimates



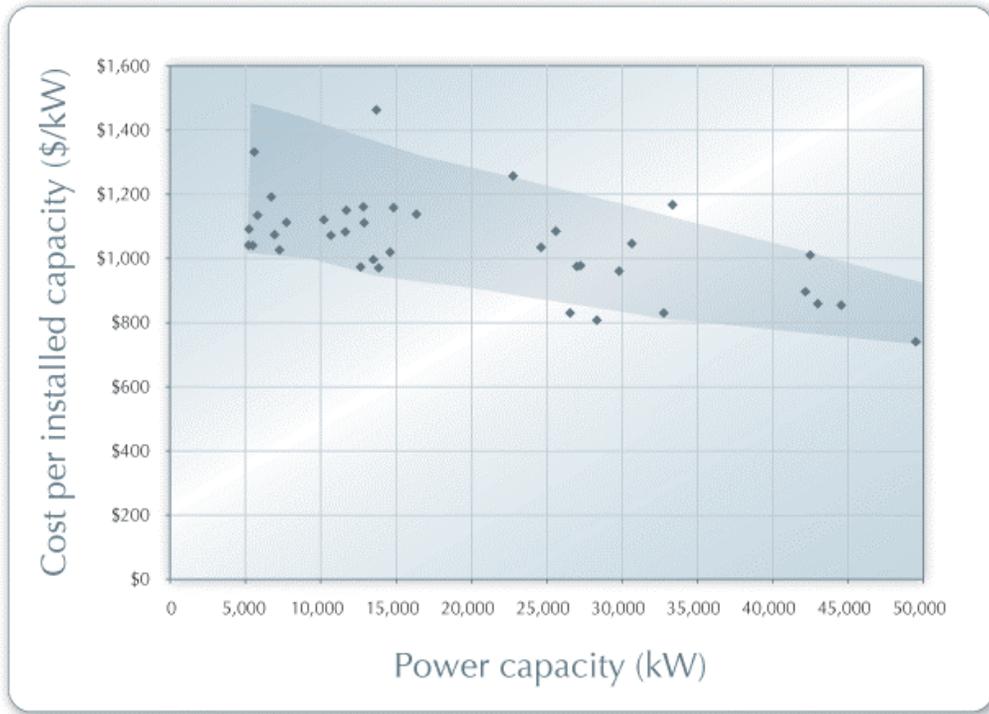
## Reciprocating Engine Installed Cost Examples



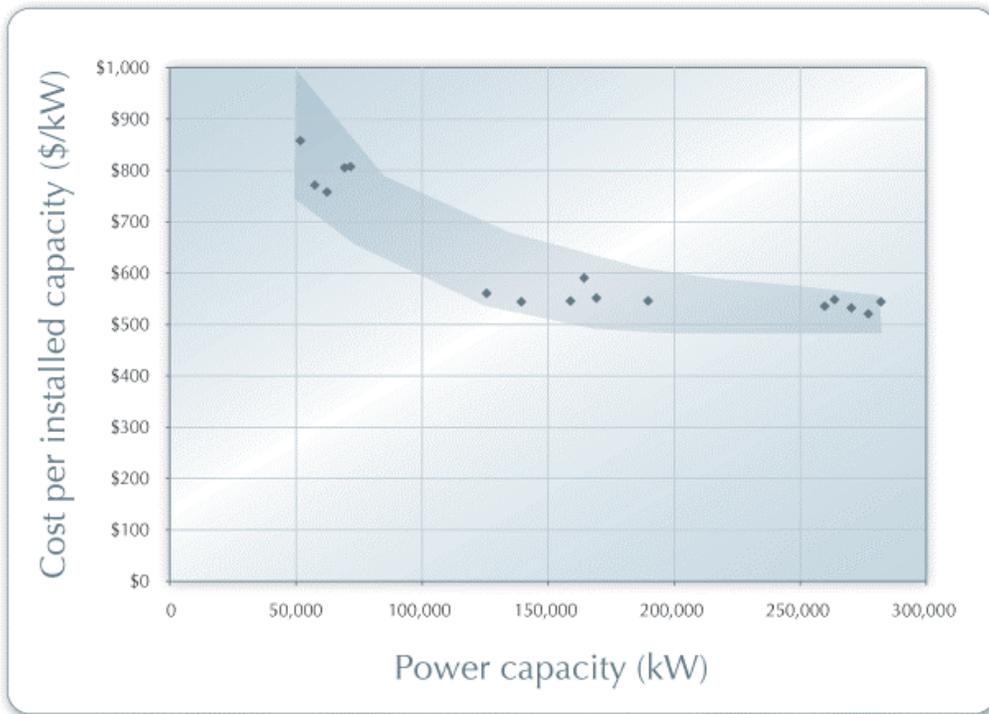
## Gas Turbine Installed Cost Examples (<5MW)



### Gas Turbine Installed Cost Examples (5 to 50MW)



### Gas Turbine Installed Cost Examples (50 to 300MW)



## Steam Turbine Installed Cost Examples

Power capacity (kW)	500	3,000	15,000
Turbine type	Back pressure	Back pressure	Back pressure
Equipment cost (\$/kW)	\$550	\$325	\$300
Total installed cost (\$/kW)	\$1,313	\$569	\$525
Steam flow (kg/h)	9,761	57,204	204,300
Operating pressure (bar)	35.5	42.4	49.3
Superheated temperature (°C)	288	302	343
Back pressure (bar)	4.4	11.3	11.3
Temperature at back pressure port (°C)	148	186	186
Turbine efficiency	47.0%	65.8%	77.6%

## Fuel Cell Installed Cost Examples

Fuel cell type	PAFC <sup>1</sup>	PEMFC <sup>2</sup>	PEMFC <sup>2</sup>	MCFC <sup>3</sup>	MCFC <sup>3</sup>	SOFC <sup>4</sup>
Power capacity (kW)	200	10	200	250	2,000	100
Total installed cost (2002 \$/kW)	\$6,300	\$7,700	\$5,040	\$7,000	\$3,920	\$4,900
O&M costs (\$/kWh)	\$0.04	\$0.05	\$0.03	\$0.06	\$0.05	\$0.03

<sup>1</sup>PAFC: Phosphoric acid fuel cell

<sup>2</sup>PEMFC: Proton exchange membrane fuel cell

<sup>3</sup>MCFC: Molten carbonate fuel cell

<sup>4</sup>SOFC: Solid oxide fuel cell

## Estimated Transmission Line Costs

Capacity (MW)	Voltage (kV)	Cost per km (\$/km)	Distance (km)
0 – 2	25	\$55,000	< 50
2 – 5	44	\$65,000	< 70
> 5	115	\$100,000	> 70

## Estimated Substation Costs

Capacity (MW)	Voltage (kV)	Substation (\$)
0 – 2	25	\$250,000
2 – 5	44	\$600,000
> 5	115	\$2,000,000

## Typical Installed Cost Range - Power Equipment

RETScreen power equipment type	Typical installed cost (\$/kW)
Reciprocating engine	700 to 2,000
Gas turbine	550 to 2,500
Gas turbine - combined cycle	700 to 1,500
Steam turbine	500 to 1,500
Geothermal system	1,800 to 2,100
Fuel cell	4,000 to 7,700
Wind turbine	1,000 to 3,000
Hydro turbine	550 to 4,500
Photovoltaic module	8,000 to 12,000
<b>Note:</b> Typical installed cost values in Canadian \$ as of January 1, 2005. Approximate exchange rate at time was 1 CAD = 0.81 USD and 1 CAD = 0.62 EUR	

## Typical Installed Cost Range - Heating Equipment

RETScreen heating equipment type	Typical installed cost (\$/kW <sub>heating</sub> )	Included in cost	Not included in cost
Biomass system	100 to 400	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Flue/Vent</li> </ul>
Boiler	25 to 200	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Flue/Vent</li> </ul>
Furnace	30 to 120	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Flue/Vent</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
Heater	30 to 80	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Flue/Vent</li> </ul>
Heat pump - air-source	800 to 1,500	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
Heat pump - ground-source	600 to 1,500 + 200 to 1,500 for horizontal loop or + 400 to 4,000 for vertical loop	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
<b>Note:</b> Typical installed cost values in Canadian \$ as of January 1, 2005. Approximate exchange rate at time was 1 CAD = 0.81 USD and 1 CAD = 0.62 EUR			

## Typical Installed Cost Range - Cooling Equipment

RETScreen cooling equipment type	Typical installed cost (\$/kW <sub>cooling</sub> )	Included in cost	Not included in cost
Compressor - air-cooled	200 to 500	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> <li>• Air cooled condenser heat exchanger</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
Compressor - water-cooled	110 to 300 + 25 to 60 for cooling tower	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> <li>• Cooling tower</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
Heat pump - air-source	375 to 650	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
Heat pump - ground-source	450 to 600 + 200 to 1,500 for horizontal well or + 400 to 4,000 for vertical well	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
Absorption	120 to 400 + 25 to 60 for cooling tower	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> <li>• Air cooled condenser heat exchanger</li> <li>• Cooling tower</li> </ul>
Desiccant	100 to 500*	<ul style="list-style-type: none"> <li>• Major equipment</li> <li>• Major installation</li> </ul>	<ul style="list-style-type: none"> <li>• Fuel connections/storage</li> <li>• Ductwork, curbs &amp; pads</li> </ul>
<b>Note:</b> Typical installed cost values in Canadian \$ as of January 1, 2005. Approximate exchange rate at time was 1 CAD = 0.81 USD and 1 CAD = 0.62 EUR			
* in \$/latent kW			

## Registration Fees for CDM Projects

Average tonnes of CO <sub>2</sub> e reductions/year	Registration fee in \$US
≤ 15,000	5,000
> 15,000 and ≤ 50,000	10,000
> 50,000 and ≤ 100,000	15,000
> 100,000 and ≤ 200,000	20,000
> 200,000	30,000

## Emission Factors for Diesel Generator Systems (in kgCO<sub>2</sub>equ/kWh \*) for Three Different Levels of Load Factor\*\*

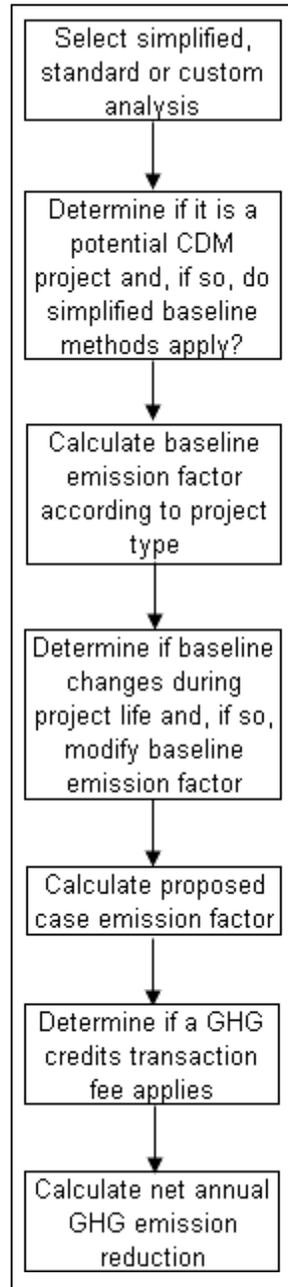
Type of grid	Mini-grid with 24-hour service	i) Mini-grid with 4- to 6-hour service ii) Productive applications iii) Water pumps	Mini-grid with storage
Load factor	25%	50%	100%
< 15 kW	2.4	1.4	1.2
≥ 15 to < 35 kW	1.9	1.3	1.1
≥ 35 to < 135 kW	1.3	1	1
≥ 135 to < 200 kW	0.9	0.8	0.8
≥ 200 kW ***	0.8	0.8	0.8

\*) A conversion factor of 3.2 kg CO<sub>2</sub> per kg of diesel has been used (following revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories).

\*\*) Figures are derived from fuel curves in the online manual of RETScreen International's PV 2000 Model.

\*\*\*) Default values.

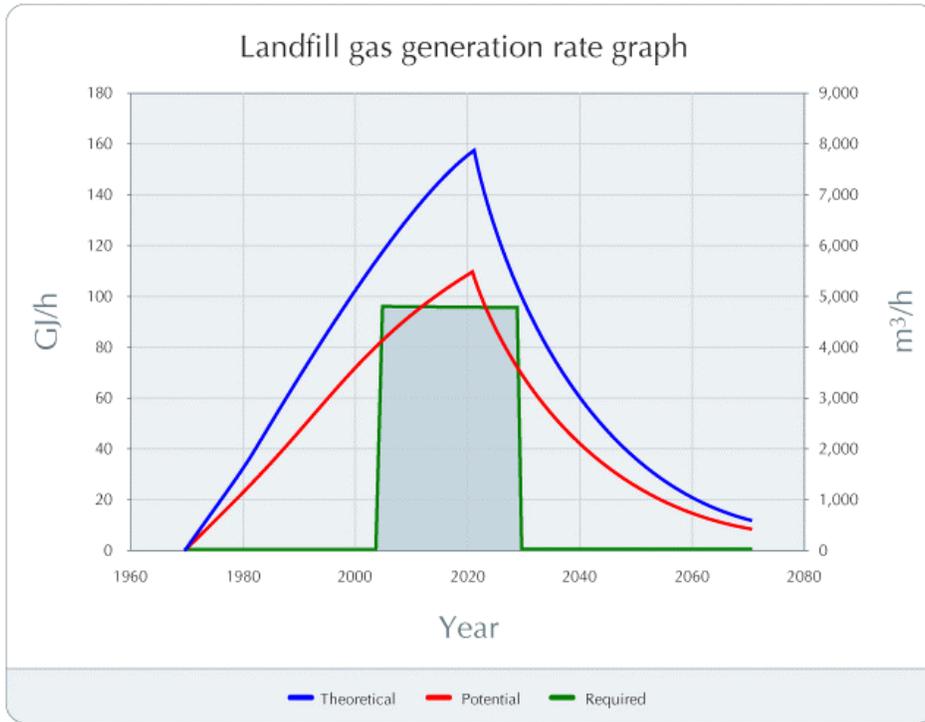
## GHG Analysis Worksheet Flow Chart



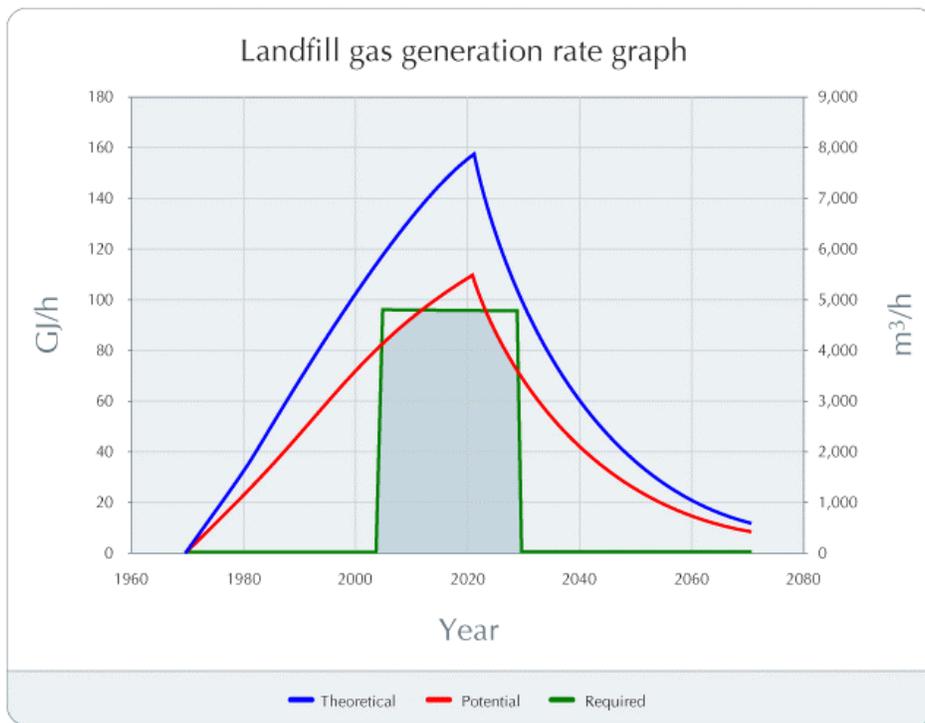
## Range of k Values by Annual Precipitation

Annual precipitation	Range of k values		
	Relatively inert	Moderately decomposable	Highly decomposable
<250 mm	0.01	0.02	0.03
250 to 500 mm	0.01	0.03	0.05
500 to 1,000 mm	0.02	0.05	0.08
>1,000 mm	0.02	0.06	0.09

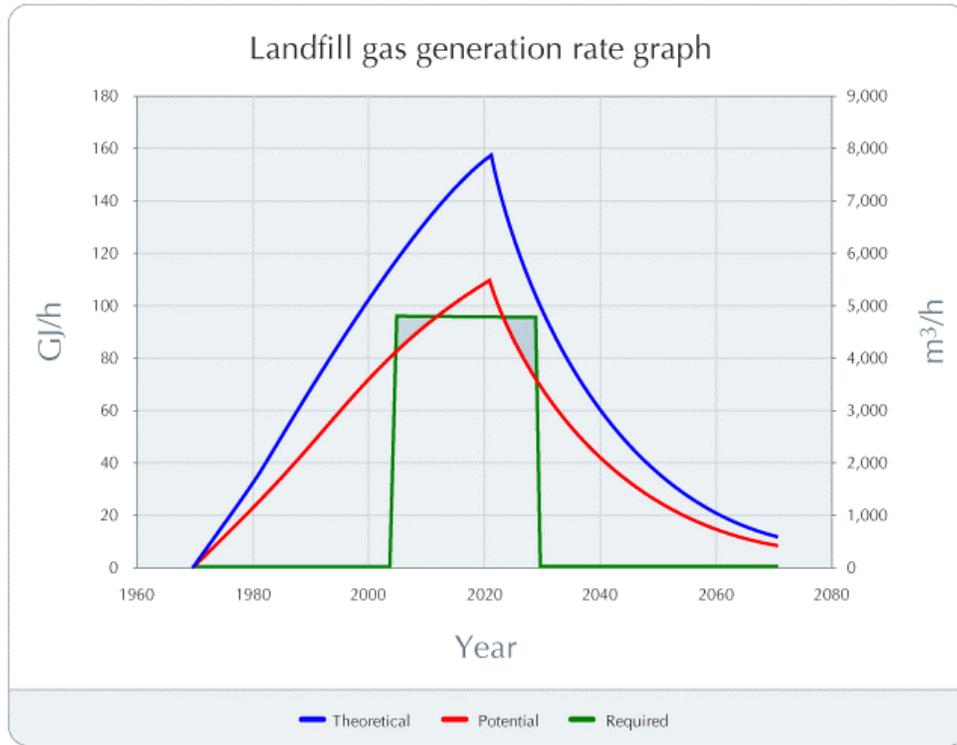
## Fuel Required - Average



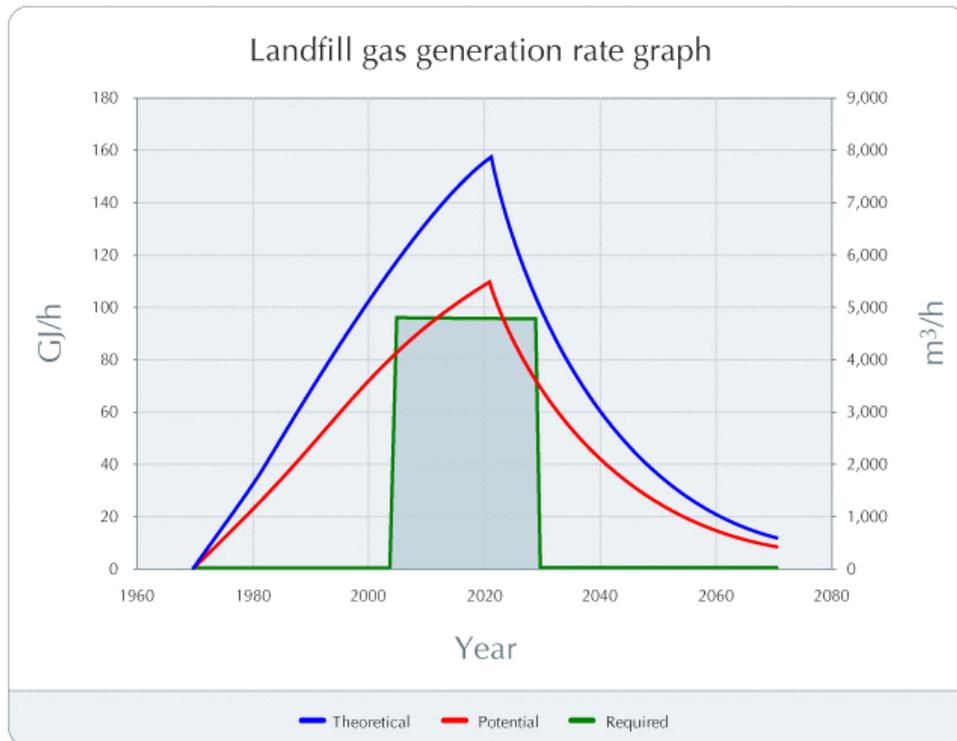
## LFG Fuel Potential



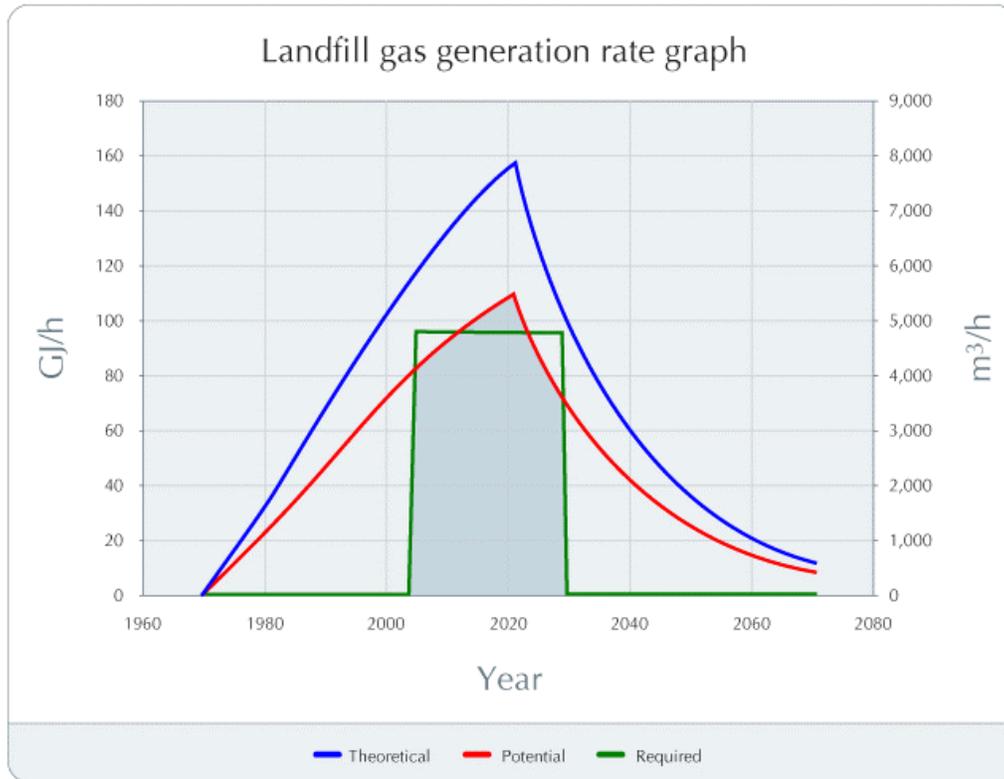
## Remaining Fuel Required



## Fuel Required - Annual



## LFG Fuel Potential - Annual



## Training & Support

The user can obtain current information on RETScreen Training & Support at the following Website address: [www.etscreen.net/e/training](http://www.etscreen.net/e/training).

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