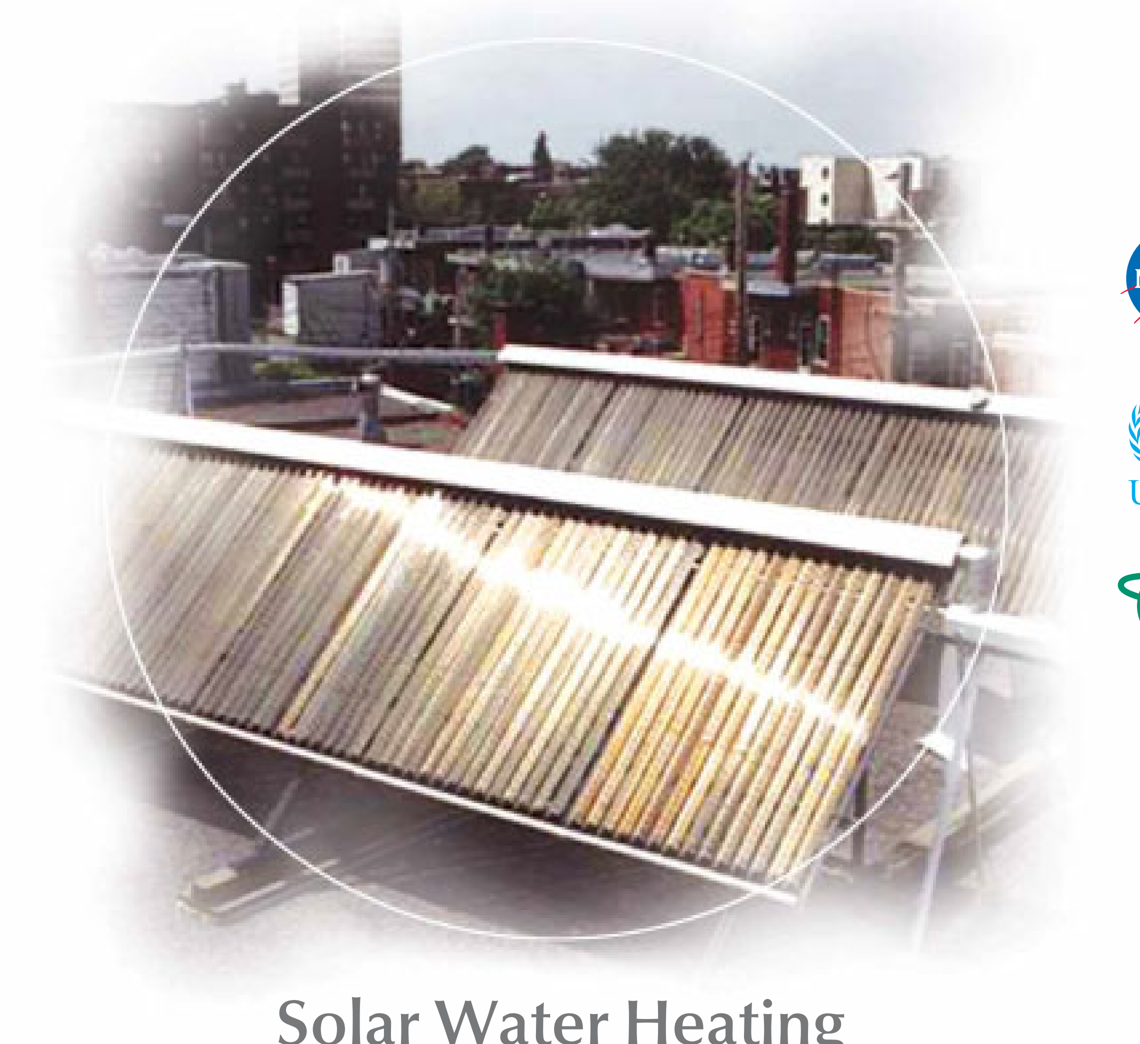
RETScreen® International

Clean Energy Decision Support Centre

www.retscreen.net

RETScreen® Software
Online User Manual



Solar Water 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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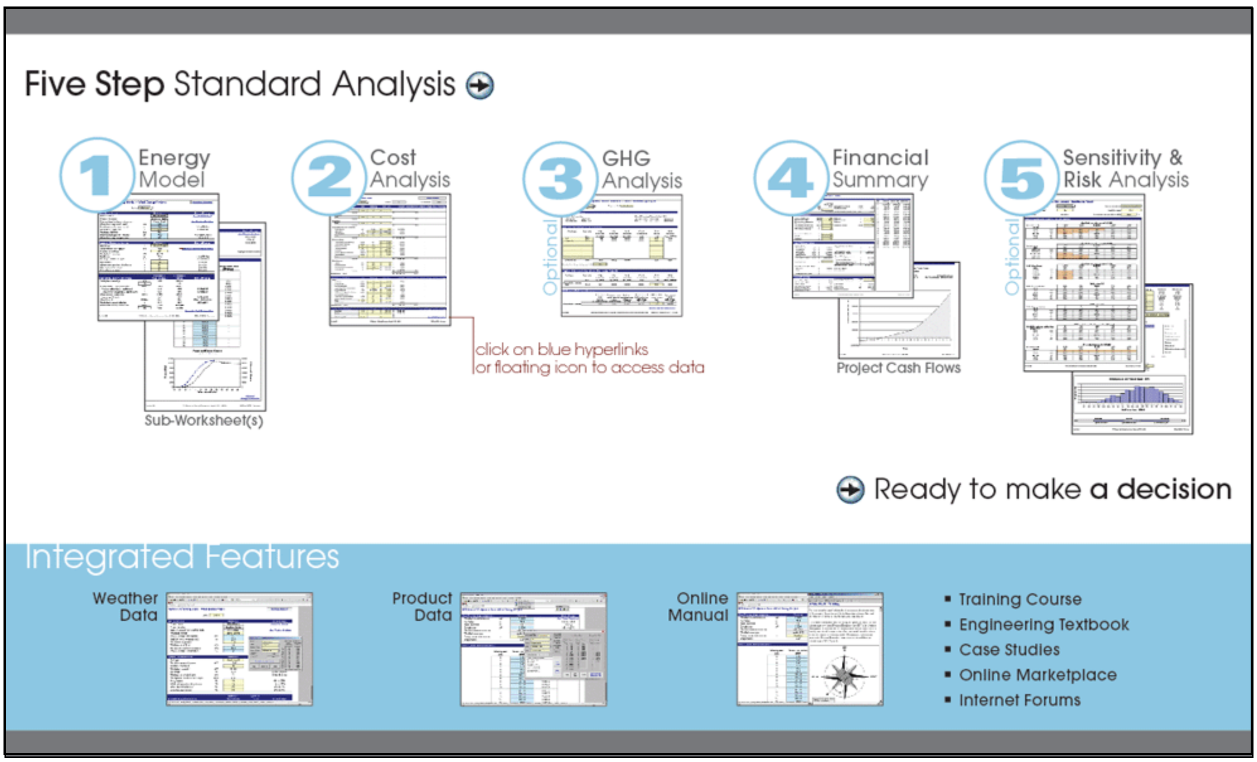
Brief Description and Model Flow Chart

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 energy technology model (e.g. Solar Water 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

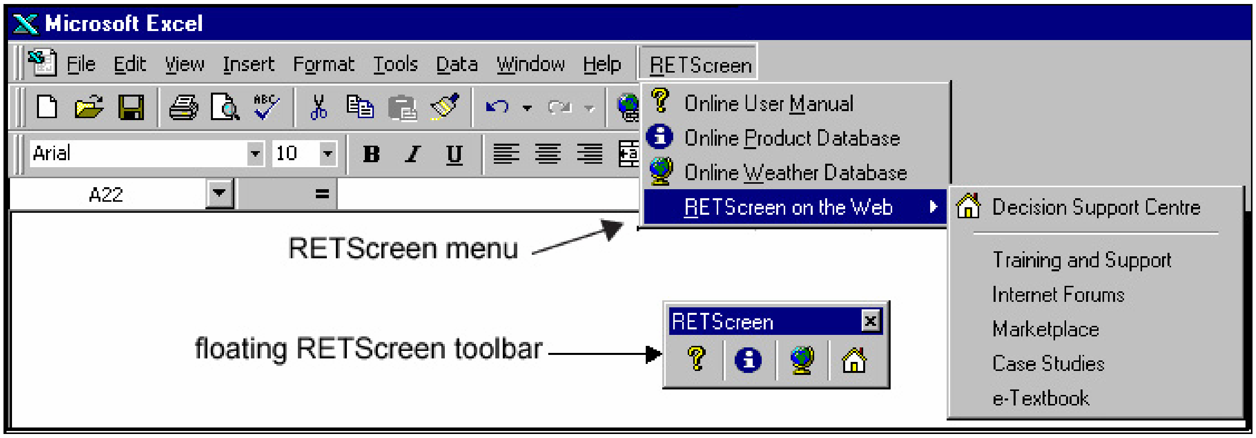
Complete each worksheet row by row from top to bottom by entering values in shaded cells. To move between worksheets simply "click" on the tabs at the bottom of each screen or on the "blue-underlined" hyperlinks built into the worksheets. The RETScreen Model Flow Chart is presented below.



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.

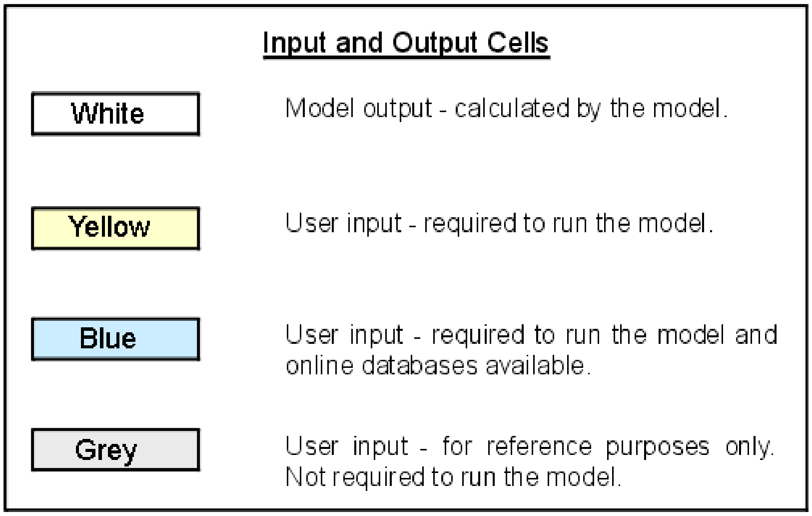


RETScreen Menu and Toolbar

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.

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-year
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

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

Units, Symbols & Prefixes

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

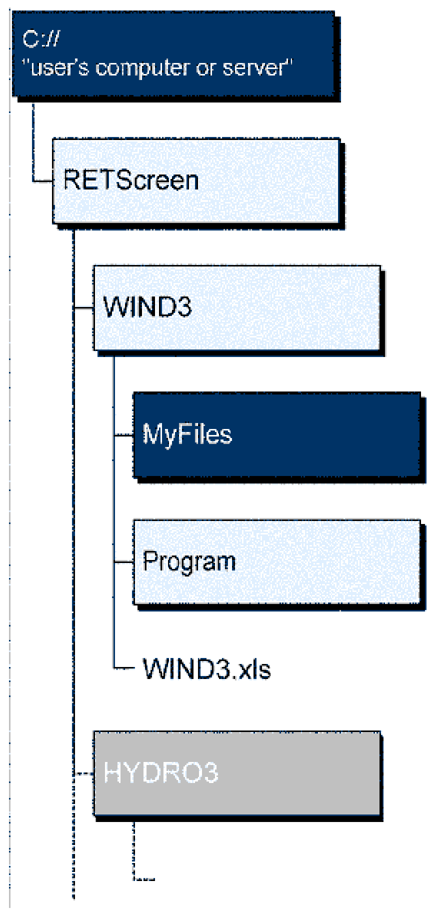
Note: 1. The gallon (gal) unit used in RETScreen refers to US gallon and not to imperial gallon.

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

Saving a File

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

The download procedure is presented in the next 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 change directory names or the file organisation automatically set by RETScreen installer program. Also, the main RETScreen program file and the other files in the "Program" directory should not be moved. Otherwise, the user may not be able to access the RETScreen Online User Manual or the RETScreen Weather and Product Databases.



RETScreen Download Procedure

Printing a File

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

Solar Water Heating Project Model

The RETScreen® International Solar Water Heating Model can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for three basic applications: domestic hot water, industrial process heat and swimming pools (indoor and outdoor), ranging in size from small residential systems to large scale commercial, institutional and industrial systems.

Six worksheets (*Energy Model, Solar Resource and Heating Load Calculation (Solar Resource and Heating Load), Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis)*, *Financial Summary* and *Sensitivity and Risk Analysis (Sensitivity)*) are provided in the Solar Water Heating Project Workbook file.

The *Energy Model* and *Solar Resource & Heating Load* 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 solar water 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 Solar Water 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 *Solar Resource and Heating Load Calculation* worksheets are used to help the user calculate the annual energy production for a solar water heating system 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 solar water heating system are detailed in the following sections.

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 *Solar Resource and Heating Load* worksheet and it is copied automatically to the *Energy Model* worksheet.

Note: At this point the user should complete the *Solar Resource & Heating Load (SR&HL)* worksheet.

Annual solar radiation (tilted surface)

The model calculates the total annual solar radiation incident on the solar collector, in MWh/m², from monthly data entered by the user in the *Solar Resource & Heating Load (SR&HL)* worksheet.

Annual average temperature

The model calculates the annual average temperature, in °C, from monthly data entered by the user in the *Solar Resource & Heating Load (SR&HL)* worksheet. The annual average temperature typically ranges from -20 to 30°C, depending upon the location.

Annual average wind speed

The model calculates the annual average wind speed, in m/s, from monthly data entered by the user in the *Solar Resource & Heating Load (SR&HL)* worksheet.

Desired load temperature

The user enters the desired load temperature (ºC) of the water delivered by the SWH system, in the *Solar Resource & Heating Load (SR&HL)* worksheet and it is copied automatically to the *Energy Model* worksheet.

Hot water use

If the user selects "Service hot water" as the application type, then the value entered for "Hot water use" in the *Solar Resource & Heating Load (SR&HL)* worksheet is copied here. It indicates the daily volume of hot water required at the desired temperature.

Number of months analysed

The model calculates the number of months for which the equipment is used, from monthly data entered by the user in the *Solar Resource & Heating Load (SR&HL)* worksheet.

Energy demand for months analysed

The model calculates the energy demand (MWh) of the SWH system, for the months used, in the *Solar Resource & Heating Load (SR&HL)* worksheet and it is copied automatically to the *Energy Model* worksheet. This is the energy required to heat main water to the required hot water temperature, in the case of service hot water; or the energy required to maintain the pool at the desired load temperature, in the case of swimming pools.

Note that the annual energy demand is calculated for the season of use of the SWH system only; that is, if the solar heating system is turned off for some months of the year or for fractions of months, the energy demand for the corresponding period is not taken into account in the calculation of the "Energy demand for months analysed." To specify the season of use of the solar heating system, see months "Fraction of month used" in the *Solar Resource & Heating Load (SR&HL)* worksheet.

System Characteristics

The system characteristics associated with estimating the annual energy production of a solar water heating system are detailed below. Some other system characteristics can be found in the Water Heating Load Calculation section of the *Solar Resource & Heating Load (SR&HL)* worksheet.

Application type

The user selects the solar water heating application type in the *Solar Resource & Heating Load (SR&HL)* worksheet and it is copied automatically to the *Energy Model* worksheet. There are four basic applications: service hot water with storage, service hot water without storage, indoor swimming pool and outdoor swimming pool.

Base Case Water Heating System

This sub-section contains information that describes the energy system displaced by the installation of the solar water heating system.

Heating fuel type

The user selects the type of heating energy displaced by the solar water heating system. This entry will be used to calculate annual heating energy savings in the *Financial Summary* worksheet. A list of common heating fuel types is provided in the drop-down list. The table below provides the heating value for various fuel types.

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)
Gasoline	33.7 MJ/L (9.36 kWh/L)
Kerosene	36.6 MJ/L (10.16 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 Value

Note:

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

2. "Propane-gal" and "Propane-L" are expressed in terms of liquefied propane.

Water heating system seasonal efficiency

The user enters the average efficiency (%) of the conventional water heating system over the season of use. This value is used to calculate the financial value of the system. It has no influence on the calculation of the annual renewable energy production. Typical values range from 50 % for conventional fossil-fuel-fired water heaters to nearly 100% for electric heaters. If a heat-pump is used as a base case (e.g. for swimming pool applications) 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 residential heating system efficiencies are tabulated below. The efficiencies of commercial and industrial water heating systems can vary significantly depending on size, age, technology, condition, installation specifics, etc. and these are not specifically included here. However, the user may use the efficiencies of residential water heating systems as a reference for similar larger systems.

Fuel	Residential Water Heating System Type	Typical Seasonal Efficiency*
Nat'l Gas or Propane	Storage tank (conventional)	50%
	Storage tank (high-efficiency)	70%
	Instantaneous	80%
	Integrated with space heating (tankless coil)	48%
	Induced draft / direct vent (conventional)	55%
	Induced draft / direct vent (high-efficiency)	70%
	Condensing	86%
Oil	Storage tank (conventional)	50%
	Storage tank (high-efficiency)	60%
	Integrated with space heating (tankless coil)	40%
Electricity	Storage tank (conventional)	88%
	Storage tank (high-efficiency)	94%
	Instantaneous	94%
	Heat pump	190%

Typical Water Heating System Seasonal Efficiencies

*Note: The efficiency of residential water heating systems is commonly expressed in terms of the Energy Factor (EF). For the purposes of the model it is assumed that the two measures are essentially the same (except that EF is expressed as a decimal). The values in the above table are in fact EF values that were converted to percentages. Seasonal Efficiency is used here because it is a more generic term and more applicable to commercial and industrial water heating systems for which EF ratings don't exist. All shown efficiency values are approximate and typical values.

Solar Collector

This sub-section deals with the characteristics (type and area) of the solar collector.

Collector type

The user selects the collector type from the three options in the drop-down list: "Unglazed," "Glazed" and "Evacuated." These three basic solar water heating collector technologies exhibit different performances under various climatic conditions, and also present large differences in cost per collector area. For more information, Technical Note 1 should be consulted. There are other technologies available such as double-glazed flat-plate collectors, concentrating collectors, or collectors with integrated storage capacity. However, they are not included in the current version of RETScreen. The user can consult the RETScreen Online Product Database for more information.

Note that different technologies have different costs, unglazed collectors having the lowest cost and evacuated collectors having the highest costs. A balance has to be reached between efficiency and cost; this issue will be addressed in detail in the *Cost Analysis* worksheet.

Solar water heating collector manufacturer

The user enters the name of the solar water heating collector manufacturer. This is for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

Solar water heating collector model

The user enters the name of the solar water heating collector model. This is for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

Gross area of one collector

The user enters the gross area of one collector, in m². Gross area is the total area occupied by the collector, including its frame. For detailed information, Technical Note 1 should be consulted. The user can consult the RETScreen Online Product Database for more information.

In RETScreen, all calculations (including collector efficiency) are based on gross area, except SWH system capacity, storage, pump energy, suggested pipe diameter, and heat exchanger cost which are based on aperture area.

Aperture area of one collector

The user enters the aperture area of one collector, in m². Aperture area is the maximum area of the collector over which useful direct solar radiation can be collected. For detailed information, Technical Note 1 should be consulted. The user can consult the RETScreen Online Product Database for more information.

In RETScreen, all calculations (including collector efficiency) are based on gross area, except SWH system capacity, storage, pump energy, suggested pipe diameter, and heat exchanger cost which are based on aperture area.

Typical aperture collector areas range from 1 to 5 m². Aperture area is always less than or equal to gross area.

Fr (tau alpha) coefficient

The user enters the Fr (tau alpha) coefficient for the collector under consideration. For detailed information, Technical Note 1 should be consulted. The user can consult the RETScreen Online Product Database for more information.

Values typically range from 0.50 to 0.90. The higher end of the range is applicable to unglazed collectors, the middle range to glazed collectors, while the lower end is applicable to evacuated collectors.

Wind correction for Fr (tau alpha)

If "Unglazed" collector type is selected, the user enters the wind correction coefficient for Fr (tau alpha), in s/m. For detailed information, Technical Note 1 should be consulted. The user can consult the RETScreen Online Product Database for more information.

Values of the wind correction for Fr (tau alpha) are typically between 0.030 and 0.050 s/m.

Fr UL coefficient

The user enters the Fr UL coefficient, in $(W/m^2)/°C$. For detailed information, Technical Note 1 should be consulted. The user can consult the RETScreen Online Product Database for more information.

Values typically range from 10.00 to 15.00 $(W/m^2)/°C$ for unglazed collectors, from 3.50 to 6.00 $(W/m^2)/°C$ for glazed collectors and from 0.70 to 3.00 $(W/m^2)/°C$ for evacuated collectors.

Wind correction for Fr UL

If "Unglazed" collector type is selected, the user enters the wind correction coefficient for Fr UL, in $(J/m^3)/°C$. For detailed information, Technical Note 1 should be consulted. The user can consult the RETScreen Online Product Database for more information.

Values of the wind correction for Fr UL typically range from 3.00 to 15.00 $(J/m^3)/°C$.

Temperature coefficient for Fr UL

If "Glazed" or "Evacuated" collector type is selected, the user enters the temperature coefficient of Fr UL (i.e. the quadratic term of the efficiency equation, if there is one) for the collector under consideration, in $W/(m \cdot °C)^2$. For detailed information, Technical Note 1 should be consulted. The user can also consult the RETScreen Online Product Database for more information. Note that when both a linear and a quadratic efficiency equations are available, the linear equation should be used since quadratic equations are linearized by RETScreen. If a linear efficiency equation is used, set the temperature coefficient of Fr UL to 0.

Values typically range from 0.000 to 0.010, this last value corresponding to collectors where thermal losses increase significantly with temperature.

Suggested number of collectors

The model calculates the suggested number of collectors. This value depends on the energy load, collector type, climatic conditions and season of use. The suggested number of collectors is used as a starting point only. It is important to vary the actual number of collectors (see "Number of collectors") in order to find the most financially viable collector area for the specific application.

Note that collector efficiency varies with season of use. Evacuated collectors, for example, are more efficient than unglazed collectors in the winter, but the situation is reversed in the summer. For this reason, depending on the climatic conditions and the season of use, the number of collectors suggested in the model may be larger with evacuated collectors than with unglazed collectors, despite the fact that evacuated collectors are, on average, more efficient.

The suggested number of collectors may vary from one, for small residential systems, to several hundred, for large commercial or industrial applications. "N/A" may appear if the model is unable to suggest the number of collectors. In this case, the user should choose a number of collectors, in an iterative process, to obtain a desirable solar fraction or financial optimum.

Note: The maximum suggested solar collector gross area is limited within the software to equal the pool area. This is a rule of thumb used in the industry.

Number of collectors

The user enters the actual number of collectors for the solar water heating system. As a first pass, use the "Suggested number of collectors" calculated by the RETScreen model, then vary the value of the number until a financial optimum is found.

The number of collectors may vary from one, for small residential systems, to several hundred, for large commercial or industrial applications.

Note: The maximum suggested solar collector area is limited within the software to equal the pool area. This is a rule of thumb used in the industry.

Total gross collector area

The model calculates the total gross area of the collectors, in m². The total gross collector area may range from a few square meters, for a residential hot water system, to up to hundreds of square meters, for large commercial or industrial applications. Note that the user may be limited by space available on the roof of the building in the case of a roof-mounted system.

Storage

This sub-section deals with the characteristics of the storage tank.

Ratio of storage capacity to collector area

The user enters the desired number of litres of storage per square meter (aperture area) of solar collector (L/m²). The larger the storage, the better the system will be at going through long periods with little sunshine, although this will increase stand-by losses and initial equipment costs.

The nominal value should be 75 L/m²; typical values range from 37.5 to 100 L/m². Note that "Ratio of storage capacity to collector area" is to be modified if the user wants to keep the same storage volume in a sensitivity analysis on collector aperture area, otherwise storage will vary proportionally to collector aperture area.

Storage capacity

The model calculates the capacity of the hot water storage tank, in L. This is calculated in the model as the product of "Ratio of storage capacity to collector area", "Aperture area of one collector" and "Number of collectors." Storage capacity is application dependent. It can range from a few hundred litres for residential applications to several thousand litres for industrial applications. For domestic hot water applications, storage capacity is typically equal to the daily hot water use or a little less.

Balance of System

This sub-section deals with the characteristics of the balance of system, which includes piping, pumps, and an optional heat exchanger. In the *Cost Analysis* worksheet, items generally supplied by the solar equipment manufacturer or directly related to the solar loop are considered as part of the "Energy Equipment," installation and materials locally purchased or supplied by the installer are listed as part of the "Balance of System." For a better understanding of the different components involved in different design configurations of a SWH system, Technical Note 2 may be consulted.

Heat exchanger/antifreeze protection

The user selects whether or not an heat exchanger is used. The user selects "Yes" if the collector loop is separated from the rest of the system by a heat exchanger. If this is the case, the model assumes that an antifreeze fluid, such as glycol, circulates through the collector loop, thereby providing antifreeze protection to the system in the winter. The user selects "No" if there is no heat exchanger. In this case service hot water or pool water is assumed to circulate through the collector loop, and the system should be turned-off whenever freezing conditions are encountered.

Heat exchanger effectiveness

The user enters the effectiveness of the heat exchanger, in %. This entry is available only if the "Heat exchanger/antifreeze protection option" is set to "Yes."

Heat exchanger effectiveness ranges from 50 to 85%, depending on the type of heat exchanger selected. As a typical starting point value for analysis, 80% is suggested. Note that the heat exchanger effectiveness is not related to the heat losses of a heat exchanger (generally negligible). A higher effectiveness characterises the ability of the heat exchanger to transfer the same amount of heat from the solar loop to the service hot water but with a narrower temperature difference. The higher the effectiveness is, the higher will be the seasonal yield of the SWH system.

Suggested pipe diameter

The model calculates the suggested nominal diameter of the solar collector piping, in mm. This value is calculated based on the collector aperture area. The "nominal" value is suggested mainly for service hot water systems where copper piping is considered for installation. Swimming pool heating systems typically use the same 35 mm (1½") plastic tubing as the filtration system.

Values range from 8 mm (3/8") for small solar collector area, up to 25 mm (1") for larger collector area. Note that a flag or N/A will advise the user when a large system will require a solar loop diameter greater than 1 inch. The user will then have to calculate piping cost manually in the *Cost Analysis* worksheet or consider splitting the solar loop in several parallel loops. Hence, the cost of piping should then be multiplied by the number of loops in parallel.

Pipe diameter

The user enters the actual pipe diameter, in mm. This is used to estimate the cost of piping installation in the *Cost Analysis* worksheet; typically, the larger the pipe, the higher the costs. Note that it is assumed in the model that the value entered has no influence on the annual energy production.

Values ranging from 8 mm (3/8") to 25 mm (1") are acceptable. As a first pass, use the "Suggested pipe diameter" or 35 mm (1½") plastic tubing for swimming pool systems.

For swimming pool SWH systems, it is common to use plastic pipes with diameters ranging from 35 to 50 mm (1½ to 2 inches), which are easily adaptable to existing pool filtration pipes. For SWH thermosiphon systems, the solar loop should be as short as possible with a larger pipe diameter. A minimum pipe diameter of ¾ inch is required even for a small residential thermosiphon system. For other solar water heating systems, installers usually use copper pipe from 8 to 25 mm (3/8" to 1") as recommended in the following table.

Pipe Diameter mm (inch)	Collector Aperture Area (m^2)
8 (3/8")	0 to 14
12 (½")	7 to 23
20 (¾")	18 to 48
25 (1")	35 to 80

Suggested (Copper) Pipe Diameters for Service Hot Water Systems

Small pipe diameters (6 mm (¼") or less) are not recommended because of the risks of blocking and requiring a high-pressure head pump. The pipe diameter choice will depend on the required flow rate in the solar loop, which is proportional to the collector aperture area. The maximum recommended flow rate to minimise excess noise in a 25 mm (1") pipe is around 45 L/min (10 GPM). Based on a fluid temperature increase of 15°C through the collector, for average solar radiation and typical temperature levels, the maximum collector area used on a 25 mm (1") solar loop is estimated to be around 80 m^2. For larger systems (> 80 m^2), it is recommended to use more than one solar loop to limit pipe diameter to 25 mm (1"). A modular system using 25 mm (1") piping diameter is often less costly to install than a single system with a larger pipe diameter. In general, it is also easier to control and operate.

Pumping power per collector area

The user enters the pumping power per unit of collector aperture area, in W/m^2. This value is used to calculate the electricity required to operate the SWH system.

This value shall be set to zero for the following systems:

- Thermosiphon systems, as a solar loop pump is not required;

- Systems with photovoltaic-powered pumps, as the required electric energy is produced by photovoltaic panels;

- Outdoor swimming pool systems when the filtration system pump can be used for the solar loop (when solar loop requires a high head (e.g. collectors placed too high above pool level), a booster pump may be required); and

- Industrial-type systems where water is simply diverted through the collectors before being delivered to the load.

In direct loop SWH systems (Technical Note 2), only one pump is generally required to circulate water from the tank through the solar collectors. Values ranging from 3 to 22 W/m^2 are typical. Use higher values if the solar loop diameter is small or length is long in proportion to solar collector aperture area. The following table provides power requirements for typical circulators.

Collector Aperture Area (m^2)	Solar Pump (W)	Specific Pump Power Range (W/m^2)
2 to 6	20 to 45	3 to 20
6 to 12	85	7 to 15
12 to 35	185	5 to 15
35 to 60	205	3.5 to 6

Typical Solar Pumps Used Depending on Collector Array Size

With indirect loop SWH systems using an antifreeze mixture and operated in cold climates, it is important to note that the pump power has to be greater than direct systems operated in mild climates. This, to compensate, when the system starts, for the high viscosity of the colder transfer fluid in outdoor piping, or the head required to fill the solar loop of a drain-back system.

In large indirect loop pumped SWH systems with storage and an external heat exchanger, (see Technical Note 2, point 3.A.ii), use 1.5 to 2 times the estimate given in the previous table, as there are typically two pumps required to operate the system.

Piping and solar tank losses

The user enters a value accounting for heat losses (%) from the pipes and/or the tank to the surrounding environment. Heat losses are represented as a fraction of renewable energy delivered. This fraction depends on several factors:

- In systems without storage the only losses for this item are piping losses which depend on the length of piping. Enter 1 or 2% if there is a short distance (relative to collector area) between the collector and the rest of the system, and between 4 and 8% otherwise. Use the lower values for well-insulated piping and the higher values for poorly insulated piping.

- In systems with storage, additional heat losses from the tank have to be taken into account. Enter an additional 5 to 10% for tank losses.

- The values above can be lowered if the system is used only during summer months or hot water tanks are installed in a warm mechanical room (often overheated in commercial buildings). Lower values may be used because losses to the environment are lower and because systems can sometimes offset some of the losses by collecting extra energy that would otherwise be wasted.

However, note that some of the heat losses from the tank and inside piping can provide space heating during winter months.

Losses due to snow and/or dirt

The user enters the percentage of energy lost due to the obstruction of the solar collector by snow and/or dirt. The value of this parameter depends on local climatic conditions, on the tilt angle of the collector, and on the presence of personnel on-site to remove the snow or clean the collector.

Depending on local conditions, use 2 to 5% for evacuated tube collectors rack-mounted on flat surfaces or well-maintained collectors, and 3 to 10% for other collectors.

Horizontal distance from mechanical room to collector

The user enters the horizontal distance between the mechanical room and the solar collector, in metres (m). It is assumed in the model that this parameter has no bearing on the energy analysis of the system. This parameter is used in the *Cost Analysis* worksheet to estimate the cost of running horizontal piping to the collector.

Values typically range from 5 m in the case of a solar collector installed on the roof of a house, to 20 m for industrial systems where solar collectors can be located on a structure outside the building, or on the roof of another building.

Number of floors from mechanical room to collector

The user enters the number of floors through which piping has to be installed to reach the solar collector. The model assumes that this parameter has no bearing on the energy analysis of the system. It is used in the *Cost Analysis* worksheet to estimate the cost of running vertical piping to the collector.

Values typically range from 0 in the case of a collector installed on a structure outside the mechanical room, to 20 floors in the case of taller buildings (e.g. apartment buildings).

Technical Note 1 - Performance of Solar Collector Technologies used in the RETScreen SWH Project Model

A - Types of collectors available in RETScreen

The three types of collectors available in RETScreen are as follows:

1. <u>Unglazed collectors</u> are usually made of a black polymer. They do not have a selective coating and do not include a frame and insulation at the back; they are usually simply laid on a roof or on a wooden support. They are good at capturing the energy from the sun, but thermal losses to the environment increase rapidly with water temperature particularly in windy locations. Unglazed collectors are commonly used for applications requiring energy delivery at low temperatures (pool heating, make-up water in fish farms, process heating applications, etc.); they are often operated in the summer season only because of the high thermal losses of the collector. Unglazed collectors are sensitive to wind and often, the efficiency of such collectors include a wind-dependent term.

2. <u>Glazed collectors</u> often have a selective coating and are fixed in a frame between a glass cover at the front and an insulation panel at the back. They are good at capturing the energy from the sun and their thermal losses to the environment are relatively low. Glazed collectors are commonly used for applications requiring energy delivery at moderate temperatures (domestic

hot water, space heating and process heating applications at 50°C or less) in medium to cold climates. They can be operated year-round with freeze protection (e.g. glycol, drain-back design). The efficiency of glazed collectors is independent of wind.

3. Evacuated collectors have a selective coating enclosed in a sealed, evacuated glass tubular envelope. They are good at capturing the energy from the sun; their thermal losses to the environment are extremely low. Systems presently on the market use a sealed heat-pipe on each tube to extract heat from the absorber (a liquid is vaporised while in contact with the heated absorber, heat is recovered at the top of the tube while the vapour condenses, and condensate returns by gravity to the absorber). Evacuated collectors are good for applications requiring energy delivery at moderate to high temperatures (domestic hot water, space heating and process heating applications typically at 60°C to 80°C depending on outside temperature) in cold climates. They can be operated year-round with freeze protection. The efficiency of evacuated collectors is independent of wind.

B - Different types of collector efficiency equations considered by RETScreen

Please note that all the efficiency equations used by RETScreen are based on *gross area*, not aperture area.

Generic (linear) efficiency equation

Typically, the performance of a glazed or evacuated solar collector is modelled by the following equation:

eta = Fr (tau alpha) - [Fr UL]*DT/G (1)

where:

eta	is the collector efficiency [dimensionless]
Fr (tau alpha)	is a parameter used to characterise the collector's optical efficiency [dimensionless]
Fr UL	is a parameter used to characterise the collector's thermal losses [(W/m²)/°C]
DT	is the temperature differential between the working fluid entering the collector and the outdoors [°C]
G	is the global incident solar radiation on the collector [W/m²]

Parameters Fr (tau alpha) and Fr UL are determined from standard tests and are available for most collectors on the market. The larger Fr (tau alpha) is, the more efficient the collector is at capturing the energy from solar radiation. The smaller Fr UL is, the better the collector is at retaining the captured energy instead of losing it through convection and conduction to the ambient air.

Quadratic efficiency equation

Some manufacturers or test laboratories also include a quadratic term in the efficiency equation:

eta = Fr (tau alpha) - [Fr UL]*DT/G - [Fr UL_T]*DT^2/G (2)

where Fr UL_T is the temperature coefficient of Fr UL. RETScreen allows such equations to be entered. However the algorithm used internally by RETScreen requires a linear equation, so quadratic equations are linearized by the program. When available, it is best to use linear efficiency equations rather than quadratic efficiency equations. The efficiency of all collectors in the RETScreen Product Database is given in linear form.

Efficiency equations in 'European' format

Some test laboratories, particularly in Europe, report collector efficiencies with linear or quadratic equations similar to those shown above (1-2), except that DT is the temperature differential between the *average* collector temperature and the outdoors. All collector efficiency equation of that form in the RETScreen product database were converted to the *linear* form using the temperature differential between *inlet temperature* and the outdoors.

If the user needs to input a collector efficiency (either linear or quadratic) in European format, the current version of RETScreen will not properly account for the fact that the coefficients were measured using average, rather than inlet, collector temperature. A rough workaround is simply to reduce collector efficiency by about 3%. This is best done by increasing the *Losses due to snow and dirt* (in the **Balance of System** subsection) by 3%.

Wind-dependent efficiency equations for unglazed collectors

Equation (1) is also used to model unglazed collectors. However the following points should be noted:

- For unglazed collectors, G also includes long-wave radiative losses to the sky.

- For most unglazed collectors, efficiency coefficients are adjusted depending on wind speed.

  Fr (tau alpha) becomes:

  [Fr (tau alpha)] - [Fr (tau alpha)]wind*V

and Fr UL becomes:

[Fr UL] + [Fr UL] wind*V

where:

[Fr (tau alpha)]wind and [Fr UL]wind are two corrective coefficients, expressed in s/m and $(J/m^3)/°C$, respectively, and
V is the wind velocity experienced by the collector.

C - Differences between gross and aperture area

Collector tests report efficiency relative to gross collector area, aperture area, or both.

- Gross area is the total area occupied by the collector, including its frame. It is simply the product of the outside length and width dimensions of the collector.

- Aperture area is the maximum area of the collector over which useful direct solar radiation can be collected.

For most unglazed collectors, gross and aperture areas are identical. For glazed collectors, aperture area is equal to gross area minus the area occupied by the frame. For evacuated tube collectors, aperture area is the area covered by the tubes themselves, whereas gross area includes the area between tubes.

RETScreen expects collector efficiencies *expressed in terms of gross area*. If the efficiency is expressed in terms of aperture area, the following conversion can be used:

$$eta\_g = eta\_a \cdot (Aa / Ag)$$

where eta_g is the efficiency based on gross area, eta_a is the efficiency based on aperture area, Ag is the gross area and Aa is the aperture area.

Example. An evacuated tube collector has a gross area of 2.140 m^2 and an aperture area of 1.412 m^2. The efficiency equation of the collector, based on aperture area, is:

$$eta\_a = 0.813 - 1.32 (DT/G) - 0.035 (DT^2/G)$$

Then the efficiency equation based on gross area is obtained by multiplying the coefficients of the equation above by 1.412 / 2.140, hence the efficiency equation based on gross area is:

$$eta\_g = 0.536 - 0.871 (DT/G) - 0.023 (DT^2/G)$$

Technical Note 2 - Preheating System Configurations for Service Hot Water Applications

1. Thermosiphon systems:

- A simple and reliable system design widely used for domestic hot water throughout the world and for seasonal use in cold climates;

- Thermosiphon systems are generally direct loop systems;

- No circulator is required; the water circulates naturally in the solar loop under the action of heat generated in the solar collectors. Heated water becomes lighter than the cold water in the tank; gravity then pulls heavier cold water down from the tank and into the collector inlet;

- The storage tank needs to be placed above the collector array level (at the roof level). Hot water is accumulated with a natural stratification which means that hot water accumulates first at the top of the reservoir;

- For better performance, the solar loop must be as short as possible and made of a larger pipe diameter than pumped systems (19 mm or ¾ inch minimum even in small residential DHWS);

(Note that well designed thermosiphon systems may have similar heat performance to pumped systems and can be considered in a pre-feasibility analysis using RETScreen.)

2. <u>Direct loop (pumped) systems</u>:

- System with no heat-exchanger; service hot water circulates directly in the solar loop;

- Simple, low-cost design suitable for warm climates or seasonal applications in cold climates.

(Note that unglazed solar outdoor pool heaters are direct loop systems connected in line with the filtration system.)

3. <u>Indirect loop pumped systems</u>:

- Possible use of an antifreeze mixture in the solar loop;

- Requires a heat-exchanger:

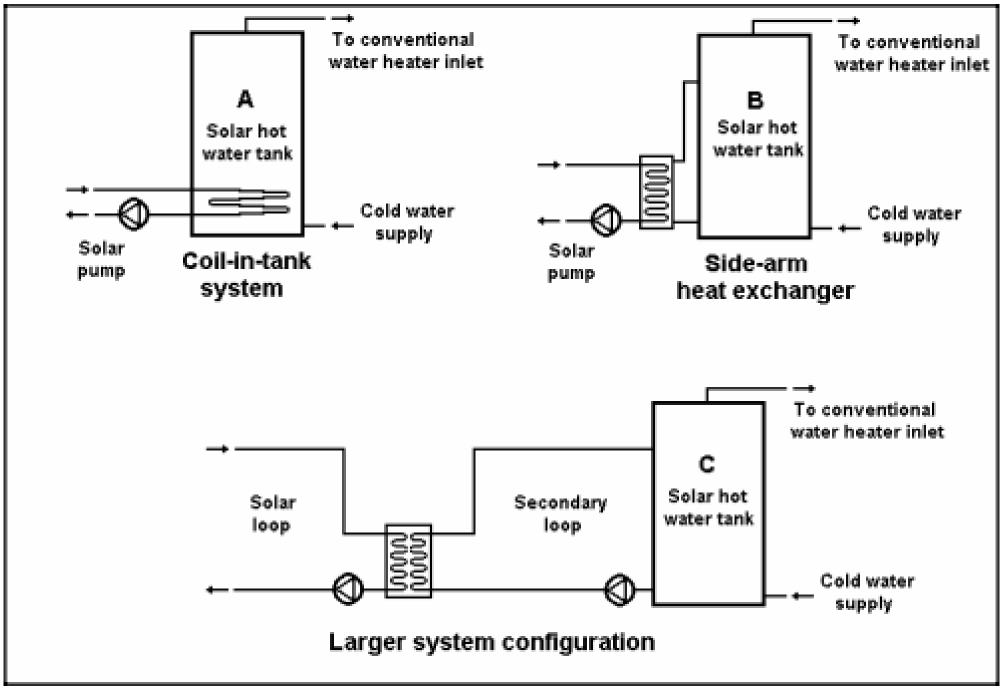
   A. external;

      i) external with natural circulation ("side-arm" type operating like a thermosiphon) avoids the use of a secondary circulator in smaller systems (following figure, example B); and

      ii) external with a secondary loop using a secondary circulator (the only configuration with 2 pumped circuits), is a common design for larger systems (15 m² and above) (following figure, example C).

   B. coil-in-tank (also called internal coil) (following figure, example A); and

   C. wrap around or tank-in-tank.



Typical Heat-Exchanger Configurations for Service Hot Water Solar Systems with Antifreeze Protection

Annual Energy Production (for months analysed)

This section summarises the annual energy production of the solar water heating project.

Note: All energy values summarised here are calculated for the part of the year when the SWH system is in use. Months during which the solar water heating system is not used are not taken into account in this analysis.

SWH system capacity

The model calculates the SWH system capacity in kW, as defined by the number of collectors and the aperture area of one collector.

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.

Pumping energy (electricity)

The model calculates the approximate amount of electricity (MWh) necessary to run the pumps of the solar water heating system during the months of use. This value depends on solar radiation and is proportional to the "Pumping power per collector area", the "Aperture area per collector" and the "Number of collector" entered in the Balance of System and Solar Collector sub-sections of the System Characteristics section. This value is transferred to the *Cost Analysis* worksheet to calculate the Electricity annual costs of the SWH system in the *Financial Summary* worksheet.

Specific yield

The model calculates the amount of energy delivered by the solar collector per unit of gross collector area for the months analysed, in kWh/m². This value depends on the technology used, climatic conditions, the use or not of an heat exchanger, the daily hot water usage, etc. This value is typically in the 200 to 800 kWh/m² range for a system that operates for 12 months of a year.

System efficiency

The model calculates the system efficiency (%) for the months analysed. System efficiency is the ratio of "Renewable energy delivered" to "Solar radiation (tilted surface)." Note that the system efficiency does not take into account the parasitic pumping energy. For service hot water applications, the annual SWH system efficiency are typically between 30 to 50%, depending on climate, system size and water heating load. Generally, the greater the solar fraction, the lower the system efficiency (to obtain high solar fractions, the collector area is increased and the system operates more often at high temperature, with a lower efficiency). Swimming pool systems may show higher efficiencies, up to 60%.

Solar fraction

The model calculates the fraction (%) of the water heating load for the months analysed (see "Energy demand for months analysed" in the Site Conditions section) met by the solar water heating system. For service hot water applications, the annual energy needs covered by a SWH system (the "solar fraction") are typically between 10 to 70% of the annual water heating load, depending on climate, system size and load. The optimal size in terms of system cost-effectiveness is generally obtained for solar fractions between 30 to 50%, on a 12 months operation basis.

- For most service hot water systems without storage, this value should not exceed 15%.

- For service hot water systems with storage, this value can range anywhere from 10 to 70%. SWH systems designed for year-long operation in temperate climates will have solar fractions typically between 30 and 50%.

- For swimming pools, this value can range from 10 to 100% (generally 70 to 100% in the case of seasonal outdoor pools).

Renewable energy delivered

The model calculates the amount of energy delivered by the solar water heating system for the months analysed, in MWh. Typical values depend on the type of application considered. This value is transferred to the *Financial Summary* 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," and "MJ." This value is for reference purposes only and is not required to run the model.

Solar Resource and Heating Load Calculation

As part of the RETScreen Clean Energy Project Analysis Software, the *Solar Resource and Heating Load Calculation* worksheet is used in conjunction with the *Energy Model* to calculate the energy load and energy savings of a solar water heating system. The user can consult the RETScreen Online Weather Database for more information.

Site Latitude and Collector Orientation

Site conditions and system characteristics associated with estimating the annual solar energy resource are detailed below.

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.

Latitude of project location

The user enters the geographical latitude of the project site location in degrees measured from the equator. Latitudes north of the equator are entered as positive values and latitudes south of the equator are entered as negative values. The user can consult the RETScreen Online Weather Database for more information.

The latitude of the closest weather location can be pasted to the spreadsheet from the online weather database. If the user knows the latitude for the project location, this value should be entered in the spreadsheet by overwriting the pasted value.

Slope of solar collector

The user enters the angle between the solar collector and the horizontal, in degrees.

In most cases, the slope of the collector will be:

- Equal to the absolute value of the latitude of the site: This is the slope which in general maximises the annual solar radiation in the plane of the solar collector. This is adequate for systems working year-round;

- Equal to the absolute value of the latitude of the site, minus 15°: This is the slope which in general maximises the solar radiation in the plane of the solar collector in the summer;

- Equal to the absolute value of the latitude of the site, plus 15°: This is the slope which in general maximises the solar radiation in the plane of the solar collector in the winter. This slope is also recommended in cold climates to minimise snow accumulation; or

- Equal to the slope of the roof on which the collector is to be installed: This does not necessarily represent an optimum in terms of energy production, but can reduce significantly installation costs by eliminating the need for a support structure, or may be more desirable from an aesthetics standpoint.

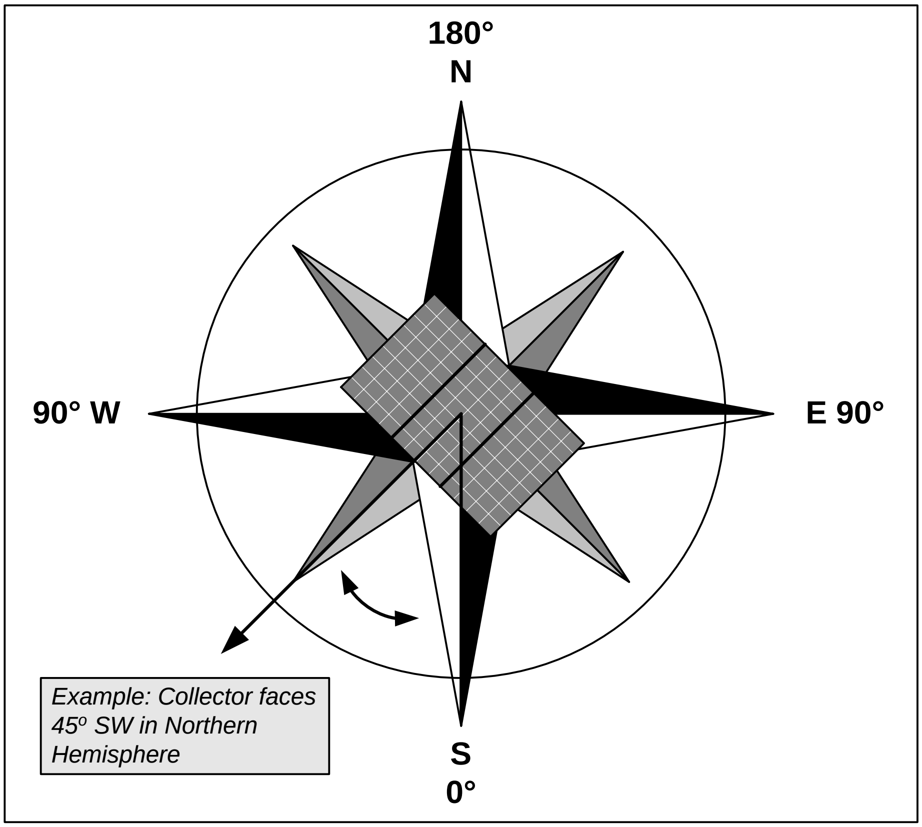
Azimuth of solar collector

The user enters the angle between the projection, on a horizontal plane, of the normal to the surface and the local meridian, with zero due south (for the purpose of this model, the sign has no importance).

The preferred orientation should be facing the equator, in which case the azimuth angle is 0° in the Northern Hemisphere and 180° in the Southern Hemisphere. In the case of a collector mounted directly on the roof of a building, the azimuth is equal to that of the roof, which should be chosen to be as close to equator facing as possible. For example, a solar collector in the Northern Hemisphere facing south-west would have an azimuth angle of 45° (see following figure).

If two walls are being used, the average of the absolute values for the orientation should be calculated. For example, if one wall is 30 degrees west of south (+30°) and the other wall is 60 degrees east of south (-60°), enter 45 degrees. Alternatively, if one wall were due east (-90°), and the other due west (+90°) the average of the absolute values would be 90°.

Note that the azimuth must be entered with respect to true south and not magnetic south. Compasses point to magnetic north (the complement of magnetic south) and azimuth directions based on this measure must be adjusted for the magnetic declination (for more information, refer to " Magnetic declination "). If the azimuth direction is being determined from site drawings, it should be determined what reference the site north is using. Site north does not always correspond to true north, as it is sometimes adjusted for convenience in the site and building drawings.



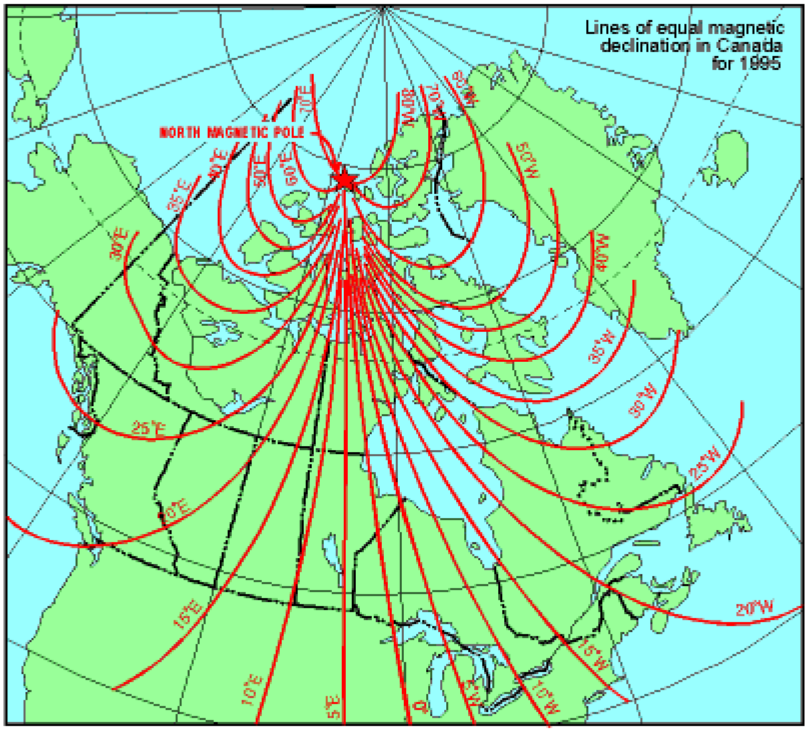
Azimuth of Solar Collector [adapted from Ross, 1999]

Magnetic declination

A magnetic compass does not normally point to true north. In fact, over most of the Earth it points at some angle east or west of true (geographic) north. The direction in which the compass needle points is referred to as magnetic north, and the angle between magnetic north and the true north direction is called **magnetic declination**. The terms "variation," "magnetic variation" or "compass variation" are often used in place of magnetic declination, especially by mariners.

Natural Resources Canada's Geomagnetic Website provides a Magnetic Declination Calculator that can calculate the magnetic declination for any location (given latitude, longitude and year) on the globe.

A chart of magnetic declination is provided for Canada based on the year 1995. Small changes from year to year do occur, but can be ignored for the purposes of this model. A magnetic declination of 10°W, means that magnetic north is 10° west of true north for that location and time.



Lines of Equal Magnetic Declination in Canada for 1995

Monthly Inputs

Monthly mean weather data are entered by the user in this section. The user also specifies the months or the fraction of months (e.g. 0.25 if the system is used only one week in a month) during which the solar energy equipment is used. All energy and cost calculations in the remainder of the Solar Water Heating Project workbook are performed for the period of use of solar energy only. In other words, months where no solar energy is used are not taken into account in the energy and financial analysis, the rationale being that there is no energy displaced or solar savings to calculate for these months. For months where equipment is used only for a fraction of the entire month, the same fraction applies for that month to all energy calculations.

Some cells may be greyed out to indicate that they are not used for energy calculations. For example, if the system under consideration is for service hot water, then monthly average relative humidity is not required - it is needed only for outdoor pools, to calculate the rate of evaporation from the pool.

Note: It is important to revisit this table to check that all required inputs are filled in if the user changes any of the following parameters which modify the cells that are greyed out: application type, solar collector type, type of pool, or method for calculating cold water temperature.

Fraction of month used

The user enters the months for which the energy equipment is used. Months during which the energy equipment is not used are not taken into account in the energy and financial analysis. For each month, the user enters a value between 0 and 1. 0 is entered if the energy equipment is not used during a month, 0.5 if it is used 50% of the time and 1 if it is used 100% of the time.

Monthly average daily radiation on horizontal surface

The user enters the amount of solar radiation received on average during one day on a horizontal surface at the site, in (kWh/m²)/d. Data in (MJ/m²)/d should be divided by 3.6 to be converted to (kWh/m²)/d. Data in BTU/ft² should be divided by 317 and data in cal/cm² or Langleys should be divided by 86 to be converted to (kWh/m²)/d. The user can consult the RETScreen Online Weather Database for more information.

The values range from 0 during polar night months in the polar regions, to values around 8.5 (kWh/m²)/d in temperate climates during summer months.

Monthly average temperature

The user enters the average temperature for the month, in °C. This temperature is used to estimate the performance of the solar collectors, the energy requirement of outdoor swimming pools and the cold (mains) water temperature. The user can consult the RETScreen Online Weather Database for more information.

Monthly average relative humidity

The user enters the average relative humidity for the month, in %. This value is used to estimate the evaporation losses for outdoor swimming pools. The user can consult the RETScreen Online Weather Database for more information.

Monthly average wind speed

The user enters the average wind speed for the month, in m/s. This value is used to estimate the energy requirements of outdoor swimming pools and the performance of unglazed solar collectors. The user can consult the RETScreen Online Weather Database for more information.

Monthly average daily radiation in plane of solar collector

The model calculates the amount of solar radiation received on average during one day on a tilted surface at the site, in (kWh/m²)/d. Typical values calculated by the model range from 0 to 10 (kWh/m²)/d.

Solar radiation (horizontal)

The model calculates the amount of solar radiation incident on a horizontal surface, in MWh/m², for the entire year and for the period (season) of use.

Solar radiation (tilted surface)

The model calculates the amount of solar radiation incident on the solar collector, in MWh/m², for the entire year and for the period (season) of use.

Average temperature

The model calculates the average ambient temperature, in °C, for the entire year and for the period (season) of use.

Average wind speed

The model calculates the average wind speed, in m/s, for the entire year and for the period (season) of use.

Water Heating Load Calculation

Water heating load characteristics are entered by the user in this section. This includes the type of application (service hot water or swimming pool), as well as sizing elements that will enable the model to estimate the energy requirements of the system.

Application type

The user selects the solar water heating application type. The options from the drop-down list are: "Service hot water" and "Swimming pool." "Service hot water" includes domestic hot water heating systems and industrial process heating systems. "Swimming pool" includes indoor and outdoor swimming pools.

System configuration

The user selects the configuration of the system from the two options in the drop-down list: "With storage" and "Without storage."

Systems with storage should be considered for domestic hot water applications, or for industrial applications requiring the solar water heating system to provide a significant part of the water heating load. Thermosiphon systems can also be evaluated using the configuration with storage, as their thermal performance is typically similar to those of pumped systems.

Systems without storage are typically industrial applications; as a rule-of-thumb, the solar energy, in a system without storage, should represent no more than 15% of the load, and the load should be continuous during daytime.

Building or load type

The user selects the type of building or load under consideration. This is used in the model to suggest, in some cases, an estimated load in "Estimated hot water use (at approx. 60°C)."

Several types of buildings or loads can be selected from the drop-down list: "House," "Apartment," "Hotel/Motel," "Hospital," "Office," "Fast food," "Restaurant," "School," "School w/ showers," "Laundry," "Car wash," "Industrial," "Aquaculture," and "Other." Depending on the selection, the model will use different algorithms to estimate the load. For the last three choices, no estimate is made and the load (volume as well as temperature) has to be calculated manually on a case-by-case basis.

Number of units

The user enters the maximum number (capacity) of occupants, units, rooms, beds, persons, meals (served per day), students, or cars (washed per day) for the facility, depending on the type of load selected. For "Laundry," the user enters the number of washers installed in the laundry; the model assumes a standard usage (ASHRAE) of a commercial washer (173 L/d of hot water). This item is used if the "Building or load type" is not "Industrial," "Aquaculture" or "Other."

Rate of occupancy

The user enters the percentage of the capacity, specified under the "Number of units" item, that is used on average during the season of use of the solar water heating equipment. This item is used if the "Building or load type" is not "Industrial," "Aquaculture" or "Other."

Estimated hot water use (at approx. 60°C)

The model calculates the daily hot water use of the facility. The user should use this estimate as a guide for determining the next item in the worksheet, "Hot water use." This item is used if the "Building or load type" is not "Industrial," "Aquaculture" or "Other."

Hot water use

The user enters the daily hot water use (L/d), averaged over the season of use of the solar water heating equipment. If this value is known, for example from energy bills, it should be used here. As a rule-of-thumb, hot water use for a residential application is 1/3 of the total water use as shown on the water bill. If it is not known, the estimate from the previous item, "Estimated hot water use (at approx. 60°C)" can be entered. For loads such as "Industrial," "Aquaculture" or "Other" the hot water use has to be estimated from energy bills through a manual calculation or from other data sources.

Desired water temperature

The user enters the temperature of the load, in °C. This is used in the model to calculate the energy requirements of the system.

Values range from less than 12°C for aquaculture applications, to 60°C or higher for domestic or industrial applications. Note that if the value provided in the model for "Estimated hot water use (at approx. 60°C)" is used as the "Hot water use" then the "Desired water temperature" should be set to 60°C.

Days per week system is used

The user enters the number of days per week the SWH system is used, during the season of use. This value is used in the model to reduce the energy requirements of the system by a proportional amount.

Values range from 1 to 7. For example, in the case of a school that is closed during the weekend, enter 5. For a cottage used during weekends only, enter 2. For a system used all week, enter 7.

Type of pool

The user selects the type of the swimming pool from the two options in the drop-down list: "Indoor" and "Outdoor."

Outdoor swimming pools experience climatic conditions defined in the Monthly Inputs section. The wind speed is multiplied by the attenuation factor defined in the "Wind sheltering coefficient" item. Direct solar radiation incident upon the pool is multiplied by the attenuation factor defined in the "Pool shading factor" item. Sky temperature is calculated from the meteorological data entered by the user.

The following assumptions are made on the climatic conditions for the evaluation of indoor swimming pools in the model: ambient temperature 27°C, ambient relative humidity 60%, inside air motion equivalent to a wind speed of 0.1 m/s. Generally, there is no direct or diffuse solar radiation incident upon the pool. Sky temperature is 27°C. In addition, a normal activity level in the pool is assumed.

Pool area

The user enters the area of the pool, in m^2. Values range from 20 m^2 for small residential pools, to 1,000 m^2 or more for city pools and aquatic parks.

Use of cover

The user enters the number of hours per day (h/d) a cover (blanket) is put on the pool. The model assumes that the cover is on predominantly at night, and that 90% of the pool is covered by the blanket.

Enter 0 if no cover is used. If the pool is open *n* hours per day and a cover is used whenever the pool is closed, enter 24-*n*; for example if a community pool is open 8 hours a day, enter 16.

Desired pool temperature

The user enters the desired minimum temperature of the pool. This is the temperature set point of the pool heater.

Typical values range from 22°C for competitive swimming, to 27°C for recreational swimming, to 35°C for therapeutic pools, whirlpools and spas.

Makeup water ratio

The user enters the percentage of pool water renewed **every week**, **not including** the addition of water to compensate for evaporation. This amount is representative of pool activity level. It includes compensation for water lost when swimmers exit the pool and periodic water renewal done for hygienic reasons (backwash: cleaning of filtration system using reverse water flows). This value is typically between 5 and 10%. Generally, the lower value will be used for a residential pool with low activity level, and the higher value for public pools with high activity level.

Note that the model can accept higher ratio values: for example, more than 25% if the user wants to represent the case of a municipal pool where water is completely renewed every month for hygienic reasons, or even higher than 100% in the case of a therapeutic or balneology centre with non-chlorinated ocean or spring water where water is renewed continuously. However, in this latter case, it is recommended to validate the results by comparing the results with those obtained when the model is set for "Service hot water" application type with aquaculture as the "Building or load type."

Wind sheltering coefficient

The user enters a coefficient characterising the attenuation of wind speed near the pool due to obstacles such as buildings, trees, and fences.

The wind speed values entered in the Monthly Inputs section are typically measured at a height of 10 m. They are multiplied by the wind sheltering coefficient prior to evaluating evaporative losses from the pool. Recommended values are between 0.1 for a very sheltered pool to 0.3 for an open-air pool. Higher values of the wind sheltering coefficient can be considered only for very exposed locations.

Note that the wind sheltering coefficient has a significant influence on the estimated energy requirement for heating the pool. Evaporative losses are strongly dependent on wind speed at the pool surface, and can represent up to 60% of all energy losses of the pool. It is usually safer to consider a larger wind shelter coefficient (0.3) than a smaller one (0.1) to estimate the amount of energy displaced by the solar heating system, because smaller values will tend to under-estimate the energy requirements of the pool. Pool covers are used primarily for this reason.

Pool shading factor

The user enters a coefficient characterising the average shading of direct solar radiation on the pool itself over the season of use of the SWH equipment. This is used by the model to reduce direct passive gains of a standard pool. (Note that pools located in a non-heated greenhouse can not be simulated using RETScreen).

Typical values range from 0% for a pool without any obstacles, to 50% for a pool surrounded by trees and buildings. **No shading factor shall be considered for the use of a pool blanket, even opaque.**

Cold water temperature - minimum and maximum

The user selects the type of method used to specify cold (mains) water temperature. The options from the drop-down list are: "Auto" and "User-defined."

If "Auto" is selected, the model automatically calculates the temperature of the cold water from temperature data specified in the Monthly Inputs section. The corresponding yearly minimum and maximum are shown in the next two lines.

If "User-defined" is selected, the minimum and maximum cold water temperature values are entered by the user. In the Northern Hemisphere the model assumes that the minimum temperature occurs in February and the maximum in August; a sinusoidal temperature profile is used for other months. The situation is reversed in the Southern Hemisphere.

If mains water comes from a deep well, of which the temperature is nearly constant throughout the year, the user should set the calculation method to "User-defined" and set the minimum and the maximum values equal to the well temperature.

Months SWH system in use

The model calculates the number of months for which the equipment is used, from data entered by the user in the Monthly Inputs section of the *Solar Resource and Heating Load Calculation* worksheet.

Energy demand for months analysed

The model calculates the annual energy demand for water heating, in MWh. This is calculated based on the months of use of the energy equipment specified in the Monthly Inputs section. This value is copied to the *Energy Model* worksheet.

The energy demand of service hot water systems is determined from cold water temperature, load temperature, and hot water use specified by the user. For swimming pools, the energy demand is determined through an energy balance between pool losses due to evaporation, convection, radiation, conduction, and fresh water supply and passive solar gains.

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," and "MJ." This value is for reference purposes only and is not required to run the model.

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 solar water 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.

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.

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

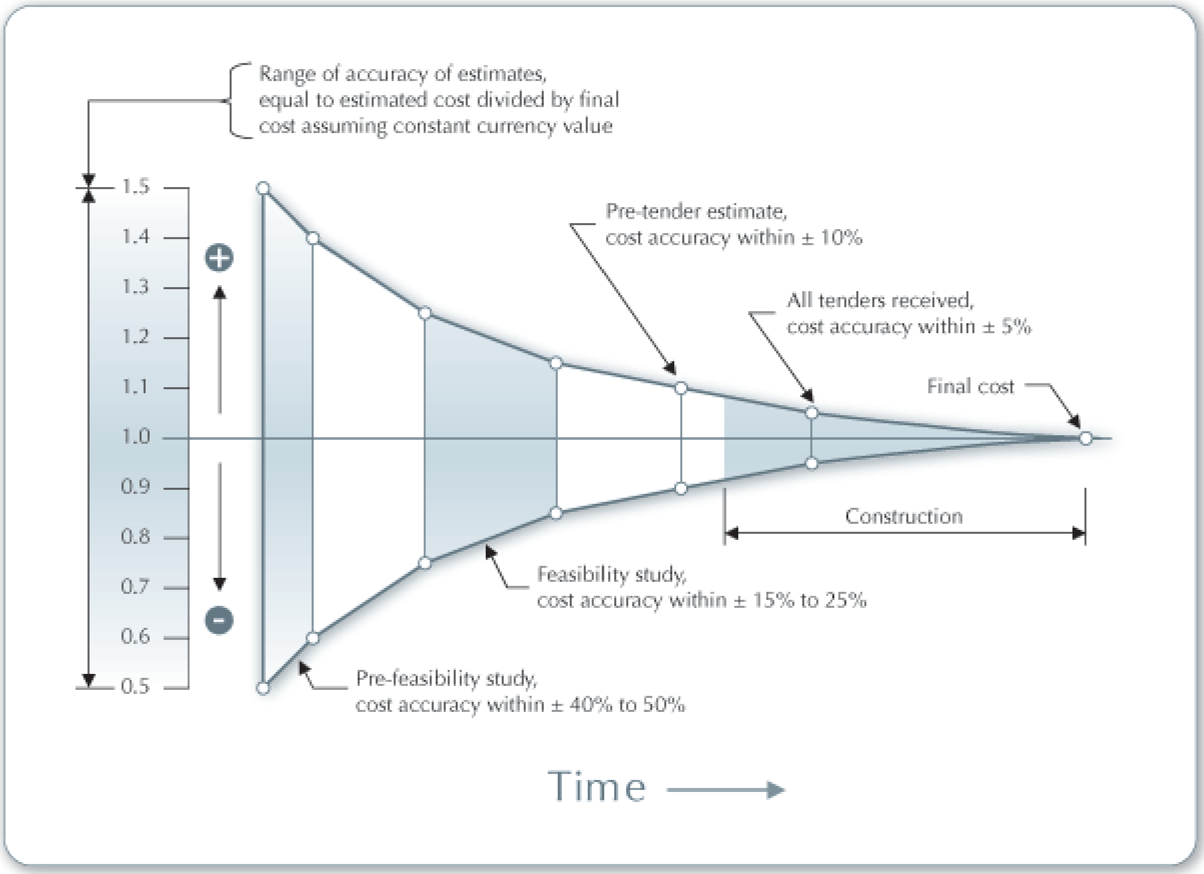
- Development (including financing) and engineering

- 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].

[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).

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]

By selecting "Pre-feasibility," initial costs for the feasibility study, development and engineering items for the solar water heating system will be assumed to be $0. For example, this selection may be appropriate for the implementation of a small residential solar DHW system or a simple swimming pool solar water heating system.

By selecting "Feasibility," the user will enter costs in all the standard initial costs categories described below. This selection is more appropriate for larger solar water heating systems and/or for projects requiring a more difficult structural integration into the existing building.

It is worth noting that for small SWH projects (capital cost less than $10,000), manufacturers and retailers may offer pre-engineered systems, based on an "off-the-shelf" concept. If this is the case, the user should select the "Pre-feasibility" option; the costs of feasibility study, development and engineering are then included in the price of the system. However, because each building has different characteristics, the user should verify the cost of anchoring the collector structure to the roof. For a better understanding of components mentioned in this section, the user should consult Technical Note 2.

Typically, the cost for an installed residential domestic SWH system using a glazed flat-plate collector ranges from $2,000 to $4,000.

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 solar water heating project are detailed below. The major categories may include costs for preparing a feasibility study, performing the project development functions, completing the necessary engineering, purchasing and installing the energy equipment, the balance of system, and costs for any other miscellaneous items.

Feasibility Study

Once a potential cost-effective solar water heating project has been identified through the RETScreen pre-feasibility analysis process, a more detailed feasibility analysis study may be required for larger solar water heating projects. Feasibility studies typically include such items as site investigations, preliminary project design and report preparation, including a detailed cost estimate. Travel costs may also be incurred. These costs are detailed in the section below.

For small projects, the cost of the feasibility study, relative to the cost of the solar water 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). In some cases a client may not require a feasibility study and will only ask for a proposal from the supplier, relying on the supplier's energy saving estimates and price quotation. This is common practice for "Standard design" (off-the-shelf) projects, which the user can select as an option at the beginning of the *Cost Analysis* worksheet in RETScreen.

Note: The RETScreen Clean Energy Project Analysis Software can also be used to prepare the Feasibility Study.

Site investigation

When a solar water heating system is being considered for an existing building, a site visit is often required to evaluate the site conditions and suitability of installing the SWH system. If the SWH system is for a new building or is to be ground mounted, then a site visit is usually not required since the analysis can be done from architectural or engineering and/or land survey drawings. Site visit time includes time required to arrange meetings, survey the site, obtain the necessary information and any travel time (but not travel expenses - see "Travel and accommodation").

For existing building installations, a solar water heating project expert should normally visit the site to meet with the client and other stakeholders, assess the exact location of the proposed installation and gather data so that the SWH system can be designed. The site will be inspected to determine a possible location for the solar collectors, piping, control, liquid handling unit and storage tanks if needed. Questions such as municipal regulations regarding installation of structures on the roof, roof membranes scheduled replacement or warranty conditions should be clarified at this stage as they may affect the system design and the cost of the structure. Preliminary data gathering, which should build upon the initial pre-feasibility analysis data, should be conducted prior to, and during the site visit.

A single site visit will suffice to conduct the feasibility study for the vast majority of retrofit projects. The cost of a site visit will be influenced by the planned duration and travel time to and from the site. The time required to gather the data prior to the site visit and during the site visit typically falls between 4 and 8 hours. For new construction, where a site visit is not normally required, estimate 2 to 4 hours to obtain drawings and required information. Solar water heating system expert fees typically range from $40/h to $100/h.

Preliminary design

A preliminary design is required in order to determine the size, layout and potential energy output of the solar water heating system. After the solar water heating system is sized, draft drawings, which consider system component integration into the building such as structures, piping and other equipment are prepared. The preliminary design is used to prepare a more detailed cost estimate.

The time required to prepare the preliminary design and detailed cost estimate typically falls between 5 and 50 hours at fees between $40/h to $100/h. Small-scale projects with standard and/or simple structural requirements are at the low end of this range. Special design and/or large-scale projects requiring optimisation and more difficult structural integration into existing buildings will be at the high end of this range. When preliminary design is not required, the user may enter 0.

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 that 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. Preparing a feasibility study report takes between 2 and 16 hours at a rate of between $40/h and $100/h. When a report is not required, the user may enter 0.

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 projects in isolated communities, where air travel is time consuming and expensive, it is 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. This is especially important where the projects being evaluated are small in size with resulting small solar water heating systems.

In the case of isolated communities, 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 communities and the range of cost so variable it is advisable 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 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 solar water heating project has been identified through the feasibility study (or sometimes just a pre-feasibility study) to be desirable to implement, project development activities 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 SWH projects, 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 solar water heating system product supplier who provides complete design/build services. General contractors may also be the developers, purchasing the solar water heating system on behalf of the building owner. It is also possible that an Energy Services Company (ESCO) could be the project developer. The ESCO purchase the solar water heating system and install it on a building owned by a third party in return receiving a portion of the annual energy savings/production. Estimating the costs of development phase will depend on the particular development arrangement established. Items here include costs for permits and approvals, project financing, development phase project management and any development related travel costs. These costs are detailed below.

Permits and approvals

A building and electrical permit may be required for the construction of the project. Drawings done in the preliminary design showing the structural integration into the building are usually required by the architect/engineer of the building to approve the load weight distribution on the roof. A roofing contractor should be consulted to approve all modifications to be done to the roof (e.g. roof penetrations). This is required to maintain the roof warranty (all modifications done on a roof must be done by a professional roofing contractor).

The cost of acquiring the necessary permits and approvals is calculated based on an estimate of the time required to complete the necessary work. For a typical solar water heating project the permit acquisition and approval process could take between 2 and 8 hours at rates of between $40/h and $100/h for project development staff. 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. When permits or approvals are not required, the user may enter 0.

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 owner and the developer is the product supplier, the project financing costs attributable to the project are minimal. The solar water heating system 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 developed project, much more effort will likely be required to arrange financing, negotiate an energy services contract with the solar water heating system owner and prepare legal documents.

The cost to obtain project financing will range from 8 and 24 hours at a rate of between $60/h and $180/h. The lower end of the range is for owner/product supplier developed projects. The higher end of the range applies to ESCO type projects. When project financing is not required, the user may enter 0.

Project management

The project management cost item should cover the estimated expenses of managing all phases of the development of the project (excluding construction supervision). Public relations are also included as part of the solar water heating project management cost item here. However, public relations is not normally a big issue with most SWH systems as the projects are usually building mounted and have little or no negative environmental impact. The project development management time will usually take between 10 and 40 hours at rates of between $50/h to $100/h. When project management is provided directly by the end-user or the supplier/installer, the user may enter 0.

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 SWH system design, structural design, tenders and contracting, and construction supervision. The costs are detailed below.

SWH system design

The SWH system design consists of the time required to prepare drawings and specifications (excluding structure), including identifying the final configuration of the SWH system, the sizing of all SWH system equipment, the exact physical placement of the solar modules, the storage tank, the heat exchanger, the control unit, pipes and the liquid handling unit. The drawing and specifications should also determine how the SWH system will be integrated with the existing plumbing system. Liaison will also be required with the SWH system designer(s), the architect/engineer of the building, the roof contractor of the building and the plumber responsible to achieve an optimum design.

Since both engineering time and drafting time are required, use a weighted average for the engineering and drafting rates and time. The time required to prepare the SWH system design and detailed drawings falls between 6 and 24 hours at fees of $40/h to $100/h. A standard system using "generic" installation drawings falls at the lower end of the time range. For small projects, "generic" installation drawings can often be used and there may not be a separate charge for design. In such cases, the user may enter 0.

Structural design

From a SWH system design standpoint, the simplest structural designs are vertical wall mounted and flush mounted roof systems, such as unglazed flat-plate collectors used in a swimming pool system, where little or no structural work is required. When the project is a large retrofit to a building or when modules are not flush mounted to the building structure, additional engineering time will likely be necessary to evaluate the structural and wind loading concerns for the installation. Some SWH system suppliers propose pre-engineered structures that can be sized to accommodate the required number of solar collectors. The pre-engineered structures are less expensive but may not be appropriate depending on the building. Liaison with the architect/engineer (load on building) and the roof contractor (roof modifications) are required when performing the final structural design and anchoring between the structure and the roof. When the roof membrane has to be replaced in the coming years, structural design should allow membrane replacement without need to dismantle the solar collector structure.

The time required to prepare the SWH system structural design and detailed drawings will depend on the simplicity of the structural layout chosen. Since both engineering time and drafting time are required, use a weighted average for the engineering and drafting rates and time. Structural design rates range from $40/h for drafting to $100/h for a professional engineer. Consult the table below to estimate the structural design time (engineering time can be 0 or very low if the structure is pre-engineered). Simple wall or flush mounted roof systems and small-scale projects with standard and/or simple structural requirements fall at the lower end of the time range. Allow 0 for most small projects. Special design and/or large-scale projects requiring optimisation and more difficult structural integration into the building will be at the higher end of the time range.

Mounting Angle	**Engineering (h)**	**Drafting (h)**
Vertical on wall	0 to 4	0 to 8
Horizontal on roof	0 to 16	0 to 8
Tilted on roof	15 to 30	20 to 40
Tilted on ground with no contour work	20 to 40	20 to 40
Tilted on ground with contour work	22 to 44	30 to 60

Structural Design Time Estimates for SWH Collectors

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, 10 to 40 hours at rates of $40/h to $100/h are common. If the SWH project is installed directly by the end-user and/or the supplier of energy equipment the user may enter 0.

Construction supervision

The construction supervision cost item summarises the estimated costs associated with ensuring that the project is constructed as designed. The consultant overseeing the project, the equipment supplier or the project manager can each act as the construction supervisor. Construction supervision involves regular visits to the job site to inspect the installation.

Depending on the project size, this task can take between 8 to 24 hours at rates of $40/h to $100/h. Travel costs should be included in the "Development" section above. If the SWH project is installed directly by the end-user and/or the supplier of the energy equipment the user may enter 0.

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 all the equipment that is typically supplied by the solar water heating system manufacturer: the solar collector, the solar hot water storage tank, the solar loop piping materials, the solar loop pump and the heat exchanger. Transportation costs are estimated separately to allow for cost differentiation in various regions. 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.

Solar collector

The cost of the solar collector depends on the type of solar collector used and the total solar collector gross area required. The user enters a $/m² price. The user enters the total array required (m²) in the *Energy Model* worksheet. Note that total area is based on the gross area of the solar collector. The user can refer to the following table to help estimate the cost of the solar collector. The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

Solar Collector Description	Cost Range ($/m²)
Plastic unglazed liquid flat-plate solar collectors	50 to 90
Single glazed flat-plate solar collectors	180 to 310
Evacuated tube solar collectors	900 to 1,100

Cost of SWH Collectors

The lower end of these cost ranges is for large projects, where volume purchase discounts may come into play. In addition to single large systems, this could include a volume purchase of multiple residential SWH systems. Small single system purchases are at the higher end of this price range. Note that the prices will vary depending on the manufacturer.

Solar storage tank

The cost of the solar hot water storage tank depends on its volume, on the material used (steel with or without glass lining, stainless steel, etc.), on the insulation thickness and quality, on the use or not of internal coil (or other type of integrated heat exchanger such as tank-in-tank design) and on the number of inlets and outlets. The user enters a $/L price. The user defines the solar hot water storage tank volume (L) in the *Energy Model* worksheet. The table below gives approximate costs of pressurised solar hot water storage tanks. Note that the volume and cost of the solar storage tank is 0 for swimming pool SWH systems and SWH systems without storage.

Volume (Litres)	Description	Cost Range ($/L)
180	Insulation, glass lined, standard	0.95 to 1.50
180	Insulation, stainless steel, internal coil	6.10 to 7.80
270	Insulation, glass lined, standard	0.85 to 1.30
270	Insulation, stainless steel, internal coil	5.55 to 6.65
360	Insulation, glass lined, standard	1.10 to 1.40
360	Insulation, stainless steel, internal coil	5.00 to 6.10
450	Insulation, glass lined, standard	1.45 to 1.70
450	Insulation, stainless steel, internal coil	4.45 to 5.55

Cost of Pressurised SWH Storage Tanks

A custom made pressurised tank can be used for very large solar water heating systems, but it is generally more expensive than an equivalent number of smaller standard tanks with the same combined volume. Storage tanks to be installed inside the mechanical room will have to pass through the doors of the building. Storage tanks should be manipulated easily by the installers, otherwise, cranes and/or hoists will have to be rented. The user may choose a storage tank with an internal coil only if he has already selected "Yes" from the drop-down list for "Heat exchanger/antifreeze protection" in the *Energy Model* worksheet. If the user has selected a storage tank with an internal coil (or a tank-in-tank), 0 will be entered in the "Heat exchanger" cost box.

For large process hot water solar heating systems requiring pressurised tanks, multiple 450 L storage tanks can be used to obtain the required volume. Contact a local supplier for the price of a custom-made pressurised storage tank (custom tank costs are typically twice the costs for multiple standard tanks of the same volume).

For very large solar water heating systems (industrial/commercial), a configuration using non-pressurised solar storage tanks, typically made of concrete or polyethylene, could be more cost-effective. Use the following table to estimate the approximate costs of non-pressurised tanks.

Volume (Litres)	Description	Cost Range ($/L)
300 to 10, 000	Polyethylene, Insulation	0.18 to 0.50
2,000 to 20,000	Fibre glass, Insulation	1.10 to 2.80
10,000 to 30,000	Concrete, Insulation, Underground	0.28 to 0.45

Cost of Non-Pressurised SWH Storage Tanks

Polyethylene tanks can be placed underground or aboveground. They can reach temperatures higher than 50°C. They can be thermally insulated or not, depending on storage temperature. Use lower cost values for large insulated tanks. The higher values are for smaller insulated tanks. Contact your local supplier for confirmation and for more specific technical data on temperature and structural resistance.

Fibreglass tanks can be placed underground or aboveground. They can reach temperatures higher than 100°C. They can be thermally insulated or not, depending on storage temperature. Use lower cost values for large insulated tanks. The higher values are for smaller insulated tanks. Contact your local supplier for confirmation and for more specific technical data on temperature and structural resistance.

Concrete tank costs are based on the costs for commercial septic tanks. This kind of tank can be used only if it is installed underground, otherwise, the tank walls can break when full of water. A concrete tank can generally withstand a rise in temperature of up to 100°C (but not a continuous temperature increase). Contact your local supplier for confirmation and for more specific technical data on temperature and structural resistance.

Solar loop piping materials

The solar loop piping materials refer to the piping, the fittings, the pipe supports, the insulation and the jacket. The cost of the solar piping loop depends on the length used, on the pipe material (copper, plastic) and diameter, on the insulation type and thickness and on the type of jacket used. The user enters a $/m price. The model calculates the solar piping length loop (m) from values entered for "Number of floors from mechanical room to collector" and "Horizontal distance from mechanical room to collector" in the *Energy Model* worksheet. Use the following table to help estimate the cost of the solar loop.

Pipe Diameter (mm)	Description	Cost ($/m)
	Copper pipe	
9 (3/8")	With fitting and insulation	8 to 10
13 (1/2")	With fitting, insulation (R7) and aluminium jacket	17 to 21
19 (3/4")	With fitting, insulation (R7) and aluminium jacket	20 to 24
25 (1")	With fitting, insulation (R7) and aluminium jacket	25 to 29
	Plastic pipe (with unglazed collectors)	
38 (1 ½")	ABS, with fitting, no insulation	3 to 6
38 (1 ½")	PVC, with fitting, no insulation	6 to 10
51 (2")	ABS, with fitting, no insulation	6 to 9
51 (2")	PVC, with fitting, no insulation	9 to 14

Cost of Solar Loop Typical Piping

Circulating pump(s)

The cost of the circulating pump depends on its capacity, on the material used for its construction (cast iron for closed loop systems, bronze or stainless steel for open loop systems), on the type of power supply (AC/DC solar circulator), and on the type of construction (flanged circulators are more expensive). The user enters a $/W price. In the *Energy Model* worksheet, the user defines the pump power per collector aperture area (W/m²).

Current costs for standard circulating pumps in commercial systems range from $1.0/W to $5/W. The lower end of this price range is for larger projects. If the SWH system configuration considered includes a secondary loop (see Technical Note 2), the consumption of the second pump is already considered if the wattage indicated under "Quantity" for the circulating pump (if the user included it under the "Pumping power per collector area" item in the *Energy Model* worksheet).

The table below shows typical costs for circulating pumps. Circulating pump costs can exceed $30/W in residential systems using low-power high-efficiency pumps. If a photovoltaic (PV) powered pump is used, use at least twice the suggested cost (as DC pump are generally more expensive than AC pumps) and a power conditioner is required to avoid overheating of the motor at low solar radiation levels.

Collector Aperture Area (m²)	Circulating Pump (W)	Circulating Pump ($/W)
2 to 6	20 to 45	5 to 30
6 to 12	85	2
12 to 35	185	1.1
35 to 60	205	1.3

Costs of Typical Circulating Pumps

Heat exchanger

The user enters a heat exchanger cost only under the two following conditions: "Heat exchanger/antifreeze protection" has been selected in the *Energy Model* worksheet and the "Solar storage tank" cost does not already include a heat exchanger (which is the case if an internal heat exchanger is used).

Heat exchanger costs depend primarily on their thermal capacity and efficiency, on the material used for its construction (copper, stainless steel, etc.) and on the type of construction (shell and single wall tube, shell and double wall tube, plate exchanger, etc.). The user enters a $/kW price, where kW is for the heat exchanger thermal power rating. The model automatically calculates the thermal rating of the heat exchanger (this parameter is not a thermal engineering value and must be evaluated more precisely under the final SWH system design task). The thermal rating value of the heat exchanger characterises the thermal power generated by the total collector area working under an average solar radiation conditions and at typical temperature levels on the load side (and not at the desired hot water temperature).

Consult the table below to help estimate the cost of standard heat exchangers. The lower end of the range is for shell and single wall tube. The higher end of the range applies to shell, double wall tube and stainless steel plate heat exchangers.

Local plumbing codes may require stainless steel or double wall (for leak detection purposes) heat exchangers when the system is connected to the main water supply. Costs for a custom made heat exchanger can be more than twice the price of a standard exchanger. For small systems (under 15 kW) the cost of the heat exchanger will rarely be lower than $150. SWH system manufacturers and/or suppliers may offer an optimal heat exchanger capacity for their systems.

Capacity (kW)	Cost ($/kW)
15 kW	13 to 20
22 kW	13 to 18
30 kW	12 to 15
45 kW	10 to 12
60 kW	8 to 11
90 kW	7 to 10
120 kW	7 to 10

Cost Estimates for SWH Heat Exchangers

Transportation

Transportation costs for equipment and materials will vary considerably depending upon the mode of transport available and the location of the project site. In many instances the cost will depend on distance and will be based on a volume/weight formula. Handling charges for the material at the receiving end should be considered. In isolated areas, many communities receive bulk shipments only once a year either by barge, ice road or sometimes only by air. Logistical control is extremely important here.

Shipping costs should be obtained from shipping agents when the scope of the project, equipment and materials are determined. As an example, typical dimensions (in m) of a 2 (3) m^2 single glazed solar collector are 0.9 (1.2) x 2.4 x 0.15 and weight is about 60 (85) kg. A 270 L storage tank is about equivalent to a volume of (in m) 0.6 x 0.6 x 1.7 and weights about 40 kg. Pump and heat-exchanger assembly with interconnections for a medium size SWH system (20 m^2) can reach 40 kg with a volume of (in m) 0.6 x 0.6 x 0.3.

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.

In the case of an outside swimming pool with no back-up water heater, a credit can be entered to take into account the installed cost of an equivalent conventional pool water heater system. The credit amount will be based on the value of the conventional water heater system displaced or "avoided."

Typically, the cost of a conventional residential pool heating system ranges from $800 for an electric heater, to $2,000 for a natural gas, propane or oil heater (including the fuel tank installation) and $2,500 to $4,000 and more for an electric heat-pump. Depending on the location and the competitiveness of local markets, these prices can increase by more than $1,000. Note that the metallic components of these heating systems are exposed to corrosion because they are in contact with chlorinated water. A well installed, high-quality UV stabilised solar collector system can have a longer lifetime than a conventional heating system, especially first generation heat pumps.

For a SWH system using an antifreeze protection, the price for antifreeze mixture can be entered here. The cost of food-grade, thermally and chemically stabilised propylene glycol, mixed 50/50 with distilled water will be about $3.50/L to $6.00/L. Typically a system uses about 10 to 100 L of the mixture, depending on the solar collector area.

If the solar pump is driven by a photovoltaic (PV) module, the cost for this PV module can be entered here. The required PV module rating (Wp) is about twice the nominal power rating of the circulator pump. Small-scale PV module costs, including a regulator, are between $10/Wp to $20/Wp. As an example, the cost of a 20 Watt 12 Volt PV module is about $400.

Balance of System

The balance of system for a SWH project typically includes the equipment that can be supplied by local suppliers: the solar collector array support structure and the interconnection plumbing and control. In addition, the installation labour for the entire SWH system and the various components are included under this heading, including, the solar loop installation and the auxiliary equipment installation.

Collector support structure

This item refers to the total cost of the equipment required to provide a support for the solar collectors. The cost of the structure will vary considerably depending upon whether the system is to be mounted on the building wall, on a flat roof, on an inclined roof, or whether it is to be ground mounted. These costs can be related to the area covered by the solar collectors which is calculated in the *Energy Model* worksheet ("Total gross collector area"). The user enters a $/m² cost.

For simple solar water heating systems, where the collectors are flush mounted to the building roof or wall, the structure costs are minimal. The user would enter $0/m² to $10/m² for a solar pool heating system using flush mounted unglazed collectors and up to $40/m² for service hot water applications using a custom designed support structure. For more elaborate structures, such as on flat roof commercial buildings, support structure costs could range from $70/m² to $200/m². The cost can be higher if the roof has to be modified. If the system is to be ground mounted, some site work will have to be done and those costs should be added to the "Other" category. Especially if sophisticated anchoring features need to be installed through the roof membrane, cost of support structure may increase by more than 50%.

Plumbing and control

The interconnection plumbing involves the plumbing interface between the solar loop, the solar pump (liquid handling unit), the heat exchanger and the storage tank(s) and/or to the load. Interconnecting plumbing also includes all the required complementary plumbing to finalise the SWH system installation, such as strainer, balancing or globe valves, gates and check valves, pressure temperature relief valves and expansion tank. A controller may also be required to activate the solar pump when there is sufficient heat available from the solar collectors.

The cost of material for the interconnection plumbing interface will depend on the pipe diameter and on the complexity of the interface plumbing (number of heat exchangers to be connected, number of storage tanks to be connected, etc.). Costs for the interconnecting plumbing can be estimated roughly to be equal to 1/3 to 1/2 of the solar loop costs. The cost for the complementary plumbing accessories is between $70/project to $500/project depending on the solar water heating system size, on the pipe diameter used and on the number of solar hot water tanks to be interconnected. The cost for a service hot water system controller is about $150 to $220. A pool controller cost is about $200 and a motorised valve is about $200 to $250.

Collector installation

Solar collector installation refers to all the site labour required to install the solar collectors, including the collector structure. Special equipment is not generally required for the installation of the solar collectors and structure, however, for larger systems, cranes and hoists can be used to save site labour (cost for the rental of a crane is around $400/h). The user enters a $/m² price (per unit of solar collector gross area).

These costs range between $10/m² and $100/m², primarily depending upon the structural requirements as described above and the site labour hourly rate. The lower value is for a simple installation using unglazed collectors directly on a roof with a low labour cost. The higher value is for commercial installations on high-rise buildings using a more elaborate structure. These costs are typical when labour hourly rates are $20/h to $40/h for a non-specialised worker and $40/h to $75/h for a professional roofing contractor. Note that all modifications on a roof must be done by a professional roofing contractor.

Installations during the winter period are more expensive due to costs associated with snow removal, difficulties working in cold conditions with gloves, etc.

Solar loop installation

Solar loop installation refers to the labour required on the site to install the pipes on the solar loop side, including the pipe insulation and jacketing, the pipe supports and all openings through walls and roof (if required) from the mechanical room to the solar collectors. Interconnection to equipment is not included in this item.

Typically the labour cost is between $20/h to $40/h for a non-specialised worker and $40/h to $70/h for a professional plumber. Roof modifications (e.g. openings through roof) must be done by a professional roofing contractor at a labour cost between $40/h and $75/h. Pipe preparation and cutting, pipe insulation and jacketing, and pipe support can be done by a non-specialised worker. Pipe soldering must be done by a professional plumber. The user enters a $/m price (per unit of solar loop length).

Costs range between $4/m and $15/m for a service hot water solar system, depending primarily upon the installation accessibility, the site labour hourly rate, the number of connections per pipe meter, the number of openings to make through walls, etc. Openings through walls and the roof can be time consuming. It is usually easier to attach pre-insulated piping along an exterior wall, or to use large existing ducts. Costs range between $2/m and $6/m for a swimming pool solar water heating system where there are no pipe insulation, no jacket and generally no openings to make.

Use the lower value for simple ground installations, where there is only one wall opening (no roof opening), and easy access. The higher value would be more appropriate in complex retrofit installations where there are many obstructions to avoid and for larger pipe diameters.

Auxiliary equipment installation

Auxiliary equipment installation refers to hot water storage tanks, heat exchangers, pumps (liquid handling unit), and controller installation, including electrical connection and interconnection plumbing between this equipment and the solar loop. This installation also includes all the required complementary plumbing accessories to be installed, such as strainer, balancing or globe valves, gates and check valves, pressure temperature relief valves and expansion tank.

Typically, the labour cost is between $20/h to $40/h for a non-specialised worker and $40/h to $75/h for a professional plumber and a professional electrician. Pipe preparation and cutting, pipe insulation and jacketing, and pipe support can be done by a non-specialised worker. Pipe soldering and connection to equipment must be done by a professional plumber. The user enters a single amount for the entire project.

The cost range for auxiliary equipment installation is between $6/m and $20/m of pipe length, depending primarily upon the number of complementary plumbing accessories required (such as strainer, valves, etc.), the number of connections per pipe meter, the installation accessibility (pipe and equipment installation facility), the pipe diameter and the site labour hourly rate. Plumbing length depends on the number of pieces of equipment and distance between each one. Typically, the pipe length for a SWH system, including a circulator, one heat exchanger and one storage tank, is 6 to 20 m.

For example, auxiliary equipment installation cost for a pool SWH system requiring no heat exchanger and no storage tank will be almost $0. In this case the interconnecting cost will only be estimated for two to three connections (solar loop, filtration system and motorised valve).

Electrical installation costs for SWH systems are relatively small. A rough estimate of total costs for electrical installation ranges between $0 to $400 (including electrical equipment). The lower end of the range is for thermosiphon systems or an outdoor pool SWH system using a filtration pump unit as a circulator and no electrical equipment. Electrical installation costs may also be $0 if a standard solar handling unit kit is used (the pump is already electrically connected to the controller) and installed near an electric plug (a standard 115 V AC line can normally be used to supply electricity to the low energy consumption solar pump). The higher end of the range is for a custom designed system: all electrical connections are to be made between the electrical equipment, an electrical line needs to be installed between the solar controller and the existing breaker panel, etc. The cost for the rental of cranes and hoists may be considered to facilitate handling of larger storage tanks.

Transportation

Transportation costs for equipment and materials will vary considerably depending upon the mode of transport available and the location of the project site. In many instances the cost will depend on distance and will be based on a volume/weight formula. Handling charges for the material at the receiving end should be considered. In isolated areas, many communities receive bulk shipments only once a year either by barge, ice road or sometimes only by air. Logistical control is extremely important here.

Shipping costs should be obtained from shipping agents when the scope of the project, equipment and materials are determined. As an example, typical dimensions (in m) of a 2 (3) m^2 single glazed solar collector are 0.9 (1.2) x 2.4 x 0.15 and weight is about 60 (85) kg. A 270 L storage tank is about equivalent to a volume of (in m) 0.6 x 0.6 x 1.7 and weighs about 40 kg. Pump and heat-exchanger assembly with interconnections for a medium size SWH system (20 m^2) can reach 40 kg with a volume of (in m) 0.6 x 0.6 x 0.3.

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 the miscellaneous costs that occur during a project and have not been taken into account in the previous sections. For SWH projects these costs can include training and contingencies.

Training

When the installation is complete, the system must be commissioned by the system designer often in the presence of the building owner. The commissioning involves a trip to the job site. This trip normally includes the final inspection and necessary training for the operation of the system. The adequate training of operators and maintenance personnel is fundamental to the successful deployment of any technology. This cost is usually small for SWH systems given their relative simplicity.

A 4 to 8 hours training session by a SWH system expert should be sufficient for the client to operate the SWH system properly. Rates for SWH system experts range from $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. Given the relative simplicity of SWH systems, it is certainly possible that the RETScreen user experienced with SWH project developments could estimate costs in the range of 5 to 20% of the total initial project costs.

Annual Costs (Credits)

There may be some annual costs associated with SWH projects, but they are likely to be very small compared to the overall system cost. These may include property taxes, insurance and O&M labour. In addition, costs for contingencies and parasitic electricity consumption will also be incurred. These costs are detailed below.

O&M

Property taxes/Insurance

Generally, SWH systems should not increase property taxes. In some cases, a community may provide a tax incentive for SWH installations. The SWH system owner may choose to insure the cost of the system. This cost can be estimated by contacting an insurance broker.

O&M labour

SWH systems typically require minimal maintenance. Usually, the solar collector is designed to last over twenty years. A water/glycol mixture, used as a transfer fluid, needs to be replaced about every four to seven years. The liquid handling unit (pump) and the controller will require an annual maintenance inspection. Because of its simplicity, the inspection of relatively small solar water heating system can be performed by the system owner.

The cost range for annual maintenance inspection of a SWH system is between $0 and $200. Use the lower value if the inspection is done by the owner. The higher value would be more appropriate if the maintenance inspection is performed by a system expert on a large and complex SWH system. Rates for system experts range from $40/h to $100/h. The replacement of water/glycol mixture should be done by a professional plumber at a cost between $40 and $80 for the labour and between $4/L and $6/L for the fluid to be replaced.

In the case of seasonal swimming pool SWH systems, the maintenance is limited to the drainage of the system before annual freezing occurs. As this operation applies to any other conventional heater, there is no incremental cost for this operation and the user should enter $0 for O&M labour cost.

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 may be included to account for unforeseen annual expenses. This may include costs for replacement of solar collectors due to vandalism (if this item is not covered by the insurance policy) and other potential cost items. However, due to the durability of the SWH system these costs will likely be minimal. A contingency allowance of 1 to 5% of total solar collector and balance of system cost per year is reasonable and will depend upon the project location.

Electricity

In most cases, the SWH system uses a low energy consumption pump. Electrical energy consumption is calculated in the *Energy Model* worksheet. The user will enter the cost for electricity used. This cost should be based upon the rate paid by the building owner.

Note: No allowance for a credit is made to account for the reduction in peak power after the installation of a SWH system.

Periodic Costs (Credits)

This section is provided to allow the user to specify the periodic costs associated with the operation of the energy 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.

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.

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. avoided cost of energy, 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 location is entered for reference purposes only in the *Energy Model* worksheet.

Renewable energy delivered

The *Energy Model* worksheet calculates the renewable energy delivered, which is equivalent to the heating energy delivered (MWh) by the project. This energy displaces the heating energy that would have otherwise been delivered by the conventional, or base case, system. The renewable energy delivered is used in conjunction with the avoided cost of heating energy and the base case heating system seasonal efficiency 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 in the *Energy Model* worksheet is transferred here. The heating fuel displaced is used in the calculation of the heating energy savings.

Electricity required

The *Energy Model* worksheet calculates the electricity required (MWh) to run the pumps of the solar water heating system during the heating season.

Net GHG emission reduction

The model calculates the net annual average GHG emission reduction in equivalent tonnes of CO_2 per year (t_{CO2}/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 is copied here automatically.

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_{CO2}), 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 in equivalent tonnes of CO_2 (t_{CO2}) resulting from the installation of the system instead of the base case, or baseline, heating system. This value is calculated by multiplying the net annual GHG emission reduction by the life of the project.

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 service company (ESCO)).

Avoided cost of heating energy

The user enters the avoided cost of heating energy. For exemple, if the user chose natural gas-m³, as the "Heating fuel type" in the *Energy Model* worksheet then the user would simply enter the local natural gas price in $/m³ for the avoided cost of heating energy.

The avoided cost of heating energy is used in conjunction with the renewable energy delivered, the heating value and the base case heating seasonal efficiency (appearing in the *Energy Model* worksheet) 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. Note that the avoided cost of energy unit for propane is expressed in terms of liquefied propane.

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 $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 to run the pumps of the solar water 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 power/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 solar water 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 solar water 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 solar water 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 a project profitable 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 $2,000 to evaluate (feasibility study) and develop, and $8,000 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 system and miscellaneous costs while the feasibility and development costs would be fully expensed during year 0.

Depreciation rate

The user enters the depreciation rate (%), which is the rate at which the undepreciated capital cost of the project is depreciated each year. The depreciation rate can vary widely according to the class of assets considered and the jurisdiction in which the project is located.

Depreciation period

The user enters the depreciation period (year), which is the period over which the project capital costs are depreciated using a constant rate. The depreciation period can vary widely according to the class of assets considered and the jurisdiction in which the project is located.

Tax holiday available?

The user indicates by selecting from the drop-down list whether or not the project can benefit from a tax holiday. If the user selects "Yes," the tax holiday applies starting in the first year of operation, year 1, up to the tax holiday duration. The income tax calculation for the development/construction year, year 0, is not affected.

Tax holiday duration

The user enters the tax holiday duration (year), which is the number of years over which the tax holiday applies, starting in the first year of operation, year 1. For example, in India, certain renewable energy projects are given a five-year tax holiday.

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 system 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 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 solar water 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 system

The balance of system 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 renewable 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.

Electricity

The annual cost of electricity to run the solar water heating system is transferred from the *Cost Analysis* worksheet. It represents the cost of electricity required to run auxiliary equipment such as pumps.

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 independent heat/power producer or 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, the cost and heating value of the heating energy avoided divided by the base case system seasonal heating efficiency. 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 solar water 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 of the project (NPV), 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 (ALCS) 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" should be set to "No" and other taxes should 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 (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 solar water 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* worksheets.

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 RET Workbook file has been developed with a common framework so as to simplify the task of the user in analysing the viability of different RET 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 SWH 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 the base case heating system fuel type, defined in the *Energy Model* worksheet, is electricity. Otherwise, this analysis applies only to the electricity used for the pump, which represents a relatively small amount of energy.

For example, in North America when preparing a GHG emission reduction analysis for a SWH 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 E-GRID Website.

To illustrate this alternative analysis method, for a solar water 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 energy 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%.

CO_2, CH_4 and N_2O 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.

CO_2, CH_4 and N_2O 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_{CO2}/MWh).

Base Case Heating System (Baseline)

The base case heating system, or baseline system, represents the system to which the solar water 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 entered by the user in the *Energy Model* worksheet is transferred to the *GHG Analysis* worksheet.

Fuel mix

The base case heating system is assumed to be fuelled by a single source of energy and the fuel mix is therefore set to 100%.

CO_2, CH_4 and N_2O 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.

CO_2, CH_4 and N_2O 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 is entered by the user in the *Energy Model* worksheet 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 water 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. 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_{CO2}/MWh).

Proposed Case Heating System (Solar Water Heating Project)

The proposed case heating system, or mitigation system, is the solar water heating system. It is defined in terms of its fuel types, its emissions of GHG and its conversion efficiencies. Note that in all cases, the pumps, if any, of the solar water heating system are assumed to be electricity-driven using 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 solar water heating system is assumed to be solar; electricity is used to drive the pumps.

Fuel mix

The fuel mix of the solar water heating system is assumed to come from two sources, i.e. solar and electricity, totalling 100%.

CO_2, CH_4 and N_2O emission factors

(Custom analysis)

The user enters the CO_2, CH_4 and N_2O emission factors corresponding to the solar energy provided by the solar water heating system. The model provides the electricity emission factors 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 heat used by the solar water heating system (kg/GJ).

CO_2, CH_4 and N_2O emission factors

(Standard analysis)

The model provides the CO_2, CH_4 and N_2O emission factors corresponding to the fuel type, i.e. solar and electricity, for the solar water 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 heat used by the solar water heating system (kg/GJ).

Fuel conversion efficiency

Fuel conversion efficiencies for both the solar energy and electricity are set to 100%. This value is used in conjunction with the CO_2, CH_4 and N_2O emission factors to calculate the aggregate GHG emission factor for the solar water heating system.

Units are given as a percentage of actual water heating energy output (gigajoules of heating energy) to primary 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_{CO2}/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 water heating energy delivered for the base case system.

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO2}/MWh).

Proposed case GHG emission factor

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

Units are given in tonnes equivalent of CO_2 emission per megawatt-hour of end-use heating energy delivered (t_{CO2}/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_{CO2}/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 energy could take.

For example, a range of 10% for an avoided cost of energy of $0.09/kWh means that the avoided cost of heating energy could take any value between $0.081/kWh and $0.099/kWh. Since $0.09/kWh is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

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

Renewable energy delivered

The RE delivered is transferred automatically from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the RE delivered range. The range is a percentage corresponding to the uncertainty associated with the estimated RE delivered 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 RE delivered could take.

For example, a range of 10% for a RE delivered of 40 MWh means that the RE delivered could take any value between 36 MWh and 44 MWh. Since 40 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 RE delivered 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 $3,000 means that the initial costs could take any value between $2,700 and $3,300. Since $3,000 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 means that the annual cost could take any value between $72 and $88. Since $80 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 $\$5/t_{CO2}$ means that the GHG emission reduction credit could take any value between $\$4.5/t_{CO2}$ and $\$5.5/t_{CO2}$. Since $\$5/t_{CO2}$ 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.

The product database sorting routine starts by using the "Collector type" selected by the user in the *Energy Model* worksheet. From the dialogue box the user selects the Region, followed by the Supplier and Model. 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 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 "Collector Type" input cell. However, if "Any" is selected, then this information is not pasted to the spreadsheets.

The product database is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of any commercial product or person. Neither Canada nor its ministers, officers, employees or agents make any warranty in respect to this database or assumes any liability arising out of this database.

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

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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 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 the RETScreen Training & Support at the following Website address: www.retscreen.net/e/training/.

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