RETScreen® International
Clean Energy Decision Support Centre
www.retscreen.net

RETScreen® Software Online User Manual

Biomass Heating Project Model

Natural Resources Canada | Ressources naturelles Canada

Canada

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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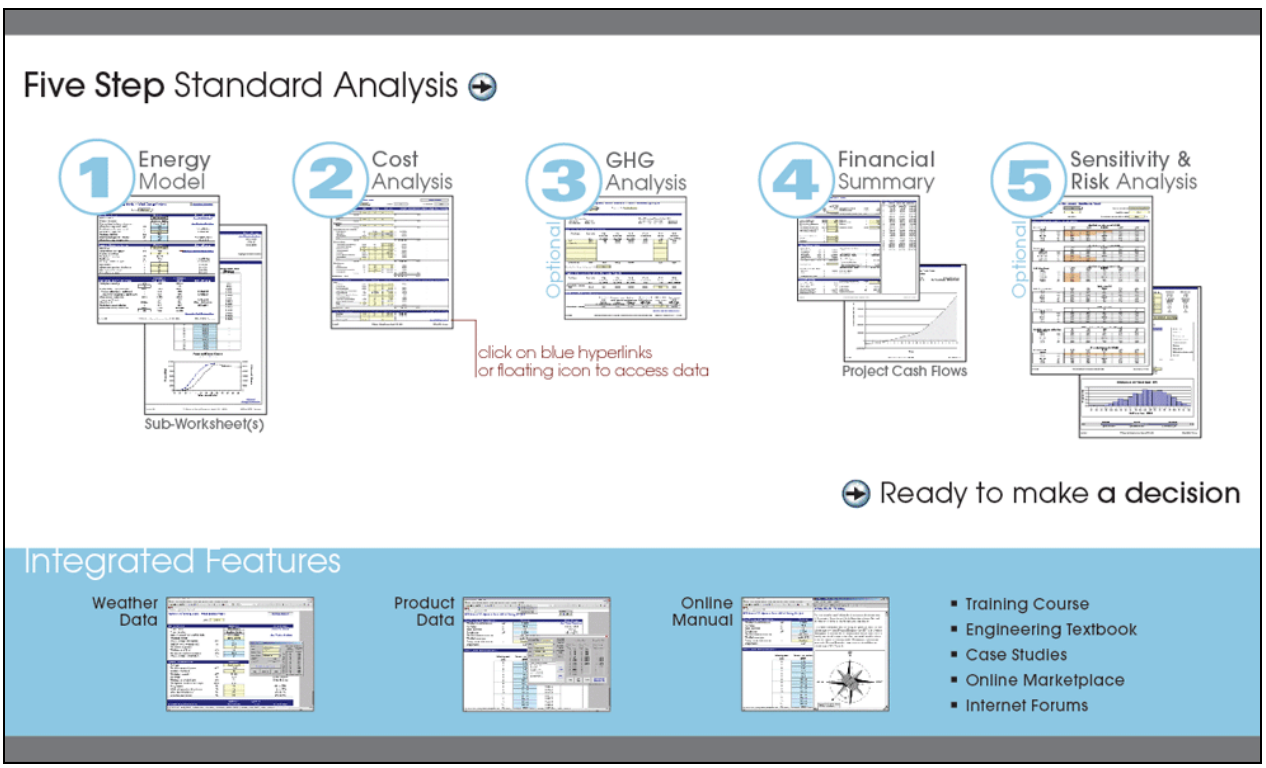
Brief Description and Model Flow Chart

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. Solar Air Heating 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

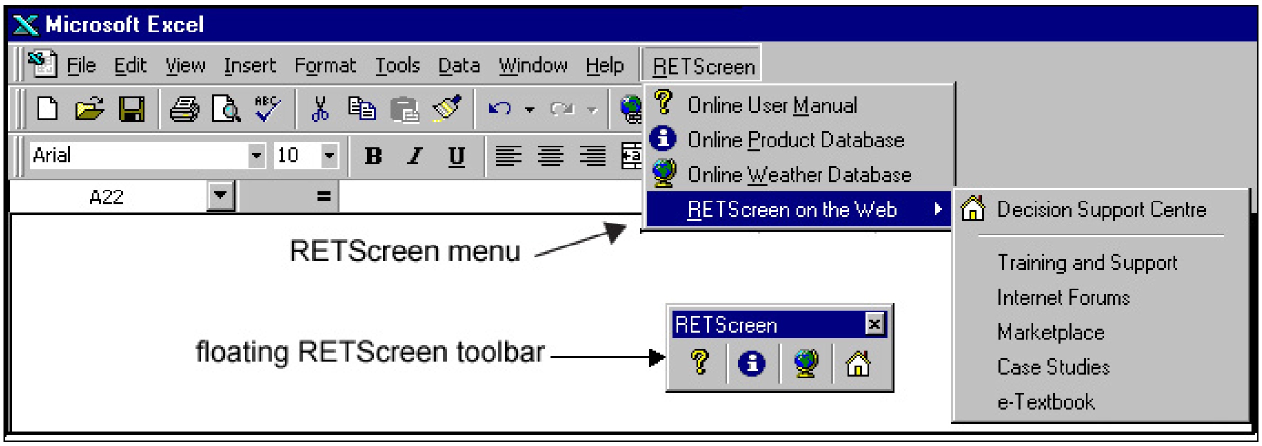
Complete each worksheet row by row from top to bottom by entering values in shaded cells. To move between worksheets simply "click" on the tabs at the bottom of each screen or on the "blue-underlined" hyperlinks built into the worksheets. The RETScreen Model Flow Chart is presented below.



RETScreen 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 next 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.

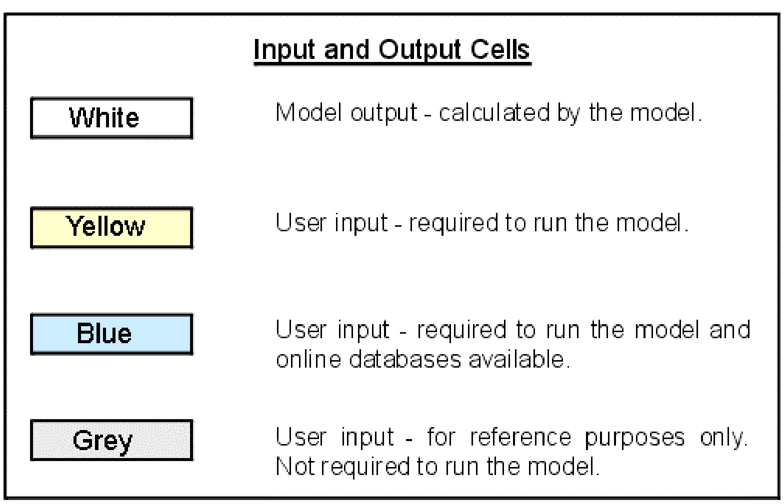


RETScreen Menu and Toolbar

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.

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 for input and output cells is presented below.



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 *Cost Analysis* 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).

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 references" drop-down list cell.

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings

Name of unit	Symbol for unit
ampere	A
calorie	cal
cubic feet per minute	cfm
day	d
degree Celsius	°C
degree Fahrenheit	°F
dollar	$
feet	ft
gallon[1]	gal
hectare	ha
hertz	Hz
horse-power	hp
hour	h
joule	J
kilogram	kg
kilometre	km
kilowatt	kW
litre	L
megawatt	MW
metre	m
mile	mi
mile per hour	mph
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/square inch	psi
second	s
tonne[2]	t
volt	V
watt	W
week	w
yard	yd
year	yr

Name of Prefix	Symbol for Prefix
kilo	k
mega	M
giga	G

List of Units, Symbols and Prefixes

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.

Note: 1. The gallon (gal) unit used in RETScreen refers to US gallon and not to imperial gallon.

2. The tonne (t) unit used in RETScreen refers to metric tonnes.

Unit Options

To perform a RETScreen project analysis, the user must choose between "Metric" units or "Imperial" units from the "Units" drop-down list.

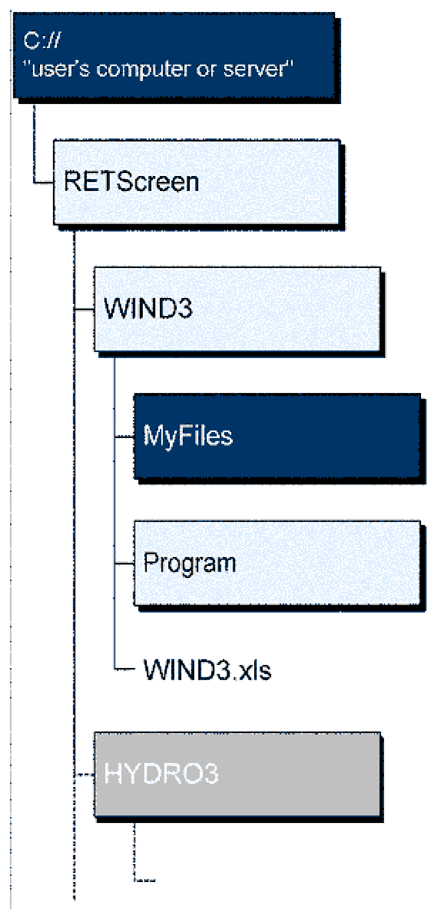
If the user selects "Metric," all input and output values will be expressed in metric units. But if the user selects "Imperial," input and output values will be expressed in imperial units where applicable.

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 ensure that values entered in input cells are expressed in the units shown.

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 cannot 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 for more information on the download procedure. It is important to note that the user should not



RETScreen Download Procedure

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.

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.

Biomass Heating Project Model

The RETScreen® International Biomass Heating Project Model can be used world-wide to easily evaluate the energy production (or savings), life-cycle costs and greenhouse gas emissions reduction for biomass and/or waste heat recovery (WHR) heating projects, ranging in size from large-scale developments for clusters of buildings to individual building applications. The model can be used to evaluate three basic heating systems using: waste heat recovery; biomass; and biomass and waste heat recovery combined. It also allows for a "peak load heating system" to be included (e.g. oil-fired boiler). The model is designed to analyse a wide range of systems with or without district heating.

Six worksheets (*Energy Model, Heating Load Calculation & District Heating Network Design (Heating Load & Network), Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis)*, *Financial Summary* and *Sensitivity and Risk Analysis (Sensitivity)*) are provided in the Biomass Heating Project Workbook file.

The *Energy Model* and *Heating Load & Network* 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. 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 biomass heating 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 Biomass Heating Project 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* and *Heating Load & Network* worksheets are used to help the user calculate the annual energy production for a biomass and/or WHR heating project based upon local site conditions and system characteristics. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies.

Site Conditions

The site conditions associated with estimating the annual energy production of a biomass and/or WHR heating project are detailed below.

Project name

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

For more information on how to use the RETScreen Online User Manual, Product Database and Weather Database, see Data & Help Access.

Project location

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

Nearest location for weather data

The user enters the weather station location in the *Heating Load & Network* worksheet and it is copied automatically to the *Energy Model* worksheet.

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

Number of buildings

The model calculates the total number of buildings from data entered by the user in the *Heating Load & Network* worksheet.

Total pipe length

The model calculates the total pipe length from data entered in the *Heating Load & Network* worksheet. The total pipe length is equal to the sum of "Total pipe length for main distribution line" and "Length of pipe section" for the secondary distribution line length. Total pipe length is equal to trench length (the trench contains both supply and return lines).

Heating energy demand

The model calculates the heating energy demand from the data entered in the *Heating Load & Network* worksheet.

Units switch: The user can choose to express the energy in different units by selecting among the proposed set of units: "GWh," "Gcal," "million Btu," "GJ," "therm," "kWh," "hp-h," "MJ." This value is for reference purposes only and is not required to run the model.

Peak heating load

The model calculates the peak heating load from data entered in the *Heating Load & Network* worksheet.

Units switch: The user can choose to express the load in different units by selecting among the proposed set of units: "MW," "million Btu/h," "boiler hp," "ton (cooling)," "hp," "W." This value is for reference purposes only and is not required to run the model.

System Characteristics

The model can evaluate heating system designs consisting of waste heat recovery and various boiler types:

1. Waste heat recovery (WHR) system;
2. Biomass heating system;
3. Peak load heating system designed to meet a small portion of the annual energy demand during peak heating periods; and
4. Back-up heating system (optional), which is used in case of system shutdown or because of an interruption in the waste heat recovery system or biomass fuel supply.

The system characteristics associated with estimating the annual energy production of a biomass and/or WHR heating project are detailed below. The system characteristics are divided into four sub-sections: Waste Heat Recovery System, Biomass Heating System; Peak Load Heating System; and, Back-up Heating System.

System type

The user selects the type of base load heating system considered from the three options in the drop-down list: "WHR" (waste heat recovery system), "Biomass" (biomass heating system) and "Biomass & WHR" (biomass heating system and waste heat recovery (WHR) combined).

The model assumes that the system type selected will provide the base load heating energy demand with the peak load system meeting the remaining energy demand not met by the base load system. Within the base load system the model assumes that the full amount of energy available from the WHR system will be used before energy is supplied by the biomass heating system.

The "System Design Graph" provided summarises essential design information for the user. For example, the stacked bar chart on the left shows the percentage of the installed heating power capacity for each of the heating systems (WHR, biomass and peak) with respect to the peak heating load. The bar chart can exceed 100% to allow the system to be oversized. The stacked bar chart on the right shows the percentage of total heating energy demand supplied by each of the heating systems. The bar chart cannot exceed 100%.

Waste Heat Recovery (WHR) System

Waste heat is available from many sources. The model does not distinguish the origin of the heat. Waste heat is assumed to be available at all times and is considered base load for the energy calculations.

Typical sources of waste heat are heat recovered from a process or cooling of a machine. Electricity generating systems are often used. For example, with a reciprocating engine that produces electricity, the jacket and lubrication cooling in combination with exhaust gas cooling can recover heat equal to the shaft power.

Waste heat recovery system capacity

The user enters the waste heat recovery system capacity available, in kW. This value is transferred to the *Cost Analysis* worksheet. For example, a 500 kW diesel electric generator used in a base load mode will provide approximately 500 kW of WHR capacity. Use the "System Design Graph" (as displayed in the *Energy Model* worksheet) as a guide.

Waste energy delivered

The model calculates the waste energy delivered, in MWh. The waste energy delivered is the annual energy production provided by the WHR system.

Percentage of peak heating load

The model calculates the percentage of the WHR system installed capacity with respect to the peak heating load.

Percentage of total heating energy demand

The model calculates the percentage of total heating energy demand supplied by the WHR system.

Biomass Heating System

Biomass is available in many forms. The model is designed to evaluate the energy available from any biomass source. It should be noted that the most successful biomass heating systems use a consistent fuel. The fuel can be a mixture of fuel types, size distribution and moisture content as long as the mixture stays constant. When the fuel changes the system might require manual re-tuning to achieve full efficiency and minimize emissions.

Biomass fuel type

The user selects the biomass fuel type from the drop-down list. If the fuel available is not listed, select a fuel that has a similar heating value as found in the table below. The heating value listed is the higher heat value on a dry basis.

Fuel type	Heating value (HV) (MJ/t)
Bagasse	18,369
Peat	20,147
Rice husks	14,622
Switchgrass	17,933
Wheat straw	17,702
Wood - high HV	19,760
Wood - medium HV	18,673
Wood - low HV	17,723

Biomass Fuel Type and Corresponding Heating Value

The heating value can change depending on its origin. Typically wood bark has a higher heating value then the white wood. The heating value is also reduced over time from harvesting.

Moisture content on wet basis of biomass

The user enters the moisture content on wet basis of the biomass to be fed into the biomass system.

Typical values for moisture content of wood range from 10 to 50%. Freshly chipped wood averages from 40 to 55% moisture content. Fuel dried until it reaches a moisture content of 30 to 40% is ideal for most small-commercial burners [Sykes, 1997]. For wood fuels, moisture content is normally expressed on a wet basis. In some cases, information of moisture content on a dry basis, instead of on a wet basis, may be available to the user and the following conversion should be applied: moisture content wet basis = moisture content dry basis/(1 + moisture content dry basis).

Typically fuels that have a moisture content above 50 to 55% require drying before they can be used as a fuel.

As-fired heating value of biomass

The model calculates the as-fired heating value of biomass using the biomass dry heating value and the moisture content. The as-fired heating value of biomass is the energy content of 1 tonne of the particular fuel type on a wet basis. This value is used to calculate the biomass annual fuel requirement for the system. Typical values for moist heating value for biomass range from 10,800 to 15,900 MJ/tonne. The lower the moisture content, the higher the heating value of the biomass fuel [Hayden, 1997].

Biomass boiler(s) capacity (# boilers)

The user enters the biomass boiler capacity. The model assumes that the capacity is the energy output of the biomass boiler as biomass energy systems are typically rated on output. Use the "System Design Graph" (as displayed in the *Energy Model* worksheet) as a guide. This value is transferred to the *Cost Analysis* worksheet. If more than one biomass boiler is proposed, then the value entered is the sum of the biomass boiler capacities. The user can consult the RETScreen Online Product Database for more information, or to change the number of boilers shown.

Biomass boiler(s) manufacturer

The user enters the name of the biomass boiler(s) manufacturer for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

Biomass boiler(s) model

The user enters the name of the biomass boiler(s) model for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

Biomass boiler(s) seasonal efficiency

The user enters the biomass boiler seasonal efficiency. 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. The seasonal efficiency is also related to the particular boiler chosen and the operating temperature of the system. This value is used to estimate the biomass fuel requirement to meet the biomass system energy demand. Typical values for seasonal efficiency of a biomass boiler range from 60 to 90%. The seasonal efficiency is typically higher for two-burner systems than a one-burner system. The user can consult the RETScreen Online Product Database for more information.

Biomass energy delivered

The model calculates the biomass energy delivered, in MWh. The biomass energy delivered is the annual energy production provided by the biomass heating system.

Percentage of peak heating load

The model calculates the percentage of the installed capacity of the biomass heating system with respect to the peak heating load.

Percentage of total heating energy demand

The model calculates the percentage of total heating energy demand supplied by the biomass heating system.

Peak Load Heating System

Peak load system fuel type

The user selects the peak load heating system fuel type from the drop-down list. The user can also choose a "biomass" peak load heating system. The model then assumes that the biomass fuel type is the same chosen under "Biomass fuel type" in the section above. For more information on the default heating values used for each peak load system fuel type see Unit cost of fuel.

Peak load system steady-state efficiency

The user enters the peak load steady-state efficiency. This value is used to calculate the suggested peak load system capacity. Use the "System Design Graph" (as displayed in the *Energy Model* worksheet) as a guide. Typical values for steady-state efficiency of a peak heating system range from 50 to 350% [Hayden, 1997] (efficiencies above 100% can occur when, for instance, the peak heating system is a heat pump). The peak load steady-state efficiency varies depending on altitude, heating system type, design temperatures, etc. Set the peak load steady-state efficiency to 100% if boilers are rated on an output basis rather than on a heating value input basis.

Suggested peak load system capacity

The model calculates the suggested peak load boiler capacity required to meet the heating load as set by the design requirements established above. This value is calculated by subtracting the WHR (if included) system capacity and the biomass boiler capacity from the peak heating load.

Peak load system capacity

The user enters the peak load system capacity. If the capacity is below the suggested peak load system capacity the system cannot meet the peak heating load at design conditions. Use the "System Design Graph" (as displayed in the *Energy Model* worksheet) as a guide. This value is transferred to the *Cost Analysis* worksheet.

Peak load system seasonal efficiency

The user enters the peak load system seasonal efficiency. This value is generally lower than the steady-state efficiency because it is calculated on a seasonal basis. This value is used to estimate the peak load fuel requirement to meet the peak load heating system energy demand. Typical values for seasonal efficiency for peak load heating systems range from 55 to 350%. Typical values of heating system efficiency are presented below.

Heating System Type	Typical Annual Heating System seasonal efficiency (%)
Standard boilers/furnaces (with pilot light)	55 to 65
Mid-efficiency boilers/furnaces (spark ignition)	65 to 75
High-efficiency or condensing boilers/furnaces	75 to 85
Electric resistance	100
Air-source heat pump	130 to 200
Ground-source heat pump	250 to 350

Typical Heating System Seasonal Efficiencies

Suggested biomass boiler capacity

The model calculates the suggested biomass boiler capacity required to meet the peak heating load as set by the design requirements established above. This value is calculated by subtracting the WHR (if included) system capacity and the base load biomass boiler capacity from the peak heating load.

Biomass boiler capacity

The user enters the peak load biomass boiler capacity. The model assumes that the capacity is the energy output of the biomass boiler as biomass energy systems are typically rated on output. Use the "System Design Graph" (as displayed in the *Energy Model* worksheet) as a guide. This value is transferred to the *Cost Analysis* worksheet. The user can consult the RETScreen Online Product Database for more information.

Biomass boiler seasonal efficiency

The user enters the peak load biomass boiler seasonal efficiency. 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. The seasonal efficiency is also related to the particular boiler chosen and the operating temperature of the system. This value is used to estimate the biomass fuel requirement to meet the peak load biomass system energy demand. Typical values for seasonal efficiency of a biomass boiler range from 60 to 90%. The seasonal efficiency is typically higher for two-burner systems than a one-burner system. The user can consult the RETScreen Online Product Database for more information.

Peak energy delivered

The model calculates the peak energy delivered, in MWh. The peak energy delivered is the annual energy production provided by the peak load heating system.

Percentage of peak heating load

The model calculates the percentage of the installed capacity of the peak load heating system with respect to the peak heating load.

Percentage of total heating energy demand

The model calculates the percentage of total heating energy demand supplied by the peak load heating system. The model assumes that the WHR system is used in base load mode, with the biomass system taking second priority. If a WHR system is not included in the design, the model assumes that the biomass heating system is used in base load mode. In each case the model assumes that energy is supplied by the peak load heating system only after all the energy is first supplied by the WHR system and/or the biomass heating system - in regards to the peak heating load and total heating energy demand.

Back-up Heating System (optional)

Suggested back-up heating system capacity

Back-up heating system capability may be part of a district heating system. A common "rule-of-thumb" is that each heating plant should have back-up capability equal to the largest unit on the system [Arkay, 1996]. For example, a back-up boiler may be utilised in the case of a boiler shutdown or during an interruption in the biomass fuel supply. The model calculates the largest unit capacity by comparing the sizes of the base load and the peak load heating systems. For new construction projects, a new oil-fired back-up boiler is likely purchased. For retrofit situations, the existing oil-fired heating system may be used as a back-up. 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. A used oil boiler will often suffice as a back-up unit. In other cases a designer may choose not to include a back-up unit, rather relying only on the peak load boiler

Back-up heating system capacity

The user enters the back-up heating system capacity according to the back-up heating system capacities available on the market, or available in a retrofit situation, and the suggested back-up heating system capacity. This value may be used in the *Cost Analysis* worksheet if a back-up system is used.

Annual Energy Production

Items associated with calculating the annual energy production and fuel required of the biomass and/or WHR heating project are detailed below.

Percentage of peak heating load

The model calculates the percentage of the installed capacity of the system type specified by the user with respect to the peak heating load.

Heating capacity

The heating system heating capacities entered by the user are summarised here.

Units switch: The user can choose to express the capacity in different units by selecting among the proposed set of units: "MW," "million Btu/h," "boiler hp," "ton (cooling)," "hp," "W." This value is for reference purposes only and is not required to run the model.

Equivalent full output hours

The model calculates the equivalent full output hours of the WHR, biomass and peak load heating systems.

Capacity factor

The model calculates the capacity factor of the WHR, biomass and peak load heating systems, which is the annual energy production of the these systems expressed as a percentage of their potential energy output if used at rated capacity continuously over a one year period.

Percentage of total heating energy demand

The model calculates the percentage of total heating energy demand supplied by the system type specified by the user.

Heating energy delivered

The model calculates the heating energy delivered by the system type specified by the user.

Units switch: The user can choose to express the energy in different units by selecting among the proposed set of units: "GWh," "Gcal," "million Btu," "GJ," "therm," "kWh," "hp-h," "MJ." This value is for reference purposes only and is not required to run the model.

Biomass requirement

The model calculates the biomass requirement. This value is the amount of biomass fuel, expressed in wet (as-fired) metric tonnes per year, consumed by the biomass heating system in order to meet the specified biomass heating system annual energy production. This output value is calculated using the annual energy delivered of the biomass system, the as-fired heating value of biomass and the biomass boiler seasonal efficiency. The value is transferred to the *Cost Analysis* worksheet.

Heating fuel requirement

The model calculates the heating fuel requirement, expressed in units as shown per year, consumed by the peak load heating system. This value is transferred to the *Cost Analysis* worksheet.

Heating Load Calculation & District Heating Network Design

As part of the RETScreen Clean Energy Project Analysis Software, the *Heating Load Calculation & District Heating Network Design* worksheet is used in conjunction with the *Energy Model* worksheet to estimate the heating load for the proposed biomass and/or WHR heating system. This worksheet is also used to prepare a preliminary design and cost estimate for the district heating network. The user should return to the *Energy Model* worksheet after completing this section.

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, 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 design temperature is used to determine the heating energy 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.

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 2ºC milder in core areas of large cities.

The user should be aware that when modifying the design temperature, the monthly degree-days and the heating load for building cluster might have to be adjusted accordingly.

Annual heating degree-days below 18°C

The model calculates the total annual heating degree-days below 18ºC 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 18ºC. The user can consult the RETScreen Online Weather Database for more information.

Domestic hot water heating base demand

The user enters the estimated domestic hot water heating base demand as a percentage of the annual heating energy demand. To simulate non-weather dependent process demands, the percentage of domestic hot water base demand can be varied.

Typical values for domestic hot water heating base demand range from 10 to 25%. As an example, a hospital will probably use 25% of its heating energy to heat domestic hot water while a regular office building may use only 10% of its heating energy to heat domestic water. If no domestic water heating is required the user will enter 0.

Equivalent degree-days for DHW heating

The model calculates the equivalent degree-days for 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 in DHW heating range from 2 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. If there is no need for hot water heating the value 0 is calculated by the model.

Equivalent full load hours

The model calculates the equivalent full load hours, which is defined as the annual energy 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 heating energy demand. The typical values for the equivalent full load hours is in the range from 1,500 to 4,200 hours. The upper range increases if the system has a high domestic hot water load or process load.

Monthly Inputs

The user enters the monthly degree-days below 18ºC. 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 18ºC. The user can consult the RETScreen Online Weather Database for more information.

Base Case Heating System and Heating Load

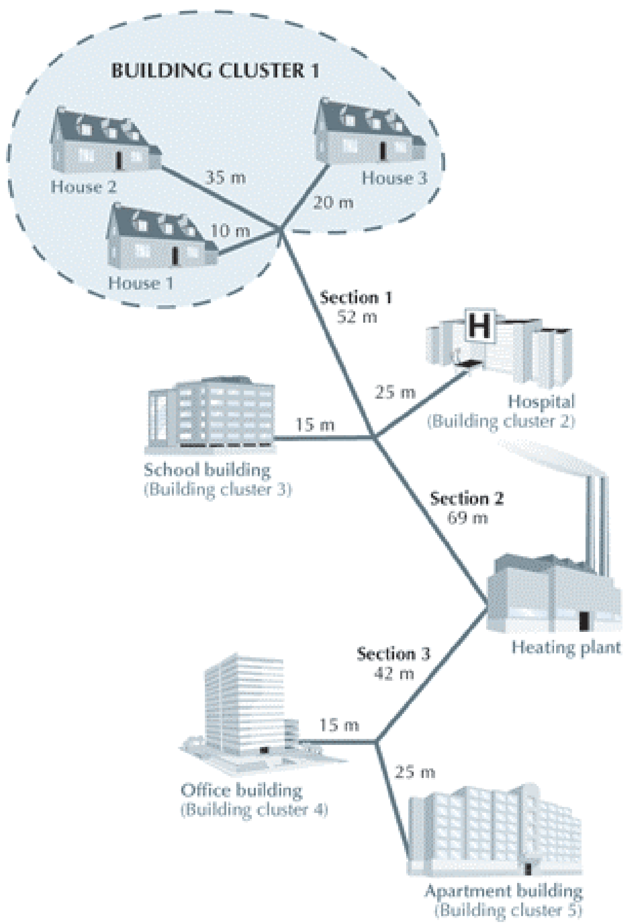
The system characteristics associated with estimating the heating load for the biomass and/or WHR heating system are detailed below.

Technical Note on 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 default values that come with the "BIOH3.xls" RETScreen workbook file for the base case and heating load section and the district heating network design section.

In a district heating system, thermal energy, in the form of hot water, is distributed from the central heating plant 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 following figure, or as a looped system.



Community System Building Cluster Layout

The previous 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 following table provides a summary of the heating loads and pipe lengths for the building clusters shown in the previous figure.

Building cluster	Heated floor area (m^2)	Number of buildings	Heating load (W/m^2)	Length of pipe (m)
Building cluster 1	450	3	70	65
House 1	*150*	*1*	*70*	*10*
House 2	*150*	*1*	*70*	*35*
House 3	*150*	*1*	*70*	*20*
Building cluster 2 (Hospital)	900	1	90	25
Building cluster 3 (School building)	800	1	70	15
Building cluster 4 (Office building)	1 000	1	65	15
Building cluster 5 (Apartment building)	1 500	1	100	25

Community System Base Case Heating System and Heating Load

Base Case Heating System

Heated floor area per building cluster

The user enters the total heated floor area for the building(s) in a cluster. A building cluster is any number of similar buildings connected to a single point of the distribution system. The heated floor area per building cluster is the floor surface area of the building(s) that have to be heated, multiplied by the number of floors. The user obtains this value for each of the buildings included in the biomass and/or WHR heating system and summarises the values to enter the cluster total heating surface area (See Technical Note on Network Design).

Typical values for total floor heating surface area range from 500 to 9,000 m². Most commercial or institutional buildings will have a heating surface exceeding 500 m². A typical value of heating surface area for an individual house is 140 m².

Note: When the user enters 0 or leaves the heated floor area per building cluster cell blank, the remaining column in this section is greyed out.

Number of buildings in building cluster

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

Heating fuel type(s)

The user selects the type of fuel that is used to heat the cluster of buildings. A list of common fuels is provided in the drop-down list.

The following table provides the heating value for the heating energy avoided.

Heating Energy Avoided	Fuel Heating Value
Natural gas	37.2 MJ/m³ (10.33 kWh/m³)
Propane	26.6 MJ/L (7.39 kWh/L)
Diesel (# 2 oil)	38.7 MJ/L (10.74 kWh/L)
# 6 oil	40.5 MJ/L (11.25 kWh/L)
Electricity	1.0 kWh/kWh
Other	1.0

Fuel Heating Content

Note: Propane is expressed in terms of liquefied propane.

Heating system seasonal efficiency

The user enters the average efficiency of the conventional heating system over the season of use. This entry is used to calculate the financial value of the system. It has no influence on the calculation of the annual energy production. Typical values range from 55% for conventional fossil-fuel-fired heaters to 100% for electric heaters. If a heat-pump is used as a base case the user will select "Electricity" as the heating fuel type and may enter values higher than 100% to reflect the heat pump coefficient of performance (COP) (e.g. enter 225% if seasonal COP is 2.25).

Typical values of heating system efficiency are presented in the table below. These values should be reduced by 10% if ducting runs outside of the insulated envelope (e.g. in attics).

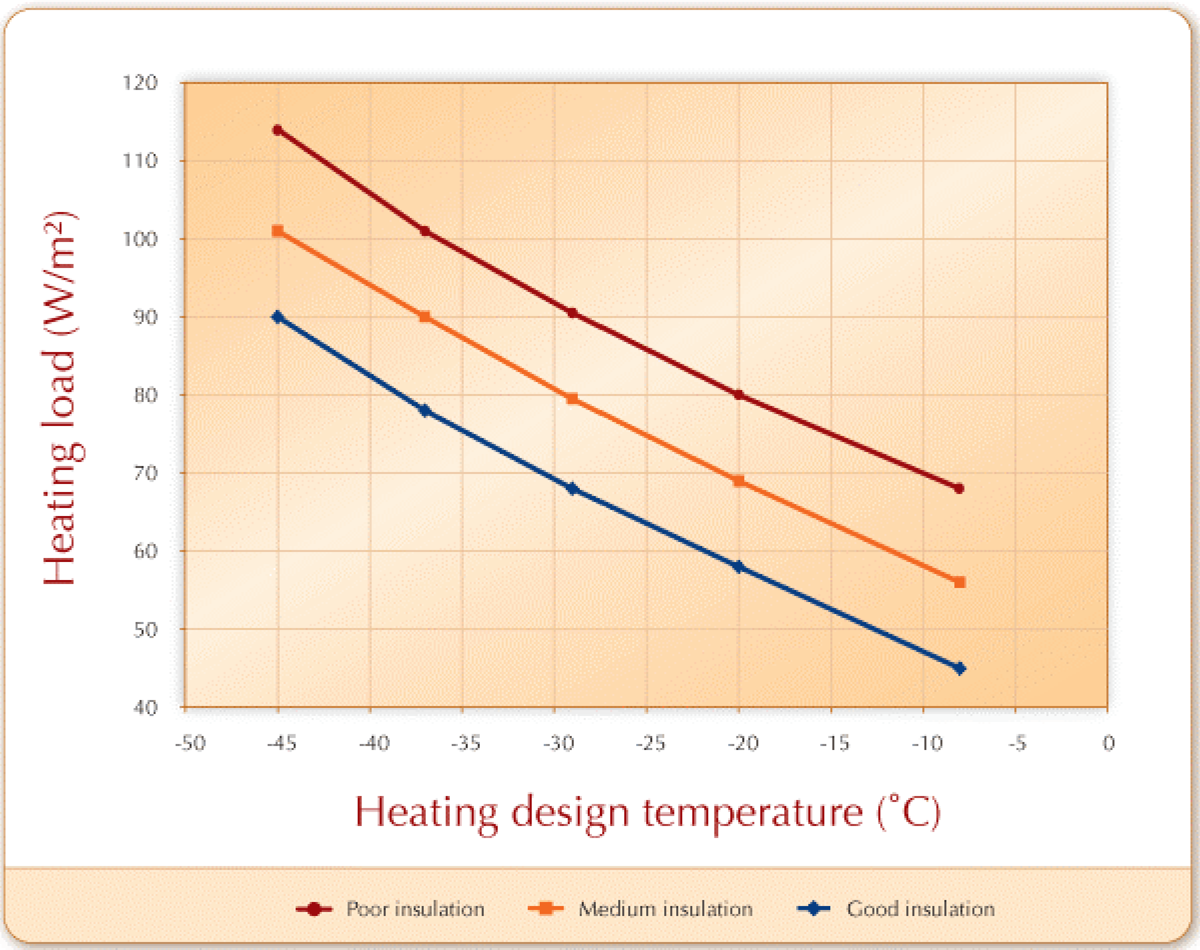
Heating System Type	Typical Annual Heating System seasonal efficiency (%)
Standard boilers/furnaces (with pilot light)	55 to 65
Mid-efficiency boilers/furnaces (spark ignition)	65 to 75
High-efficiency or condensing boilers/furnaces	75 to 85
Electric resistance	100
Air-source heat pump	130 to 200
Ground-source heat pump	250 to 350

Typical Heating System Seasonal Efficiencies

Heating Load Calculation

Heating load for building cluster

The user enters the heating load for building cluster. The user can refer to the next figure [CET, 1997] to estimate the building heating load per unit of building heating surface area. This value depends on the design temperature for the specific location and on the building insulation efficiency. The heating load for building cluster is used to calculate the peak heating load for the heating system. Typical values for building heating load range from 40 to 120 W/m².



Building Heating Load Chart

Note: The values in this figure are more appropriate for residential buildings.

Heating energy demand

The model calculates the buildings cluster's annual heating energy demand, which is the amount of energy required to heat the building(s) in the building cluster (including domestic hot water).

This value is calculated from the heated floor area per building cluster, the heating load for building cluster and the equivalent full load hours.

Total peak heating load

The model calculates the building cluster's total peak heating load, which is the heating power required to meet the largest heating load for the year. It typically coincides with the coldest day of the year. This value is transferred to the *Energy Model* worksheet.

Fuel consumption - units

The model displays the units used for the heating fuel type selected for each building cluster. Note that the fuel consumption unit for propane is litres of liquefied propane.

Fuel consumption - annual

The model calculates the annual fuel consumption for each building cluster. If the fuel consumption is known for the building(s) this row can be used to determine the "Heating load for building cluster." For example, the user may know (from previous years heating bills) how many litres of heating oil are purchased. In this case the user would vary the "Heating load for building cluster" value until the fuel consumption value converges to the value shown on their heating bills.

Cost of fuel - units

The model displays the units used for the heating fuel type selected for each building cluster. Note that the cost of fuel unit for propane is expressed in terms of litres of liquefied propane.

Unit cost of fuel

The user enters the unit cost of the heating fuel type selected for each building cluster. The user is given the flexibility in the model to determine what is the "conventional," or base case, energy system. The user will need to determine this value according to the cost units given in the table. Heating values are also given in the table below.

Heating Energy Avoided	Cost Unit	Fuel Heating Value
Natural gas	$/m³	37.2 MJ/m³ (10.33 kWh/m³)
Propane	$/L	26.6 MJ/L (7.39 kWh/L)
Diesel (#2 oil)	$/L	38.7 MJ/L (10.74 kWh/L)
#6 oil	$/L	40.5 MJ/L (11.25 kWh/L)
Electricity	$/kWh	1.0 kWh/kWh
Other	$/MWh	1.0

Energy Cost Unit and Heating Content (Energy Mines and Resources Canada, 1985)

Note that the cost unit of propane is expressed in terms of litres of liquefied propane. The unit cost of fuel is used in conjunction with the total heating energy demand, the heating value and the base case heating system seasonal efficiency to calculate the total fuel cost.

In cases when the heating energy avoided is electricity, the user will normally enter the retail price of electricity as the unit cost of fuel. Note that the heating value for the "Other" type of heating energy avoided has been set to 1.0. This implies that the user must enter the cost in terms of $ per MWh of heating energy content of the fuel considered.

Total fuel cost

The model calculates the total fuel cost for each building cluster.

District Heating Network Design

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

Small-commercial biomass and/or WHR heating systems usually use 32 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 Biomass Heating 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 delivered energy. These numbers change if the pipe length is short and delivered energy is high.

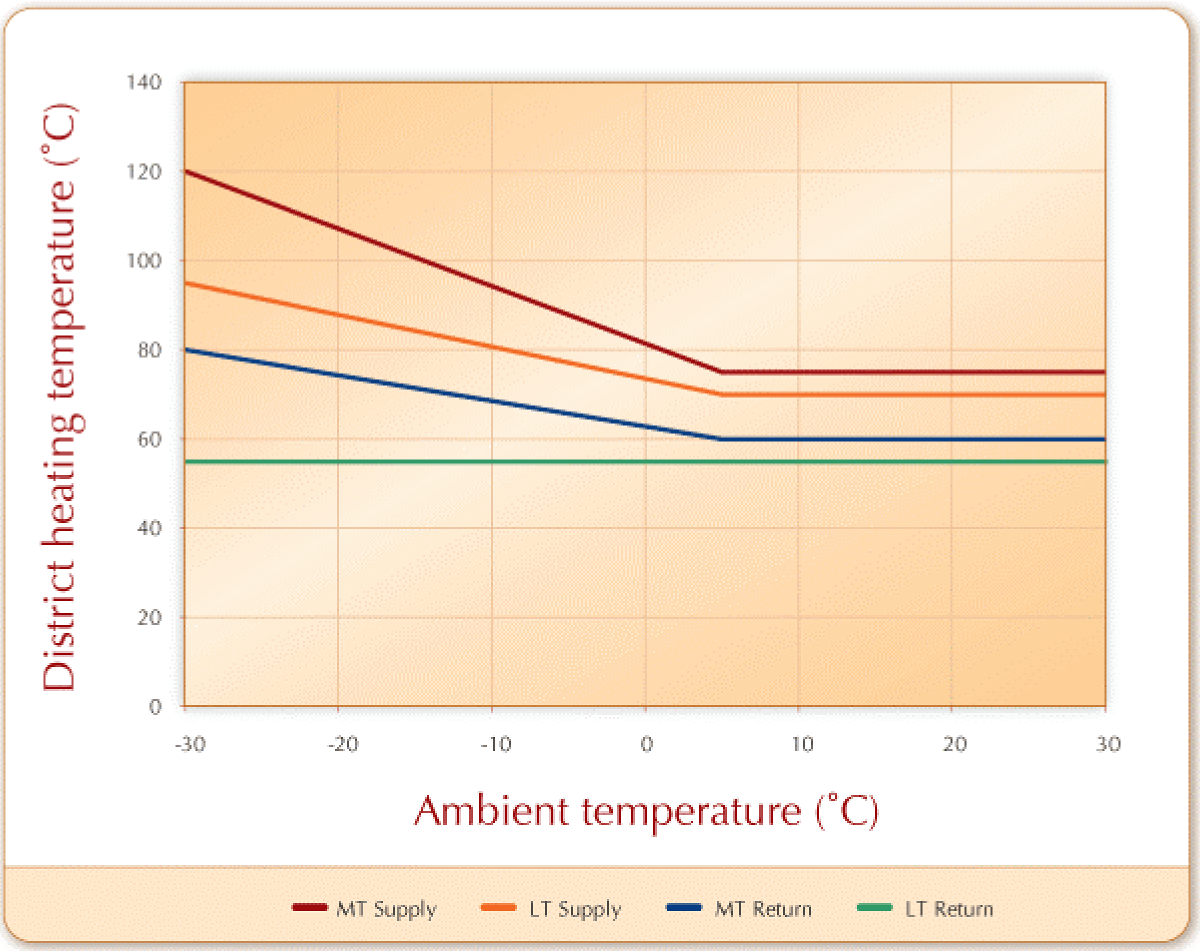
As an example, the heat loss is approximately 58 W/m for a two-pipe system of a DN125 pipes using an average annual supply temperature of 100°C and an average annual return temperature of 50°C. The capacity is 3,400 kW for a DN125 pipe assuming a temperature difference of 45°C. Additional information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

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

The next figure illustrates typical district heating temperatures in relation to ambient temperature. Medium Temperature (MT) supply is typical for steel pipe systems. Low Temperature (LT) supply is typical for plastic pipe or mixed type systems. MT return is typical for district heating systems with a mixture of old and new buildings. 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 and typically use supply temperatures that are well above temperatures shown in the following figure - i.e. about 150°C).



Typical District Heating Supply and Return Temperatures

Design return temperature

The user enters the design return temperature for the district heating network. A low return temperature is desirable. Lower return temperatures makes 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, 50°C can be achieved. (See the Typical District Heating Supply and Return Temperatures graph for more information.)

Differential temperature

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

Main Distribution Line

The main distribution line is the part of the district heating pipe system that connects several buildings, or clusters of buildings, to the heating plant. The first section exiting the heating 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 heating 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 heating plant, this pipe is considered to be a secondary line.

Main pipe network oversizing

The user enters a pipe network oversizing factor. The selected pipe sizes 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 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. For more information, see example in *Technical Note on 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 per 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 distribution network.

Secondary Distribution Lines

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

Secondary pipe network oversizing

The user enters a pipe network oversizing factor. The selected pipe sizes 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. For more information, see *Technical Note on 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 per 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 Costs

In this section two alternative methods are provided for assessing the costs for district heating pipes and energy transfer stations - Formula costing and Detailed costing.

Total pipe length

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

Costing method

The user selects the type of costing method. The options from the drop-down list are: "Formula" and "Detailed." If the formula method is selected, the model calculates the costs according to built-in formulas. If the detailed method is selected, the user enters the Energy Transfert 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 method are based on typical Canadian project costs as of January 2000. The user can adjust these costs to local conditions using the cost factors in the cells below and by the "Exchange rate" cell.

Energy transfer station(s) connection type

The user selects the energy transfer connection type from the two options in the drop-down list: "Direct" and "Indirect." If "Direct" is selected, the model sets the costs for energy transfer stations to $0. If "Indirect" is selected, the model calculates the costs according to built-in formulas if "Formula" costing method is selected, or the user enters these costs if "Detailed" costing method is chosen.

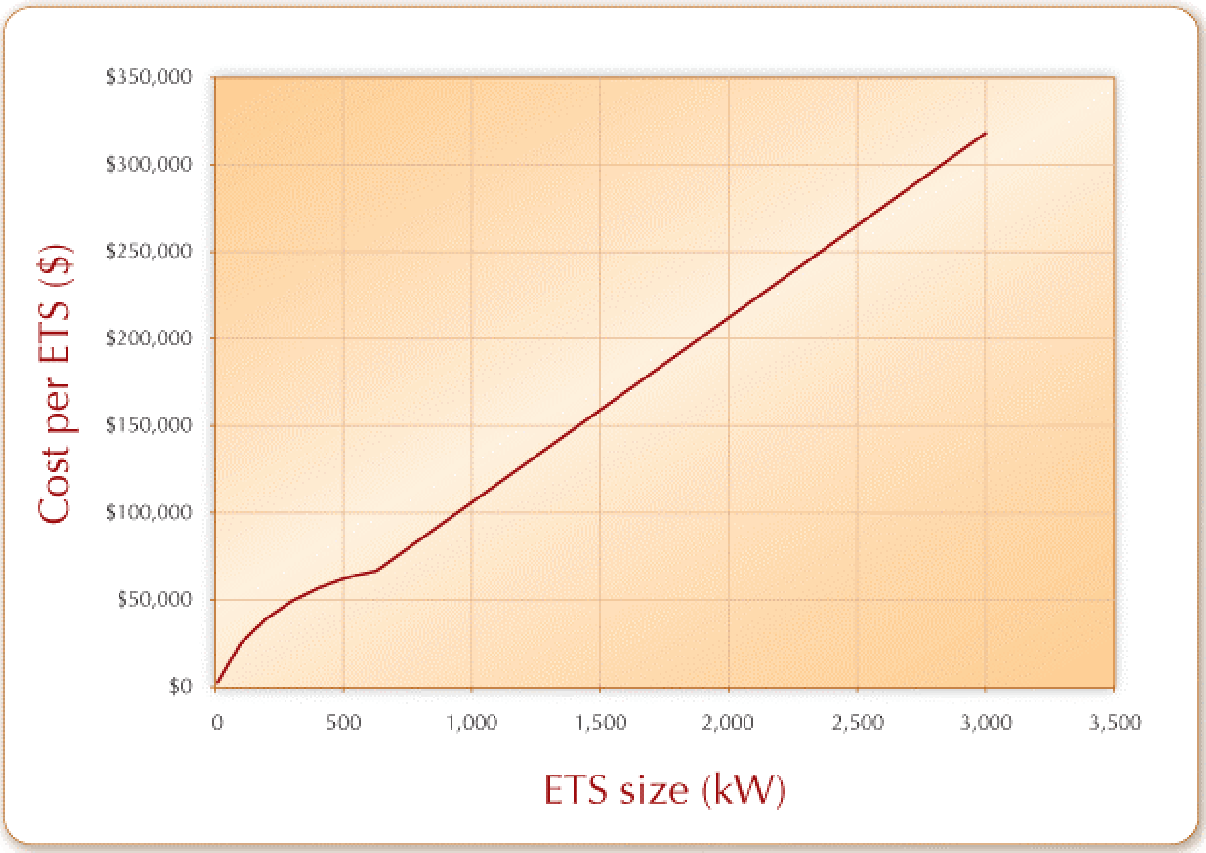
The building's heating system is normally connected indirectly to the district heating system via energy transfer stations located in the basement or where a boiler would normally be located. Direct systems connect the district heating system directly to the building's heating system.

Energy transfer station(s) cost factor

If the user selects the "Formula" costing method, then an energy transfer station 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.

Energy transfer station(s) cost

If the user selects the "Formula" costing method, then the energy transfer station cost for all the buildings in each cluster is calculated by the model. The costs are calculated using the next figure. This figure can also be useful if the user has selected the "Detailed" costing method. 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.



Typical Costs for Energy Transfer Station(s)

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 - one for the space heating system and a second for domestic hot water 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 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.

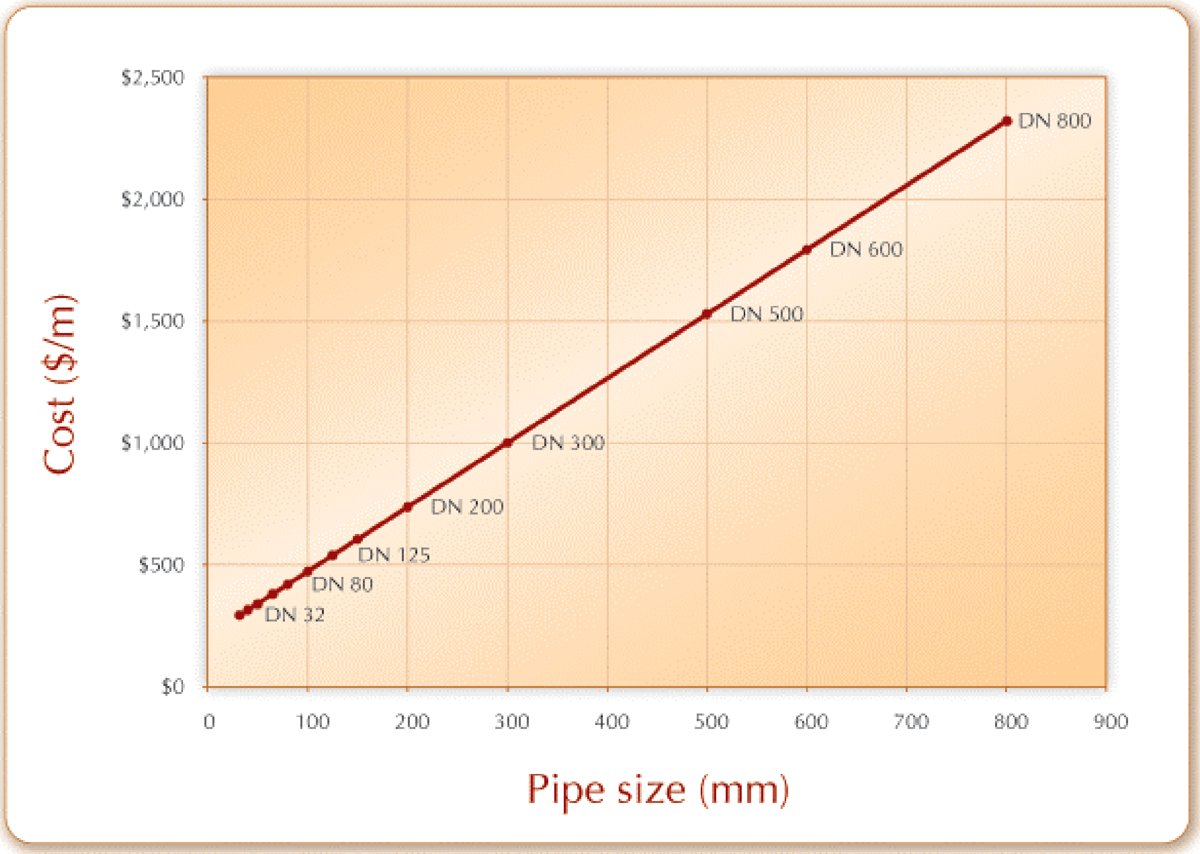
Exchange rate

The user enters the exchange rate to convert the calculated Canadian dollar costs into the currency in which the project costs will be reported. The rate entered must be the value of one Canadian dollar expressed in the currency in which the project costs will be reported.

Note: The user should first select the currency at the top of the *Cost Analysis* worksheet.

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. The costs are calculated using the next figure. This figure can also be useful if the user has selected the "Detailed" costing method. If the "Detailed" costing method is selected, then the user enters the total cost for the secondary distribution pipes cost per building cluster. The model then calculates the total costs for all building clusters.



Typical Costs for Secondary Distribution Line Pipes

The costs shown are for the supply and installation of the supply and return pipes in the (i.e. 2 pipes) trench. The cost per meter in the previous figure is for two pre-insulated district heating type pipes, in a trench approximately 600 mm deep; the costs also include repair of the existing sidewalk or road. Rocky terrain or installations in areas with a number of existing 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 using the values entered by the user (detailed method) or calculated by the model (formula method) for energy transfer stations and secondary distribution pipes. The model also calculates the total cost of connecting all building clusters.

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.

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 main distribution line pipe cost for all main pipe sections is calculated by the model. The costs are calculated using the same formula as for secondary distribution line pipe costs (see the Typical Costs for Secondary Distribution Line Pipes graph).

If the "Detailed" costing method is selected, then the user enters the total cost for the main distribution line pipe cost for each pipe size categories. The model calculates the total costs for all the main distribution pipe costs.

The costs shown are for the supply and installation of two 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; the costs also include restoration of the existing sidewalk or road. Rocky terrain or installation in areas that have many old utility services (e.g. telephone, electricity, sewage, water, etc.) could substantially increase the quoted costs.

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 costs

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

Note: The user should return to the *Energy Model* worksheet.

Cost Analysis[1]

As part of the RETScreen Clean Energy Project Analysis Software, the *Cost Analysis* worksheet is used to help the user estimate costs associated with a biomass and/or WHR heating 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.

Typically, the lowest cost automated biomass heating installations normally occur in the following situations:

- distances between buildings are relatively short;
- existing heating systems use hot water and are easy to connect into;
- an existing building can house the heating plant; and
- new access roads are not required.

The most cost effective installations of biomass and/or WHR heating systems normally occur in new construction, particularly where a district heating system is planned, since many of the costs associated with the "Balance of Plant" will be installed, even if the biomass and/or WHR heating project does not go forward. The second most cost effective installation is likely for retrofit situations when there are plans to either repair or upgrade an existing heating system. However, it is certainly possible that high heating costs could make the biomass and/or WHR heating system financially attractive, even in retrofit situations that do not meet the above criteria.

The first two situations give examples where the installation of the biomass and/or WHR heating project is "credited" for material and labour costs that would have been spent on a "conventional" heating system had the biomass and/or WHR component not been utilised. 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 a conventional heating system. A "credit" input cell is provided to allow project decision-makers to keep track of these items when preparing the project cost analysis.

Type of analysis

The user selects the type of analysis from the drop-down list. 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.

[1] A reminder to the user that the range of values for cost items mentioned in the manual are for a 2000 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 and to the Euro was 0.68 as of January 1, 2000).

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 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.

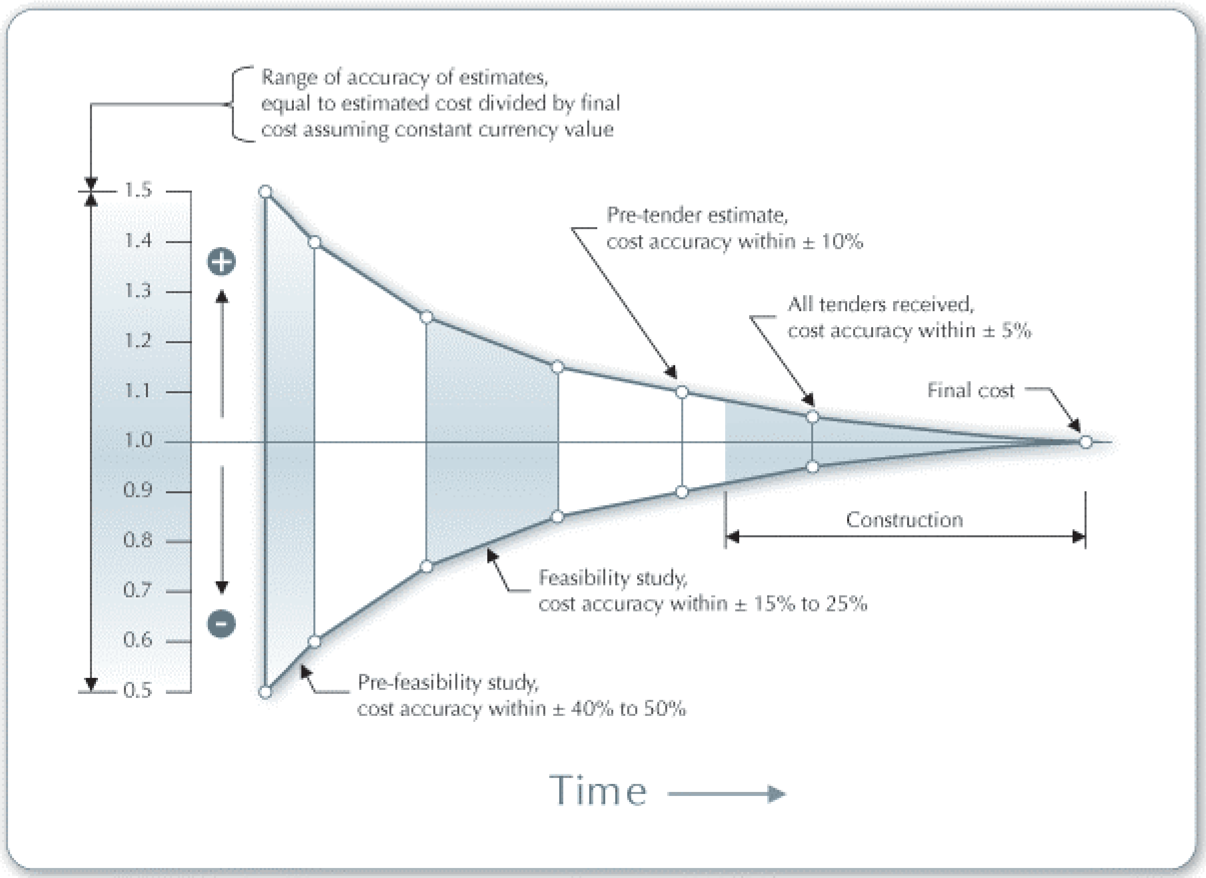
- Spend additional money and time on engineering to more clearly delineate potential project costs and to more precisely estimate the amount of energy produced or energy saved.

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.



Accuracy of Project Cost Estimates [Gordon, 1989]

Currency

To perform a RETScreen project analysis, the user may select a currency of their choice from the "Currency" cell in the *Cost Analysis* 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).

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 references" drop-down list cell.

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.

Cost references

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 - 2000," "None," "Second currency" and a selection of 8 user-defined options ("Enter new 1," "Enter new 2," etc.).

If the user selects "Canada - 2000" the range of values reported in the "Quantity Range" and "Unit Cost Range" columns are for a 2000 baseline year, for projects in Canada and in Canadian dollars. This is the default selection used in the built-in example in the original RETScreen file.

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 the user selects "Second currency" two additional input cells appear in the next row: "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. Note that this selection is for reference purposes only, and does not affect the calculations made in other worksheets.

If "Enter new 1" (or any of the other 8 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 "Enter new 1" to enter a specific name (e.g. Japan - 2001) 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 ("Enter new 1" to "Enter new 8") enables the user to keep track of different cost scenarios. Hence the user may retain a record of up to 8 different quantity and cost ranges that can be used in future RETScreen analyses and thus create a localised cost 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. The second currency option is activated by selecting "Second currency" in the "Cost references" drop-down list cell. 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 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, 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 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" and the currency selected in "Second currency." The exchange rate is used to calculate the values in the "Foreign Amount" column. Note that this selection is for reference purposes only, and does not affect the calculations made in other worksheets.

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) - this is the 1st currency. The user then selects United States currency (USD) from the "Second currency" input cell - 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.

% 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 switch."

Foreign Amount

The model calculates 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 items costs 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 a biomass and/or WHR heating 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 equipment, construction of the balance of plant and costs for any other miscellaneous items.

Feasibility Study

Once a potential cost-effective biomass and/or WHR heating project has been identified through the RETScreen pre-feasibility analysis process, a more detailed feasibility analysis study may be required. This is particularly the case for large projects, with more than one building. Feasibility studies typically include such items as a site investigation, a local biomass resource assessment, a preliminary project design, and a final report. Feasibility study project management and travel costs are also normally incurred. These costs are detailed in the following section.

For small projects (single buildings with small heating requirement), the cost of the feasibility study, relative to the cost of the biomass and/or WHR heating system, may not be justified. In this case the project proponent may 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 prepare the Feasibility Study.

Site investigation

A site investigation is normally required for biomass and/or WHR heating projects with district heating. The site visit involves a brief survey of all major buildings under consideration. In small district heating systems, the user would likely look for clusters of oil or electricity heated buildings with a distance not exceeding 500 m. Typical major buildings heated with oil or electricity include schools, hospital/health clinics, churches, senior's apartments, service garages and community offices.

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 heating systems and locations, including notes on any attributes or problems for conversion to biomass energy; selection of a possible site for the biomass heating plant; preparation of a layout of approach roads and a plant yard for outdoor storage of chipped wood. 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 and accommodation".)

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 heating 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 range at the site is typically 7 to 16 hours at a rate of approximately $40/h to $100/h.

Biomass resource assessment

Biomass and/or WHR heating projects are not considered "renewable energy" unless the biomass is harvested in a sustainable manner. The user must carefully consider the biomass resource to ensure that there is a sufficient local biomass resource to meet the projects energy requirements in a environmentally appropriate and financially feasible manner. With small-commercial wood biomass systems, it is unlikely that the annual woodchip consumption will exceed 1,500 tonnes, which is relatively small for most forested regions. Because of this limited wood resource use, it is assumed here that only a brief biomass resource assessment is required during the feasibility analysis stage.

One basic question must be answered by the user: "Are there substantial sustainable wood resources within a reasonable transport distance using efficient vehicles?" This can be addressed by conducting a brief aerial survey or by travelling surrounding roads and waterways to assess standing wood resources.

The time required to carry out a brief biomass resource assessment is typically 6 to 12 hours, depending on the extent of the field survey and the amount of data collection and analysis involved. Typical rates for biomass resource assessment experts range from $40/h to $100/h. This assessment can usually be combined with the site investigation. The costs of charter flights may need to be added if an aerial survey is required (add to "Travel and accommodation").

Preliminary design

A preliminary design that synthesizes the above information is required. The design is usually based on design approaches used in most existing small biomass and/or WHR heating systems. Some elements such as the building yard or approach roads will be specific to the proposed plant sites.

The time required for a preliminary design analysis is 6 to 8 hours, depending on the number of buildings involved and any features unique to the site. The rate is approximately $40/h to $100/h.

Report preparation

A summary report should be prepared which describes the feasibility study, its findings and recommendations. The written report will contain data summaries, charts, tables and illustrations which clearly describe the proposed project. This report should be in sufficient detail regarding costs, performance and risks to enable project lenders 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 a professional to complete the necessary work, and should also include the time required to manage the overall feasibility study preparation. Typically 16 to 32 hours is required. The major variables are: the number of buildings involved; the complexity of interconnecting the buildings; any unique requirements regarding the location of the plant, any unusual wood supply requirements (e.g. the need for a wood supply yard), and conclusions and recommendations regarding the supply of woodchips. The rate is approximately $40/h to $100/h.

Travel and 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. For local travel, a supplier may not charge for time and expenses. For isolated areas, where air travel is time consuming and expensive, it may be better to include more than one potential project in the feasibility study to spread the site visit costs over a number of projects and not just one building.

In the case of isolated areas, rates for air travel will vary considerably. 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.

Other

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. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." 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 be entered in the grey input cell as "Credit." 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.

Development

Once a potential biomass and/or WHR heating project has been identified through the feasibility study to be desirable to implement, project development activities may follow. For some projects, the feasibility study, development and engineering activities may proceed in parallel, depending on the risk and return acceptable to the project proponent.

For biomass heating projects with district heating, 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 biomass and/or WHR system product supplier who provides complete design/build services. General contractors may also be the developer, purchasing the biomass and/or WHR heating system 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 biomass and/or WHR heating system and sell the energy to local building owners. Estimating the costs of the development phase will depend on the particular development arrangement established. Items here include costs for contract negotiations, permits and approvals, project financing, development phase project management and any development related travel costs. These costs are detailed in the following section.

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.

This can be very time consuming, particularly if there are a number of different stakeholders involved, for example, a fuel supplier, a heating plant operator and several clients who wish to purchase heat. The time required typically ranges from 32 to 80 hours at rates ranging from $50/h to $100/h.

Permits and approvals

A number of permits and approvals may be required by local authorities for the construction of the project. The cost of acquiring the necessary permits and approvals is calculated based on an estimate of the time required to complete the necessary work. These agencies include local building and electrical inspectors, boiler inspectors, fire safety inspectors, forestry (fuel supply) and an emissions regulating authority.

The time required depends on the number of agencies involved and what is specifically required to meet their rules and regulations. The time requirement is typically 40 to 80 hours at rates ranging from $40/h to $100/h. The user can also add to the number of hours, or unit costs, an amount to cover the actual permit itself. Permit costs are usually minor relative to the total project cost.

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 or local utility developed project much more effort will likely be required to arrange financing, negotiate an energy services contract with the building owner and prepare legal documents.

The cost to obtain project financing will range from 32 to 48 hours at a rate of between $50/h to $100/h. The lower end of the range is for building owner/product supplier developed projects. The higher end of the range applies to ESCO/utility type projects.

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 here. The time required for public relations varies according to the technical complexity of the project, the number of stakeholders involved, the volume of fuel required and the size of the potential fuel supply area.

The elapsed time for the development of a biomass and/or WHR heating project falls in the mid range as compared with other projects. Projects can be developed within a one to two year time period. The project development management time will usually take between 30 to 80 hours at rates of between $50/h to $100/h.

Travel and accommodation

This cost item includes all travel related costs (excluding time) required to develop the project.

Other

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. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." 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 be entered in the grey input cell as "Credit." 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.

Engineering

The engineering phase includes costs for the biomass and/or WHR heating plant site and building design, energy system design, tenders and contracting, and construction supervision. 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 and building design

Site layout includes the selection of the building or cluster of buildings to be heated by the biomass and/or WHR heating system; selecting the site for the biomass heating plant; determining where approach roads should go for site access and determining the boundaries of the plant yard. The buildings used to house small-commercial heating plants and for 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 time required to carry out a site layout and building design is typically 12 to 18 hours. Variables include site restrictions, type of delivery vehicles to be used and the turning space required and space needed to store woodchips. Rates of $40/h to $100/h are common.

Energy system design

The heating plant design is generally quite straight forward for small-commercial biomass systems with only small variations. Factors to be determined include: the number of burner/boiler units; the size/capacity of the units; the fuel type; the auger size; the auger speed;

the gearbox reduction ratio; the auger motor size (3/4 or 1 hp); and unique system options such as alarms. The heat distribution system design is an important design component in small-commercial biomass systems. Design tasks include: selection of a routing for the heat distribution piping; determining the appropriate diameter of piping; determining where and how to interconnect with the heating systems of the various buildings; and selecting and locating any heat metres to be used.

The time required to design a biomass and/or WHR heating system is typically 14 to 30 hours at rates of $40/h to $100/h. The primary time variables are: the level of automation required; the number of buildings involved; the different types of heat distribution systems present in the existing buildings (e.g. hot water, hot air); and the ease or difficulty of interconnecting with each building.

Tenders and contracting

Upon completion of the various engineering tasks, tender documents may be required by the project developer. They 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 time required to produce a set of bid documents will vary depending upon the complexity and the size of the project. If bid documents are required 12 to 20 hours at rates of $40/h to $100/h are possible.

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 regular visits to the job site to inspect the installation.

Depending of the project size, this task can take between 30 to 80 hours at rates of $40/h to $100/h. Travel time to the site for construction supervision is in addition to the range given. Travels costs should be included in the "Development" section.

Other

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. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." 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 be entered in the grey input cell as "Credit." 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.

Energy Equipment

The energy equipment, as defined here, includes the waste heat recovery system, biomass boilers and burners, and the associated spare parts, chimney stacks, plumbing, electrical, equipment installation and transportation costs. 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.

Waste heat recovery system

The user enters the waste heat recovery cost per kW. The kW capacity is transferred from the *Energy Model* worksheet. This value includes both equipment and installation costs.

The cost for the waste heat recovery (WHR) system varies considerably depending on the source of waste heat. For example, a reciprocating engine, with a 100 kW WHR system consisting of heat exchangers, a control system for jacket cooling and a recovery boiler for exhaust gas and lubrication oil, the typical cost would be $100,000 or $1,000/kW.

Biomass heating system

The user enters the biomass heating system cost per kW. The kW capacity (and number of boilers) is transferred from the *Energy Model* worksheet. The following tables provide typical values of "cost per capacity" in $/kW. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

The biomass boiler(s) cost is determined by the capacity. The price differential between the biomass systems in each category is relatively small because the labour and many ancillary components such as pumps, fittings and controls remain largely the same regardless of capacity.

The cost of biomass burner(s) is determined by the overall capacity and cost of components used. However, the price differential between small burners and large ones is normally small. This is due to the fact that certain standard components are required regardless of the capacity rating.

Examples include: the control panel; the auger drive motor; fabrication labour. Components for which the costs vary somewhat include: reduction gearboxes; augers; size and weight of the fuel hoppers and combustion cells.

Typical range of costs for small-commercial biomass systems are illustrated in the following table:

Power Capacity (kW)	Component Costs ($) Boiler	Burner	Chimney	Spare Parts	Total Cost $	Cost per Capacity $/kW	Fuel Bin Size m^3
75	6,600	8,000	1,400	2,500	18,500	**247**	2.5
100	8,800	10,000	1,500	2,700	23,000	**230**	3.0
150	13,200	14,000	1,700	2,800	31,700	**211**	3.0
180	14,300	15,500	1,900	2,900	34,600	**192**	4.0
250	15,400	17,000	2,000	3,000	37,400	**150**	4.0

Small-Commercial Biomass System Costs

The user should refer to the biomass boiler system capacity to select the appropriate cost for the burner. The number of biomass burners is assumed (for this level of analysis) to be equal to the number of biomass boilers. The burners normally range from 1 to 3 units.

Typical range of costs for commercial/industrial biomass systems are illustrated in the following table:

Power Capacity (kW)	Total Cost ($)	Cost per Capacity $/kW	Fuel Bin Size m^3
1,000	245,000	**245**	76
1,500	272,000	**181**	114
2,000	300,000	**150**	153
2,500	335,000	**134**	191
3,000	378,000	**126**	229

Commercial/Industrial Biomass System Costs

The biomass systems given in the previous table are built for commercial or industrial usage and are more heavy duty than small-commercial biomass systems. The above costs include automatic fuel handling system, combustion chamber, boiler, fluegas handling equipment, induced draft fan, multi-cyclone or wet venturi scrubber, stack and 1% for initial spare parts.

For systems with district heating, the cost of the distribution pump and the cost of installation are included in the pipe costs. The size and cost of the pumps (typically one for operations and one for standby or emergency) vary by the size and complexity of the system. The built-in formulas for estimating pipe costs include the cost of the pump and the cost of installation.

Biomass equipment installation

The user enters the biomass equipment installation costs per kW. The kW capacity of the biomass heating system is transferred from the *Energy Model* worksheet.

Typical equipment installation costs for small-commercial and commercial/industrial boilers are illustrated in the following tables.

Power Capacity (kW)	Labour @ $40-70/h (hours)	Plumbing materials ($)	Electrical materials ($)	Cost per Capacity ($/kW) @ $40/h	@ $70/h
75	80 h	3,200	1,500	105	137
100	80 h	3,300	1,700	82	106
150	90 h	3,500	2,000	61	79
180	90 h	3,700	2,300	53	68
250	100 h	3,800	2,500	41	53

Small-Commercial Boiler Installation Costs

Power Capacity (kW)	Piping Installation (hours)	Electrical Installation (hours)	Refractory Installation (hours)	Equipment Installation (hours)	Cost per Capacity ($/kW) @ $40/h	@ $70/h
1,000	500	300	100	350	50	88
1,500	525	315	120	375	36	62
2,000	550	330	140	400	28	50
2,500	575	345	160	425	24	42
3,000	600	360	180	450	21	37

Commercial/Industrial Boiler Installation Costs

Installation costs for district heating distribution pumps are included in the pipe costs.

Transportation

The transportation costs for the biomass heating and/or WHR system equipment vary depending on weight and size of material to be shipped and distance from the factory. Normally, the material is shipped by truck unless there is no road access to the site, in which case, other methods, such as rail, air, winter road or boat are required. Some projects will require more than one freight carrier. For example, truck to rail line, then to a barge or plane. Each time the material is transferred, someone must be on hand to receive it and/or arrange for the transfer. Freight costs to isolated areas may be difficult to estimate and it is advisable to check for best routing.

As an example, the weight of the energy equipment for a common biomass heating system sold in North America is approximately 460 kg for a 75 kW unit (biomass burner, boiler and miscellaneous parts) and 1,840 kg for a 200 kW unit.

Other

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. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." 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 be entered in the grey input cell as "Credit." 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 Plant

The balance of plant for a biomass and/or WHR heating project typically includes a number of items such as a peak load heating system, and possibly a back-up heating system. It will also include the heat distribution system components such as distribution piping and trenching, and the balance of plant will include the building interconnection plumbing required. In addition, plant building and yard will usually have to be constructed and separate costs for equipment installation and transportation will be included. These costs are detailed below. The user should remember to consider cost items, listed below, that may be **"credited"** due to the fact that they are required even if the biomass and/or WHR heating project does not go forward. The user should try to establish the capital cost of equipment that would be installed as an alternative to the biomass and/or WHR heating system. Typically, there are four alternatives, in order of largest to lowest potential capital cost crediting:

1. New construction where a district heating system is considered "conventional."
2. New construction where a district heating system would not otherwise be planned.
3. Retrofit situations when there are plans to either repair or upgrade an existing heating system.
4. Retrofit situations when there are <u>no</u> plans to either repair or upgrade an existing heating system.

[Biomass] Peak load heating system

As discussed in the *Energy Model* description, a typical biomass and/or WHR heating system includes a heating system that is utilised to meet the peak period load.

The cost of a peak load heating system ranges from approximately $85/kW for large oil units (e.g. 400 kW unit), to $100/kW for small oil units (e.g. 75 kW unit). The cost of an oil tank, plumbing and breaching (smoke pipe) should also be included, these costs range from $3,000 to $6,000 for each boiler. The capacity of the boiler(s) is automatically copied from the *Energy Model* worksheet. The combined costs will likely range from approximately $10,000 to $34,000 ($133/kW to $85/kW) per oil boiler.

Back-up heating system

As discussed in the *Energy Model* section, a typical biomass and/or WHR heating system may also include an optional back-up heating system which will provide back-up in case of a heating system shut-down. The installation of a new oil- fired back-up heating system may be necessary unless the existing boiler can be utilised as a back-up.

The cost of a back-up heating system ranges from $6,000 to $28,000 for oil boilers ranging in size from 75 to 400 kW. The cost of plumbing and breaching (smoke pipe) should also be included, these costs range from $3,000 to $4,000. The combined costs range from $9,000 to $32,000 ($107/kW to $75/kW) per oil boiler (also see description of "Peak load heating system" - note that the fuel tank is not included with the back-up heating system).

Energy transfer station(s)

The number of buildings and cost of the energy transfer station(s) is automatically copied from the *Heating Load & Network* worksheet.

Secondary distribution line pipe

The total length and cost of the secondary distribution line pipe is automatically copied from the *Heating Load & Network* worksheet.

Main distribution line pipe

The total length and cost of the main distribution line pipe is automatically copied from the *Heating Load & Network* worksheet.

Building and yard construction

To prepare an initial estimate of the total building and yard construction cost, the user could simply insert the building size and then use a combined cost based on plant building of $220/m² to $470/m².

Typical building sizes for small-commercial biomass combustion systems are given in the table.

Boiler Size	Floor area		Ceiling Height	
(kW)	(m)	(ft)	(m)	(ft)
75	3.6 x 5.5 = 19.8 m²	12' x 18'	3.6	12'
250	4.3 x 7.3 = 31.4 m²	14' x 24'	3.6	12'
2 x 250	7.2 x 7.2 = 51.8 m²	24' x 24'	3.6	12'
2,500	13 x 12 = 156 m²	43' x 39'	10	33'
	+ fuel storage			
	4.5 x 17 = 76.5 m²	15' x 56'		

Typical Building Sizes for Small-Commercial Biomass Systems

Note that for a 2,500 kW system, fuel storage space should also be included. The building, including the fuel reserve space, should be insulated to keep the woodchips from freezing. Free space may be used as a heated work space. The buildings will have a concrete pad with containment walls at the front door upon which vehicles can dump fuel, unless a small enough vehicle is available to unload inside the building.

Plant building construction material costs will likely range from $\$170/m^2$ to $\$350/m^2$. 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 wood 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. The cost is typically $\$100/m^2$ to $\$200/m^2$ and sizes range between 90 to 150 m^2. In some cases additional land may need to be purchased for the yard and building construction. If this is the case, add the land costs in $\$/m^2$, to the yard construction costs. If land is to be leased, include the lease cost under "Other" in the "Annual Costs" section.

Equipment installation

The labour required to install the balance of plant will typically range from $25/h to $50/h and will require 500 to 700 hours to construct the building, and carry out the installation of all the equipment listed above for the "Balance of Plant" sub-section.

Transportation

The transportation costs for the biomass system equipment vary depending on weight and size of material to be shipped and distance from the factory. Normally, the material is shipped by truck unless there is no road access to the site, in which case, other methods, such as rail, air, winter road or boat are required. Some projects will require more than one freight carrier. For example, truck to rail line, then to a barge or plane. Each time the material is transferred, someone must be on hand to receive it and/or arrange for the transfer. Freight costs to isolated areas may be difficult to estimate and it is advisable to check for best routing.

As an example, a 75 kW oil boiler weighs approximately 770 kg while a 400 kW oil boiler weighs approximately 5,900 kg.

Other

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. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." 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 be entered in the grey input cell as "Credit." 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.

Miscellaneous

This category is for all of the miscellaneous costs that occur during a project and have not been taken into account in the previous sections. For biomass and/or WHR heating projects these costs can include, contractors overhead, training and contingencies.

Overhead

A general contractor will normally apply a mark-up on their costs to cover overhead and on sub-contractors costs to cover contract administration. The overhead rate ranges from 10 to 30% of the entire project cost. For biomass and/or WHR heating projects, another way to estimate this cost is to consider the time a general contractor, or project manager would be required to manage the construction of the project. A range of 36 to 120 hours, depending upon the scale of the project, at rates of $50/h to $100/h could be expected. The incremental overhead includes only the amount directly related to the energy project. Any overhead that would otherwise be allocated to the "conventional" energy system should not be included here.

Training

The training required by automated biomass plant operators varies, depending on their responsibilities and capabilities. The training ranges from about 8 hours for basic operation training to about 30 hours for skilled operators who are being trained to handle all aspects of operation and repairs. Repairs mainly involve replacement of electrical components such as motors, capacitors, timers, contractor switches, aquastats as well as mechanical components such as the fuel agitator and the feed auger. The training rate is approximately $40/h to $100/h.

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. 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 estimate of the project costs. Typically, a pre-feasibility level cost analysis should be accurate within 40 to 50%. 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 study and the availability of accurate information. It is certainly possible that the RETScreen user experienced with biomass and/or WHR heating project developments could estimate costs in the range of 5 to 40% of the total initial project costs.

Annual Costs (Credits)

There are a number of annual costs associated with the operation of a biomass and/or WHR heating system. These could include property taxes, insurance, spare parts, O&M labour, travel and accommodations and general, administrative expenses and contigencies. In addition, costs for biomass fuel, peak load fuel oil and parasitic electricity consumption will also be incurred. These costs are detailed in the following section.

O&M

Property taxes/Insurance

Generally, biomass and/or WHR heating systems should not increase property taxes, with the exception of the plant building constructed. In some cases, a community may even provide a tax incentive for biomass and/or WHR heating installations. The owners of a biomass and/or WHR heating system will normally require insurance to protect their interests. This will include: fire insurance, public liability insurance and accident insurance to cover repairs in the event of accidental damage.

The cost of fire insurance; public liability insurance and accident insurance normally amount to $500 to $1,500 per year. The costs vary, depending on the capital value of the biomass and/or WHR heating system and whether the heating plant must be insured on its own or whether insurance for the plant is merely added to insurance for other equipment and facilities. A more accurate cost can be estimated by contacting an insurance broker.

Spare parts

The annual maintenance and repair costs for "wear items" in small-commercial biomass plants range from roughly $200 to $600 per year per burner. For larger systems use 1% of equipment costs. The variables include: the number of burners; the size of the fuel hopper and the fuel type. Larger fuel hoppers have greater mechanical stresses. Sawdust and bark generally contain some dirt that causes much more wear on fuel feed augers.

O&M labour

Labour is required to fill the fuel hopper and scraping the ash off the grate on a daily basis. Every three to four weeks accumulated fly ash must be cleaned out of the boiler. Automated biomass plants are rugged and reliable, but annual maintenance and repair labour costs must be expected for "wear items" such as pumps, feed motors, capacitors and feed augers.

The labour for the filling of the fuel hopper, the scraping of the grate and for periodic cleaning of the boiler normally takes 8 to 12 hours per month (96 to 144 hours per year) at a rate of $15/h to $30/h. In many cases, the operator(s) perform these tasks as part of a job that includes other related or non-related tasks.

For larger plants assume 1 to 2 hours per day for general maintenance including filling fuel storage, monitoring of the equipment and emptying ash bins.

Travel and accommodation

For larger biomass and/or WHR heating systems in isolated areas, it is possible that an annual allowance may be required for travel, room and board costs associated with annual maintenance and inspection by an system expert. However, for well-designed and maintained systems this will not be required.

General and administrative

Annual general and administrative costs include the costs of bookkeeping, preparation of annual statements, bank charges, communication, a billing heat clients, etc. General and administrative costs are project specific and depend on the nature of the business enterprise. These costs normally start at a range of $500 to $2,000 per year and can be significantly higher for larger scale projects with many heat clients.

Other

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. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." 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 be entered in the grey input cell as "Credit." 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. It is usual 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 1.25 to 10%, but could be as high as 20%. This is especially true in the case of project in isolated areas. To meet repair costs for a biomass and/or WHR heating system a contingency fund of $2,000 to $3,000, depending on the size and fuel type, is minimally required.

Fuel/Electricity

Waste heat

The *Energy Model* worksheet calculates the amount of waste heat used on an annual basis. This value is copied to the *Cost Analysis* worksheet.

The user enters the cost of waste heat in $/MWh. A cost might be charged if the owner of the waste heat is not the developer of the biomass and/or WHR heating system. In other cases removing the waste heat can improve the generators efficiency and no cost or a negative cost is applied.

Biomass

The *Energy Model* worksheet calculates the amount of biomass fuel used on an annual basis. This value is copied to the *Cost Analysis* worksheet.

Biomass fuel (e.g. woodchips or sawdust) may be purchased from a separate independent company on a weight or volume basis. Alternatively, the organisation that owns and operates the biomass heating plant may also have a forest operation and produce its own fuel. However, for the purpose of this analysis, methods for supplying biomass fuel are not covered in detail. At the pre-feasibility analysis stage, a range of values for biomass fuel, in $/tonne, is sufficient to prepare a study. The user can perform a sensitivity analysis for various biomass fuel costs. If the biomass and/or WHR heating project passes this "quick screen" during the pre-feasibility analysis study, the follow-up feasibility level analysis can consider various supply options in much more detail.

Typical costs for biomass fuel (e.g. woodchips or sawdust) range from $0/tonne to $85/tonne. In some cases wood waste may be available at no charge ($0) to the biomass plant owner other than loading and trucking costs. For example, retail prices (delivered to large customers) for woodchips in the area of Charlottetown, Prince Edward Island are in the range of $27/tonne. The retail price of sawmill waste is in the range of $15/tonne [McCallum, 1995]. In isolated areas, biomass fuel costs can be significantly higher (as high as $85/tonne). The user may want to contact the local government forestry office or local woodchip suppliers to obtain more information on local fuel woodchip costs.

Peak load system fuel

The *Energy Model* worksheet calculates the volume of peak load heating system fuel required on an annual basis. This value is copied to the *Cost Analysis* worksheet.

Cost for peak load heating system fuel in a specific location can be obtained from local suppliers. The purchase of fuel for peak load heating purposes is usually under the responsibility of the heating plant owner assuming that the boiler is located in the biomass heating plant. In some cases, the peak load heating systems may be located in the client buildings and the client may then incur the charges for the peak load system fuel.

Parasitic electricity

The parasitic electricity is the electrical energy required to run the biomass and/or WHR heating system, and the district heating distribution pumps on an annual basis. The user enters the approximate kWh electrical consumption in the quantity cell and the price of electricity ($/kWh) in the unit cost cell.

A rough estimate of the parasitic electricity required to run the biomass and/or WHR heating system is approximately 1 to 2% of the total annual energy delivered by the biomass system. The low end is for larger systems while the higher end of the range is for smaller systems.

Small-commercial biomass systems use electricity to run the fuel feed system, the burner fan and the circulation pumps. The electricity to run the fuel feed system, the burner fan and the circulation pumps of a small commercial biomass system can vary from roughly 2,000 kWh for small systems (75 kW) to 6,000 kWh for large systems (250 kW).

For a commercial size biomass system the parasitic load varies between manufacturers – The following table can be used as a guideline.

Power Capacity (kW)	Connected Load (hp)	Parasitic Load (hp)	Parasitic Load (kW)
1,000	23.5	13.5	10.1
1,500	31.8	19.1	14.2
2,000	45.8	27.4	20.4
2,500	53.3	32.2	24.0
3,000	65.8	39.7	29.6

Parasitic Load for Commercial Size Biomass Systems

For a system with less than 500 m of total pipe length and 500 kW of peak heating load, the parasitic electricity for the district heating distribution pumps can be estimated to be 0.5 kW. The approximate district heating pump load for a larger district heating system can be estimated using the following formula:

$$P = M*Q*C/T$$

where:

P = pump load (kW)

M = total pipe length for main distribution line (m)

Q = total peak heating load (kW)

C = constant, 58.7*10^-6 (ºC/m)

T = difference between the supply temperature and the return temperature of the distribution system

The parasitic annual demand can be estimated using the following formula:

$$D = P*E$$

where:

D = parasitic annual demand (kWh)

P = pump load (kW)

E = equivalent full load hours (h)

For example, the pump capacity for a system with 2,000 m total pipe length, 1,500 peak heating load and 40ºC differential temperature is estimated as follows:

$$P = 2{,}000 \text{ m} * 1{,}500 \text{ kW} * 58.7*10^{-6} \text{ºC/m} / 40\text{ºC}$$
$$= 4.4 \text{ kW}$$

With 2,500 equivalent full load hours the parasitic annual demand for the distribution pumps is estimated as follows:

$$D = 4.4 \text{ kW} * 2{,}500 \text{ h}$$
$$= 11{,}000 \text{ kWh}$$

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. The user must enter a positive numerical value in the "Unit Cost" column.

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 period 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 period 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. The user must enter a positive numerical value in the "Unit Cost" column.

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 common financial analysis worksheet contains six sections: **Annual Energy Balance**, **Financial Parameters**, **Project Costs and Savings**, **Financial Feasibility, Yearly Cash Flows** and **Cumulative Cash Flows Graph**. The Annual Energy Balance and the Project Costs and Savings sections provide a summary of the *Energy Model*, *Cost Analysis* and *GHG Analysis* worksheets associated with each project studied. In addition to this summary information, the Financial Feasibility section provides financial indicators of the project analysed, based on the data entered by the user in the Financial Parameters section. The Yearly Cash Flows section allows the user to visualise the stream of pre-tax, after-tax and cumulative cash flows over the project life. The *Financial Summary* worksheet of each Workbook file has been developed with a common framework so the task of the user in analysing the viability of different project types is made simpler. This also means the description of each parameter is common for most of the items appearing in the worksheet.

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 feasibility 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 Energy Balance

The summary items here are calculated and/or entered in the *Energy Model* and *GHG Analysis* worksheets and transferred to the *Financial Summary* worksheet.

Project name

The user-defined project name is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

Project location

The user-defined project name is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

Renewable energy delivered

The *Energy Model* worksheet calculates the renewable energy delivered (MWh) by the project, which is the sum of the waste heat recovery and biomass heating energy delivered.

Heating energy delivered

The *Energy Model* worksheet calculates the heating energy delivered (MWh). This energy displaces the heating energy that would have otherwise been delivered by the base case heating system. The heating energy delivered is used in conjunction with the weighted average avoided cost of heating energy to calculate the heating energy savings.

Heating fuel displaced

The heating fuel displaced is the type of heating energy displaced by the addition of the project. The heating fuel type selected for each cluster are entered in the *Heating Load & Network* worksheet. The following types of fuels are available in the model: Natural gas, Propane, Diesel (#2 oil), #6 oil, Electricity and Other.

Electricity required

The electricity required is the sum of the parasitic electricity entered in the *Cost Analysis* worksheet and the electricity used by the peak load heating system, if any, as selected in the *Energy Model* worksheet.

Net GHG emission reduction

The model calculates the net annual average GHG emission reduction in equivalent tonnes of CO_2 per year (t_{CO_2}/yr) resulting from the implementation of the system instead of the base case, or baseline, heating system. This value is calculated in the *GHG Analysis* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

Net GHG emission reduction - credit duration

The model calculates the cumulative net greenhouse gas (GHG) emission reduction for the duration of the GHG credit, in equivalent tonnes of CO_2 (t_{CO_2}), resulting from the implementation of the project instead of the base case, or baseline, system. This value is calculated by multiplying the appropriate net annual GHG emission reduction by the GHG reduction credit duration.

Net GHG emission reduction - project life

The model calculates the net project life GHG emission reduction for the duration of the project, in equivalent tonnes of CO_2 (t_{CO_2}) resulting from the installation of the project instead of the base case, or baseline, heating system. This value is calculated by multiplying the net annual GHG emission reduction by the project life.

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. building owner vs. energy services company (ESCO)).

Avoided cost of heating energy

The model calculates the weighted average avoided cost of heating energy from individual cluster values entered in the *Heating Load & Network* worksheet. The avoided cost of heating energy is used in conjunction with the heating energy delivered to calculate the annual heating energy savings. The model escalates the avoided cost of heating energy yearly according to the energy cost escalation rate starting from year 1 and throughout the project life.

GHG emission reduction credit

The user enters the GHG emission reduction credit per tonne of CO_2 (t_{CO2}). It is used in conjunction with the net GHG emission reduction to calculate the annual GHG emission reduction income.

Preliminary estimates predict the market price of GHG emission reduction credits in the USA will range from $US 4 to $US 95 per tonne of CO_2, 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_2.

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 emission reduction credit value yearly according to the GHG credit escalation rate starting from year 1 and throughout the project life.

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 annual GHG reduction income.

GHG credit escalation rate

The user enters the GHG credit escalation rate (%), which is the projected annual average rate of increase in the GHG emission reduction credit over the life of the project. This permits the user to apply rates of inflation to the market price of GHG emission reduction credits which may be different from general inflation.

Retail price of electricity

The retail price of electricity is transferred from the *Cost Analysis* worksheet. This value is used in conjunction with the electricity required by the biomass and/or WHR heating system in order to calculate the system annual cost of fuel/electricity.

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 retail price of electricity yearly according to the energy cost escalation rate starting from year 1 and throughout the project life.

Energy cost escalation rate

The user enters the energy cost escalation rate (%), which is the projected annual average rate of increase for the cost of energy over the life of the project. This permits the user to apply rates of inflation to fuel/electricity costs which are different from general inflation for other costs. For example, North American electric utilities currently use energy cost escalation rates ranging anywhere from 0 to 5% with 2 to 3% being the most common values.

Inflation

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 feasibility 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 feasibility 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 heat purchase or energy service agreement. Although the model can analyse project life's up to 50 years, the project life of a well designed biomass and/or WHR heating system typically falls between 20 and 30 years.

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. In cases where the biomass and/or WHR heating system cost is incorporated into the cost of a house or building and tied to its mortgage, the debt ratio will likely be between 50 and 75%.

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 a 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.

Income tax analysis?

The user indicates by selecting from the drop-down list whether or not income tax should be factored into the financial analysis. If the user selects "Yes" certain input fields will be added to allow the user to customise 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. For biomass and/or WHR heating systems installed in private homes and paid for by the home-owner, it is likely that the user would select "No" given all cash flows would come from after-tax money.

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 derived from the project is 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 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 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 equipment, balance of plant 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.

Project Costs and Savings

Most of the summary items here are calculated and/or entered in the *Cost Analysis* worksheet and transferred to the *Financial Summary* worksheet. Some calculations are made in 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 (or income). The total initial costs are the sum of the estimated feasibility study, development, engineering, energy equipment, balance of plant and 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 a biomass and/or WHR heating 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, the RETScreen 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 prepare the Feasibility Study.

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 also includes costs for construction supervision. It is net of any "credits" for not having to develop the base case project.

Energy equipment

The energy equipment item typically represents the sum of the purchasing and installation costs of the energy equipment, less any "credits" for not having to purchase or install base case equipment.

Balance of plant

The balance of plant item represents the sum of the purchasing, 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.

Miscellaneous

The miscellaneous item 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/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. The incentive is deemed not to be refundable and is treated as income during the development/construction year, year 0, for income tax purposes.

For example, in Canada the Renewable Energy Deployment Initiative (REDI) may provide a 25% contribution for certain energy systems used for heating and cooling applications. The contribution is 40% for systems installed in Canada's remote communities. More information may be obtained from the REDI Website or by calling 1-877-722-6600.

Annual Costs and Debt

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 costs, the fuel/electricity costs 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 energy system. The model uses the O&M cost to calculate the total annual costs and the yearly cash flows.

Fuel/Electricity

The annual cost of fuel/electricity to run the biomass, WHR heating system and/or peak load heating system is transferred from the *Cost Analysis* worksheet.

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 project debt.

Annual Savings or Income

The total annual savings represent the yearly savings realised due to the implementation of the project. From the perspective of an energy services company, these "savings" will be viewed as "income." It is directly related to the avoided cost of heating energy derived from implementing the project.

Heating energy savings/income

The model calculates the heating energy savings which represent the additional cost that would have been incurred if this heating energy had been delivered by the base case energy system. The heating energy savings are equal to the product of the heating energy delivered and the avoided cost of heating energy. The yearly value of heating energy savings is escalated at the energy cost escalation rate.

GHG reduction income - duration

The model calculates the GHG emission reduction income which represents the income (or savings) generated by the sale or exchange of the GHG emission reduction credits. It is calculated from the annual net GHG emission reduction and the GHG emission reduction credit value. The yearly value of GHG emission reduction income is escalated at the GHG credit escalation rate.

Periodic Costs (Credits)

The periodic costs and periodic credits entered by the user in the *Cost Analysis* worksheet 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 entered by the user in the *Cost Analysis* worksheet 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.

Financial Feasibility

The results provide the decision-maker with various financial indicators for the proposed project.

Pre-tax Internal Rate of Return and Return on Investment

The model calculates the pre-tax internal rate of return (%), which represents the true interest yield provided by the project equity over its life before income tax. It is also referred to as the return on investment (equity) (ROI) or the time-adjusted rate of return. It is calculated by finding the discount rate that causes the net present value of the project 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 of the project 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 of the project 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. The model uses the pre-tax yearly cash flows and the project life to calculate the internal rate of return.

After-tax Internal Rate of Return and Return on Investment

The model calculates the after-tax internal rate of return (%), which represents the true interest yield provided by the project equity over its life. It is also referred to as the return on investment (equity) (ROI) or the time-adjusted rate of return. It is calculated by finding the discount rate that causes the net present value of the project 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 of the project 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 of the project 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. The model uses the after-tax yearly cash flows and the project life to calculate the internal rate of return.

Simple Payback

The model calculates the simple payback (year), which represents the length of time that it takes for an investment project to recoup its own initial cost, out of the cash receipts it generates. The basic premise of the 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 a biomass and/or WHR heating 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 smaller 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 repayment, but a long payback period. The reason is that the organisation may simply need a faster return of its cash investment. The model uses the total initial costs, the total annual costs (excluding debt payments) and the total annual savings, in order to calculate the simple payback. The calculation is based on pre-tax amounts and includes any initial cost incentives.

Year-to-positive cash flow

The model calculates the number of years to positive (cumulative) cash flow, which represents the length of time that it takes for the owner of a project to recoup its own initial investment out of the project cash flows generated. The year-to-positive cash flow considers project cash flows following the first year 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.

The year-to-positive cash flow differs from the discounted payback indicator in that it considers the nominal value of future cash flows rather than the discounted value of future cash flows.

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 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 revenues (or 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 (B-C) ratio, similar to the profitability index, leads to the same conclusion as the net present value indicator.

Calculate GHG reduction cost?

The user indicates by selecting from the drop-down list whether or not the project GHG emission reduction cost should be calculated. In order to calculate the true economic (not financial) cost of GHG emission reductions, a number of other parameters such as the GHG emission reduction credit, debt ratio, etc. should be set to 0. In addition "Income tax analysis" would be set to "No" and other taxes would also be set to 0. This option is more applicable to economists as it requires a careful analysis of assumptions used.

GHG emission reduction cost

The model calculates the GHG emission reduction cost. The GHG emission reduction cost is calculated by dividing the annual life cycle savings (ALCS) of the project by the net GHG emission reduction per year, averaged over the project life. For projects with a net increase in GHG emission, the GHG emission reduction cost is irrelevant and hence not calculated.

Project 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, the initial cost incentives and the debt ratio.

Project 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 project equity.

Debt payments

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 project debt.

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 or 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 its 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.

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 initial costs are 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 given in the *Financial Summary* worksheet, which reflect amounts valid for year zero, are thus escalated one year in order to determine the actual costs and savings 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 initial costs are 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 given in the *Financial Summary* worksheet, which reflect amounts valid for year zero, are thus escalated one year in order to determine the actual costs and savings 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 cumulative 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 common GHG emission reduction analysis worksheet contains four main sections: **Background Information, Base Case System (Baseline), Proposed Case System (Project)** and **GHG Emission Reduction Summary**. The Background Information section provides project reference information as well as GHG global warming potential factors. The Base Case Electricity System and the Base Case Heating System sections provide a description of the emission profile of the baseline system, representing the baseline for the analysis. The Proposed Case Heating System section provides a description of the emission profile of the proposed project, i.e. the biomass and/or WHR heating 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 and from values entered or calculated in the other RETScreen worksheets (e.g. annual energy delivered). Results are calculated as equivalent tonnes of CO_2 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 worksheet.

Greenhouse gases include water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) 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_2), methane (CH_4) and nitrous oxide (N_2O); these gases are considered in the RETScreen GHG emission reduction analysis.

The *GHG Analysis* worksheet of each Workbook file has been developed with a common 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. 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, fuel conversion efficiency) 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.

Use GHG analysis sheet?

The user indicates by selecting from the drop-down list whether or not the optional *GHG Analysis* worksheet is used to conduct an analysis of GHG emission reduction.

If the user selects "Yes" from the drop-down list, then 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 emission reduction income and cost.

If the user selects "No" from the drop-down list, then the user should go directly to the *Financial Summary* worksheet.

Type of analysis

The user selects the type of analysis from the two options in the drop-down list: "Standard" and "Custom." "Standard" analysis uses many pre-defined parameters in the calculations whereas "Custom" analysis requires that these parameters be entered by the user.

Background Information

Project name

The user-defined project name is entered for reference purposes only in the Energy Model worksheet, and it is copied automatically to the *GHG Analysis* worksheet.

Project location

The user-defined project location is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *GHG Analysis* worksheet.

Global Warming Potential of GHG

The model indicates the global warming potential of methane (CH_4) and nitrous oxide (N_2O). 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_2), which is assigned a reference value of 1 (i.e., the GWP of CO_2 is 1 and the GWP of N_2O 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 will need to define the baseline (also called base case or reference case) electricity system. Often this will simply imply defining a "proxy" plant and its associated fuel.

Note: Defining the Base Case Electricity System carefully is more important if one of the base case heating system fuel types, defined in the *Heating Load & Network* worksheet, or the peak heating system, defined in the *Energy Model* worksheet, is electricity. Otherwise, this analysis applies only to the parasitic electricity used for the pumps, fans and other auxiliary equipment, which represents a relatively small amount of energy.

For example, in North America when preparing a GHG emission reduction analysis for a biomass and/or WHR heating project where central-grid electricity is used, it is often reasonable to assume that a combined-cycle natural gas power plant is the proxy plant. In this case the user need only 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, a diesel genset would likely be the "proxy" power plant with "Diesel (#2 oil)" chosen as the fuel type.

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 .

To illustrate this alternative analysis method, for a biomass and/or WHR heating project based in Nova Scotia, Canada, the provincial government might determine the baseline to be the weighted average of the current 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.

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 T & D losses and using the "Custom" option under the "Type of analysis" drop-down list, 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.

Fuel type

The user selects the fuel type from the options in 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. The default emission factors and conversion efficiencies of various fuel types are given in the table below [Fenhann, J., 1999], [Fenhann, J., 2000] and [The Danish Energy Agency, 1999].

For "Custom" projects, if a specific fuel type is not included in the drop-down list, the user may choose "Other" and manually enter values for the remainder of the row inputs. The order in which reference fuels or power plants are listed in this table is irrelevant.

Fuel type	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency %
Coal	94.6	0.0020	0.0030	35%
Natural gas	56.1	0.0030	0.0010	45%
Nuclear	0	0	0	-
Large hydro	0	0	0	-
#6 oil	77.4	0.0030	0.0020	30%
Diesel (#2 oil)	74.1	0.0020	0.0020	30%
Geothermal	0	0	0	-
Biomass (wood)	0	0.0320	0.0040	25%
Small hydro	0	0	0	-
Wind	0	0	0	-
Solar	0	0	0	-
Propane	63.1	0.0010	0.0010	45%

Default Emission Factors and Conversion Efficiencies

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%.

CO2, CH4 and N2O emission factors

(Custom analysis)

The user enters the CO_2, CH_4 and N_2O emission factors for the different fuel types. They represent the mass of greenhouse gas emitted per unit of energy. 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 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 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_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

CO2, CH4 and N2O emission factors

(Standard analysis)

The model provides the CO_2, CH_4 and N_2O emission factors which represent the mass of greenhouse gas emitted per unit of energy. 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_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

The default values provided by the model are given in the Default Emission Factors and Conversion Efficiencies table.

Fuel conversion efficiency

(Custom analysis)

The user enters the fuel conversion efficiency for the selected fuel type. The fuel conversion 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_2, CH_4 and N_2O emission factors).

For example, a typical coal-fired power plant could have a fuel conversion 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%.

Fuel conversion efficiency

(Standard analysis)

The model provides the fuel conversion efficiency for the selected fuel type. The fuel conversion 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_2, CH_4 and N_2O emission factors).

For example, a typical coal-fired power plant could have a fuel conversion 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%.

The default values provided by the model are given in the Default Emission Factors and Conversion Efficiencies table.

Transmission and distribution 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. 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

The model calculates the GHG emission factor for each reference fuel type. Values are calculated based on the individual emission factors, the fuel conversion 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 are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use electricity delivered (t_{CO_2}/MWh).

Base Case Heating System (Baseline)

The base case heating system, or baseline system, represents the system to which the biomass and/or WHR heating system is compared. The base case heating system is defined in terms of its fuel types, its emissions of GHG and its conversion efficiencies.

The base case system is normally referred to as the reference or baseline option in standard economic analysis.

Fuel type

The fuel type of the base case heating system for each building cluster entered by the user in the *Heating Load & Network* worksheet is transferred to the *GHG Analysis* worksheet.

Fuel mix

The fuel mix of the base case heating system is calculated from the total average heating demand value derived in the *Heating Load & Network* worksheet. It represents the ratio of the demand of a single building cluster to the total demand of all building clusters.

CO2, CH4 and N2O emission factors

(Custom analysis)

For the base case heating system, the user enters the CO_2, CH_4 and N_2O emission factors corresponding to the heating fuel type selected. If the heating fuel type is electricity, emission factors of the base case electricity mix are used.

CO_2, CH_4 and N_2O 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 heating equipment.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heating energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. CO_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

CO2, CH4 and N2O emission factors

(Standard analysis)

For the base case heating system, the model provides the CO_2, CH_4 and N_2O emission factors corresponding to the heating fuel type selected. If the heating fuel type is electricity, emission factors of the base case electricity mix are used.

CO_2, CH_4 and N_2O 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 heating equipment. The default factors provided are those which are representative of large heating plants. For smaller plants and for greater accuracy, the user may select the "Custom" type of analysis and specify the emission factors.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of primary heating energy generated (kg/GJ).

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. CO_2 emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. CH_4 and N_2O emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual.

The default values provided by the model are given in the Default Emission Factors and Conversion Efficiencies table.

Fuel conversion efficiency

The base case heating system fuel conversion efficiency for each building cluster is entered by the user in the *Heating Load & Network* worksheet as the heating system seasonal efficiency and is transferred to the *GHG Analysis* worksheet. The fuel conversion efficiency represents the annual average efficiency of energy conversion from primary heat potential to actual heating energy 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_2, CH_4 and N_2O emission factors).

Units are given as a percentage of actual heating energy output (gigajoules of heating energy) to primary heat potential (gigajoules of heat or electricity).

GHG emission factor

The model calculates the GHG emission factor for the base case heating system for each building cluster. Values are calculated based on the individual emission factors and the fuel conversion efficiency.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO_2}/MWh).

Proposed Case Heating System (Biomass Heating Project)

The proposed case heating system, or mitigation system, is the proposed project. It is defined in terms of its fuel types, its emissions of GHG and its conversion efficiencies. Note that in all cases, the parasitic electricity for pumps and fans, if any, of the biomass and/or WHR heating system are assumed to use the base case electricity system.

The proposed case system is normally referred to as the mitigation option in standard economic analysis.

Fuel type

The fuel type of the biomass, WHR heating system, peak load heating system and parasitic electricity entered by the user in the *Energy Model* worksheet is transferred to the *GHG Analysis* worksheet.

Fuel mix

The fuel mix of the biomass heating system is calculated from values entered by the user in the *Energy Model* worksheet. The parasitic electricity, as entered by the user in the *Cost Analysis* worksheet, forms part of the fuel mix. Hence, the total fuel mix may exceed 100% given it accounts for parasitic electricity which does not generate any useful heating energy.

CO2, CH4 and N2O emission factors

(Custom analysis)

The user enters the CO_2, CH_4 and N_2O emission factors corresponding to the fuel types used by the biomass and/or WHR heating system. The model provides the electricity values corresponding to the electricity mix of the base case electricity system.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of primary heating energy generated (kg/GJ).

CO2, CH4 and N2O emission factors

(Standard analysis)

The model provides the CO_2, CH_4 and N_2O emission factors corresponding to the fuel types for the biomass and/or WHR heating system. The electricity values correspond to the electricity mix of the base case electricity system.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of primary heating energy generated (kg/GJ).

Fuel conversion efficiency

Fuel conversion efficiencies for both the biomass and the peak heating system are entered in the *Energy Model* worksheet and transferred to the *GHG Analysis* worksheet. Fuel conversion efficiencies for both the waste heat recovery and parasitic electricity are set to 100%.

Units are given as a percentage of actual heating energy output (gigajoules of heating energy) to primary energy input (gigajoules of heat).

GHG emission factor

The model calculates the GHG emission factor for the proposed project. Values are calculated based on the individual CO_2, CH_4 and N_2O emission factors and the fuel conversion efficiency.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO_2}/MWh).

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.

Base case GHG emission factor

The model transfers the base case GHG emission factor calculated in the base case heating system (baseline) section. This value represents the amount of GHG emitted per unit of heating energy delivered for the base case system.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of heating energy delivered (t_{CO_2}/MWh).

Proposed case GHG emission factor

The model transfers the proposed case GHG emission factor calculated in the proposed case heating system section. This value represents the amount of GHG emitted per unit of heating energy delivered if the biomass and/or WHR heating system is installed.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO_2}/MWh).

End-use annual energy delivered

The model displays the end-use annual energy delivered, as calculated in the *Energy Model* worksheet.

Units are given in megawatt-hours of end-use heating energy delivered (MWh).

Annual GHG emission reduction

The model calculates the annual reduction in GHG emissions estimated to occur if the proposed project is implemented. The calculation is based on emission factors of both the base case and the proposed case system and on the end-use annual energy delivered.

Units are given in equivalent tonnes of CO_2 emission per year (t_{CO_2}/yr).

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 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.

Use sensitivity analysis sheet?

The user indicates, by selecting from the drop-down list, whether or not the optional *Sensitivity and Risk Analysis* worksheet is used to conduct a sensitivity analysis of the important financial indicators.

If the user selects "Yes" from the drop-down list, the sensitivity analysis section will open and the user should complete the top part of the worksheet. The user will need to click on "Calculate Sensitivity Analysis" button to get the results.

Perform risk analysis too?

The user indicates, by selecting from the drop-down list, whether or not the optional risk analysis section is used to conduct a risk analysis of the important financial indicators, in addition to the sensitivity analysis. 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 selects "Yes" from the drop-down list, then the risk analysis section will open and the user should complete the lower-half of the worksheet. The analysis will be performed on the financial indicator selected by the user in the "Perform analysis on" input cell at the top-right. The user will need to click on "Calculate Risk Analysis" button in the Risk Analysis section at the lower-half of this worksheet to get the results.

Project name

The user-defined project name is entered for reference purposes only in the Energy Model worksheet, and it is copied automatically to the *Sensitivity* worksheet.

Project location

The user-defined project location is entered for reference purposes only in the *Energy Model* worksheet, and it is copied automatically to the *Sensitivity* worksheet.

Perform analysis on

The user selects, from three options in the drop-down list, the financial indicator to be used for both the sensitivity and risk analyses. 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. This value is used in the sensitivity analysis section only.

The sensitivity range entered by the user must be a percentage value between 0 and 50%.

Threshold

The user enters the threshold value for the financial indicator selected. The threshold is the value under which (for the "After tax IRR and ROI" and "Net Present Value - NPV") or over which (for "Year-to-positive cash flow") 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. This value is used in the sensitivity analysis section only.

Click here to Calculate Sensitivity Analysis

The "Click here to Calculate Sensitivity Analysis" button updates the sensitivity analysis calculations using the input parameters specified by the user (i.e. "Perform analysis on" and "Sensitivity range" input cells). The sensitivity analysis tables are updated each time the user clicks on this button.

The sensitivity analysis calculations can take up to 15 seconds to run depending on the Excel version and the speed of the computer. When the sensitivity analysis is updated, the button disappears.

If the user makes any changes to the input parameters, or navigates through any of the other worksheets, the button will reappear. The user will then have to click on the button to update the sensitivity analysis calculations so that the results reflect the changes.

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 and ROI) when two key parameters (e.g. Initial costs and Avoided cost of heating energy) are varied by the indicated percentages. 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. This is a partial limitation of this sensitivity analysis worksheet since some parameter values are calculated from inputs in other worksheets, but those inputs are not changed. However, for most cases, this limitation is without consequence. If required, the user can use the blank worksheets (Sheet1, etc.) to perform a more detailed analysis.

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 and ROI, year-to-positive cash flow 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 and ROI, year-to-positive cash flow 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.

Avoided cost of heating energy

The avoided cost of heating energy is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the avoided cost of heating energy range. The range is a percentage corresponding to the uncertainty associated with the estimated avoided cost of heating energy value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 50%. The range determines the limits of the interval of possible values that the avoided cost of heating energy could take.
For example, a range of 10% for an avoided cost of heating energy of $90/MWh means that the avoided cost of heating energy could take any value between $81/MWh and $99/MWh. Since

$90/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 avoided cost of heating energy is known exactly by the user (no uncertainty), the user should enter a range of 0%.

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 specified by the user must be between 0 and 50%. 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 $300,000 means that the initial costs 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 initial costs are known exactly by the user (no uncertainty), the user should enter a range of 0%.

Annual costs

The annual cost is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet, but does not include debt payments.

The user enters the annual cost range. The range is a percentage corresponding to the uncertainty associated with the estimated annual costs value. The higher the percentage, the greater the uncertainty. The range specified by the user must be between 0 and 50%. The range determines the limits of the interval of possible values that the annual costs could take.

For example, a range of 10% for an annual cost of $80,000 means that the annual cost could take any value between $72,000 and $88,000. Since $80,000 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 annual costs are 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 50%. 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%.

GHG emission reduction credit

The GHG emission reduction credit is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the GHG emission reduction credit range. The range is a percentage corresponding to the uncertainty associated with the estimated GHG emission reduction credit value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0 and 50%. The range determines the limits of the interval of possible values that the GHG emission reduction credit could take.

For example, a range of 10% for a GHG emission reduction credit of $\$5/t_{CO_2}$ means that the GHG emission reduction credit could take any value between $\$4.5/t_{CO_2}$ and $\$5.5/t_{CO_2}$. Since $\$5/t_{CO_2}$ 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 emission reduction credit 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, and the distribution 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 1 minute 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. 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 year-to-positive cash flow is immediate, the result is not a numerical value, and therefore these values cannot be plotted.

Median

The model calculates the median of the financial indicator. The median of the financial indicator is the 50^{th} 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 selects from the drop-down list the acceptable level of risk for the financial indicator under consideration. The options are: 5%, 10%, 15%, 20% and 25%.

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 select 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, a level of risk of 10% means that 5% (half the level of risk) of the possible IRR 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 25% IRR, a level of risk of 10% means that 95% of the possible IRR values are lower than 25%.

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 year-to-positive cash flow is immediate, the result is not a numerical value, and therefore these values cannot be plotted.

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.

Product Data

Some of the product data requirements for the model are provided in the RETScreen Online Product Database. To access the product database the user may refer to "Data & Help Access." 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.

From the dialogue box the user selects the Region, followed by the Supplier, Individual Boiler Capacity, Model and Number of Boilers. 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 weight and/or dimensions, 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 or can contact the supplier by other means (email, etc.).

Note: To see all the suppliers listed in the product database and their contact information, the user can choose "Any" from the "Region" input cell.

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.
Some of the product data requirements for the model are provided in the RETScreen Online Product Database. To access the product database the user may refer to "Data & Help Access." 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.

Product manufacturers interested in having their products listed in the product database can reach RETScreen International at:

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CANMET Energy Technology Centre - Varennes
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Fax: +1-450-652-5177
E-mail: 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. NASA's satellite data is obtained via a link to NASA's Website from the dialogue box.

Ground Monitoring Stations Data

From the dialogue box, the user selects a region, then a country, then a sub-region (provinces in Canada, states in the United States 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. 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 renewable 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 2000 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 - 2000," "None," "Second currency" and a selection of 8 user-defined options ("Enter new 1," "Enter new 2," etc.).

If the user selects "Canada - 2000" the range of values reported in the "Quantity Range" and "Unit Cost Range" columns are for a 2000 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 the user selects "Second currency" two additional input cells appear in the next row: "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. Note that this selection is for reference purposes only, and does not affect the calculations made in other worksheets.

If "Enter new 1" (or any of the other 8 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 "Enter new 1" to enter a specific name (e.g. Japan - 2001) 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 ("Enter new 1" to "Enter new 8") enables the user to keep track of different cost scenarios. Hence the user may retain a record of up to 8 different quantity and cost ranges that can be used in future RETScreen analyses and thus create a localised cost database.

Training and Support

The user can obtain current information on RETScreen Training & Support at the following Website address: www.retscreen.net/e/training.

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Bibliography

American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), ASHRAE Handbook, Fundamentals Volume, 1997.

Arkay, K. and Blais, C., The District Energy Option in Canada, Community Energy Technologies, CANMET, Natural Resources Canada, 1996.

Chabot, B. "Personal Communication," 1999.

Community Energy Technologies, CETC, 1997.

The Danish Energy Agency, Engerstatistics 1995, 1999.

Fenhann, J., "Personal Communication," January, 2000.

Fenhann, J., Projections of Emissions of Greenhouse Gases, Ozone precursors and Sulphur Dioxide from Danish Sources until 2010, The Danish Energy Agency, December 1999.

Hayden, S., "Personal Communication," CETC, 1997.

Leng, G., RETScreen International: A Decision-Support and Capacity-Building Tool for Assessing Potential Renewable Energy Projects, UNEP Industry & Environment, 3rd Quarter, 2000.

Martinot, E. and McDoom, O., Promoting Energy Efficiency and Renewable Energy: GEF Climate Change Projects and Impacts, October 1999 Pre-Publication Draft, Global Environment Facility, 1999.

McCallum, B., Small-Scale Automated Biomass Energy Heating Systems: A Viable Option For Remote Canadian Communities?, Natural Resources Canada, Canadian Forest Service, Great Lake Forestry Centre, and CEDRL, 1997.

McCallum, B., Case Studies of Small Commercial Biomass Combustion Systems in PEI, Natural Resources Canada, June 1995

Randløv, P., District Heating Handbook, European District Heating Pipe Manufacturers Association, ISBN87-90488-00-8, 1997.

Sandor, R., Walsh, M. and Leblanc, A., Creating a Market for Carbon Emissions: Gas Industry Opportunities, published in Natural Gas, June 1999.

Sykes, B., "Personal Communication," CFS, 1997.

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