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

RETScreen® Software Online User Manual

Photovoltaic 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.

Reproduction

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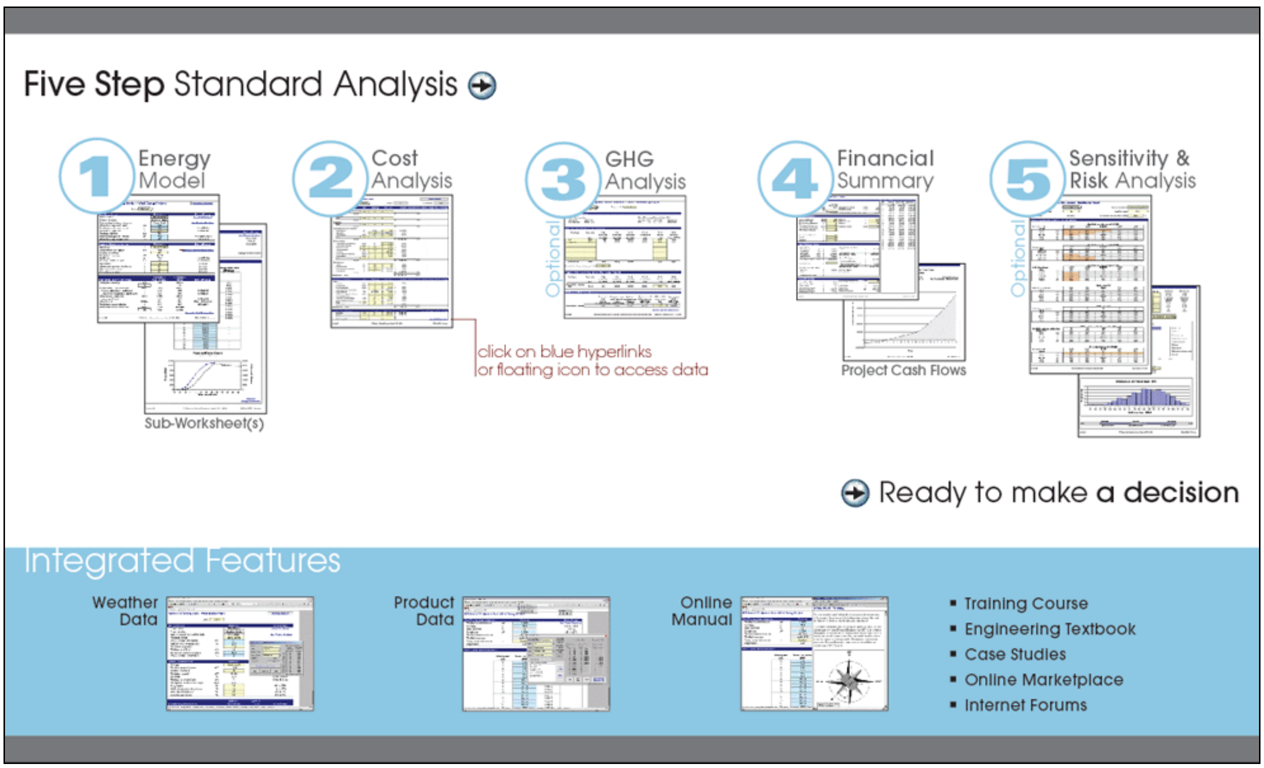
Brief Description and Model Flow Chart

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. Photovoltaic Project, etc.) is developed within an individual Microsoft® Excel spreadsheet "Workbook" file. The Workbook file is in-turn composed of a series of worksheets. These worksheets have a common look and follow a standard approach for all RETScreen models. In addition to the software, the tool includes: product, weather and cost databases; an online manual; a Website; an engineering textbook; project case studies; and a training course.

Model Flow Chart

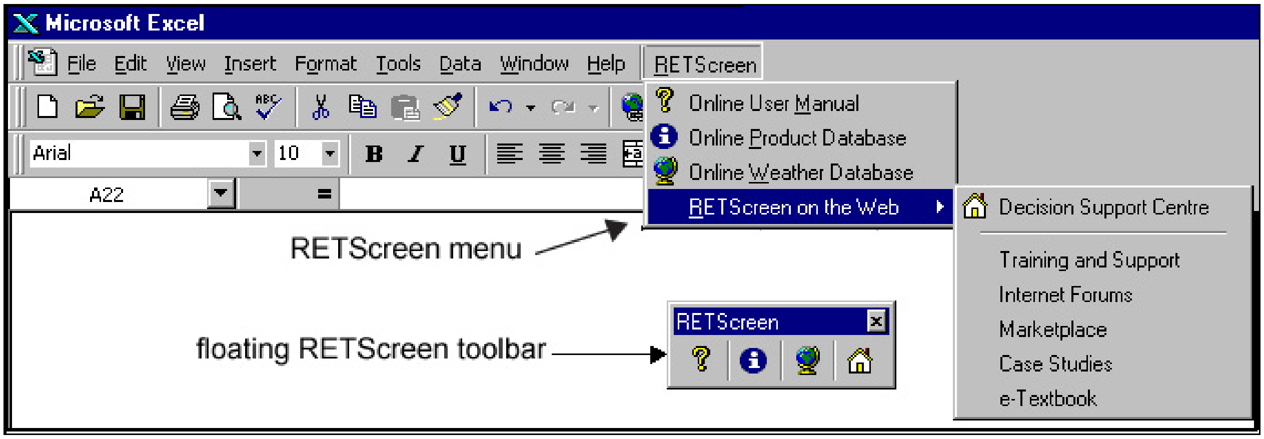
Complete each worksheet row by row from top to bottom by entering values in shaded cells. To move between worksheets simply "click" on the tabs at the bottom of each screen or on the "blue-underlined" hyperlinks built into the worksheets. The RETScreen Model Flow Chart is presented below.



RETScreen Model Flow Chart

Data & Help Access

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

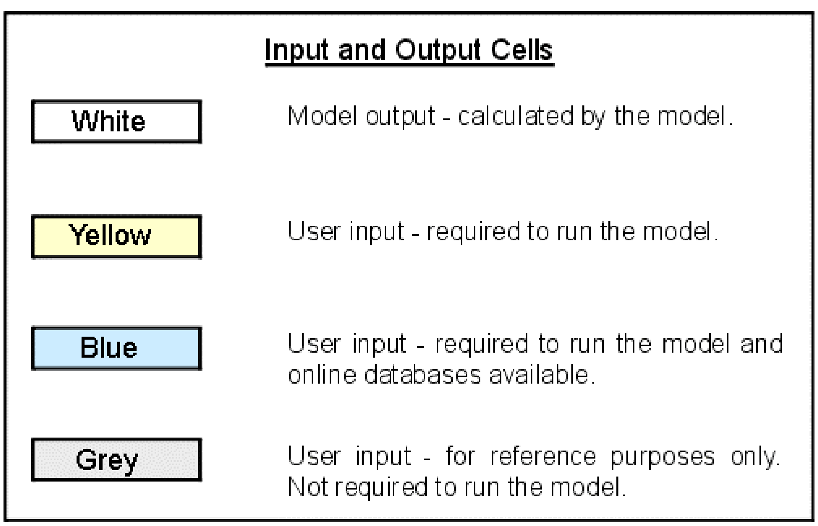


RETScreen Menu and Toolbar

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

Cell Colour Coding

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



RETScreen Cell Colour Coding

Currency Options

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

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

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

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

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

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

Some currency symbols may be unclear on the screen (e.g. €); this is caused by the zoom settings of the sheet. The user can increase the zoom to see

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

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

List of Units, Symbols and Prefixes

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.

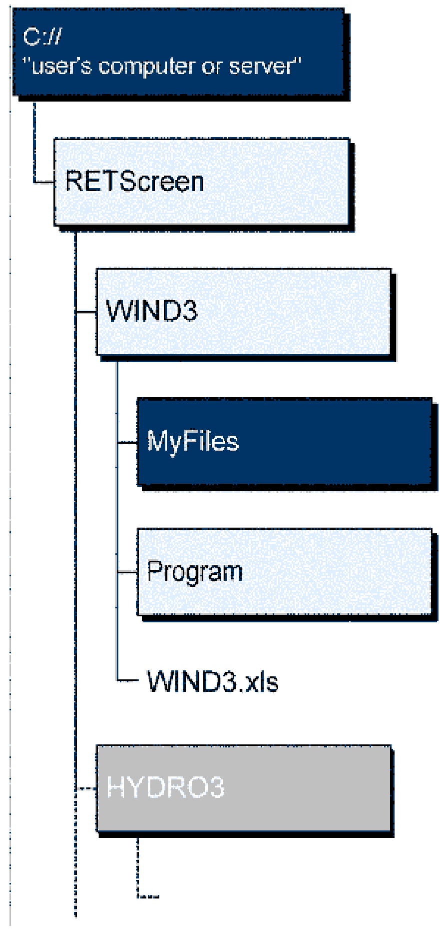
Note: 1. The gallon (gal) unit used in RETScreen refers to US gallon and not to imperial gallon.

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 following figure. The user may also visit the RETScreen Website at www.retscreen.net for more information on the download procedure. It is important to note that the user should not 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.

Photovoltaic Project Model

The RETScreen® International Photovoltaic Project Model can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for three basic PV applications: on-grid; off-grid; and water pumping. For on-grid applications the model can be used to evaluate both central-grid and isolated-grid PV systems. For off-grid applications the model can be used to evaluate both stand-alone (PV-battery) and hybrid (PV-battery-genset) systems. For water pumping applications the model can be used to evaluate PV-pump systems.

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

The *Energy Model* and *Solar Resource & System 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 photovoltaic 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 Photovoltaic 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 System Load Calculation* worksheets are used to help the user calculate the annual energy production for a photovoltaic project based upon local site conditions and system characteristics. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies.

Site Conditions

The site conditions associated with estimating the annual energy production of a photovoltaic project are detailed below.

Project name

The user-defined project name is given for reference purposes only.
For more information on how to use the RETScreen Online User Manual, Product Database and Weather Database, see Data & Help Access.

Project location

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

Nearest location for weather data

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

Note: At this point, the user should complete the *Solar Resource & System Load (SR&SL)* worksheet.

Latitude of project location

The user enters the latitude of the project location in the *Solar Resource & System Load (SR&SL)* worksheet and it is copied automatically to the *Energy Model* worksheet.

Annual solar radiation (tilted surface)

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

Annual average temperature

The model calculates the annual average temperature, in ºC. This is calculated from monthly data entered by the user in the Solar Resource & System Load (SR&SL) worksheet.

The annual average temperature typically ranges from -20 to 30°C, depending upon the location. The temperature at standard conditions is 15°C.

DC energy demand for months analysed

The model calculates the DC energy demand, in MWh, for the season of use. This is calculated from data entered in the Load Characteristics section of the *Solar Resource & System Load (SR&SL)* worksheet.

AC energy demand for months analysed

The model calculates the AC energy demand, in MWh, for the season of use. This is calculated from data entered in the Load Characteristics section of the *Solar Resource & System Load (SR&SL)* worksheet.

Water demand for months analysed

The model calculates the water demand for the season of use, in m^3. This is calculated from data entered in the Load Characteristics section of the *Solar Resource & System Load (SR&SL)* worksheet.

Equivalent pumping energy demand

The model calculates the amount of mechanical energy required to deliver the water demand over the season of use, in MWh. This is purely the mechanical energy necessary to lift water from the point of origin to the point of delivery and overcome fluid friction losses. It does not include losses due to the inefficiency of the pump or the inefficiency of any electrical component of the system.

System Characteristics

The system characteristics associated with estimating the seasonal energy production of a photovoltaic system are detailed below. Some other system characteristics (particularly those used to calculate the system load) can be found in the Load Characteristics section of the *Solar Resource & System Load (SR&SL)* worksheet.

Application type

The user enters the type of PV application in the *Solar Resource & System Load (SR&SL)* worksheet and it is copied automatically to the *Energy Model* worksheet.

There are three basic applications: On-Grid, applicable to systems without batteries and connected to a utility grid; Off-Grid, applicable to systems with batteries and gensets; and Water Pumping, applicable to photovoltaic water pumping systems without batteries.

Grid type

The user selects the type of grid from the two options in the drop-down list: "Central-grid" and "Isolated-grid." Central-grid is recommended for systems where the size of the grid (and the load it satisfies) is so large that the utility will always be able to use all the energy produced by the PV system. Isolated-grid should be chosen for smaller, local grids, for which some of the electricity produced by the PV system will be wasted because of mismatches between PV output and utility energy demand. In this case the "PV energy absorption rate" should be specified.

PV energy absorption rate

The user enters the PV energy absorption rate (%). This is the amount of energy produced by the PV system that will actually be delivered to the utility. The remaining energy is available for other potential uses, or possibly "wasted" because of mismatches between PV output and utility energy demand.

For central-grid connected systems, the absorption rate will typically be 100% (that implies that electricity can be sent back to the grid). This will be the case of a central PV generation plant or distributed generation PV systems with a grid interactive connection. A lower absorption rate can be entered to simulate a reverse, or net-metering, scheme. In this case, the portion not absorbed is deemed to be sold back to the utility at a rate different from the avoided cost of energy. In cases where the utility would not allow electricity to be fed back into the grid (such a system is referred to as "grid-connected non-grid interactive system"), the user should specify an isolated-grid system and the absorption rate should be reduced to reflect the amount energy wasted.

For isolated grids, experience and studies indicate that less than 5% of the electrical energy produced by the PV system will be "wasted" because of mismatches between PV output and utility energy demand. For this reason, the absorption rate will likely be greater than 95%, being as high as 100% if the size of the PV system is small compared to the load on the grid.

PV system configuration

The user selects from the drop-down list the type of off-grid system under consideration: "PV/battery" or "PV/battery/genset." PV/battery should be used if the system does not include a back-up generator. Use PV/battery/genset if the system includes a generator (genset). Genset, as defined here, also includes thermoelectric generators (TEGs).

The user will need to decide whether or not to include a genset in the PV system. In some systems a genset is added to provide very high reliability without having to substantially oversize the PV array and the battery bank. If the batteries become depleted, for example after a long period with little sun, the genset quickly recharges the batteries, and the delivery of energy to the load remains uninterrupted. In other systems, usually with a lower reliability, a genset is not used due to environmental (noise, fumes), convenience (fuel transportation), or cost considerations. In a third case the use of a genset providing a significant portion of the load may prove more financially viable, the extra cost of the genset and its fuel being offset by the lower cost of the photovoltaic array. This configuration may also apply to the case of retrofit installations, where PV modules are added to displace energy produced by an existing genset.

Base Case Power [and Pump] System

This sub-section deals with the definition of the base case scenario. For water pumping applications, the base case power system includes the pump system. The base case is used for financial calculations and does not have any bearing on the energy calculations for the energy system.

Source

The user selects, from the drop-down list, the source of power/energy being displaced. The options available address the replacement of conventional electrical sources (genset, thermoelectric generator, grid extension or non-rechargeable batteries), light source (non-electric lantern) and mechanical sources (engine driven pump or other mechanical pumps, such as hand pump or animal driven pumps) with a photovoltaic system. A final option, "Other," can be selected for cases not falling in one of the above categories.

Although the drop-down list contains no "genset/battery system" or "cycle-charger" option, this type of system can be simulated by adjusting the fuel consumption to account for losses in the battery and charger. With "Genset" selected as the base case power source, the specific fuel consumption input is set to the specific fuel consumption of the genset alone divided by the efficiency of the battery and the efficiency of the charger.

In cases where the source being displaced is not an electrical system, the user should be careful when comparing conventional energy sources such as lanterns or hand pumps with PV systems as the latter may have a higher value (convenience, productivity, safety, etc.). For example, a PV lantern may give a better quality light than a kerosene lamp and an electric water pump may free a person's time allowing them to accomplish other tasks. Such aspects must be considered in the decision process.

Fuel type

The user selects the type of fuel displaced by the PV system. A list of common fuel types are provided in the drop-down list.

The fuel options address the replacement of conventional fossil-fuel generators and engine driven pumps (Natural gas, Propane, Diesel (#2 oil), Gasoline, Kerosene) or fossil fuel lanterns (Kerosene, Propane) with a photovoltaic system. A final fuel option, "Other," can be selected for cases not falling in one of the above categories.

For water pumping applications, if the source of power/energy being displaced is set to "Grid extension" then the fuel type is automatically set to "Grid mix."

Specific fuel consumption

Depending on the "Application type" being evaluated, the user enters the amount of fuel consumed by the base case system to either provide a given amount of electrical energy (kWh) or provide a given amount of water (L - litres of water pumped) or to produce a given amount of light over a certain period (year).

Note that for fossil-fuel generators the efficiency is a function of its operational point. A small generator running at full load will be more efficient than a larger one running at half load. Typical values can be found in the Average Genset Specific Fuel Consumption table; note that these values are for a generator running at full capacity, and that they should be increased if the generator is running only at a fraction of its full capacity. The next graph shows genset fuel efficiency vs. capacity used, for various sizes of diesel generators; in the absence of additional data this figure can be used to estimate fuel efficiency as a function of the average operational point of the genset.

For water pumping applications, the specific fuel consumption encompasses the efficiencies of both the source and the pump. Hence, in the grid extension case, the specific fuel consumption, expressed in kWh/L, allows the user to specify the number of kilowatt hours needed per litre of pumped water. If the user is comparing PV to an existing pumping system, the specific fuel consumption can be calculated by dividing the measured fuel consumption over a certain period (in L of fuel or kWh of electricity) by the amount of water pumped in that same period. If the user does not have this data from an existing installation, the specific fuel consumption for a fossil fuel generator system can be estimated by:

L of fuel/L of water = (9.81*total head) / (Energy content of fuel*genset efficiency*pump efficiency)

where the total head (in m) is given in the *Solar Resource & System Load (SR&SL)* worksheet and the energy content of the fuel (in J/L) is approximately 38.7 MJ/L for diesel, 26.6 MJ/L for propane, 33.7 MJ/L for gasoline, 37.2 MJ/L for natural gas and 36.6 MJ/L for kerosene.

The specific fuel consumption for grid extension can be estimated by:

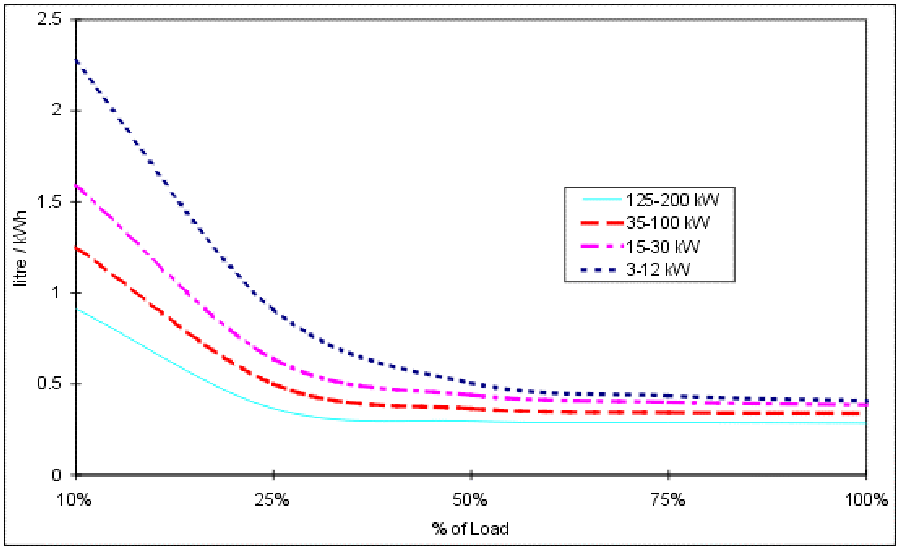
kWh of electricity/L of water= (9.81*total head)/ (3,600,000*pump efficiency)

where the total head (in m) is given in the *Solar Resource & System Load (SR&SL)* worksheet.

For lanterns, the L/year unit is used. The user may calculate this value by multiplying the number of lanterns, the number of hours of use per day, the number of days per year and the number of litres of fuel per hour used by the lantern, i.e.:

L/year = # lanterns * # hours/day * #days/year * #L/h

For comparison purposes, the user may consider that a typical kerosene lantern rated at 450 W would consume about 0.04 L/h (34 g/h) and produce a light intensity of roughly 250 lumens, about the equivalent of a 25 W incandescent bulb or a 5 W compact fluorescent bulb.



Diesel Genset Fuel Efficiency vs. Capacity Used [Royer, 1999]

PV Water Pump

This sub-section deals with the characteristics of the PV powered water pump.

Motor type

The user enters the type of motor (AC or DC) used to drive the PV powered water pump.

The choice between a DC and an AC motor to drive the pump will depend on many factors, including price, reliability, and technical support available. DC motors are usually very efficient and are easier to match with the photovoltaic array, however, they may be more expensive and available only through a limited number of locations. AC motors, on the other hand, are less expensive and more widely available, but they require an inverter to be connected to the PV array.

Pump system efficiency

The user enters the efficiency (%) of the PV powered water pump system. This efficiency should be understood to be the "wire-to-water" efficiency, that is, the ratio of mechanical power delivered to the water, to the electrical power to the motor. The following table can be used to obtain an estimate of pump efficiency for different kinds of pumps. Note that the wire-to-water efficiencies reported in this table are for well matched-systems. Efficiencies may be lower if the pump is poorly matched to the water head. Efficiencies may also be lower if the PV array operates under low light conditions or if the pump system is not well matched to the type of controller used.

Suggested pump type	Head (m)	Wire-to-water efficiency (%)[1]
Surface centrifugal	0-5	15-25
Surface centrifugal	5-20	10-20
Submersible centrifugal multi-stage		20-30
Submersible centrifugal multi-stage	20-100	30-40
Displacement pumps		30-45

Pump System Efficiency

1. Some new pumps have been reported to have efficiencies as high as 75%.

Power Conditioning

This sub-section deals with the characteristics of the power conditioning hardware.

Suggested inverter (DC to AC) capacity

The model calculates the suggested capacity of the inverter, in kW AC (that is, the nominal **output** of the inverter). This value corresponds to the AC peak load.

Inverter capacity

The user enters the inverter capacity, in kW AC (that is, the nominal **output** of the inverter).

By default the user will likely enter the Suggested inverter (DC to AC) capacity calculated above. If the detailed load calculator in the *Solar Resource & System Load (SR&SL)* worksheet is used, the AC peak load may be overestimated, because the load calculator assumes that all AC loads can occur simultaneously. In practice, some of the appliances may be on at varying times, thus reducing the maximum power required from the inverter. If this is the case, the user may want to enter a lower value. Zero should be entered if the PV system has no AC load.

Average inverter efficiency

The user enters the combined efficiency, expressed in %, of the electronic devices (maximum power point tracker and inverter) used to control the PV array and transform its DC output to AC. Values between 80 and 95% are typical. A value of 90% is suggested as a starting point. Zero should be entered if the PV system has no AC load.

Miscellaneous power conditioning losses

The user enters power conditioning losses (%), if any, not taken into account elsewhere. For example, this could include losses incurred in DC-DC converters or in step-up transformers. In most cases this value will be zero.

Battery

This sub-section deals with the characteristics of the battery bank.

Days of autonomy required

The user enters the size of the battery, expressed in days of autonomy (d). In other words this is the number of days that the system, starting from a state of full charge, would be able to meet the load using the batteries only.

Depending on site conditions and system characteristics, values usually range from a couple of days to 10 days. Systems with a few days of autonomy will have a poor availability or rely more on the genset, if there is one. Systems with many days of autonomy will have greater availability or use the genset (if there is one) less often.

Note also that smaller batteries will tend to have a somewhat lower useful capacity (see "Average battery temperature derating") and age faster than larger batteries (see "Batteries" in the *Cost Analysis* worksheet).

Note: The RETScreen PV model is not designed to analyse "PV-battery" or "PV-battery-genset" systems that have less than one day of storage or more than 15 days of storage.

Nominal battery voltage

The user enters the nominal voltage of the batteries to be used, in V.

Usual battery voltages are 6, 12, 18, 24, 36, 48, or 72 Volts. The nominal battery voltage has no influence on the energy predictions of the model; it is simply used to convert battery capacity from Ah to Wh, according to the relationship: Wh = V × Ah

Battery efficiency

The user enters the average efficiency (%) of the battery, as specified at the nominal temperature of 25ºC. In the absence of information from the battery supplier, an efficiency of 85% may be used.

Maximum depth of discharge

The user enters the percentage of the rated battery capacity that can be withdrawn repeatedly without abnormal loss of battery life.

The maximum depth of discharge depends on the size and type of the battery. In the absence of additional information (for example from manufacturer's data) the user can refer to the values in the table below.

Battery type	Default maximum depth of discharge
Lead-acid (car)	20%
Lead-acid (gel)	20%
Lead-acid (PV, vented)	60%
Nickel-Cadmium	85%

Maximum Depth of Discharge for Rechargeable Batteries

Charge controller (DC to DC) efficiency

The user enters the average efficiency of the charge controller, in %. A default value of 95% is suggested. Because controllers often draw a fixed current from the system - regardless of its size, controller efficiency tends to be higher in larger systems and lower in smaller systems.

Battery temperature control

The user enters the type of temperature control applied to the battery. The options from the drop-down list are: "Ambient," "Constant" and "Minimum." This item is used to derate the battery capacity according to the temperature conditions it experiences.

The user may select "Ambient" if the battery is subject to fluctuations in outdoor temperature, for example if the battery is located in a non-insulated shed. If the battery is kept at a constant temperature, for example if it is located in the basement of a house, the user may select "Constant." The user may select "Minimum" if the battery follows the fluctuations of outdoor temperature except when it falls below a certain level, for example if the battery is located inside a phase-change box or if the battery is heated.

This model does not consider battery freezing. In cases where batteries are subject to freezing, the user may select "Constant" or "Minimum." In the absence of information on the freezing point of lead acid batteries, -10ºC may be considered as the lower limit (note that this varies with the state of charge of the battery).

Constant battery temperature

The user enters the constant temperature at which the battery is kept, in ºC. For example if the battery is located in a basement a value of 18ºC is appropriate.

Minimum battery temperature

The user enters the minimum temperature at which the battery is kept, in ºC. For example if the battery temperature is kept above the freezing point of water, enter 0ºC.

If lead-acid batteries are chosen, this value should be higher than -15ºC to prevent the batteries from freezing.

Average battery temperature derating

The model calculates the loss of nominal (25ºC) battery capacity resulting from temperature conditions experienced by the battery, in ºC. This value is averaged over the season of use.

Battery derating depends mainly on the temperature at which the battery operates. Lower temperatures result in a larger temperature derating.

If the battery is kept at a constant temperature of 25ºC year round, the battery temperature derating is zero. It can reach as high as 30% or more if the battery operates part of the year at very low temperatures.

Suggested nominal battery capacity

The model calculates the suggested nominal capacity of the battery bank, in Ah. This is the capacity that would provide the system with the autonomy specified by the user in the "Days of autonomy required," given the temperature conditions experienced by the battery. Values can range from less than one hundred Ah for small systems (e.g. on board electricity for recreational vehicles) to several thousand Ah for large systems requiring high availability (e.g. radio repeaters).

The model assumes discharge rates typical of PV systems, i.e. C/20 or slower. The user should note that a faster than normal discharge rate will reduce the actual battery capacity.

Note: The RETScreen PV model uses the daily average DC energy demand and the number of "Days of autonomy required" to calculate the suggested nominal battery capacity. If this average is exceeded on certain days of the week, the model may underestimate the battery capacity required for a specified level of autonomy. For example, in the case of a 2 day autonomy battery for a cottage PV system that is used on weekends only, the model will suggest a battery capacity that is 2/7 of what is required. The user can account for this by specifying a battery capacity larger than that suggested by the model.

Nominal battery capacity

The user enters the actual nominal capacity of the battery bank, in Ah.

By default the user will likely enter the value calculated in the model under "Suggested nominal battery capacity." However, if the user has a specific battery model in mind, the user should enter a multiple of the nominal capacity specified by the manufacturer.

Note: The RETScreen PV model is not designed to analyse "PV-battery" or "PV-battery-genset" systems that have less than one day of storage or more than 15 days of storage.

PV Array

This sub-section deals with the characteristics of the photovoltaic array.

PV module type

The user selects the type of PV module considered for the application. The seven options from the drop-down list are: "mono-Si," "poly-Si," "a-Si," "CdTe," "CIS," "spherical-Si" and "User-defined." The Nominal Efficiencies of PV Modules table presents a comparative summary of the different types of modules.

The PV module type selected will depend on a number of factors, including: price from suppliers, product availability, warranties, efficiencies, etc. Without further information either "mono-Si" or "poly-Si" may be used as a first selection as each have similar prices on a $/Wp basis and are the most common PV modules used today.

PV module manufacturer / model

The user enters the name of the PV module manufacturer or model number. This is for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

Nominal PV module efficiency

The user enters the nominal efficiency (%) of the PV module under consideration. The user can consult the RETScreen Online Product Database for more information.

Module efficiency depends primarily on the type of cell used (mono-Si, poly-Si, a-Si, CdTe, CIS, spherical-Si). However within each of these categories there are wide variations in module efficiency from manufacturer to manufacturer, depending on the manufacturing processes used. Keeping this in mind, in the absence of other data the following values may be used.

Cell type	Default efficiency (%)	Default temperature coefficient (1/°C)
mono-Si	13	0.004
poly-Si	11	0.004
a-Si	5	0.0011
CdTe	7	0.0024
CIS	7.5	0.0046

Nominal Efficiencies of PV Modules

NOCT (Nominal Operating Cell Temperature)

The model calculates the Nominal Operating Cell Temperature (NOCT), in ºC. NOCT is defined as the module temperature that is reached when the PV module is exposed to a solar radiation level of 800 W/m^2, a wind speed of 1 m/s, an ambient temperature of 20ºC, and no load.

In the case where the user selects "sperical-Si" or "User-defined" under "PV module type," the user enters the Nominal Operating Cell Temperature (NOCT). The NOCT can usually be found in the datasheets provided by the PV module manufacturer.

PV temperature coefficient

The model calculates the PV temperature coefficient.

In the case where the user selects "User-defined" under "PV module type," the user enters the temperature coefficient of the PV module. The efficiency of photovoltaic cells varies with their operating temperature. Most cell types exhibit a decrease in efficiency as their temperature increases. The PV temperature coefficient, μ (expressed in % / ºC), is defined in the RETScreen PV model as:

$$\eta(T) = \eta(T_{ref})(1-\mu(T-T_{ref}))$$

where

$\eta(T)$ = the efficiency of the solar cell at temperature T,
$\eta(T_{ref})$ = the efficiency of the cell at temperature T_{ref},
T = the operating temperature of the module, and
T_{ref} = the reference temperature (usually 25ºC).

The value of μ depends primarily on the type of cell used. It is often fairly difficult to find this value on manufacturer datasheets, therefore in the absence of this information the default values found in the Nominal Efficiencies of PV Modules table may be used.

PV array controller

The user selects from the drop-down list the type of PV array controller that is used to interface the PV array to the rest of the system: "MPPT" and "Clamped." A Maximum Power Point Tracker (MPPT) is an electronic device used to maintain the operating voltage of the array at a value that maximises array output, regardless of changes in load impedance or changes in array operating conditions due to variations in temperature or insolation. If the user selects "MPPT," the efficiency of the array will be optimal. A "Clamped" PV array controller is a direct connection between the array and the batteries; in this configuration the array operates at the voltage set by the battery. This may not be the optimal voltage for the array and therefore its efficiency will be lower.

The MPPT is often combined with other electronic devices such as the charge controller for off-grid systems (on-grid systems include a MPPT as part of the inverter). When this is the case, the efficiency of the device in question should include the efficiency of the MPPT. In cases where the MPPT is not combined with another device, its efficiency should be accounted for separately, for example in the "Miscellaneous power conditioning losses."

Miscellaneous PV array losses

The user enters array losses (%) from miscellaneous sources not taken into account elsewhere in the model. This includes, for example, losses due to the presence of dirt or snow on the modules. Typical values range from zero to a few percent. In some exceptional circumstances (e.g. very harsh environment) this value could be as high as 20%.

Suggested nominal PV array power

The model calculates the suggested nominal power of the PV array, expressed in kWp (kilowatt peak). The nominal power of the array is expressed under an irradiance of 1,000 W/m², a temperature of 25ºC, and an air mass of 1.5. This value can range from a few hundred Wp to many kWp, depending on the type of system under consideration.

The value calculated by the model provides a reasonable estimate for the purposes of a preliminary feasibility analysis study. For stand-alone systems (PV-battery), the suggested nominal PV array power aims at providing 100% of the load for the worst month; for hybrid systems (PV-battery-genset) the suggested power aims at providing 25% of the load for the worst month, and no more than 75% of the load for the best month (values are approximate).

Nominal PV array power

The user enters the nominal power of the PV array, in kWp. For "Off-grid" or "Water pumping" applications, as a first guess the user will likely enter the "Suggested nominal PV array power" then enter lower or higher values to perform a sensitivity analysis of the system.

The value entered by the user may be slightly different from the suggested value to match the output of PV modules available from specific manufacturer. The user can consult the RETScreen Online Product Database for more information.

PV array area

The model calculates the area that will be covered by the PV array, in m². This is simply the nominal PV array power divided by the nominal module efficiency. The user should verify the value calculated by the model. If the PV array is mounted on a wall, the required array area should not exceed the surface available on the wall. For roof-mounted systems, the size should not exceed approximately half the total roof area. For ground-mounted systems, the size is limited only by the available land area.

If the calculated area exceeds the available space, a smaller system size should be specified under "Nominal PV array power," or higher efficiency modules should be used.

Genset

This sub-section deals with the characteristics of the genset. Note that genset, as defined here, also includes thermoelectric generators (TEGs).

Charger (AC to DC) efficiency

The user enters the efficiency (%) of the battery charger/rectifier. Values usually range between 80 and 95%. If data from the manufacturer is not available a value of 80% will likely be a reasonable estimate.

Suggested genset capacity

The model calculates the suggested capacity of the genset, in kW. The genset is sized so that:

i) it can always meet the AC load, and
ii) it can nominally recharge the batteries in 8 h.

Suggested genset capacities usually range from very small values (which should be considered as impractical) to a few kW.

Genset capacity

The user enters the genset capacity, in rated kW for continuous operation.

By default the user will likely enter the "Suggested genset capacity." If the user has a specific genset in mind, the nameplate capacity of that genset will likely be entered. In the case of a retrofit situation, where a PV system is added to an installation with an existing genset, the nameplate capacity of the existing genset will likely be used.

The genset capacity will likely be within ± 25% of the suggested genset capacity; significant deviations from the suggested value may affect battery operation and life expectancy.

Fuel type

The user selects the type of fuel used by the genset. A list of common fuels is provided in the drop-down list.

Specific fuel consumption

The user enters an estimate of the fuel consumption of the genset, per unit kWh of electricity delivered.

Typical values can be found in the table below; note that these values are for a generator running at full capacity, and that they should be increased if the generator is running only at a fraction of its full capacity (see also the Diesel Genset Fuel Efficiency vs. Capacity Used graph).

Fuel type	Units	Suggested value
Natural gas	m^3/kWh	0.55 – 0.60
Propane[1]	L/kWh	0.90 – 1.10
Diesel (#2 oil)	L/kWh	0.40 – 0.50
Kerosene	L/kWh	0.80 – 1.00
Gasoline	L/kWh	0.60 – 0.75

Average Genset Specific Fuel Consumption
1. Liquid propane at 15ºC: 1.97 L/kg

Power Conditioning

This sub-section deals with the characteristics of the power conditioning hardware.

Average inverter efficiency

The user enters the combined efficiency, expressed in %, of the electronic devices (maximum power point tracker and inverter) used to control the PV array and transform its DC output to AC. Values between 80 and 95% are typical. A value of 90% is suggested as a starting point.

Suggested inverter (DC to AC) capacity

The model calculates the suggested capacity of the inverter, in kW AC (that is, the nominal **output** of the inverter). This value is calculated based on "Nominal PV array power" and "Average inverter efficiency" entered by the user.

Inverter capacity

The user enters the inverter capacity, in kW AC (that is, the nominal **output** of the inverter). By default the user will likely enter the Suggested inverter (DC to AC) capacity provided above.

Miscellaneous power conditioning losses

The user enters power conditioning losses (%), if any, not taken into account elsewhere. For example, this could include losses incurred in DC-DC converters or in step-up transformers. In most cases this value will be zero.

Annual Energy Production (for months analysed)

This section summarises the annual energy production of the photovoltaic project.

Equivalent DC energy demand

The model calculates the equivalent DC energy demand, in MWh. This is the sum of the DC demand and the AC demand divided by inverter efficiency, over the season of use.

Energy from genset

The model calculates the energy delivered by the genset over the season of use, in MWh.

Equivalent DC demand not met

The model calculates the electrical demand that is not met by the system over the season of use, in MWh. This quantity is expressed as an equivalent DC demand, that is, it is the amount of energy that the photovoltaic system is unable to provide to meet both DC and AC loads.

This value provides an indication of whether the system is properly sized: if it is, the demand not met should be equal to zero. However the user should refrain from using this value to calculate a "loss of load probability" for the system, that is, the chance that the system will fail to meet the load over a given number of years. The algorithms used in the RETScreen PV model have been chosen to provide a reasonable estimate of the energy delivered during a typical season, but they are not designed to provide a detailed estimate of the loss of load probability.

Water delivered

The model calculates the amount of water delivered, in m^3, over the season of use.

Specific yield

The model calculates the specific yield, in kWh/m^2. This is the renewable energy delivered by the PV system over one year, divided by the PV array area. Depending on PV array technology type, climatic conditions, latitude, power conditioning efficiency and losses, this value will likely be in the range 30 to 250 kWh/m^2.

Overall PV system efficiency

The model calculates the overall efficiency of the PV system, in %. This value is the amount of renewable energy delivered divided by the amount of solar radiation incident on the photovoltaic array. Typical values range from 3% to 13%, depending on module type, power conditioning efficiencies and solar radiation distribution.

PV system capacity factor

The model calculates PV system capacity factor (%) which represents the ratio of the average power produced by the system over a year to its nominal rated PV array power. It is calculated as the ratio of the renewable energy delivered over the nominal PV array power multiplied by the total hours in a year.

Renewable energy collected

The model calculates the amount of electrical energy produced by the photovoltaic array during the season of use, in MWh. Depending on latitude and system size this value may range from a fraction of one MWh to several hundred MWh or more.

Renewable energy delivered

The model calculates the annual renewable energy delivered (MWh), which is the amount of equivalent DC electrical energy actually delivered by the PV system to the load, or the utility in the case of an on-grid system. This value is transferred to the *Financial Summary* worksheet as an input to conduct the financial analysis.

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." These values are for reference purposes only and are not required to run the model.

Excess RE (Renewable Energy) available

The model calculates the excess renewable energy available (MWh), which is the amount of renewable energy produced by the system, that could not be used by the grid because of mismatches between PV output and utility energy demand (see "PV Energy absorption rate"). This value is transferred to the *Financial Summary* worksheet as an input to conduct the financial analysis.

Solar Resource & System Load Calculation

As part of the RETScreen Clean Energy Project Analysis Software, the *Solar Resource & System Load Calculation* worksheet is used in conjunction with the *Energy Model* worksheet to calculate the energy load and energy savings of a photovoltaic system.

The first two sections of this worksheet, Site Latitude and PV Array Orientation, and Monthly Inputs, are used to calculate monthly and annual average daily radiation in the plane of the photovoltaic array, by using the orientation of the array, the latitude of the site, and values of monthly average daily radiation on a horizontal surface for the twelve months of the year. The third section, Load Characteristics, is used to specify the type of system under consideration (on-grid, off-grid or water pumping) and the characteristics of the load.

Site Latitude and PV Array 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 used 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 this 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.

PV array tracking mode

The user selects the type of sun tracking device upon which the PV system is mounted. The options from the drop-down list are: "Fixed," "One-axis," "Two-axis" and "Azimuth." If the PV array is mounted on a fixed structure the user may select "Fixed." The remaining choices may be selected if the PV array is mounted on a tracker.

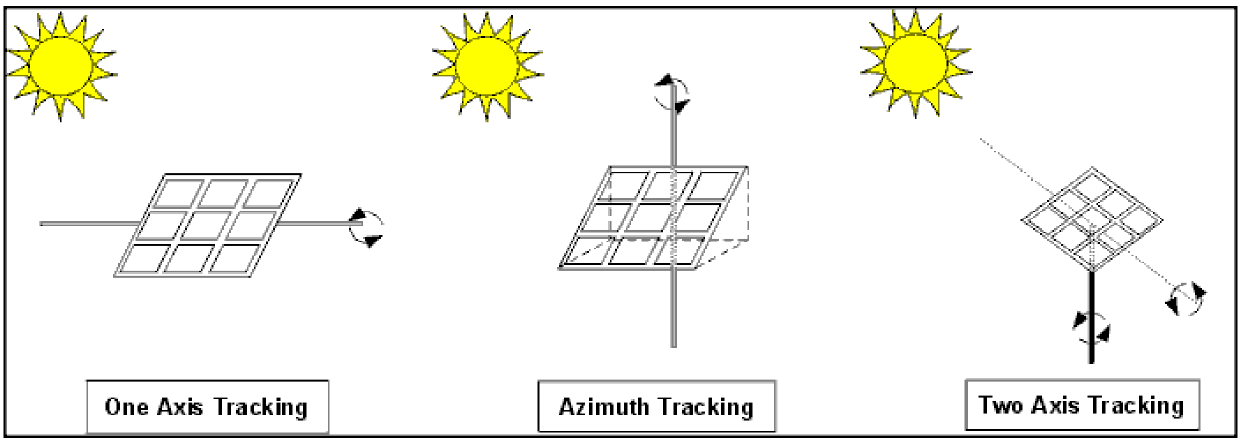
A tracker is a device supporting the photovoltaic array which moves the array in a prescribed way to minimize the angle of incidence of beam radiation on the array's surface. Hence incident beam radiation (i.e. solar energy collected) is maximized. PV trackers may be classified as follows:

One-axis trackers track the sun by rotating around an axis located in the plane of the array. The axis can have any orientation but is usually horizontal east-west, horizontal north-south, or parallel to the earth's axis;

Azimuth trackers have a fixed slope and rotate about a vertical axis; and

Two-axis trackers always position their surface normal to the beams of the sun by rotating about two axes.

The next figure illustrates the three tracking types defined above.



Sun-tracking Devices

Depending on whether or not a tracking device is used, the following parameters also need to be entered in the PV model:

Tracking Mode	Parameters required
No tracking	Slope and azimuth of PV array
1-axis tracking	Slope and azimuth of tracking axis
2-axis tracking	None
Azimuth tracking	Slope of tracking axis

PV Array Tracking Mode

Slope of PV array

The user enters the angle between the photovoltaic array and the horizontal, in degrees.

In most cases, the slope of the PV array 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 photovoltaic array. 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 photovoltaic array 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 photovoltaic array in the winter. This slope is also suggested in cold climates to minimise snow accumulation;
- For fixed arrays, equal to the slope of the roof on which the photovoltaic array 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; or
- For fixed arrays, equal to 90° : This corresponds to a photovoltaic array mounted on the façade of a building. This never corresponds to a optimum in terms of energy production, but can reduce significantly installation costs by eliminating the need for costly cladding and a support structure, or may be more desirable from an aesthetics standpoint.

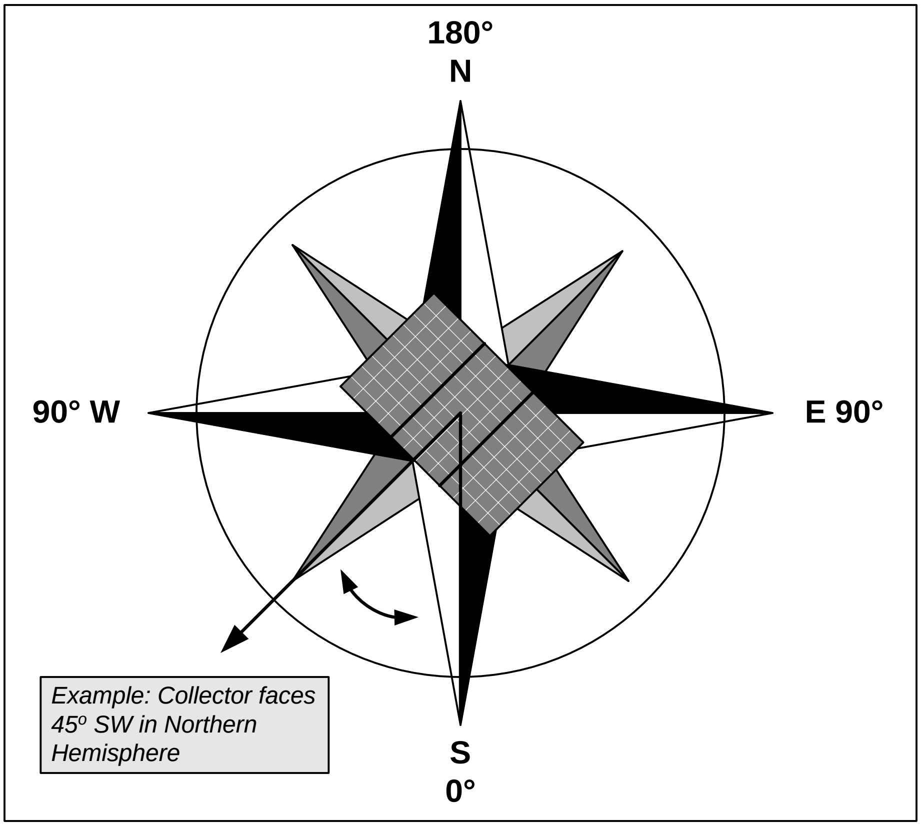
Azimuth of PV array

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 PV array 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 next 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.



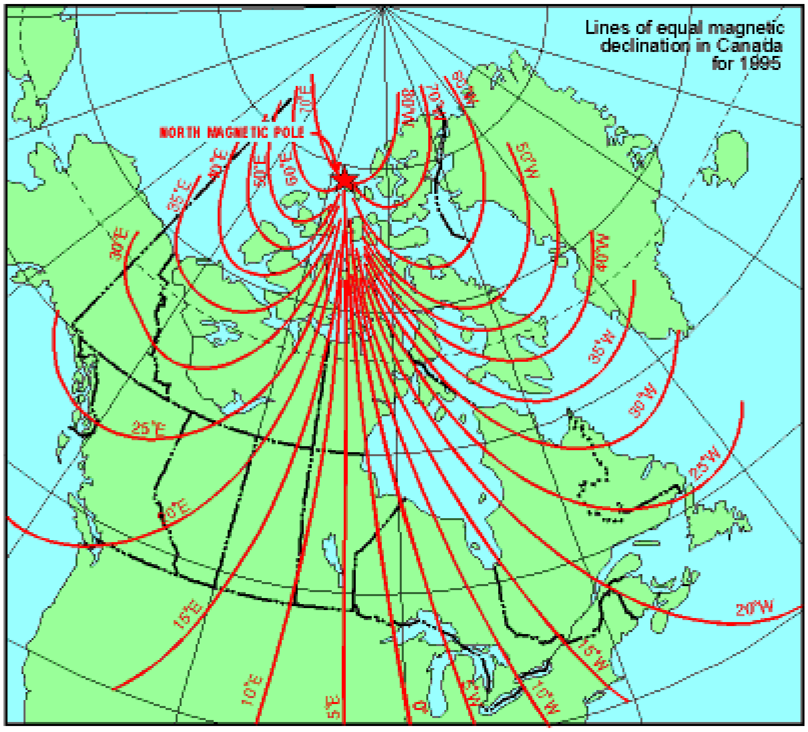
Azimuth of a Photovoltaic Array [adapted from Ross, 1999]

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 Photovoltaic 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 and written in italic to indicate that they are not used for energy calculations. For example, if the month of January is not considered in the analysis (thus "Fraction of month used" is set to zero for January), then "Monthly average daily radiation on horizontal surface" and "Monthly average temperature" are not required for January. Hence the corresponding cells are greyed out to indicate that the information is not required to run the model.

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/m^2)/d. Data in (MJ/m^2)/d should be divided by 3.6 to be converted to (kWh/m^2)/d. Data in (BTU/ft^2)/d should be divided by 317 and data in (cal/cm^2)/d or Langleys should be divided by 86 to be converted to (kWh/m^2)/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/m^2)/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 photovoltaic array as well as the efficiency of the battery. The user can consult the RETScreen Online Weather Database for more information.

Monthly average daily radiation in plane of PV array

The model calculates the amount of solar radiation received on average during one day on a tilted surface at the site, in $kWh/m^2/d$. Typical values calculated by the model range from 0 to 10 $kWh/m^2/d$.

Monthly solar fraction

The model calculates the monthly fraction (%) of the load met by the photovoltaic system (off-grid and water pumping systems only). This value is calculated for reference purposes only. The user first needs to complete the "Load Calculation" section as well as the *Energy Model*worksheet, in order for the "Monthly solar fraction" value to have meaning.

Solar radiation (horizontal)

The model calculates the amount of solar radiation incident on a horizontal surface, in MWh/m^2, 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/m^2, 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.

Load Characteristics

The load characteristics of the PV system are entered by the user in this section. The user specifies the type of application (on-grid, off-grid, or water pumping) as well as load details that will enable the model to estimate the energy requirements.

Application type

The user selects the type of application under consideration. The three options from the drop-down list are: "On-grid," "Off-grid" and "Water pumping." On-grid applications cover both central-grid and isolated-grid systems with no batteries. Off-grid applications include both stand-alone systems, that have a photovoltaic array and batteries but no back-up energy system, and hybrid systems which include a photovoltaic array, batteries, and a fossil fuel generator. Water pumping PV systems do not include batteries.

Use detailed load calculator?

The user selects whether or not the detailed load calculator is to be used. If "Yes" is selected the detailed load calculator can be used to specify the load on an item-by-item basis. If "No" is selected then the user must enter global estimates of the load.

Detailed load calculator (off-grid system)

The user enters a detailed description of the various loads that the system will have to meet.

Description

The user enters a description of the load. This is for reference purposes only. For example if the load in question is an electric vacuum cleaner the user may enter "Vacuum cleaner."

AC/DC

The user selects whether the load is direct current (DC) or alternating current (AC). For example if the load is a standard electric vacuum cleaner the user would select AC.

Solar-load correlation

The user selects the solar-load correlation. The three options from the drop-down list are: "Negative," "Zero" and "Positive." The solar load correlation is a qualitative estimate of how the load is correlated with the solar resource.

"Negative" (i.e. negative correlation) corresponds to cases where the load is very irregular or occurs mostly at night. The model considers that the load is always met from the battery. A light used exclusively at night, for example, falls into this category. "Zero" (i.e. zero correlation) corresponds to steady loads. The model considers that the load is constant throughout the day and is met partly from the battery, partly directly by the photovoltaic array without going through the battery. A cathodic protection system would fall into this category. "Positive" (i.e. positive correlation) corresponds to loads that are turned on only when there is enough solar energy to power them directly. The model then considers that the load is met directly by the photovoltaic array and the battery does not play a role. A direct fan would fall into this category. In most cases the solar/load correlation will be "Negative." Only in very particular cases, such as the ones given in the example, will the solar/load correlation be "Zero" or "Positive." In the vacuum cleaning example the user will likely enter "Negative."

Load

The user enters an estimate of the load, in kW. The following table provides an estimate of typical loads encountered in an household. In the vacuum cleaning example the user would enter 0.8 (800 W converted to kW: 800/1,000 = 0.8).

Appliance	Estimated Power Rating (W)
AC appliances	
Block heater	500
Coffee maker	1,000
Clothes washer (excl. hot water)	450
Computer (desktop)	200
Dishwasher (excl. hot water)	1,200
Hair dryer, iron	1,000
Light, 25 W incandescent	25
Light, 10 W fluorescent	10
Light, 40 W fluorescent	40
Microwave oven	800
Power tools	250-1,000
Radio	30
Refrigerator	330
Television (B/W)	200
Television (color)	330
Toaster	1,000
Vacuum cleaner	800
Video cassette recorder	30
Water heater (electric)	5,000
DC appliances	
Computer, laptop	25
Fan, ceiling	25
Fan, 8"	15
Refrigerator	65
Security system	6
Telephone, cellular (standby)	0.02
Telephone, radio (standby)	25
Television (B&W)	10-20
Television (color)	45-60

Typical Loads in a Household

Hours of use per day

The user enters an estimate of the number of hours that the load is used during a typical day (h/d). For example if it takes one half-hour to vacuum the house the user would enter 0.5.

Days of use per week

The user enters an estimate of the number of days during which the load is used per week (d/wk). In the vacuum-cleaning example, if vacuuming is done on Mondays, Wednesdays and Fridays the user should enter 3.

DC energy demand

The DC energy demand is the weekly averaged daily amount of DC energy required by all the individual loads. This value is automatically calculated in the model if the detailed load calculator is used. It must be entered manually by the user if the detailed load calculator is not used. Values can range from zero (if the entire load is AC) to a few tens of kWh or more.

AC energy demand

The AC energy demand is the weekly averaged daily amount of AC energy required by the load. This value is automatically calculated by the model if the detailed load calculator is used. It must be entered manually by the user if the calculator is not used. Values can range from zero (if the entire load is DC) to a few tens of kWh or more.

AC peak load

The AC peak load is the maximum power drawn at any time during one day by the load. This value is automatically calculated by the model if the detailed load calculator is used. It must be entered manually by the user if the calculator is not used. Values can range from zero (if the entire load is DC) to a few kW or more. The AC peak load is required to estimate the size the inverter.

If the detailed load calculator is used, the AC peak load is obtained by summing all AC loads. This may lead to an overestimation of the total AC peak load in systems where not all AC loads occur simultaneously. For example, if the system comprises both a TV and a vacuum cleaner, the user may choose to turn the TV off when vacuuming. If this is the case, a smaller inverter size than the one proposed by the model in the *Energy Model* worksheet can be selected. In other words, the user should select an inverter with capacity to meet the maximum AC load with selected AC devices operating simultaneously.

Detailed load calculator (water pumping system)

The user enters a detailed description of the various water pumping loads that the PV system will have to meet.

Description

The user enters a description of the load. This if for reference purposes only. For example, if the water will be used to irrigate a field of corn the user may enter "Corn field."

Water pumping application

The user selects the water pumping application under consideration. The four options from the drop-down list are: "Domestic," "Livestock," "Irrigation" and "Other." For the example of the corn field the user would select "Irrigation."

Unit

Based on the water pumping application selected, the model displays the unit used to calculate the daily water required. If "Other" is selected as the water pumping application no units are displayed. For the example of the corn field the units displayed are "ha" (hectares). See the Typical Water Requirements table for more information.

of units

The user enters the number of units for which water will be supplied. For the example of the corn field that is 50 m wide by 100 m long, the user should enter "0.5" (note: one hectare is 100 m × 100 m).

Water use per unit

The user enters an estimate of the amount of water required by each unit on a daily basis. The following table can be used as a guideline for estimating water requirements. For corn field example the user would likely enter 45 m^3/d/ha. Note that water requirements vary widely with type of irrigation system, hence when precise data is available it should be used in the place of typical requirements suggested in the following table.

Type	Water consumption
Domestic (People)	
WHO recommended minimum	30 L/d
Average use (Africa, Asia)	45 to 85 L/d
Average use (Europe, South-America)	250 L/d
Average use (North-America)	450 L/d
Livestock	
Cow	40 L/d
Sheep and goat	5 L/d
Horse	40 L/d
Donkey	20 L/d
Camel	20 L/d
Irrigation	
Market gardening	60 m^3/d/ha
Rice	100 m^3/d/ha
Cereals	45 m^3/d/ha
Sugar cane	65 m^3/d/ha
Cotton	55 m^3/d/ha

Typical Water Requirements[1]

1. Data in this table from: Royer, J. et al. (1998) and United Nations Population Information Network

Daily water required

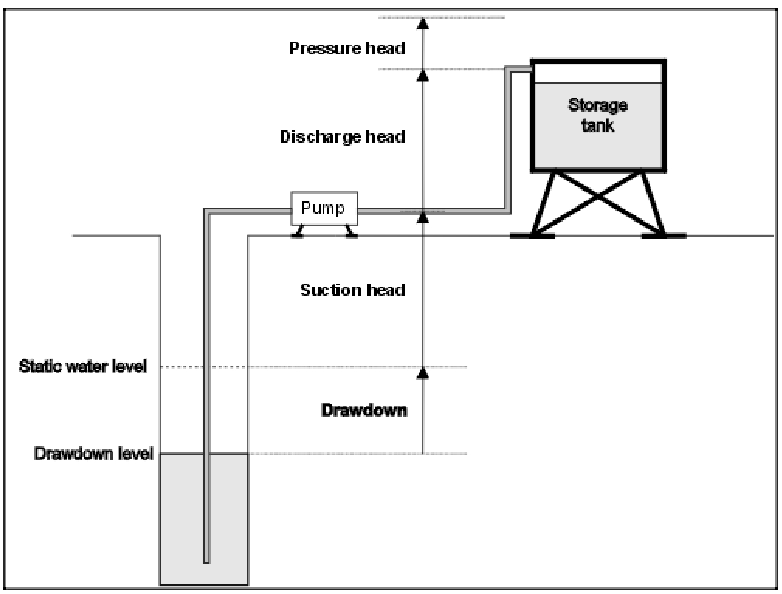
The model calculates the daily water requirement, in m³/d. This value is based on the number of units and the water use per unit specified by the user. For typical PV water pumping applications values can range from a fraction of a cubic meter per day to several hundred cubic meters per day.

Daily water requirement

The model calculates the total daily water requirement, in m³/d. This value is automatically calculated in the model if the detailed load calculator is used. It must be entered manually by the user if the calculator is not used. For typical PV water pumping applications values can range from a fraction of a cubic meter per day to several hundred cubic meters per day.

Suction head

The user enters the vertical distance, in meters, from the centre of the pump to the water surface, when the pump is located above water and no water is being pumped (see the figure below). There is no suction head for floating and submerged pumps. This value can range from zero (for immersed pumps) and should not exceed 8 m for hydraulic considerations.



Pumping Head Nomenclature

Drawdown

The user enters the vertical distance, in meters, between the static water level to the actual (or drawdown) water level, when water is pumped from the source (see Pumping Head Nomenclature figure). For wells this value is best determined by test pumping. The drawdown depends on the rate of pumping and the ability of the surrounding aquifers to replenish the well. If no test data is available use 1 m. For immersed pumps or for river-based pumping systems the value is zero.

Discharge head

The user enters the total vertical distance, in meters, that the water will be lifted from the centre of the pump to the point of free discharge or the surface of water in the storage tank (see Pumping Head Nomenclature figure). This value usually ranges from zero to a few tens of meters.

Pressure head

The user enters the pressure head, in meters, at which the water exits the discharge point or enters into an irrigation system (see Pumping Head Nomenclature figure). For most systems such as non-pressurized tanks or irrigation troughs this value will be zero; it will be non-zero for pressurized systems and irrigation sprinklers.

Friction losses

The user enters an allowance for dynamic friction losses (%). This value is expressed as a percentage of the total head. Friction losses are the pressure losses caused by friction when water moves through the pipes and fittings. This value is a function of the length of piping, diameters of the pipes, the material they are made of, and the water flow. In well-designed systems the friction losses are kept below 10% of the total head.

Total head

The model calculates the total equivalent vertical distance, in metres, that the pumped water will be lifted (see Pumping Head Nomenclature figure). This is the sum of the suction head, the drawdown, the discharge head, the pressure head, and the friction losses. This value can range from 0 to a few tens of meters.

Equivalent energy demand

The model calculates the mechanical energy corresponding to moving water from the source to the point of discharge, in kWh/d. This quantity does not include energy lost because of inefficiencies of the pump or of the motor. For typical PV water pumping applications this value can range from a fraction of one kWh/d to tens of kWh/d, depending on the system configuration.

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 PV 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 by clicking on the appropriate radio button. For a "Pre-feasibility analysis," less detailed and lower accuracy information is typically required while for a "Feasibility analysis," more detailed and higher accuracy information is usually required.

To put this in context, when funding and financing organisations are presented with a request to fund an energy project, some of the first questions they will likely ask are "how accurate is the estimate, what are the possibilities for cost over-runs and how does it compare financially with other options?" These are very difficult to answer with any degree of confidence, since whoever prepared the estimate would have been faced with 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

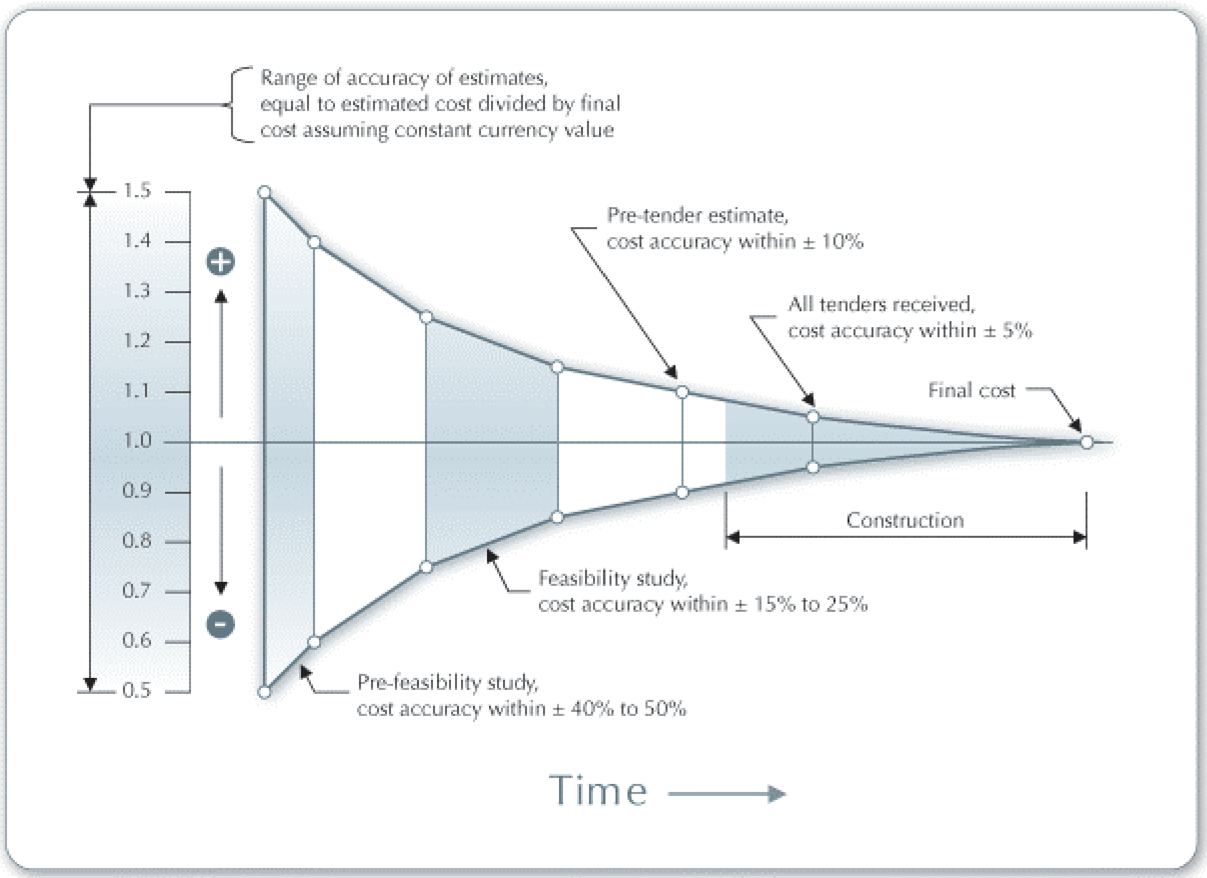
- Development (including financing) and engineering

- 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]

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" cell.

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

Feasibility Study

Once a potential cost-effective photovoltaic project has been identified through the RETScreen pre-feasibility analysis process, a more detailed feasibility study may be required for larger photovoltaic projects (greater than 3 kWp of PV). Feasibility studies typically include such items as site investigations, a preliminary project design and a final report with detailed cost estimates. Feasibility study project management and travel costs are also normally incurred. These costs are detailed in the section below.

For smaller projects, the cost of the feasibility study, relative to the cost of the PV 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) and enter "0" for cost items not applicable.

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

Site investigation

When a photovoltaic system is being considered for an existing application or building, a site visit is often required to evaluate the site conditions, such as solar access, and the requirements of installing the PV system. If the PV system is for a new building or if it is to be ground mounted, then a site visit is usually not required since the analysis can be done from architectural, engineering and/or land survey drawings.

For existing building installations, a photovoltaic project expert should 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 PV system can be designed. The site will be inspected to determine a possible location for the photovoltaic modules, electrical conduit and inverter. 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, which usually requires one day on site, will suffice to conduct the feasibility study for most projects. The cost of a site visit will be influenced by the planned duration and travel time (travel costs separate - see below) 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 8 and 16 h (travel time extra). Photovoltaic expert fees typically range from $40/h to $100/h, depending on their experience.

Preliminary design

A preliminary design is required in order to determine the size, layout and potential energy output of the PV modules. After the PV system is sized, draft drawings, which also consider other system components such as inverter(s), structures and other electrical equipment, are then prepared. The preliminary design is then used to prepare a more detailed cost estimate.

The time required to prepare the preliminary design and detailed cost estimate typically falls between 20 and 60 h at fees between $40/h to $100/h. Smaller scale projects with simple structural requirements are at the low end of this time range. Larger scale projects requiring more difficult structural integration into existing buildings will be at the high end of this time range.

Report preparation

A summary report should be prepared which describes the feasibility study, its findings and recommendations. The report will contain data summaries, charts, tables and illustrations which clearly describe the proposed project. In addition, the 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 summary 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 the report and managing the feasibility study takes between 8 and 16 h at a rate of between $40/h and $100/h.

Travel and accommodation

This cost item includes all travel related costs (excluding time) required to prepare all sections of the feasibility study by the various members of the feasibility study team. These expenses include such things as airfare, car rental, lodging and per diem rates for each trip required.

In the case of isolated areas, rates for air travel will vary markedly. Airfares are typically twice those for similar distances in populated areas. Since travel is a large component of the cost of doing work in isolated areas, and the range of cost is so variable, the user should contact a travel agent with experience in arranging such travel. Accommodation rates are typically twice the going rate for modest accommodation in populated areas. Typical rates for modest hotel rooms can range from $180 to $250 per day in the more isolated areas.

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Development

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

For photovoltaic projects, there are a number of possible project developers. Currently, one common approach is for electric utilities to manage a program where a large number of PV systems are purchased for individual building/home owners. The utility may purchase the systems and then install them on the roof of the utility customer or near a utility substation. In other programs, the utility and/or government provides a subsidy directly to the customer or product supplier to defray the initial cost of the PV system. For these present day photovoltaic project development activities, development costs typically include items such as permits and approvals, project development management and travel costs. These costs are detailed in the section below.

Permits and approvals

A number of permits and approvals may be required for the construction of the project. These include building and electrical permits from local authorities. In addition, when the PV system can supply energy into the existing electrical grid, authorization from the local electric utility will likely be required. Some equipment may be required to undergo testing by national standards associations and/or laboratories.

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 PV project it normally takes between 4 and 8 h at rates of between $40/h and $100/h. The user can also add to the number of hours, or unit costs, an amount to cover the actual permit itself. Permit costs often range from 0.25 to 1.5% of electrical equipment materials costs, depending on the jurisdiction and project scale. Large scale projects, which can supply significant energy to the electrical grid, would take considerable more time to obtain approvals and permits.

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 and project financing activities are also included as part of the PV project management cost item here. However, public relations is not normally a big issue with most PV systems as the projects are usually building mounted and have little or no negative environmental impact.

The elapsed time for the development of a PV project is relatively short. An entire project can certainly be developed within a one year time period with actual construction time only taking a few days or weeks, depending on the project scale. The project development management time will usually take between 16 and 80 h at rates of between $50/h to $100/h.

Travel and accommodation

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

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Engineering

The engineering phase includes costs for the photovoltaic system, structural and electrical design, as well as tenders and contracting, and construction supervision. These costs are detailed below.

PV system design

The PV system design includes the time required to specify and draw the exact physical placement of the PV modules at the project site. Liaison will also be required with the structural and electrical designer to achieve an optimum design.

The time required to prepare the PV system design and detailed drawings falls between 12 and 24 h at fees of $40/h to $100/h. Simple wall or flush mounted roof grid-connected systems fall at the lower end of this scale in terms of time while large hybrid or grid-connected systems will tend to fall on the higher end.

Structural design

From a PV system design standpoint, the simplest structural designs are flush roof mounted and vertical wall mounted systems, where little structural work is required. When the project is a large retrofit to a building and/or where 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.

The time required to prepare the PV 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 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. The user may refer to the table below to estimate the structural design costs.

Mounting Angle	Engineering (h)	Drafting (h)
Vertical on wall	4	8
Flush mount (horizontal or at roof tilt)	16	8
Tilted on roof	32	40
Tilted on ground with no contour work	40	40
Tilted on ground with contour work	44	60

PV Structural Design Time Estimates

Electrical design

Electrical engineering design will be required to determine how the PV system will be integrated into the existing electrical system. The electrical engineer will provide details for PV module and inverter connections, fusing, conductors and conduit routing as well as for other generator or electrical equipment required. Co-ordination between the PV system designer and the electrical engineer will be required (they can also be the same person).

Electrical design time will vary with the size of the system. Since both engineering time and drafting time are required, use a weighted average for the engineering and drafting rates and time. Electrical design rates range from $40/h for drafting to $100/h for a professional engineer. The user may refer to the following table to estimate the electrical design costs.

PV System Size (kW)	Engineering (h)	Drafting (h)
0.5 – 3 (stand-alone)	10	10
0.5 – 3 (hybrid)	16	16
3 – 10 (grid connected)	20	20
11 – 25 (grid connected)	30	40
26 – 50 (grid connected)	35	60

PV Electrical Design Time Estimates

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. A minimum 16 h for a 3 kWp system and 40 h for a 50 kWp system provides a reasonable range. If the project is to be handled completely by one firm (i.e. engineering, design and construction) then do not include any time for preparing bid documents. Rates of $40/h to $100/h are possible.

Construction supervision

The construction supervision cost item summarises the estimated costs associated with ensuring that the project is constructed as designed. This cost item also includes final commissioning of the PV system. Depending on the project size, this task can take from 8 to 24 h at rates of $40/h to $100/h. Travel time to the site for commissioning are in addition to the range given. Travel costs should be entered in the "Development" section above. For smaller projects, especially at isolated sites, commissioning will generally be assumed by the installer.

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 includes PV modules, which produce direct current (DC) voltage and current. Transportation costs are provided separately to allow cost differentiation for 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.

PV module(s)

The total cost of the PV module depends on the total PV array power (kWp) output required, which is specified in the *Energy Model* worksheet as "Nominal PV array power," and the price per kWp for PV modules. The user enters a $/kWp price.

Current costs for PV modules range from $5,500/kWp to $8,000/kWp. The lower end of this price range is for larger projects (20 kWp or greater), where volume purchase discounts come into play. In addition to single large systems, this could include a volume purchase of multiple residential PV systems (e.g. an electric utility may purchase many systems of 2 kWp each). Costs of smaller single systems (4 kWp or below) are at the higher end of this price range. It is important to note that over the last two decades PV module prices have continued to decrease. This trend is expected to continue in the foreseeable future. The user should obtain updated price information for PV modules.

Transportation

Transportation costs for equipment and materials will vary considerably depending on the mode of transportation available and the location of the project site. In many instances the cost will depend on distance and be based on a volume/weight formula. Costs to handle the material at the receiving end should also be considered. In isolated areas, many communities can receive bulk shipments at given periods of 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, one 120 Wp polycrystalline PV module has dimensions (mm) of 1,227 (length) x 991 (width) x 50 (thickness) and a weight of 14.0 kg. Likewise, a typical 4 kWp inverter has a weight of 50 kg.

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

For "PV in the Built Environment" on-grid applications, the table below can be used to estimate possible "credit" amounts for PV modules versus conventional building materials.

PV Product	$/m²	Conventional Material	$/m²
Standard sized PV modules	1,400	Aluminium pitched roof	100
Glass/glass module for curtain walling	1,800	Stone wall cladding	700
Glass/glass module for curtain walling	1,800	Granite faced pre-cast concrete	1,500
PV array incorporated into a tracking shading system	2,800	Shading system	1,000
PV wall cladding	1,400	Rainscreen overcladding	450
Double glazed, glass-glass PV modules	2,000	Double glazing	800
PV roof tiles	1,200	Roof tiles (concrete of clay)	75
Double glazed, glass-glass PV modules (with higher quality support for façade)	2,200	Glazing with higher quality support	1,000

Cost of PV Products Compared With Conventional Building Materials
[adapted from: ECOTEC, 1998]

Balance of Equipment

The balance of equipment, or Balance of Systems (BOS), for a PV project typically includes the PV module/array support structure, the inverter, a genset (for hybrid systems), batteries, a water pump and pipes/reservoirs for water pumping applications and the various electrical components such as fuses, switches, conductors and conduit. In addition, the installation labour for the entire PV system and for the various components is included under this section.

Module support structure

This item refers to the total cost of the equipment required to provide a support for the PV modules. The cost of the support structure will vary considerably depending on whether the system is to be mounted on the building wall, or roof, or whether it is to be ground mounted. These costs can be related to the area covered by the PV modules which is calculated in the *Energy Model* worksheet ("PV array area"). The user inputs a $/m² cost.

For simple PV systems, where the PV modules are flush mounted to the building roof or wall, the structure costs are minimal and will typically be included as part of the PV module price. In this case the user enters 0. For more elaborate structures, such as on flat roof commercial buildings, support structure costs could be as high as $200/m².

For systems using tracking devices, the cost per unit of area will vary depending of the type of tracker used (passive tracking or electrical drives), its complexity (one/two axis or azimuth tracking) and size. Trackers can cost anywhere between $300/m² and $1,200/m². As a general rule, the lower end of this price range is for simpler and larger trackers (up to about 11 m²) while the higher end will reflect the cost of small units with full tracking (two axis) capability. For arrays exceeding 11 m² multiple tracking units may be required.

If the system is to be ground mounted (fixed or tracking) some site work will have to be done and those costs should be added in the "Other" category provided.

Inverter

The cost of the inverter depends on the application it is used for, the quality (waveform) of its output, its output capacity, and other integrated functions such as battery charging or genset automatic starting. Here, the user enters a $/kW AC[1] price.

For on-grid PV systems, the cost of inverters is in the $1,000/kW AC to $1,500/kW AC range, where bigger units are on the lower end of this range and smaller units on the higher end. A high volume purchase of small units may bring the cost in the middle range. Note that some PV module manufacturers are offering "AC PV modules" for grid intertie systems. These modules have a small built-in inverter. In this case, the user will not include an inverter cost here.

For off-grid PV systems, the cost of inverters ranges from $1,000/kW AC to $2,000/kW AC. The lower end of this price range is for larger inverters or lower output quality inverters (modified square-wave), while the costs of smaller or higher quality (sine-wave) units will be at the higher end of this price range. Small (less than 1 kW) pure sine wave inverter are still relatively new on the market and can easily exceed this price range depending on their quality and application they are built for. The following table presents the costs according to inverter size and type. Note that for stand-alone sine wave inverters of less than 1 kW, a large price range exists.

[1] "kW AC" refers to the nominal output of the inverter. Technically this should read kVA, but for simplicity purposes, it is referred to as kW. This should not make a difference for this level of analysis.

Inverters	Grid-tied Inverters ($/kW)	Stand-alone Inverters Modified square-wave ($/kW)	Stand-alone Inverters Sine-wave ($/kW)
< 1 kW	N/A	1,300	2,000-10,000
1 to 10 kW	1,500	1,000	1,500
20 to 100 kW	1,150	N/A	1,250
> 100 kW	1,000	N/A	1,000

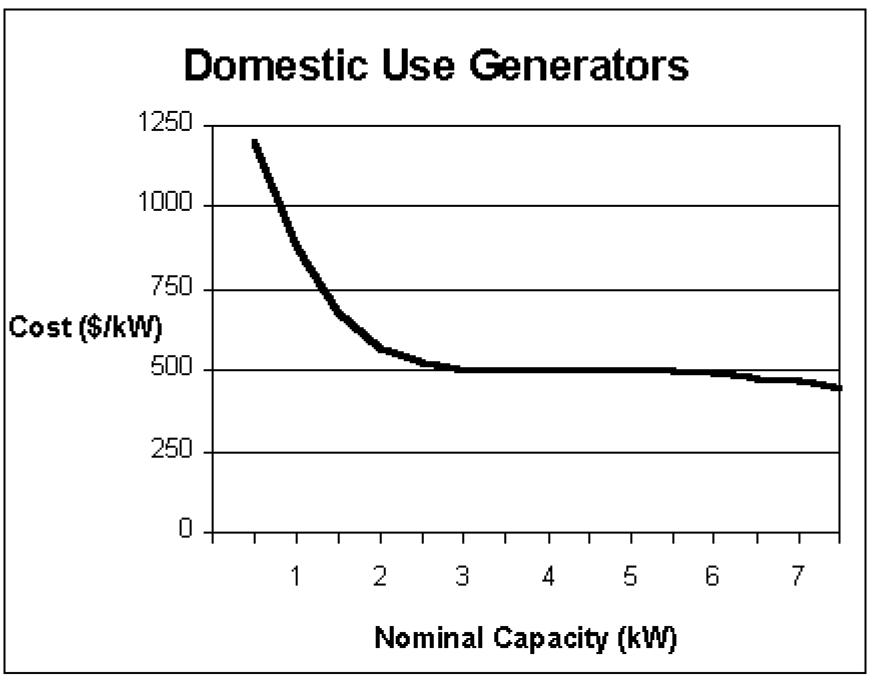
Typical Cost of Inverters

Note: Inverter prices have been decreasing over time. As technology advances, better quality and lower cost inverters will be available on the market. The user should contact suppliers for current prices.

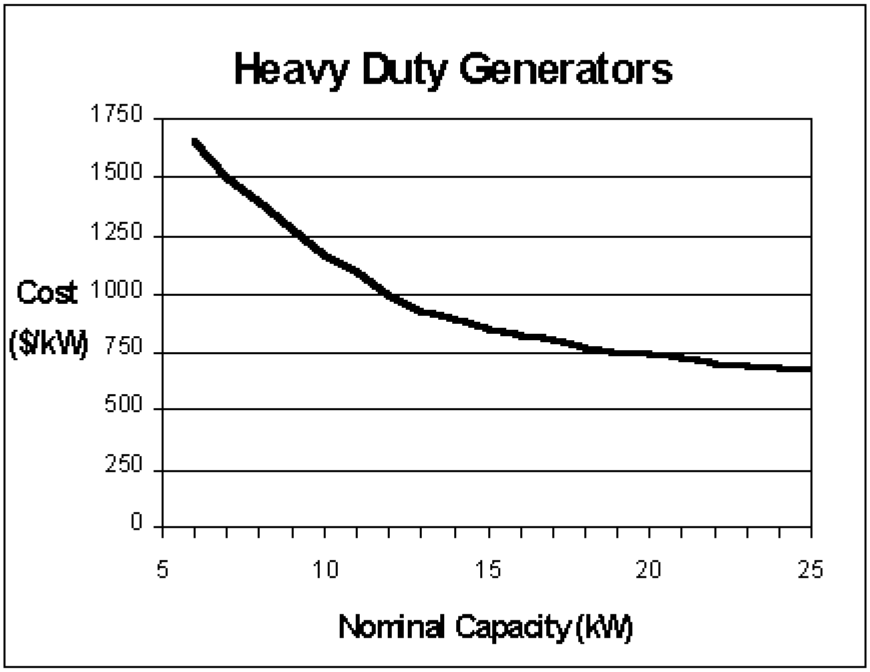
Genset

The user enters a $/kW AC cost (nominal genset AC output). Generator costs depend mainly on the size of the generator but also on the construction type (i.e. domestic or heavy duty), maintenance requirements, fuel type, manufacturers and integrated functions such as automatic starting.

As a first estimate, the user can enter the costs indicated in the two following figures. Generators made for domestic use (for cottages for example) can cost anywhere from $450/kW AC to $1,200/kW AC for capacities up to 7.5 kW. As a general rule smaller or heavy duty type generators tend to be more expensive (per kW AC). Heavy duty generators such as those used for commercial/industrial applications will typically cost between $500/kW AC and $1,700/kW AC for units up to 25 kW.



Typical Costs of Domestic Use Generators per Nominal kW AC Output



Typical Costs of Heavy Duty Generators per Nominal kW AC Output

Batteries

This item refers to the total cost of the battery bank required in off-grid PV systems. The battery cost will vary depending on the type of batteries selected. This cost is related to the battery size selected in the *Energy Model* worksheet ("Nominal battery capacity" and "Nominal battery voltage"). The user inputs a $/kWh cost (note that this is in "kWh of battery capacity" not "accumulated kWh of energy stored and discharged through the battery over its lifetime").

The user should note that the lifetime of the battery and its maintenance are highly correlated to the type of batteries selected; therefore, this should also be reflected in the maintenance cost (annual costs) and battery replacement cost (periodic costs, as entered in the *Cost Analysis* worksheet). The following table presents ranges of cost, expected lifetime and need for maintenance for different types of batteries.

Battery type	Cost range ($/kWh)	Lifetime (years)	Maintenance
Lead-acid: automotive	75-125	1-3	Varies
Lead-acid: RV/golf-cart	100-150	2-4	Yes
Lead-acid: vented industrial	175-400	5-12	Yes
Lead-acid: inexpensive gel or AGM	250-400	3-6	No
Lead-acid: industrial gel or AGM	350-1,000	5-12	No
Nickel-cadmium: industrial	1,000-1,900	15-20	Yes

Cost, Lifetime and Maintenance Requirements for Different Types of Batteries [adapted from Ross, 1999]

Water pump

The user enters a cost per water pump. This may also include electric cable (suited for use in water) if supplied with the pump. The cost of a water pump depends on the type of pump used, its design, size, capacity, quality and built-in features. Because it depends on so many different aspects, the cost of the pump can range anywhere from $300 to $3,500 per unit. The user should consult a supplier for more accurate estimates. A well matched pump for the application is key to an efficient system.

Pipes/reservoir

This item refers to the total cost of reservoir and pipes/hoses required. This includes the pipes running from the bottom of the well to the reservoir as well as the pipes used for distribution of water. The cost of these items will vary depending on the application, type of material used and size required. (See "Total head" in the *Solar Resource & System Load (SR&SL)* worksheet for an initial estimate of length required - additional pipes/hoses will be required if the storage tank is not near the well).

Often, reservoirs are made of polyvinylchloride (PVC) or cement. The cost of reservoirs made of local material such as cement will be highly dependent on labour costs; the user should obtain information on local suppliers. For piping, the most popular material is polyethylene and piping will cost between $0.75/m and $3.00/m depending on the location, size, material and quantity.

Other electrical equipment

Other electrical equipment may be required, such as conduit and fittings required to connect the PV modules to the inverter and the inverter to an existing breaker panel, and includes such items as lightning protection or special electric cable for water pumping systems. Each system will also require circuit protection, and a disconnect so as to be able to isolate the inverter. The input value has been estimated on a kWp basis (rated PV array power). The user enters a $/kWp price.

These costs can range from $700/kWp for simple and more standard residential PV systems, up to $1,500/kWp for industrial scale systems.

System installation

System installation refers to all the site labour required to install the PV systems, including the PV modules, inverter, genset, batteries, structure and electrical equipment. Special equipment is not generally required for the installation of the system, however, for larger systems, cranes and hoists can be used to save site labour. The input value has been estimated on a kWp basis (rated PV array). The user enters a $/kWp price.

These costs range between $900/kWp and $2,500/kWp, depending primarily upon the structural requirements as described above.

Transportation

The user enters the cost of transportation for material and/or personnel required to complete the installation of the PV system. For equipment and materials, transportation costs will vary considerably depending on the mode of transportation 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. Costs to handle the material at the receiving end should also be considered. In isolated areas, many communities can receive bulk shipments at given periods of the year either by barge, ice road or sometimes only by air. Logistical control is extremely important here. For many remote telecom sites a helicopter rental may have to be included in the transportation cost estimate. Shipping costs should be obtained from shipping agents when the scope of the project, equipment and materials are determined. As an example, a 4 kWp inverter has a weight of about 50 kg.

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Miscellaneous

This category is for all of the miscellaneous costs that occur during a project and have not been taken into account in the previous sections. For photovoltaic projects these costs can include training and contingencies.

Training

The adequate training of operators and maintenance personnel is fundamental to the successful deployment of any technology. This cost is usually very small for PV systems given their relative simplicity.

A 4 to 8 h training session by a PV system expert should be sufficient for the client to operate the PV system properly. Rates for PV 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 excluding miscellaneous 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 PV systems, it is certainly possible that the RETScreen user experienced with PV project developments could estimate costs in the range of 5 to 40% of the total initial project costs.

Annual Costs (Credits)

There may be some annual costs associated with PV systems, but they are likely to be relatively small compared to the overall system cost and other electric power generation technologies. For hybrid PV systems the cost of fuel for the fossil-fuel gensets can represent a substantial annual cost. These costs are detailed below.

O&M

Property taxes/Insurance

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

O&M labour

PV systems typically require little maintenance. Usually, the PV modules will last more than 25 years and will need minimal maintenance (e.g. occasional cleaning in dusty areas, etc.). Components of a PV system more likely to need maintenance are batteries (e.g. watering, etc.), fossil-fuel generators (e.g. oil change, etc.) and pumping equipment. An annual visual inspection is recommended to check for loose wires, structure solidity, etc. Components such as the controller or inverter should also be inspected on an annual basis although these components are more susceptible to fail completely instead of operating on an accelerated aging or wear and tear mode. The inspection of PV systems can be performed by the system owner.

The cost range for annual maintenance inspection of a PV system is between $0 and $200. Use the lower value if the inspection is done by the owner. Higher values would be more appropriate for larger and more complex PV systems where the maintenance inspection is performed by a paid technician or a system expert. Rates for system experts range from $40/h to $100/h.

Other

These input cells are provided to allow the user to enter cost or credit items that are not included in the information provided in the above cost category. The user must enter a positive numerical value in the "Unit Cost" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost. This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

A credit item may be entered in the grey input cell as "Credit." The user then selects "Credit" from the drop-down list in the unit column. The project may be credited for material and/or labour costs that would have been spent on the base case, or conventional, energy system. The user can input both a quantity amount and unit cost. Note that the credit item is expressed as a negative value in the "Amount" column.

Contingencies

A contingency allowance may be included to account for unforeseen annual expenses. Grid connected PV systems generally require no maintenance as the PV cells are a solid state device without any moving parts and the modules are designed to last over 25 years. A contingency allowance of 1 to 5% of total PV system and balance of equipment cost per year is reasonable and will depend upon the project location. For off-grid systems in isolated areas, a larger contingency allowance is probably required.

Fuel

In the case of hybrid PV systems that incorporate a genset, the cost of fuel will be given in $ per unit of volume. These costs will vary substantially depending on the type of fuel selected and the project location.

Transportation

The user enters the cost associated with the transportation of the fuel to the site. This is for the case where trips to the sites are required to specifically bring the fuel in. If transportation costs are already included in the price of the fuel or in the previous O&M section, do not duplicate here.

Periodic Costs (Credits)

This section is provided to allow the user to specify the periodic costs associated with the operation of the system over the project life. Grey input cells are provided to allow the user to enter the name of a periodic cost and periodic credit item. The user must enter a positive numerical value in the "Unit Cost" column.

A periodic cost represents recurrent costs that must be incurred at regular intervals to maintain the project in working condition. A periodic cost item is entered in the grey input cell. The user then selects "Cost" from the drop-down list in the unit column. The interval (in years) over which the periodic cost is incurred is entered in the period column. The amount of the cost incurred at each interval is entered in the unit cost column.

The energy 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 RET 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.

Energy from genset

The energy delivered by the genset (MWh) over the season of use is calculated 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, and it is copied automatically to the *Financial Summary* worksheet.

Renewable energy delivered

The *Energy Model* calculates the annual renewable energy production (MWh) of the project. This renewable energy delivered by the project also equates to the annual energy savings as compared with the base case electricity or pumping system.

For central-grid applications, the user can simulate a reverse metering scheme by entering the portion of solar energy fed back into the grid in the "PV energy absorption rate" cell of the *Energy Model*. For example, an absorption rate of 80% would be specified for a situation in which 80% of electricity produced is consumed on the premises and 20% is not fed back into the grid. The user can then specify two different electricity rates by entering the utility rate in the "Avoided cost of energy" cell and the utility buy-back rate in the "Avoided cost of excess energy" cell in the *Financial Summary* worksheet.

For isolated-grid applications, all the energy produced may not be absorbed by the grid due to a mismatch between energy demand and the energy supply. The model does not consider storage of excess renewable energy.

For water pumping applications, the renewable energy delivered corresponds to the mechanical pumping energy delivered by the PV pumping system.

Excess RE available

For "On-grid" applications, the *Energy Model* calculates the excess renewable energy available (MWh), which is the energy from the system that is not absorbed by the load and, therefore, is available as a by-product for heating or other uses in the case of isolated-grid, or is fed and sold back into the grid in the case of a central-grid.

Firm RE capacity

The firm RE capacity refers to the "guaranteed" electrical power (kW) that a renewable energy electric power project can deliver. For PV projects, which are inherently intermittent, the user enters an "avoided cost of capacity" that is agreed upon with (may need to be negotiated) the local electric utility. This avoided cost of capacity credit will depend upon the profile of the local electrical demand and energy supply conditions. In the most conservative cases, due to the intermittent nature of solar energy resources, the firm renewable energy capacity value would equal zero.

Application type

The application type is selected in the *Solar Resource & System Load (SR&SL)* worksheet and it is copied automatically to the *Financial Summary* worksheet.

Genset capacity

For "Off-grid" applications, the genset capacity (kW) of the project is entered in the *Energy Model* worksheet and it is copied automatically to the *Financial Summary* worksheet.

Nominal PV array power

For "Off-grid" applications, the nominal PV array power (kW) of the project is entered in the *Energy Model* worksheet and it is copied automatically to the *Financial Summary* worksheet.

Equivalent energy demand

For "Off-grid" applications, the equivalent DC energy demand is calculated in the *Energy Model* worksheet and it is copied automatically to the *Financial Summary* worksheet.

For water pumping applications, the equivalent pumping energy demand is calculated in the *Energy Model* worksheet and it is copied automatically to the *Financial Summary* worksheet.

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 energy system instead of the base case, or baseline, system. This value is calculated in the *GHG Analysis* worksheet and is copied here automatically to the *Financial Summary* worksheet.

Net GHG emission reduction - credit duration

The model calculates the cumulative net greenhouse gas (GHG) emission reduction for the duration of the GHG credit, in equivalent tonnes of CO_2 (t_{CO2}), resulting from the implementation of the project instead of the base, or baseline, case 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 energy system instead of the base case, or baseline, system. This value is calculated by multiplying the net annual GHG emission reduction by the life of the project.

Type of fuel displaced

The type of fuel displaced is the primary fuel source displaced by the project. The fuel type selected in the *Energy Model* worksheet is transferred here. The type of fuel displaced is used in the calculation of energy savings. Depending on the application, the following types of fuels are available in the model: Natural gas, Propane, Diesel (#2 oil), Gasoline, Kerosene, Grid mix and Other.

Financial Parameters

The items entered here are used to perform calculations in this *Financial Summary* worksheet. Values for each parameter will depend on the perspective of the user (e.g. utility vs. independent power producer or service provider).

Avoided cost of energy

The user enters the avoided cost of energy. This value typically represents either the "average" or the "marginal" unit cost of energy for the base case system and is directly related to the cost of fuel for the base case system. The user is given the flexibility in the model to determine what the base case system is. The avoided cost of energy is used in conjunction with the renewable energy delivered and, for off-grid and water pumping applications, the specific fuel consumption (entered in the *Energy Model* worksheet) to calculate the annual energy savings. The model escalates the avoided cost of energy yearly according to the energy cost escalation rate starting from year 1 and throughout the project life. For example, for on-grid applications, the base case energy costs being avoided may be for a new combined-cycle natural gas fired power plant established as a "proxy" or baseline reference case by the local utility. The user will need to determine this value. For off-grid and water pumping applications the avoided cost of energy will be the price of fuel where fossil fuel generators are defined as the "Base Case Power System."

Avoided cost of energy calculations for on-grid electric power generation usually require a relatively detailed analysis [Leng, 1993]. For electric power generation, electric utilities will normally calculate this value for their service area. This value may also be the amount that utilities may pay independent power producers (IPP) for electricity produced by the IPP. Utilities may assign a higher value where distributed generation benefits are obtainable [Leng, 1994]. A more detailed description is beyond the scope of this manual (for a more detailed description see Johansson, 1993). However, a brief description of possible values follows.

The range of values for avoided cost of energy for on-grid electric power generation will depend upon a number of factors. As an example, for a recently constructed 10 kW PV project in North America, the local utility pays a building owner approximately 12 ¢/kWh ($0.12/kWh) for electricity sold to the utility for a central-grid application. Under "net-metering" schemes the avoided cost of energy would probably equal the retail price of electricity.

For "Isolated-grid" applications, the following figure [Sigma, 1985] can be used to estimate the "ball park" avoided cost of energy for diesel fuel electric generation. Note that the values presented in this figure include diesel plant maintenance at 20% of fuel costs. As an example, from that same figure, within the normal operating efficiency of diesel generators and assuming diesel fuel costs of $0.60/L, avoided costs of energy would range from approximately $200/MWh to $300/MWh. The user needs to correct these values to $/kWh units by dividing by 1,000.

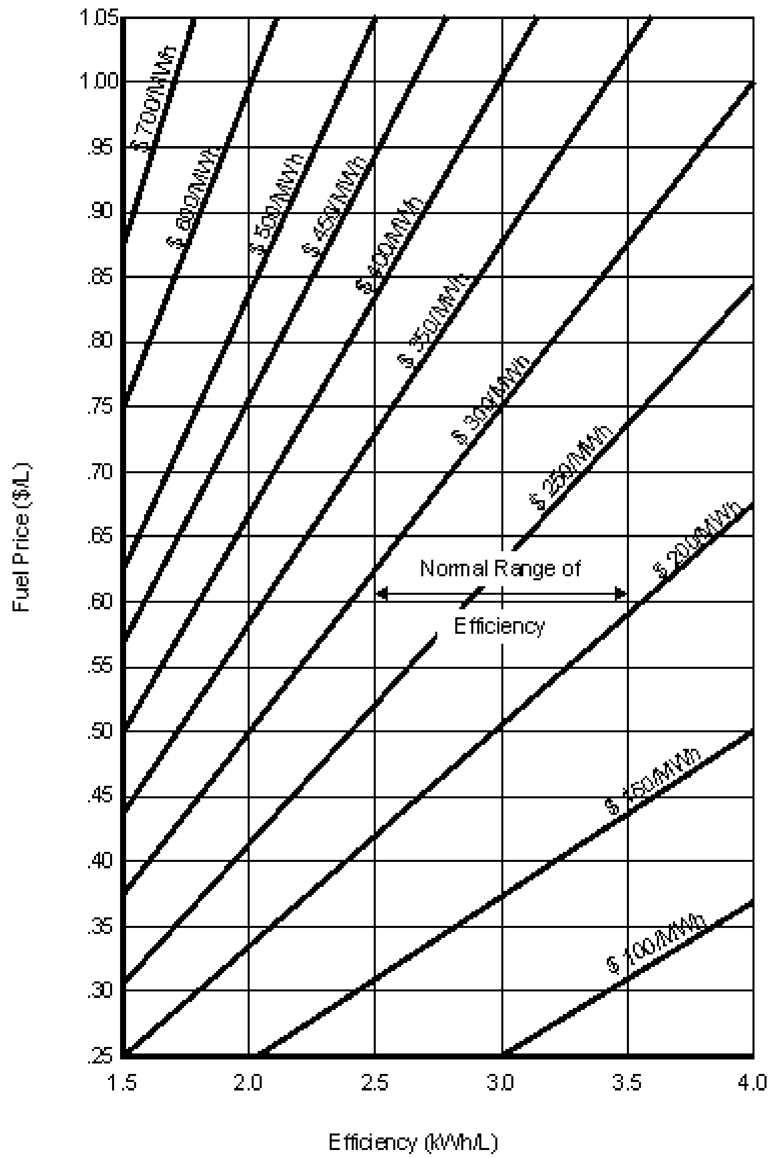
Note that the avoided cost of energy unit for propane is expressed in terms of litres of liquefied propane.

RE production credit

The user enters the renewable energy (RE) production credit per kWh. This value typically represents the amount that can be credited to the project in exchange of the production credit generated by the renewable energy delivered by the PV system. It is used in conjunction with the renewable energy delivered to calculate the annual RE production credit income.

RE production credits are most common for electricity generation from renewable energy projects. For example, it is possible to receive a tax credit of 1.5 ¢/kWh in the USA for electricity produced from wind, biomass or chicken manure. Whether or not a given project would qualify to receive such payments depends on the rules of the specific programs in the jurisdiction in which the system is installed.

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). For tax purposes, the RE production credit is treated as supplemental income. The model escalates the RE production credit value yearly according to the RE credit escalation rate starting from year 1 and throughout the RE production credit duration.



Diesel Electrical Generation Avoided Cost of Energy [Sigma, 1985]

RE production credit duration

The user enters the renewable energy (RE) production credit duration (year). This value typically represents the number of years for which the project receives a RE production credit. It is used to calculate the annual RE production credit income.

RE credit escalation rate

The user enters the renewable energy (RE) credit escalation rate (%), which is the projected annual average rate of increase in the renewable energy credit over the RE production credit duration. This allows the user to apply rates of inflation to the value of renewable energy production credits which may be different from general inflation.

GHG emission reduction credit

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

Preliminary estimates predict the market price of GHG emission reduction credits in the USA will range from $US 4 to $US 95 per tonne of CO_2, with $5 to $8 per tonne being the most likely range [Sandor, 1999]. As of 2003, the global market price has typically been in the range of $US 3 to $US 5 per tonne of CO_2.

The value entered is assumed to be representative of year 0, i.e. the development year prior to the first year of operation (year 1). The model escalates the GHG emission reduction credit value yearly according to the GHG credit escalation rate starting from year 1 and throughout the project life.

GHG reduction credit duration

The user enters the GHG reduction credit duration (year). This value typically represents the number of years for which the project receives GHG reduction credits. It is used to determine the annual GHG reduction income.

For Clean Development Mechanism (CDM) projects, two options are available for the length of the crediting period (i) a fixed crediting period of 10 years or (ii) a renewable crediting period of 7 years that can be renewed twice (for a maximum credit duration of 21 years). If a crediting period of 10 years is selected, once the project has been validated and registered, Certified Emission Reductions (CERs) can be certified and issued for the 10 years of the project without revisiting the baseline. However, in the case of a renewable 7 year crediting period, the project will have to be validated after each 7 year period in order to receive CERs for the subsequent 7 years.

Thus in selecting a crediting period, the benefits of the potentially longer crediting period of the renewable crediting period (e.g. up to 21 years) must be weighed against the additional transaction costs of re-validating the project after each 7 year period, and the risk of the project potentially not meeting validation requirements at that time.

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.

Avoided cost of excess energy

The user enters the avoided cost of excess energy per kWh. The avoided cost of excess energy may range from zero, where there is no need for the excess energy, to a value close to the local retail price for electricity.

For "On-grid" applications, to simulate reverse-metering schemes, the user must enter the utility buy-back electricity rate as the avoided cost of excess energy.

Avoided cost of capacity

The user enters the avoided cost of capacity per kW-yr. Unless the user knows this value, it is safer to assume a zero for this entry as this number is often incorporated into the "avoided cost of energy" value. If the project being evaluated has a zero "Firm RE capacity" then this item is hidden in the spreadsheet. The value of avoided cost of capacity typically represents either the "average" or the "marginal" unit cost of capacity for a base case power system. This value is directly related to the cost of generation capacity for the base case electricity system. Avoided cost of capacity calculations for electric power generation usually requires a relatively detailed analysis. For on-grid electric power generation, electric utilities will normally calculate this value for their service area. This value may also be the amount that utilities will pay IPPs for electric capacity provided to the utility. Utilities may assign a higher value where distributed generation benefits are obtainable to account for Transmission and Distribution (T&D) capacity attributes [Leng, 1994]. A more detailed description is beyond the scope of this manual (for a more detailed description, see Johansson, 1993).

As a brief example, a New England electric utility has valued avoided capacity costs at roughly $100/kW-yr for a proxy gas turbine and marginal avoided T&D costs at $250/kW-yr for central-grid applications [Leng, 1993].

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 electricity or fuel 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 purchase agreement. Although the model can analyse project life's up to 50 years, the project life of a well designed PV project 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.

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 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.

The income tax analysis allows the model to calculate after-tax cash flows and after-tax financial indicators. In all cases, the model assumes a single income tax rate valid throughout the project life and applied to net income. Note that the analysis is based, among others, on net initial and annual costs, i.e. any credits entered in the *Cost Analysis* worksheet for these two categories are not treated separately. This leads to a reasonably accurate tax analysis unless the initial and/or annual credits are of the same order of magnitude as the corresponding costs and fall under a different depreciation schedule for tax purposes.

Effective income tax rate

The user enters the effective income tax rate (%), which is the effective equivalent rate at which the net income derived from the project is taxed. For example, in most jurisdictions, this would correspond to the combined federal, provincial /state and/or local income tax rates for businesses. Net taxable income is derived from the project cash inflows and outflows assuming that all revenues and expenses are paid at the end of the year in which they are earned or incurred.

The effective income tax rate is assumed to be constant throughout the project life. Note that sales tax should be considered in the "Initial Costs" section of the *Cost Analysis* worksheet and that property tax should be considered in the "Annual Costs" section.

Loss carryforward?

The user indicates by selecting from the drop-down list whether or not losses are carried forward, i.e. whether or not a loss (a negative taxable income) in a given year can be used to lower taxes owed in that same year or can be deferred to offset profits from future years. If the user selects "Yes," losses are carried forward and applied against taxable income in the following years, thereby reducing the income tax owed up to the accumulated losses, years after the losses occur. If the user selects "No," losses are not carried forward but rather lost and thereby never used to offset any other year taxable income. If the user selects "Flow-through," losses are not carried forward but rather used in the year in which they occur and applied against profits from sources other than the project (or qualify and generate a refundable tax credit), thereby reducing the income tax owed in the years in which losses occur.

Whether losses must be carried forward or not will depend on the tax laws in the jurisdiction in which the project is located. The "Flow-through" situation is typically the most advantageous for the project owner and can contribute to make profitable a project which would not appear financially attractive on a pre-tax basis.

The model does not allow losses to be carried backward and does not set a limit on the number of years for carryforwards.

Depreciation method

The user selects the depreciation method from three options in the drop-down list: "None," "Declining balance" and "Straight-line." This selection of the yearly depreciation of assets is used in the model in the calculation of income taxes and after-tax financial indicators. The user should select the method accepted by the tax departments in the jurisdiction of the project. The difference between the "End of project life" value and its undepreciated capital costs at the end of the project life is treated as income if positive and as a loss if negative.

When "None" is selected, the model assumes that the project is fully capitalised at inception, is not depreciated through the years and therefore maintains its undepreciated value throughout its life.

When "Declining balance" is selected, the model assumes that the capitalised costs of the project, as specified by the depreciation tax basis, are depreciated at the depreciation rate. The portion of initial costs not capitalised is deemed to be expensed during the year of construction, i.e. year 0.

When "Straight line" is selected, the model assumes that the capitalised costs of the project, as specified by the depreciation tax basis, are depreciated with a constant rate over the depreciation period. The portion of initial costs not capitalised is deemed to be expensed during the year of construction, i.e. year 0.

For both declining balance and straight-line depreciation, the model assumes that the full depreciation allowed for a given year is always taken. Also, the model does not incorporate the half-year rule used in some countries and according to which depreciation is calculated over only half of the capitalised cost during the first year of operation of the equipment.

Depreciation tax basis

The user enters the depreciation tax basis (%), which is used to specify which portion of the initial costs are capitalised and can be depreciated for tax purposes. The remaining portion is deemed to be fully expensed during the year of construction (year 0).

For example, if a PV 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 equipment 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 equipment and miscellaneous costs and are inputs in the calculation of the simple payback, the net present value and the project equity and debt.

It is important to note that the range of possible costs listed throughout RETScreen **do not include sales taxes**. In a number of jurisdictions, clean energy project costs are often exempt from sales taxes. Users will have to consider these costs for their region when preparing their evaluations. For example, if in a particular region sales tax is applicable to the cost of a PV 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 equipment

The balance of equipment 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.

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

Fuel

For "Off-grid" applications with PV/battery/genset system configuration, the annual cost of fuel to run the system is transferred from the *Cost Analysis* worksheet. This value represents the cost of fuel to run the genset.

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 power producer or service provider, these "savings" will be viewed as "income." It is directly related to the avoided cost of energy derived from implementing the project. It is an input in the calculation of the simple payback and the debt service coverage.

Energy savings/income

For "On-grid" applications, the annual energy savings are equal to the sum of the product of the "Renewable energy delivered" and "Avoided cost of energy" and the product of the "Excess RE available" and the "Avoided cost of excess energy."

For "Off-grid" applications, the annual energy savings are equal to the product of the "Renewable energy delivered," "Specific fuel consumption" and "Avoided cost of energy."

For water pumping applications, the annual energy savings are equal to the product of the "Water delivered," "Specific fuel consumption" and "Avoided cost of energy."

The yearly value of energy savings is escalated at the energy cost escalation rate.

Capacity savings/income

The annual capacity savings are equal to the product of the "Firm RE capacity" and the "Avoided cost of capacity." The yearly value of capacity savings is escalated at the inflation rate.

RE production credit income - duration

The model calculates the RE production credit income, which represent the income (or savings) generated by the sale or exchange of the RE production credits during the RE production credit duration. It is calculated from the renewable energy delivered and the RE production income value. The yearly value of RE production credit income is escalated at the RE credit 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 energy 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 photovoltaic project, a negative payback period would be an indication that the annual costs incurred are higher than the annual savings generated.

The simple payback method is not a measure of how profitable one project is compared to another. Rather, it is a measure of time in the sense that it indicates how many years are required to recover the investment for one project compared to another. **The simple payback should not be used as the primary indicator to evaluate a project**. It is useful, however, as a secondary indicator to indicate the level of risk of an investment. A further criticism of the simple payback method is that it does not consider the time value of money, nor the impact of inflation on the costs.

On the other hand, the payback period is often of great importance to smaller firms that may be cash poor. When a firm is cash poor, a project with a short payback period, but a low rate of return, might be preferred over another project with a high rate of repayment, but a long payback period. The reason is that the organisation may simply need a faster return of its cash investment. The model uses the total initial costs, the total annual costs (excluding debt payments) and the total annual savings, in order to calculate the simple payback. The calculation is based on pre-tax amounts and includes any initial cost incentives.

Year-to-positive cash flow

The model calculates the number of years to positive (cumulative) cash flow, which represents the length of time that it takes for the owner of a project to recoup its own initial investment out of the project cash flows generated. The year-to-positive cash flow considers project cash flows following the first year as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. The model uses the year number and the cumulative after-tax cash flows in order to calculate this value.

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

Net Present Value - NPV

The model calculates the net present value (NPV) of the project, which is the value of all future cash flows, discounted at the discount rate, in today's currency. NPV is thus calculated at a time 0 corresponding to the junction of the end of year 0 and the beginning of year 1. Under the NPV method, the present value of all cash inflows is compared against the present value of all cash outflows associated with an investment project. The difference between the present value of these cash flows, called the NPV, determines whether or not the project is generally a financially acceptable investment. Positive NPV values are an indicator of a potentially feasible project. In using the net present value method, it is necessary to choose a rate for discounting cash flows to present value. As a practical matter, organisations put much time and study into the choice of a discount rate. The model calculates the NPV using the cumulative after-tax cash flows. In cases where the user has selected not to conduct a tax analysis, the NPV calculated will be that of the pre-tax cash flows.

Annual Life Cycle Savings

The model calculates the annual life cycle savings (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 energy production cost?

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

Energy production cost

The model calculates the energy production cost per kWh. The energy production cost could be used to either calculate the avoided cost of energy for the project to break even or the economic energy production cost. Hence it is the value that, when assigned to the avoided cost of energy, results in a NPV of zero and thus the after-tax IRR is equal to the discount rate. The energy production cost is calculated assuming that all financial parameters other than the avoided cost of energy are kept constant.

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 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 PV 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 Workbook file has been developed with a common framework so as to simplify the task of the user in analysing the viability of different projects. Hence the description of each parameter is common for most of the items appearing in the worksheet. One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers.

The *GHG Analysis* worksheet with its emission related input items (e.g. fuel mix, fuel conversion efficiency) and its calculated emission factor output items (e.g. GHG emission factor), allows the decision-maker to consider various emission parameters with relative ease. However, the user should be aware that this ease of use may give a project developer a too optimistic and simplified view of what is required in setting a baseline for a proposed project. As such, it is suggested that the user **take a conservative approach in calculating the baseline emission factor for the project**, particularly at the pre-feasibility analysis stage. In order to determine the net benefits of obtaining carbon finance for the project, the user can evaluate the project twice, once including the value of the carbon credits and the associated transaction costs and once without, and then compare the results.

Use GHG analysis sheet?

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

If the user selects "Yes" from the drop-down list, then the user should complete the *GHG Analysis* worksheet. Certain input fields will be added to the *Financial Summary* worksheet in order to calculate the GHG emission reduction income and cost.

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

Type of analysis

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

Background Information

Project name

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

Project location

The user-defined project location for reference purposes only, as entered 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 PV 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.

For example, in North America when preparing a GHG emission reduction analysis for a PV 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 PV 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.

For "Off-grid" applications, the user selects the base case electricity system in the *Energy Model* worksheet from the following list of available power sources: Genset, Thermoelectric generator, Grid extension, Non-rechargeable batteries, Lantern and Other.

For "Water pumping" applications, the user selects the base case electricity system in the *Energy Model* worksheet from the following list of available power sources: Genset, Grid extension, Engine driven pump and Other mechanical pump.

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

For "On-grid" projects and for applications where the base case power/energy source is "Grid extension," the user selects the fuel type from the options in the drop-down list. The RETScreen software can model the GHG emissions of any electricity supply system. The fuel type is the fuel(s) or power plant(s) which will be displaced by the proposed project.

For "Off-grid" and "Water pumping" applications that do not use "Grid extension" as the base case power/energy source, the user selects the fuel type in the *Energy Model* worksheet and it is copied automatically to the *GHG Analysis* worksheet.

For "Standard" projects, 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

For "On-grid" projects for applications where the base case power/energy source is "Grid extension," the user enters the fuel mix (%) of the base case electricity system for each fuel type.

For "Off-grid" and "Water pumping" applications that do not use "Grid extension" as the base case power/energy source, there is a single fuel type displaced and the fuel mix is thus set to 100%.

Units are given as percentages of total end-use energy supplied. Note that the sum of all fuel types listed in the fuel mix column should equal 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 "On-grid" projects and for applications where the base case power/energy source is "Grid extension," 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 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 "Off-grid" and "Water pumping" applications, the user should enter emission factors representative of the power source for the system specified, e.g. emission factors typical of internal combustion engines should be entered for systems that include the use of a genset.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heat 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)

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, if any, 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)

For "On-grid" projects and for applications where the base case power/energy source is "Grid extension," 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 useful 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).

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 useful energy output (gigajoules of electricity, lighting energy or pumping energy). Fuel types which do not involve a thermal to electric conversion (e.g. hydro) 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 useful 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).

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 useful energy output (gigajoules of electricity, lighting energy or pumping energy). Fuel types which do not involve a thermal to electrical conversion (e.g. hydro) 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, if any. For "On-grid" projects and for applications where the base case power/energy source is "Grid extension," 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).

Proposed Case Electricity System (Photovoltaic Project)

The proposed case electricity system, or mitigation system, is the proposed project.

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

Fuel type

The fuel type of the PV project is assumed to be entirely solar, except for "Off-grid" applications for which the PV/batteries/genset configuration has been selected. In this case the fuel mix will be the percentage of the energy supplied by each fuel type, i.e. solar and genset fuel type.

Fuel mix

The fuel mix of the PV project is assumed to be entirely solar, except for "Off-grid" applications for which the PV/batteries/genset configuration has been selected. In this case the fuel mix will be the percentage of the energy supplied by each fuel type, i.e. solar and genset fuel type.

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 fuel type, i.e. the proposed system.

Units are given in kilograms of gas emitted per gigajoule of end-use energy (kg/GJ).

CO_2, CH_4 and N_2O emission factors

(Standard analysis)

The model provides default values for the CO_2, CH_4 and N_2O emission factors corresponding to the fuel type, i.e. the proposed system. The default values provided by the model are given in the Default Emission Factors and Conversion Efficiencies table.

Units are given in kilograms of gas emitted per gigajoule of end-use energy (kg/GJ).

Fuel conversion efficiency

If the user selects "Standard" type of analysis, the solar energy conversion efficiency is set to 100% for all applications, except "Water pumping." For water pumping applications the fuel conversion efficiency equals the PV pump system efficiency specified in the *Energy Model* worksheet.

For PV/battery/genset configurations, the genset fuel conversion efficiency is calculated from the specific fuel consumption, as entered in the *Energy Model* worksheet.

For "Custom" type of analysis, the user enters the solar energy conversion efficiency.

The fuel conversion efficiency is used in conjunction with the CO_2, CH_4 and N_2O emission factors and the transmission and distribution losses, if any, to calculate the aggregate GHG emission factor for the proposed project.

Transmission and distribution losses

The user enters the transmission and distribution (T & D) losses (%) of the proposed case PV project, which includes all energy losses between the point at which the power plant is connected to the grid and the end-user. This value will vary based on the voltage of transport lines, the distance from the site of energy production to the point of use, peak energy demands, ambient temperature and electricity theft. In addition, T & D system type (e.g. AC vs. DC) and quality may also influence losses.

Units are given as a percentage of all electricity losses to electricity generated. As a first estimate, it is reasonable to assume T & D losses of 8 to 10% in modern grids in industrialised countries and 10 to 20% in grids located in developing countries.

GHG emission factor

The model calculates the GHG emission factor for the PV project. 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 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.

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 end-use energy delivered for the base case system.

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

Proposed case GHG emission factor

The model transfers the PV project GHG emission factor calculated in the proposed case electricity system section. This value represents the amount of GHG emitted per unit of end-use energy delivered if the PV project is installed.

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

End-use annual energy delivered

The model calculates the end-use annual energy delivered by the PV project which is the amount of PV energy delivered to the electricity grid for "On-grid" applications, as calculated in the *Energy Model* worksheet, minus the T & D losses for the grid vis-à-vis the proposed project. For "Off-grid" and "Water pumping" applications it is simply the amount of end-use annual energy delivered to the load.

Note that for an "Off-grid" application with a PV/battery/genset configuration, the end-use annual energy delivered corresponds to the sum of the renewable energy delivered and the genset energy delivered.

Units are given in megawatt-hours of end-use 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 energy delivered by the PV project on an annual basis.

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 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 energy

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

The user enters the avoided cost of energy range. The range is a percentage corresponding to the uncertainty associated with the estimated avoided cost of 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 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 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 40,000 MWh means that the RE delivered could take any value between 36,000 and 44,000 MWh. Since 40,000 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 $300,000 means that the initial costs could take any value between $270,000 and $330,000. Since $300,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the initial costs are known exactly by the user (no uncertainty), the user should enter a range of 0%.

Annual costs

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

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

For example, a range of 10% for an annual cost of $800 means that the annual cost could take any value between $720 and $880. Since $800 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%.

RE production credit

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

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

For example, a range of 10% for a RE production credit of $0.05/kWh means that the RE production credit could take any value between $0.045/kWh and $0.055/kWh. Since $0.05/kWh is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the RE production 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 "PV module type" selected by the user in the *Energy Model* worksheet. From the dialogue box the user selects the Region, Supplier, Model and the Number of PV modules. 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 "User-Defined PV Module 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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CANMET Energy Technology Centre - Varennes
Natural Resources Canada
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Varennes, Quebec, CANADA J3X 1S6
Tel: +1-450-652-4621
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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 provided 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 resource maps or 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 RETScreen Training & Support at the following Website address: www.retscreen.net/e/training/

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