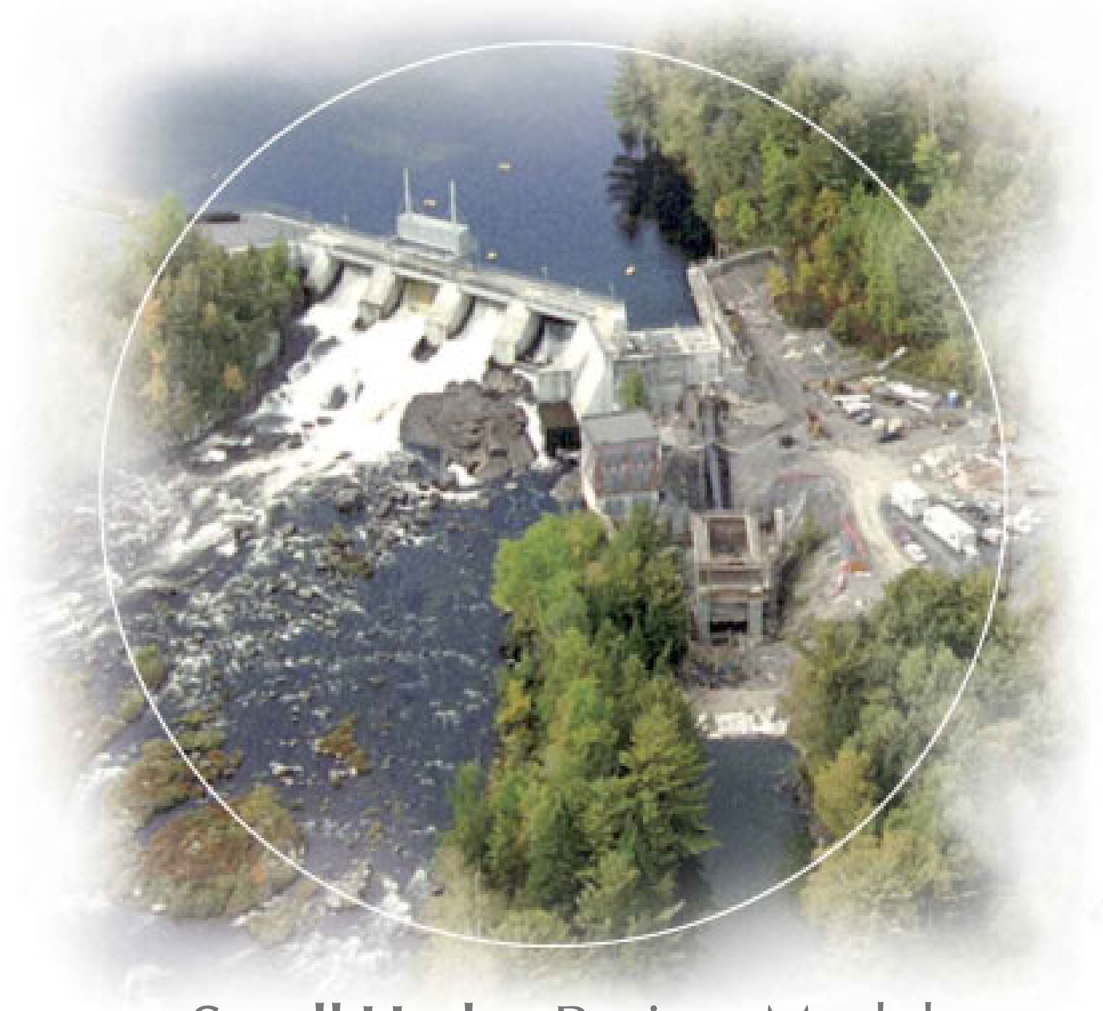
RETScreen® International
Clean Energy Decision Support Centre
www.retscreen.net

# RETScreen® Software Online User Manual



## Small Hydro 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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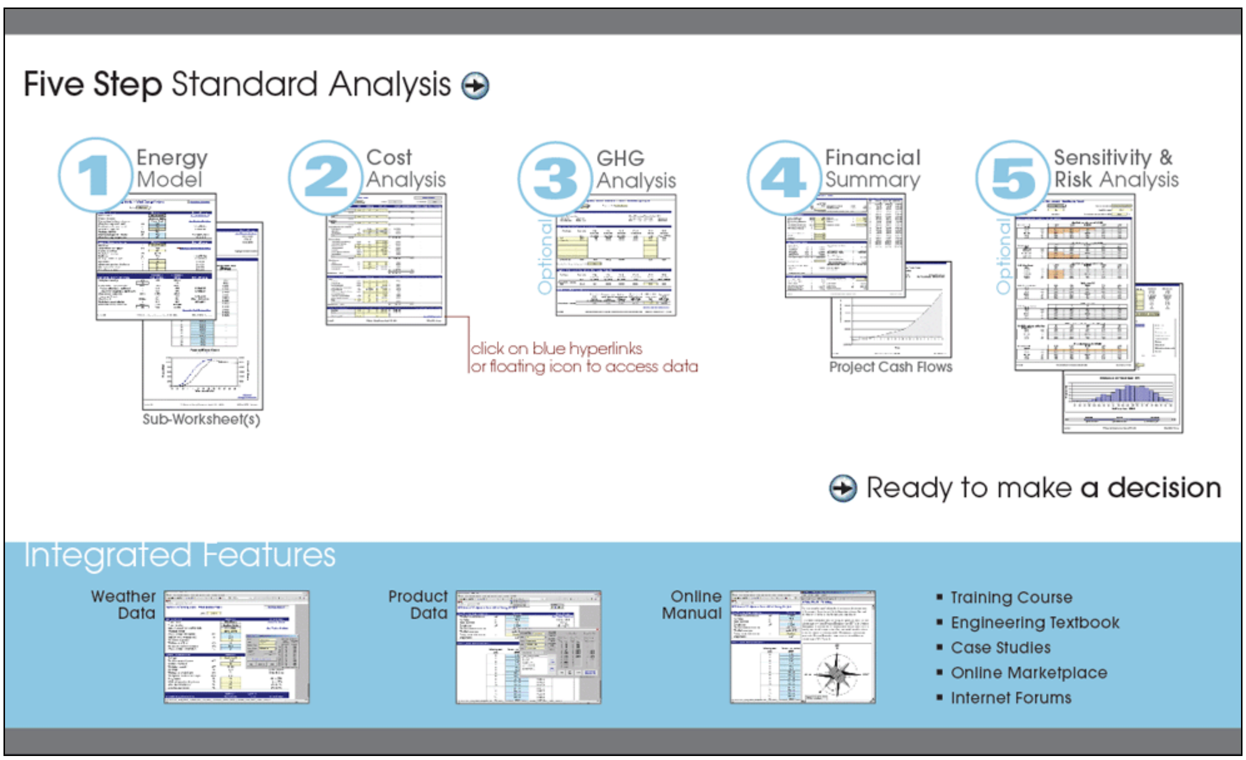
# Brief Description and Model Flow Chart

**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 technology model (e.g. Small Hydro 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

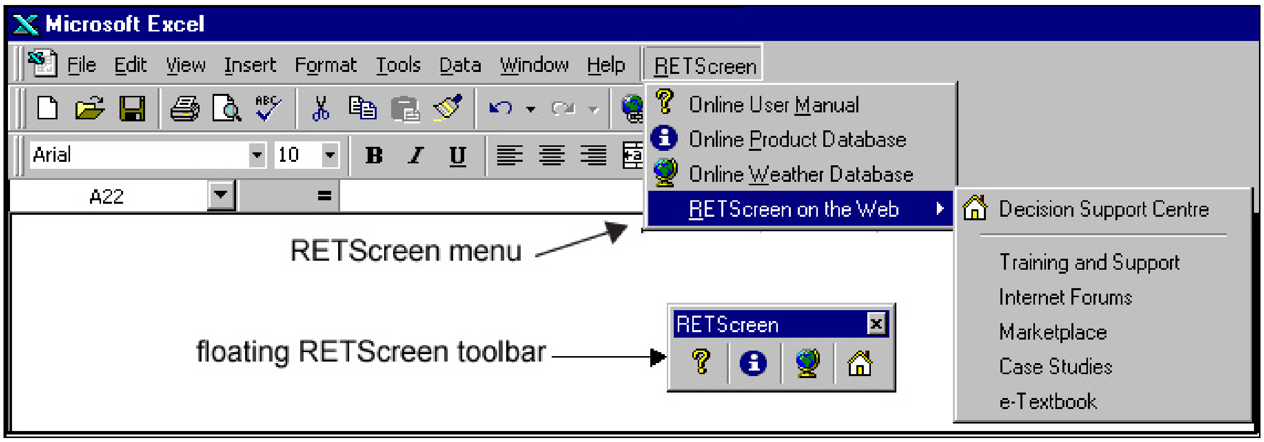
Complete each worksheet row by row from top to bottom by entering values in shaded cells. To move between worksheets simply "click" on the tabs at the bottom of each screen or on the "blue-underlined" hyperlinks built into the worksheets. The RETScreen Model Flow Chart is presented below.




**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.

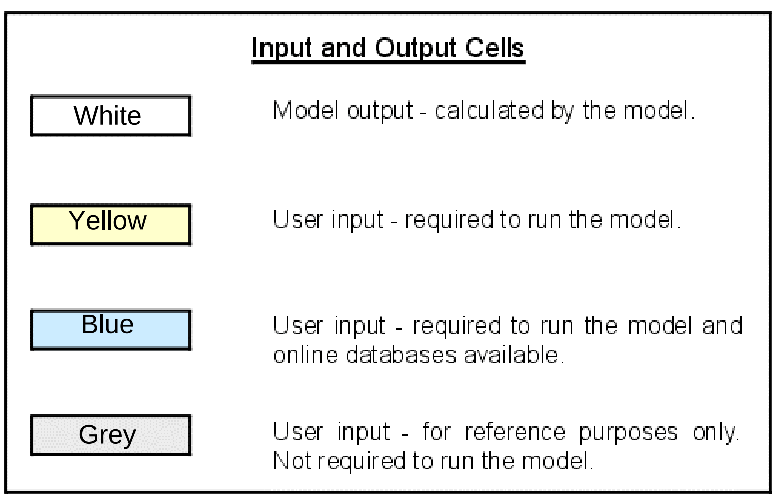



**RETScreen Menu and Toolbar**

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 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.

| Name of unit | Symbol for unit |
|---|---|
| ampere | A |
| day | d |
| degree Celsius | °C |
| dollar | $ |
| hectare | ha |
| hertz | Hz |
| hour | h |
| joule | J |
| kilogram | kg |
| kilometre | km |
| kilowatt | kW |
| litre | L |
| megawatt | MW |
| metre | m |
| pascal | Pa |
| percentage | % |
| person day | p-d |
| person trip | p-trip |
| person year | p-yr |
| second | s |
| tonne | t |
| volt | V |
| watt | W |
| week | wk |
| year | yr |

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

**List of Units, Symbols and Prefixes**

## Units, Symbols & Prefixes

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

## Unit Options

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

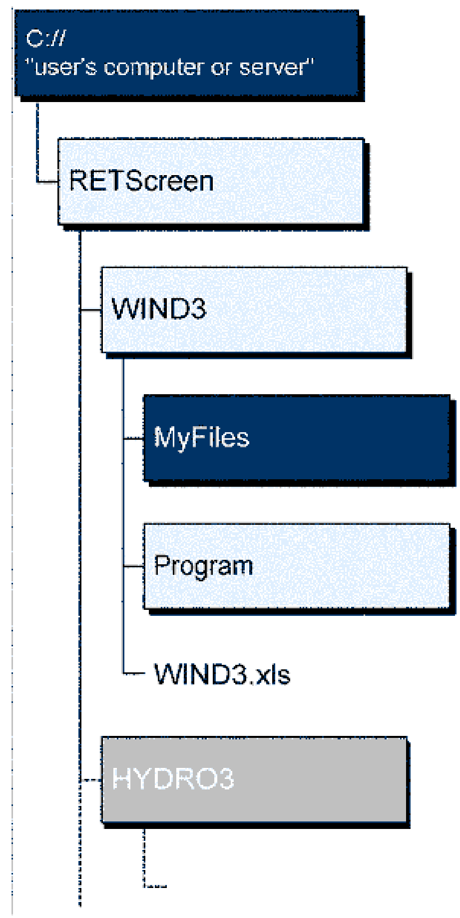
If the user selects "Metric," all input and output values will be expressed in metric units. But if the user selects "Imperial," input and output values will be expressed in imperial units where applicable.

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

## Saving a File

To save a RETScreen Workbook file, standard Excel saving procedures should be used. The original Excel Workbook file for each RETScreen model 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.

# Small Hydro Project Model

The RETScreen® International Small Hydro Project Model can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for central-grid, isolated-grid and off-grid small hydro projects, ranging in size from multi-turbine small and mini hydro installations to single-turbine micro hydro systems.

Seven worksheets (*Energy Model*, *Hydrology Analysis and Load Calculation (Hydrology & Load), Equipment Data, Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis), Financial Summary* and *Sensitivity and Risk Analysis (Sensitivity)*) are provided in the Small Hydro Project Workbook file.

The *Energy Model*, *Hydrology & Load* and *Equipment Data* 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 small hydro 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 Small Hydro 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* worksheet is used to help the user calculate the annual energy production for a small hydro project based upon local site conditions and system characteristics. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies.

# Units

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

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

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

# Site Conditions

The site conditions associated with estimating the annual energy production of a small hydro 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.

# Latitude of project location

The latitude of project location is given for reference purposes only. The user enters the geographical latitude for the intake location of the proposed small hydro project 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.

## Longitude of project location

The longitude of project location is given for reference purposes only. The user enters the geographical longitude for the intake location of the proposed small hydro project in degrees measured from the Greenwich meridian. Longitudes east of the Greenwich meridian are entered as positive values and longitudes west of the Greenwich meridian are entered as negative values.

## Gross head

The user enters the gross head, which is the drop in elevation at the site. This value is used to calculate the potential power output at the site. If the gross head at the site is unknown, it might be available from the International Energy Agency's International Small-Hydro Atlas.

To determine the head manually, a site survey is required unless very large-scale and accurate mapping is available. This is especially important for low-head small hydro because of the small differences in elevation involved, where the elevation drop can be 10 m or less. The scale of mapping required for determining such a drop would have to be at least 1:5,000.

For projects that incorporate a canal, the gross head is the drop in elevation as measured from the end of the canal to the tailrace. Hence the gross head does not include any drop in elevation arising from a canal. The drop in elevation over the length of the canal can be approximated assuming that the canal drops approximately 1 m every 1,000 m (i.e. has a 0.001 slope). When using the formula costing method (described later) the approximate loss of head over the length of the canal is calculated and provided to assist the user in selecting the appropriate gross head for the site.

For reservoir projects, the anticipated reservoir draw down needs to be taken into account when specifying a value for the gross head of the project. For the purposes of RETScreen the average gross head can be used (based on the anticipated average reservoir level).

## Maximum tailwater effect

The user enters the maximum reduction in available gross head that will occur during times of high flows in the river.

At most sites, during high flows, the tailwater level rises more than the level upstream of the intake and causes a reduction in the gross head. Consequently, during these periods, less power and energy are available. The tailwater effect can be significant, especially for low-head sites.

## Residual flow

The user enters the residual flow in the *Hydrology & Load* worksheet and it is copied automatically to the *Energy Model* worksheet.

**Note:** At this point, the user should complete the *Hydrology & Load* worksheet to specify the flow data and the energy demand data (for isolated-grid and off-grid applications) for the site under study.

## Firm flow

The model calculates the firm flow in the *Hydrology & Load* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Peak load

The user enters the peak load in the *Hydrology & Load* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Energy demand

The model calculates the energy demand in the *Hydrology & Load* worksheet and it is copied automatically to the *Energy Model* worksheet.

## System Characteristics

The system characteristics associated with estimating the annual energy production of a small hydro project are detailed below.

## Grid type

The grid type is selected in the *Hydrology & Load* worksheet, and it is copied automatically to the *Energy Model* worksheet.

## Design flow

For the purposes of the RETScreen Small Hydro Project Model, the design flow is defined as the maximum flow that can be used by the turbine.

The selection of the design flow depends, primarily, on the available flow (hydrology) at the site. For central-grid connected run-of-river projects the optimum design flow is usually close to the flow that is equalled or exceeded about 30% of the time. For isolated-grid and off-grid applications, the flow required to meet the peak load may be the deciding factor for selecting the design flow, provided that this flow is available.

## Turbine type

The user selects the type of turbine in the *Equipment Data* worksheet and it is copied automatically to the *Energy Model* worksheet.

**Note:** At this point, the user should complete the *Equipment Data* worksheet to specify the small hydro equipment for the project.

## Number of turbines

The user enters the number of turbines in the *Equipment Data* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Turbine peak efficiency

The turbine peak efficiency is calculated in the *Equipment Data* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Turbine efficiency at design flow

The turbine efficiency at design flow is calculated in the *Equipment Data* worksheet and it is copied automatically to the *Energy Model* worksheet.

## Maximum hydraulic losses

The user enters a value that represents the estimated equivalent hydraulic losses (%) in the water passages. This value is used in combination with the gross head, design flow and the various efficiencies/losses to calculate the plant capacity.

In a small hydro system, energy is lost as water flows through the water passages. A value of 5% is appropriate for most small hydro plants. For plants with very short water passages, a value of 2% is appropriate. For low-head small hydro plants with long water passages, the factor can be increased to 7%.

When using the formula costing method care must be taken to ensure that the maximum hydraulic losses are equal to or greater than the sum of the individual losses for each of the selected water conveyance structures. For more details the user may refer to the "Formula Costing Method" in the *Cost Analysis* worksheet and also to the description of "Gross head."

## Generator efficiency

The user enters a value corresponding to the estimated generator efficiency (%) at plant capacity. This value is used in combination with the gross head, design flow and the various efficiencies/losses to calculate the plant capacity of the small hydro plant.

Generator efficiencies can range from 93 to 97%. In many small hydro systems, a gearbox, or speed increaser, between the turbine and generator is required to match the ideal rotational speeds of each. A gearbox also permits the use of high-speed, lower cost generators but reduces the overall efficiency of the plant by approximately 2%.

A value of 95% represents the efficiency of most generators used for small hydro plants. This value should be reduced to 93% for plants that require a gearbox (based on information provided by a turbine manufacturer).

## Transformer losses

The user enters a value corresponding to the estimated transformer losses (%) at plant capacity. This value is used in combination with the gross head, design flow and the various efficiencies/losses to calculate the plant capacity. Transformer losses are typically minor. A value of 1% is appropriate as an estimate of transformer losses.

A transformer is generally required to match the voltage of the generator with that of the transmission line or distribution system to which it is connected.

## Parasitic electricity losses

The user enters a value which represents the estimated equivalent parasitic electricity losses (%) of the system. This value is used in combination with the gross head, design flow and the various efficiencies/losses to calculate the plant capacity.

Some of the energy generated by a small hydro plant is used by the plant itself for auxiliary equipment (e.g. shut-off valves, by-pass gates, protection and control systems, etc.) lighting, heating, etc. For small hydro, parasitic electricity losses are typically minimal. Parasitic electricity losses can range from 1 to 3%. A value of 2% is appropriate for most small hydro plants.

## Annual downtime losses

The user enters a value to represent the estimated percentage of time that the small hydro plant will have to be shut down in order to carry out routine and emergency maintenance. This value is one of the factors used to calculate the available annual energy production of the small hydro plant.

A value of 4% represents approximately 15 days of downtime (assuming 100% capacity factor) and is an appropriate value for most small hydro plants. For small hydro plants located in regions where increased maintenance requirements are anticipated (e.g. due to ice problems), more downtime should be anticipated and a higher value (e.g. 6%) should be used.

## Annual Energy Production

Items associated with calculating the annual energy production of a small hydro project are detailed below.

## Small hydro plant capacity

The model calculates the small hydro plant capacity, or maximum power output of the site in kW, as defined by the gross head, design flow and the efficiencies/losses. Note that the plant capacity, as defined in RETScreen, is the output of the site as delivered to the grid (central-grid or isolated-grid) or to the off-grid application and not the installed capacity. The installed capacity is a term that refers to the output of the turbine(s) and generator(s) and does not take into account the parasitic losses.

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

## Small hydro plant firm capacity

The model calculates the firm capacity (kW) at the site based on the firm flow, the gross head, design flow and efficiencies/losses. This value is compared to the plant capacity and the lower of the two values is entered as the firm capacity.

For isolated-grid and off-grid applications, comparing the firm capacity with the peak load provides an indication of the additional power that is required from other sources (e.g. diesel generators). This value is transferred to the *Financial Summary* worksheet as an input to conduct the financial analysis.

## Available flow adjustment factor

The available flow adjustment factor provides the user with a means to adjust the renewable energy available and is provided primarily for purpose of conducting sensitivity analyses. Using this adjustment factor, the user can easily check the effect of changes in the renewable energy available on the project's financial viability.

The available flow adjustment factor is applied to each value in the flow-duration curve as selected in the *Hydrology & Load* worksheet during the calculation of the renewable energy available (e.g. a value of 1.1 increases each value in the flow-duration curve by 10%). Note that the available flow adjustment factor does not change the values in the *Hydrology & Load* worksheet.

## Small hydro plant capacity factor

The model calculates the available annual capacity factor (%) based on the renewable energy available and the plant capacity. Typical values range from 40 to 95%.

The average output of a small hydro plant compared to its plant capacity is expressed as the annual capacity factor. The annual capacity factor is a measure of the available flow at the site and how efficiently it is used. For a selected river with a given small hydro system design, the higher the design flow, the lower the capacity factor. Provided that there are no restrictions on the maximum output of a small hydro plant, the optimum size of the plant will depend primarily on the availability of water (illustrated by the flow-duration curve). At some point, the cost of building a larger plant cannot be justified by the resulting increase in energy production. Typically, for a run-of-river small hydro plant, this point is usually close to the mean flow at the site.

## Renewable energy available

For "Isolated-grid" and "Off-grid" grid types, the model calculates the annual renewable energy available (MWh) from the small hydro plant based on the adjusted available flow (adjusted flow-duration curve), the design flow, the residual flow, the gross head and the efficiencies/losses.

## Renewable energy delivered

The model calculates the annual renewable energy delivered (MWh) based on the adjusted available flow (adjusted flow-duration curve), the design flow, the residual flow, the load (load-duration curve), the gross head and the efficiencies/losses. The calculation involves comparing the daily renewable energy available to the daily load-duration curve for each of the flow-duration curve values. The renewable energy delivered 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," "MJ." This value is for reference purposes only and is not required to run the model.

## Excess RE (Renewable Energy) available

For "Isolated-grid" and "Off-grid" grid types, the model calculates the excess renewable energy available (MWh), which is the difference between the renewable energy available and the renewable energy delivered. The value is transferred to the *Financial Summary* worksheet as an input to conduct the financial analysis.

## Flow-Duration and Power Curves

This graph shows the relationship between the available flow (FDC), the flow used by the small hydro plant and the corresponding power that would be generated. The line representing the available power is based on the site conditions (gross head, tailwater effect, residual flow) and the system characteristics (gross head, turbine type, efficiencies and losses) over the range of available flows.

# Hydrology Analysis and Load Calculation

As part of the RETScreen Clean Energy Project Analysis Software, the *Hydrology Analysis and Load Calculation* worksheet is used to enter the flow data and the electrical demand data (for isolated-grid and off-grid applications) for the site under study. The data entered in this worksheet provides the basis for calculating the renewable energy that is available and delivered. The results of this worksheet are transferred to the *Energy Model* worksheet. The user should return to the *Energy Model* worksheet after completing the *Hydrology & Load* worksheet.

# Hydrology Analysis

To complete the hydrology analysis the user must select the project type and the hydrology method to be used as well as provide the corresponding hydrology parameters that are required.

# Project type

The user selects the type of project from the two options in the drop-down list: "Run-of-river" and "Reservoir." For reservoir projects, the user must directly enter the flow-duration curve data that takes into account the effect of storage.

# Hydrology method

The user selects the hydrology method from the two options in the drop-down list: "Specific run-off" and "User-defined." When "User-defined" is selected the flow-duration curve data is entered directly by the user. The "Specific run-off" method is used in conjunction with the RETScreen Online Weather Database.

# Hydrology Parameters

The hydrology parameters that are required depend on the project type and the hydrology method selected.

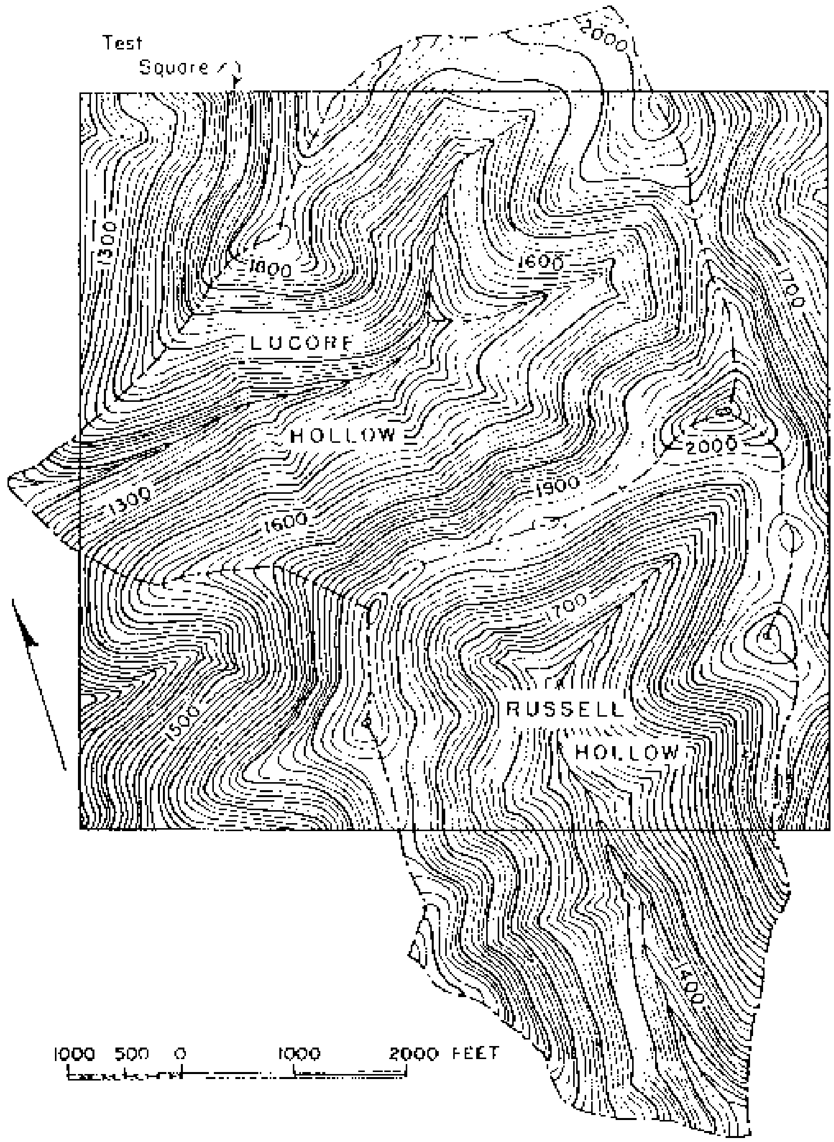
# Mean flow method

The user selects the mean flow method from the two options in the drop-down list: "Calculated" and "User-defined." If "Calculated" is selected, the model calculates the mean flow based on drainage area above site and specific run-off. If "User-defined" is selected, the user enters the mean flow.

# Drainage area above site

The user enters the drainage area above the site. The drainage area above the site is the area of land that collects precipitation, which contributes to the flow of water in the river at the site. This value is used to estimate the mean streamflow at the site.

The drainage area for the site might be available in the International Energy Agency's International Small-Hydro Atlas or from previous hydrological studies. If the drainage area is unknown, it can be delineated manually by using 1:250,000 or larger scale topographic maps. Starting at the site, a line is drawn which represents the approximate boundary of the drainage area. Land outside the drainage area boundary contributes to flow in other streams and rivers. An example is illustrated in the following figure [Leopold, 1974]. The user may also refer to [Acres, 1984] for more information. For areas where delineation of the drainage area is difficult (flat terrain), assistance from an expert might be required.



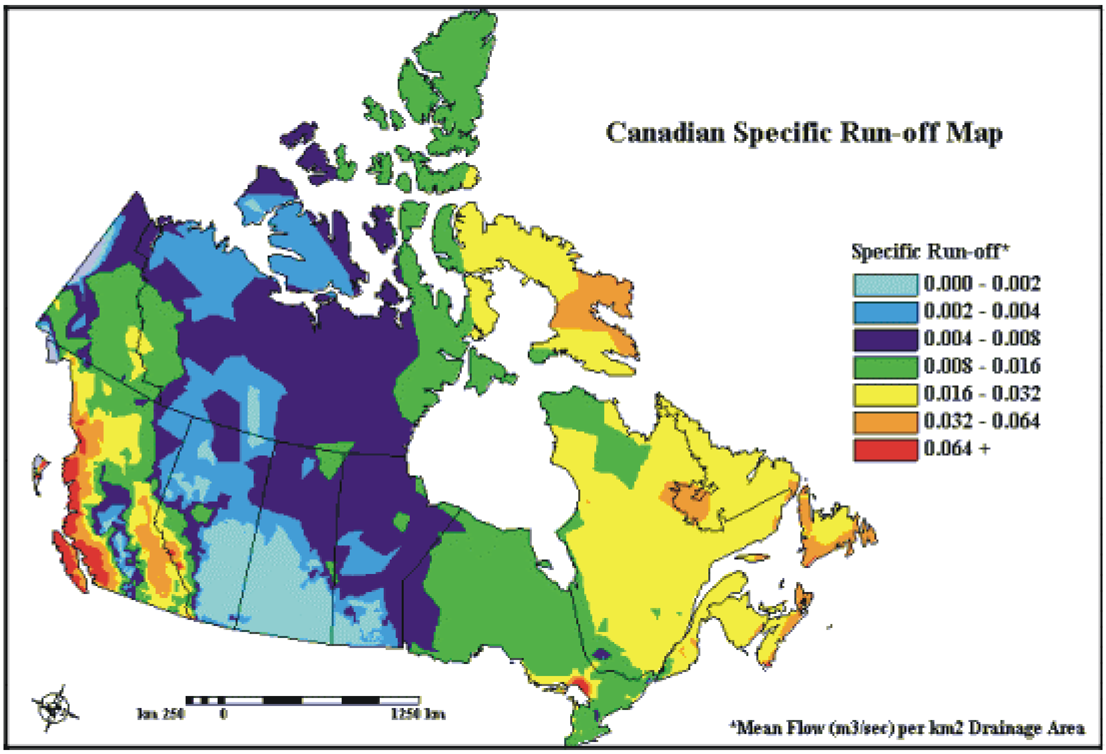

**Example of Drainage Area Delineation**

## Specific run-off

The user enters the specific run-off. For projects where a hydrologic assessment has already been undertaken, the user enters the corresponding flow-duration curve values by selecting the user-defined hydrology method and entering the flow-duration curve data.

## Canadian Specific Run-Off Map

For projects in Canada, the user may refer to the figure below to estimate the specific run-off at the small hydro site.




**Canadian Specific Run-Off Map**

## Mean flow

If the "Calculated" option is selected for the "Mean flow method," the model calculates the estimated mean flow based on the drainage area above site and the specific run-off. If the "User-defined" option is selected for the "Mean flow method," the user enters this value.

## Residual flow

The user enters the residual flow that must be left in the river throughout the year for environmental reasons. The residual flow is deducted from the available flow as part of the calculation of available energy.

The residual flow can have a significant effect on the available energy of a small hydro plant and selecting a value may be difficult without conducting environmental studies. A value of 0 can be used initially but will lead to optimistic results. Varying the residual flow value should be done as part of a sensitivity analysis.

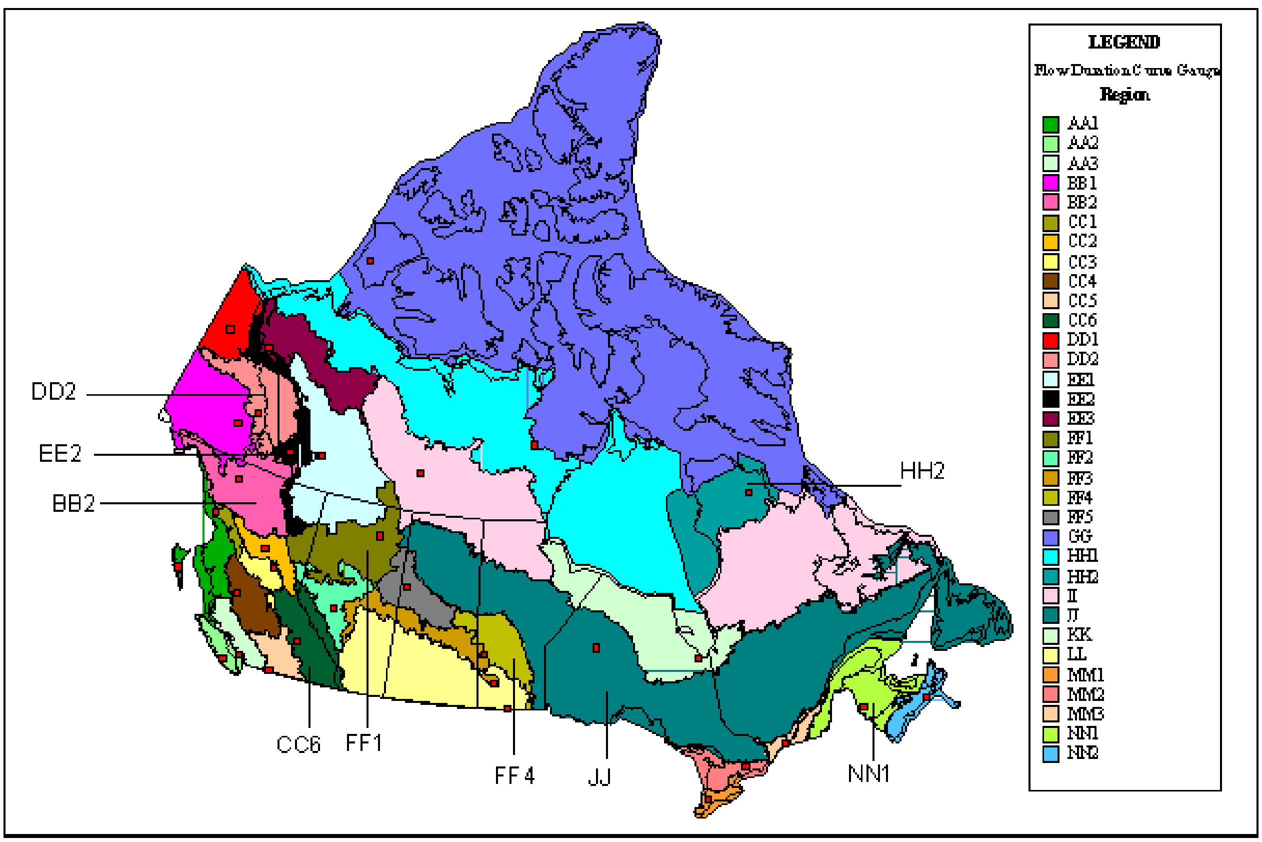
## FDC type / Proxy gauge #

The user enters the Flow-Duration Curve (FDC) type or proxy gauge number using information in the RETScreen Online Weather Database or other sources of data. Where it has been determined that a specific gauge represents the hydrology more accurately than the general FDC type, a proxy gauge can be selected from the RETScreen Online Weather Database.

If the hydrology at the site is known, the user can enter the corresponding flow-duration curve values directly, by selecting "User-defined" as the hydrology method.

## Canadian Regional Flow-Duration Curves

For projects in Canada, the user may refer to the figure below to estimate the flow-duration curve at the small hydro site. Daily flow-duration curves (i.e. calculated using average daily streamflow data) can be used to estimate the small hydro energy available at Canadian sites. The curves have been normalised, i.e. flows are expressed as a ratio of the mean flow.




**Canadian Regional Flow-Duration Curves**

## Percent time firm flow available

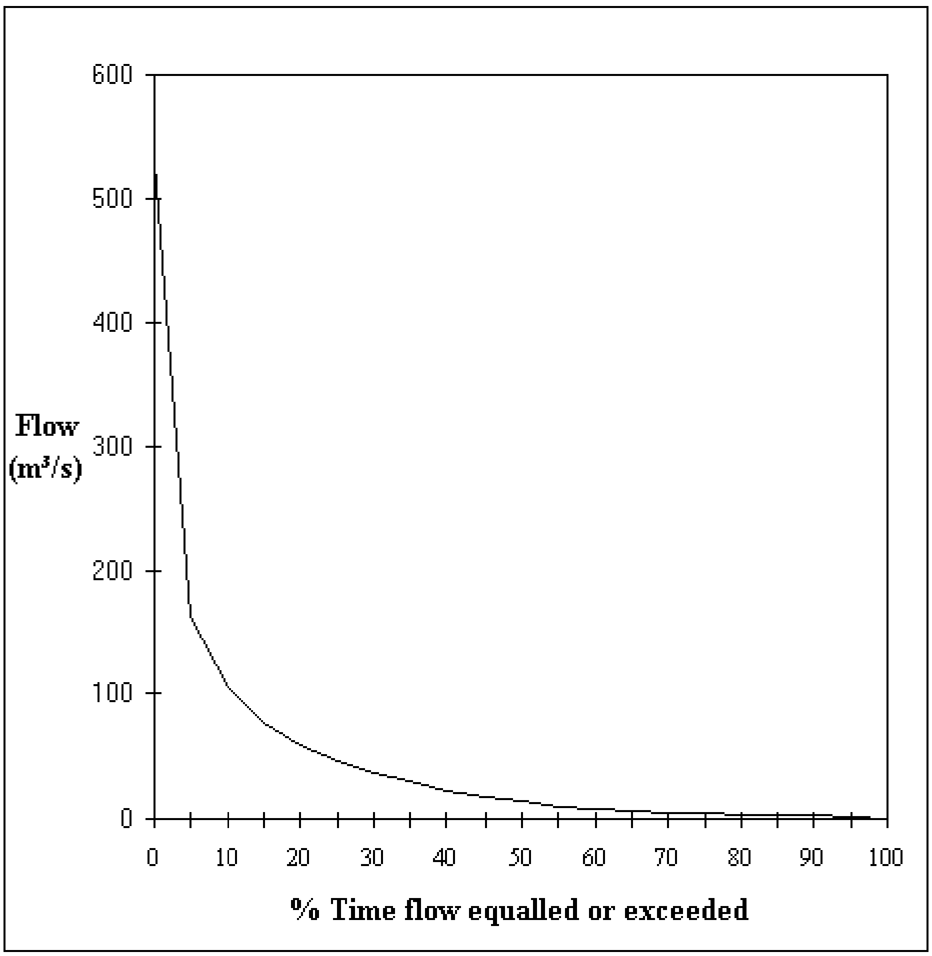
The user enters the percentage of the time that the firm flow should be available. Typical values range from 90 to 100%.

## Firm flow

The model calculates the firm flow that will be available for electricity production based on the flow-duration curve data, the percentage of time the firm flow should be available and the residual flow. The firm flow is often defined as the flow available at least 95% of the time.

## Flow-Duration Curve

A flow-duration curve (FDC) is a graph of the historical flow at a site ordered from maximum to minimum flow. An example is shown in the figure below. The flow-duration curve is used to assess the anticipated availability of flow over time, and consequently the power and energy, at a site.




**Sample Flow-Duration Curve**

It should be noted again that each small hydro site is unique. In the absence of site specific hydrologic information, the specific run-off method used in the RETScreen model for assessing the hydrology at a site will provide useful preliminary information. The user can consult the RETScreen Online Weather Database for more information.

## Load Characteristics

In this section, the user provides information related to the electricity demand, or load, to which the small hydro site will be supplying electrical power and energy.

## Grid type

The user selects the grid type from the three options in the drop-down list: "Central-grid," "Isolated-grid" and "Off-grid." For the central-grid option, no other information is required and the user should return to the *Energy Model* worksheet.

## Load Conditions

For sites providing energy to isolated-grid and off-grid applications the user is required to select the type of load-duration curve and enter the peak load.

## Load-Duration Curve

The user selects the type of load-duration curve from the two options in the drop-down list: "Typical" and "User-defined." If "Typical" is selected, the model calculates the load-duration curve data based on peak load. If "User-defined" is selected, the user enters data in the appropriate load-duration curve data cells. The graph displayed shows the estimated average daily load condition of the isolated-grid or off-grid application (ordered from maximum to minimum).

For isolated-grid and off-grid applications in isolated areas, the energy demand has been assumed to follow the same pattern for every day of the year. For isolated locations where energy demand and available energy vary significantly over the course of a year, adjustments will have to be made to the estimated amount of renewable energy delivered. This is done by changing the "Available flow adjustment factor" in the *Energy Model* worksheet.

## Peak load

The user enters the peak load (kW) for isolated-grid and off-grid applications, if "Typical" is selected for "Load-duration curve" in the cell above. This is the maximum electric power demand faced during the year. If "User-defined" was chosen for "Load-duration curve" then the user enters the load in the load-duration curve data table. The peak load shown is entered in the first cell (0%) of the load-duration curve data table.

## Energy demand

The model calculates the average annual and daily energy demand (MWh) based on the peak load and the load-duration curve data.

## Average load factor

The model calculates the average load factor (%). This is the ratio of the average load to the peak load and provides an indication of the variability of the load. Thus the lower the load factor the more variable the load.

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

# Equipment Data

As part of the RETScreen Clean Energy Project Analysis Software, the *Equipment Data* worksheet is used to specify the small hydro turbine(s) for the project. The results of this worksheet are transferred to the *Energy Model* worksheet. The user should return to the *Energy Model* worksheet after completing the *Equipment Data* worksheet.

## Small Hydro Turbine Characteristics

In this section, the user provides information about the characteristics of the turbine component of the small hydro project.

## Gross head

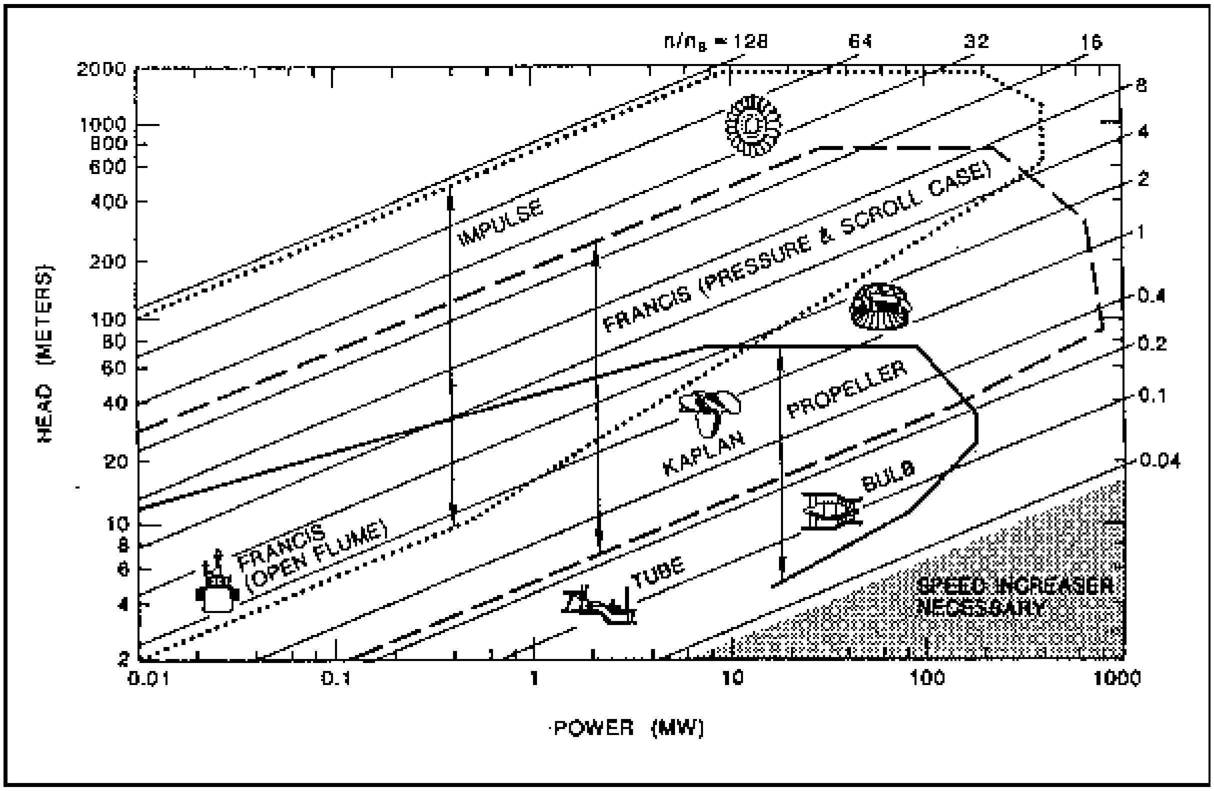
The user enters the gross head in the *Energy Model* worksheet and it is copied automatically to the *Equipment Data* worksheet.

## Design flow

The user enters the design flow in the *Energy Model* worksheet and it is copied automatically to the *Equipment Data* worksheet.

## Turbine type

The user selects the turbine type. The options from the drop-down list are: "Kaplan," "Francis," "Propeller," "Pelton," "Turgo," "Cross-flow," and "Other." A number of turbine types have been developed to suit different site conditions (i.e. as defined by head and flow). The following figure [Gulliver, 1991] provides a guide for the user to select the most appropriate turbine type. Pelton, Turgo and Crossflow turbines are classified as "Impulse" turbines in the figure below. Crossflow turbines are generally limited to outputs of approximately 1 MW. The user can consult the RETScreen Online Product Database for more information.




**Small Hydro Turbine Selection Chart [Gulliver, 1991]**

**Note:** If the user selects "Other" as the turbine type, the costing method used in the *Cost Analysis* worksheet is automatically set to the detailed costing method.

## Turbine efficiency curve data source

The user selects the turbine efficiency curve data source from the two options in the drop-down list: "Standard" and "User-defined." Where the manufacturer efficiency data are known, "User-defined" should be selected and the data can then be entered in the appropriate turbine efficiency column. By selecting "Standard" the model calculates the efficiency curve for the selected turbine type except for "Other," in which case the user would enter turbine efficiency data directly.

**Note:** The "Standard" efficiency curve as calculated by the model for "Francis" turbines applies for projects with net heads (gross head less maximum hydraulic losses) between 30 m and 1,000 m. "Propeller" and "Kaplan" turbines can be selected for projects with net heads below 60 m.

## Number of jets for impulse turbine

The user enters the number of jets, if the user selected "Pelton" or "Turgo" as the type of turbine. The number of jets can vary from 1 to 6 and has an impact on the turbine efficiency. A value of 2 can be used as a default.

## Number of turbines

The user enters the number of turbines required. It is assumed that multiple turbines are all identical. The corresponding combined turbine efficiency curve is displayed in the Efficiency Curve graph in the *Equipment Data* worksheet.

The number of turbines selected will affect both the amount of energy available and the cost of the energy equipment (refer to the *Cost Analysis* worksheet).

## Small hydro turbine manufacturer

The user enters the name of the small hydro turbine manufacturer. This information is given for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

## Small hydro turbine model

The user enters the name of the small hydro turbine model. This information is given for reference purposes only. The user can consult the RETScreen Online Product Database for more information.

## Turbine manufacture/design coefficient

The user enters the turbine manufacture/design coefficient. This coefficient adjusts the turbine efficiency to take into account varying manufacturing techniques. The coefficient is a dimensionless factor used in the formulae to calculate the estimated peak efficiency of turbines. Typically, the more sophisticated the manufacture/design of the turbine, the higher the efficiency of the turbine. The turbine manufacture/design coefficient can be selected using the following table. A default value of 4.5 can be used. Typical values range from 2.8 to 6.1.

| Turbine Runner Material and Manufacturing/Design Method | Turbine Manufacture/Design Coefficient |
|---|---|
| Cast or fabricated carbon steel runner, by a small manufacturer | 2.8 |
| Cast carbon steel runner with a stainless overlay in critical areas, by a small manufacturer. | 3.8 |
| Cast or fabricated stainless steel runner, by a small or large manufacturer (default value) | 4.5 |
| Cast or fabricated stainless steel runner by a major manufacturer designed with the benefit of computational fluid dynamics (CFD) software and blades bent to desired profile in a press. | 5.0 |
| Fabricated stainless steel runner designed by a major manufacturer using CFD, blades cast, or bent in a press, and finished with a five-axis milling machine. | 5.6 |
| Fabricated stainless steel runner designed by a major manufacturer using CFD, design confirmed by a hydraulic model, blades cast, or bent in a press, and finished with a five-axis milling machine. | 6.1 |

**Turbine Manufacture/Design Coefficient**

## Efficiency adjustment

The user enters an adjustment factor for the turbine efficiency. The adjustment, expressed as a percentage, applies to the entire efficiency curve. For example, a value of -2% will reduce the turbine efficiency by 2% over its entire operating range.

The turbine efficiency adjustment can be varied as part of a sensitivity analysis to determine the effect of possible differences in turbine efficiency and to make adjustments to the calculated turbine efficiency curve, if required. Values in the range of -5 to +5% may be used.

## Turbine peak efficiency

The model calculates the turbine peak efficiency (%) based on the standard turbine efficiency curve data.

## Flow at peak efficiency

The model calculates the flow at which the turbine performs at peak efficiency.

## Turbine efficiency at design flow

The model calculates the turbine efficiency at design flow (%) for the type of turbine selected. This value can range from 80% to over 90%.

**Note:** If "User-defined" is selected as the "Turbine efficiency curve data source," or if "Other" is selected as the "Turbine type," then the user enters data directly into the turbine efficiency data column. If "Standard" is selected as the "Turbine efficiency curve data source," the model calculates the efficiency curve for the selected turbine type, hence the user should return to the *Energy Model* worksheet.

## Turbine Efficiency Curve Data

The turbine efficiency curve data are provided in table format and show the combined efficiency of the selected number of turbines over the full flow range (from 0 to 100% of the design flow). The combined efficiency is also presented in a graph.

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

# Cost Analysis[1]

As part of the RETScreen Clean Energy Project Analysis Software, the *Cost Analysis* worksheet is used to help the user estimate costs associated with a small hydro 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.

Two options exist for estimating the cost of the proposed small hydro project: "Formula" and "Detailed." The user selects the costing method used in the evaluation of the small hydro project from the drop-down list.

## Costing method

The user selects the costing method used in the evaluation of the small hydro project from the two options in the drop-down list: "Formula" and "Detailed."

**Note:** If the user selects "Other" as the turbine type in the *Equipment Data* worksheet, the costing method used is automatically set to the detailed costing method.

## 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

[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).

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.

## Formula Costing Method

The formula costing method estimates project costs using formulae derived from the costs of numerous completed small hydro projects. This method helps the user minimise the amount of information required to complete the cost analysis. Unless enough information is available to allow use of the detailed costing method, the formula method should be used to estimate small hydro project costs. The formula costing method is particularly useful for costing a large number of projects in the same area in order to determine the most attractive projects.

## Input Parameters

The input parameters are used to estimate small hydro project costs using the formula costing method.

## Project country

The user selects the country in which the project is located from the two options in the drop-down list: "Canada" and "Enter name." The option "Canada" is selected to estimate the cost of small hydro projects in Canada. The option "Enter name" is selected for all other countries. The formula method uses Canadian projects as a baseline and then allows the user to adjust the results for local conditions.

If "Enter name" option is selected, the user can input, for reference purposes, the name of the country in which the small hydro project will be located. The cost of projects outside Canada compared to the cost of projects in Canada will depend, to a great extent, on the relative cost of equipment, fuel, labour and equipment manufacturing. For projects outside Canada, costs are adjusted based on the relative costs of these items.

## Local vs. Canadian equipment costs ratio

The user enters the relative costs of construction equipment in the country as compared to Canadian costs. This value is entered as the decimal ratio relative to Canadian costs. (Note that costs must be expressed in the same currency when calculating the ratios.) This value is used in the model to estimate the costs of projects outside Canada by adjusting the calculated costs for the local components of the work. For more information on equipment costs, the user may refer to the quarterly statistics published by the Engineering News Record.

## Local vs. Canadian fuel costs ratio

The user enters the relative costs of fuel in the country as compared to Canadian costs. This value is entered as the decimal ratio relative to Canadian costs. (Note that costs must be expressed in the same currency when calculating the ratios.) This value is used in the model to estimate the costs of projects outside Canada by adjusting the calculated costs for the local components of the work.

## Local vs. Canadian labour costs ratio

The user enters the relative costs of labour in the country as compared to Canadian costs. This value is entered as the decimal ratio relative to Canadian costs. (Note that costs must be expressed in the same currency when calculating the ratios.) This value is used in the model to estimate the costs of projects outside Canada by adjusting the calculated costs for the local components of the work. For more information on labour costs, the user may refer to the quarterly statistics published by the Engineering News Record.

## Equipment manufacture cost coefficient

The user enters an adjustment factor to allow for the relative cost of manufacturing the equipment in the country as compared to in Canada. This value is entered as a decimal ratio that expresses the cost of equipment manufacturing relative to Canadian costs. This value is used in the model to adjust the cost of the foreign (i.e. imported) components (e.g. energy equipment, substation and transformer, penstock, civil works and also engineering).

## Exchange rate

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

## Cold climate?

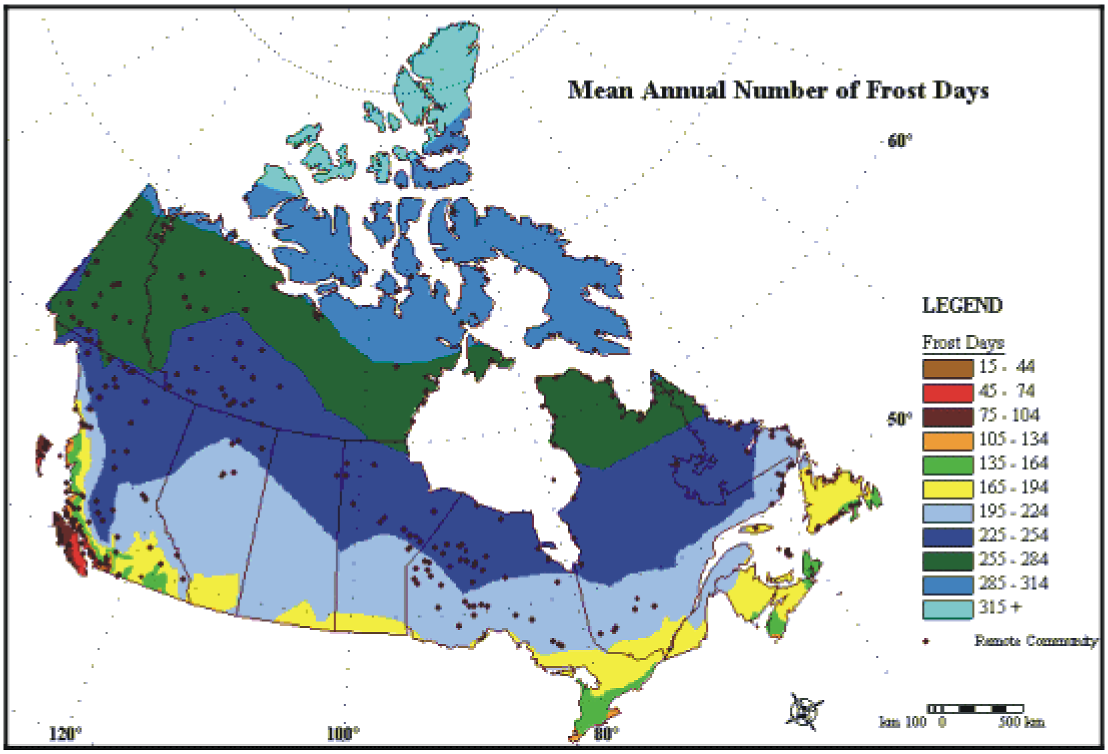
The user indicates by selecting from the drop-down list whether or not the small hydro project is located in a cold climate. Projects that are located in cold climates will cost more due to the increased difficulty of construction (i.e. due to increased transportation costs, shorter construction season, higher cost of equipment, material and labour, etc.). For the purposes of RETScreen, sites are located in a cold climate if, on average, they are situated in locations that experience at least 180 days with frost (temperatures below 0ºC) per year.

## Frost days at site

The user enters the number of frost days at the site for projects located in cold climates. The number of frost days at the site is the factor in the costing formulae that increases the cost as the site becomes further north and more isolated. The number of frost days at the site can be determined from maps provided by national weather and/or environmental organisations, or by visiting the NASA Surface Solar meteorology and Energy Data Set Website. For projects in Canada, maps (see topics below) are also included in the manual. The minimum value that can be entered is 180. Below this value, no adjustment is made to the project costs.

## Mean Annual Number of Frost Days for Canada

For projects in Canada, the user may refer to the figure below to estimate the number of frost days at the small hydro site.



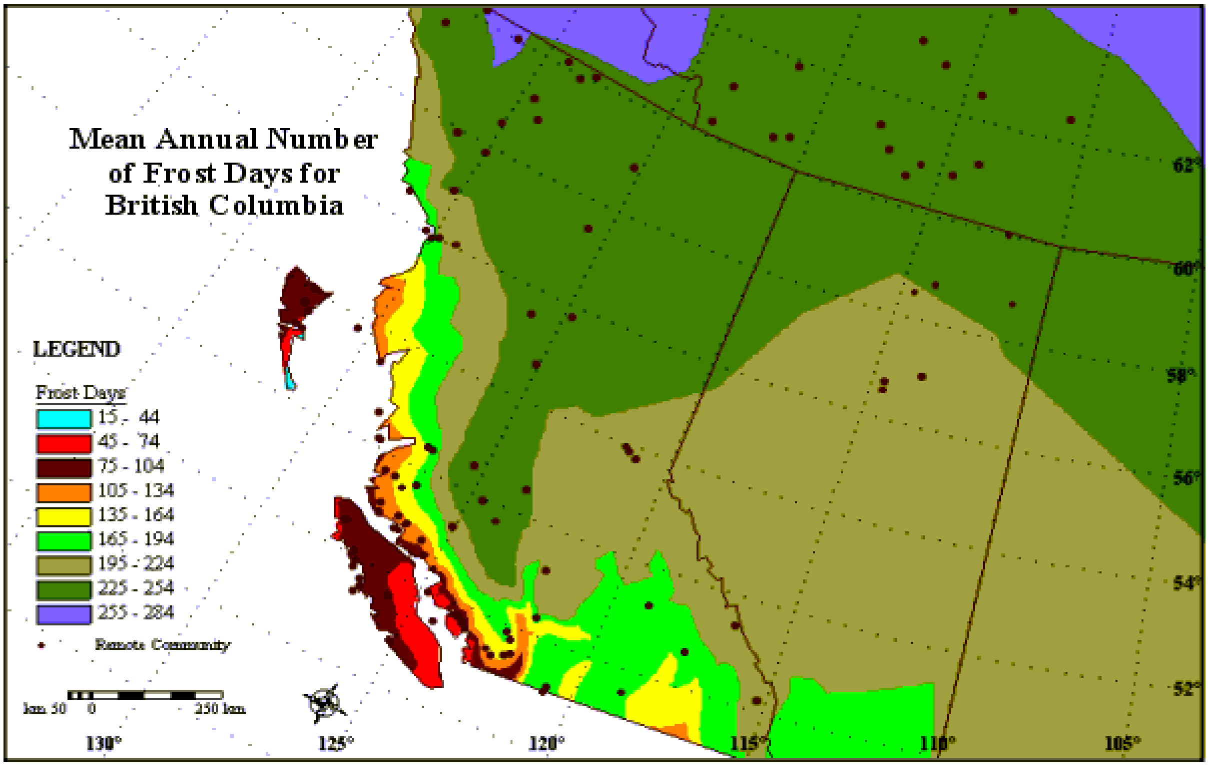

**Mean Annual Number of Frost Days for Canada**

## Number of turbines

The user enters the number of turbines in the *Equipment Data* worksheet and it is copied automatically to the *Cost Analysis* worksheet.

## Mean Annual Number of Frost Days for British Columbia

For projects in British Columbia, Canada, the user may refer to the following figure to estimate the number of frost days at the small hydro site.




**Mean Annual Number of Frost Days for British Columbia, Canada**

## Flow per turbine

The model calculates the flow per turbine based on the design flow and the number of turbines.

## Approximate turbine runner diameter (per unit)

The model calculates the approximate turbine runner diameter assuming that each turbine is identical. The turbine runner diameter provides an indication of the size of each turbine and therefore, the size of the required powerhouse.

## Project classification

## Suggested classification

The model calculates the project category as either micro; mini; or small hydro. In RETScreen, a micro hydro plant consists of a turbine with a runner diameter of less than 0.3 m and a corresponding maximum flow of about 0.4 $m^3/s$. A mini hydro plant has a turbine(s) with a runner diameter of 0.8 m or less. The runner diameter limit of 0.8 m was selected as being the largest turbine-generator set which can be assembled on skids and transported as one package by truck to an isolated site.

The cost of four "mini" hydro turbine-generator units is about equal to the cost of one larger "small" hydro unit of the same total capacity. The approximate maximum flow through a turbine with a runner diameter of 0.8 m is calculated as 3.2 m³/s. As such, in RETScreen, mini hydro plants are defined as plants with total design flows between 0.4 m³/s and 12.8 m³/s.

## Selected classification

The user selects the project category from the 3 options in the drop-down list: "Micro," "Mini" and "Small." The costing formulae used for assessing the costs of certain components, particularly the civil works, are affected by the project category. This is due to larger projects requiring more conservative designs due to higher associated risks, especially with respect to flood conditions.

The same classification as the suggested classification (previous cell) should be selected except under the special circumstances as described below. The user may override the recommended project classification by selecting a different project category from the drop-down list. This can be useful when conducting sensitivity analyses particularly when the design flow being considered is close to the categorisation limits described above. Also, in certain circumstances it may be desirable to classify the project differently (e.g. mini hydro projects where high flood risks exist and/or complicated project designs are required could warrant categorising the other project components as "small").

## Existing dam?

The user indicates by selecting from the drop-down list whether or not there is an existing dam at the small hydro project site. The presence or absence of an existing dam at the site can dramatically affect the cost of a project. This fact is taken into account in the formula used to calculate the cost of civil works. Note that if the existing dam is old, it may not meet current dam safety standards. In this case, an appropriate adjustment can be made to the calculated "Civil works (other)" cost category.

Note that in RETScreen, it is assumed that a new dam will be built primarily to divert water and not to develop head. If this is not the case (e.g., a dam will be built for the purposes of creating a reservoir and head) an appropriate adjustment can also be made to the calculated "Civil works (other)" cost category.

## New dam crest length

The user enters the estimated crest length of the required dam. This value is used in the formula to calculate the cost of the civil works. A field visit will normally be required to estimate the anticipated length of a required dam unless detailed mapping is available.

## Rock at dam site?

The user indicates by selecting from the drop-down list whether or not there is rock at the small hydro project site. The presence or absence of suitable rock at a proposed dam site affects the cost of the project and is taken into account in the formula to calculate the cost of civil works.

It may be possible to determine the presence of rock at a proposed dam site by referencing available geological information for the local area or by visiting the site. If the presence of rock at the site is unknown, the user should select "No."

## Maximum hydraulic losses

The user enters the maximum hydraulic losses in the *Energy Model* worksheet and it is copied automatically to the *Cost Analysis* worksheet. This value is used to assist the user with the selection of allowable losses in the different project hydraulic structure costing categories.

## Intake and miscellaneous losses

The user enters a value to account for the allowable intake and miscellaneous losses in the water conveyance structures. This value accounts for hydraulic losses other than in a tunnel, canal or penstock, which are accounted for separately.

## Access road required?

The user indicates by selecting from the drop-down list whether or not an access road is required to be built to the small hydro project site. An access road to the site is required during construction to transport equipment and construction materials and for maintenance after the project is complete.

To estimate the cost of a required access road, the user specifies the road length, whether or not it is to be constructed as a tote road only and the difficulty of terrain through which the road is to be built.

## Length

The user enters the estimated length of the access road required to connect the site to the nearest existing suitable road. The length of the required access road can be estimated from topographic maps.

## Tote road only?

The user indicates, by selecting from the drop-down list, whether or not the access road is to be constructed for construction purposes only.

## Difficulty of terrain

The user enters a value between 1 and 6 representing the difficulty of the terrain through which the access road will be built. The following table provides a guide to the selection of the value that should be used.

| Type of Terrain | Difficulty of Terrain |
|---|---|
| Flat, gently undulating terrain, no rock outcrops | 1 |
| Hilly terrain, some rock outcrops | 2 |
| Hilly terrain with rock outcrops | 3 |
| Hilly terrain with many rock outcrops | 4 |
| Hilly terrain, mostly in rock with cuts and fills | 5 |
| Mountainous terrain with large rock cuts and fills | 6 |

**Guide to Selecting Access Road Difficulty of Terrain Factors**

## Tunnel required?

The user indicates, by selecting from the drop-down list, whether or not a tunnel is required for the small hydro project. This value is not applicable for micro hydro projects. It is assumed that any tunnel required for a micro hydro project would make the project financially unviable

## Length

The user enters the estimated length of the tunnel. The length of the tunnel can be determined from a preliminary layout of the project on a topographic map. This value, in conjunction with the allowable tunnel headloss factor and the percent length of tunnel that is lined, is used to calculate the cost of the tunnel.

## Allowable tunnel headloss factor

The user enters the allowable tunnel headloss factor. It is the ratio of the allowable headloss in the tunnel compared to the available gross head expressed as a decimal. Values from 4 to 7% are typical.

If the total of the intake and miscellaneous losses, the allowable tunnel headloss factor, and the allowable penstock headloss factor exceeds the value entered for the maximum hydraulic losses *(Energy Model)* a message is displayed in the Notes/Range column indicating by how much the maximum hydraulic losses have to be increased in the *Energy Model* so that the energy calculations coincide with the project costs.

## Percent length of tunnel that is lined

The user enters the percent length of tunnel that is lined. It is the ratio of the length of tunnel that requires lining compared to the total tunnel length and is expressed as a decimal. Values from 15 to 100% are typical.

## Tunnel excavation method

The user selects from the drop-down list the type of tunnel excavation method. The two options from the drop-down list are: "Hand-built" and "Mechanised." This selection is used to calculate the diameter of the tunnel.

## Tunnel diameter

The model calculates the approximate diameter of the tunnel based on the tunnel length and allowable tunnel headloss factor. A minimum diameter of 1.8 m has been used to represent the minimum size of a hand-built tunnel that can be constructed. For Canadian projects, and where excavation would be done using mechanised equipment, the minimum tunnel diameter has been set as 2.4 m.

## Canal required?

The user indicates, by selecting from the drop-down list, whether or not a canal is required for the small hydro project.

## Length in rock

The user enters the estimated length of the canal constructed in the rock. For canals in varying terrain, the lengths in rock and soil should reflect the totals of the individual sections that would be constructed in each type of terrain. The length of the canal can be determined from a preliminary layout of the project on a topographic map.

## Terrain side slope in rock (average)

The user enters the cross-sectional slope of the terrain through which the canal would be constructed. Canals constructed in rock with terrain side slopes greater than approximately $45^0$ are typically not financially viable, as the volume of excavation becomes too large.

## Length in impervious soil

The user enters the estimated length of the canal constructed in impervious soil. For canals in varying terrain, the lengths in rock and soil should reflect the totals of the individual sections that would be constructed in each type of terrain. The length of the canal can be determined from a preliminary layout of the project on a topographic map.

## Terrain side slope in soil (average)

The user enters the cross-sectional slope of the terrain through which the canal would be constructed. Canals constructed in soil with terrain side slopes greater than approximately $15^0$ are generally typically not financially viable.

## Total canal headloss

The model calculates the total canal headloss by assuming an average bottom slope of approximately 0.001 (i.e. 1 m drop per 1,000 m length). The total canal headloss is used to assist the user in selecting an appropriate value for the project gross head (*Energy Model*). The total canal headloss should be reflected in the selected gross head for the site, i.e. the gross head should be determined as the drop in elevation from the end of the canal to the tailrace.

## Penstock required?

The user indicates, by selecting from the drop-down list, whether or not a penstock is required for the small hydro project. For projects that include one or more parallel penstocks, the user enters the estimated length of the required penstock(s), the number of identical parallel penstocks that will be required as part of the small hydro project and the allowable penstock headloss factor. These values are used to calculate the cost of the penstock portion of the project.

## Length

The user enters the length of the penstock(s). The anticipated length of the penstock(s) can be determined from a preliminary layout of the project on a topographic map. The user should make sure to adjust the horizontal layout length to account for the slope of the terrain. As a guideline, short penstock lengths are usually associated with low-head projects while higher head projects will require longer penstock(s).

## Number of identical penstocks

The user enters the number of identical, parallel penstocks to be used in the project.

## Allowable penstock headloss factor

The user enters the allowable penstock headloss factor. It is the ratio of the allowable headloss in the penstock(s) compared to the available gross head and is expressed as a percentage. Values from 1 to 4% are typical.

If the total of the intake and miscellaneous losses, the allowable tunnel headloss factor, and the allowable penstock headloss factor exceeds the value entered for the maximum hydraulic losses (*Energy Model*) a message is displayed in the Notes/Range column indicating by how much the maximum hydraulic losses has to be increased so that the energy calculations coincide with the project costs.

## Pipe diameter

The model calculates the approximate diameter of each identical, parallel penstock. This information is given for reference purposes only.

## Average pipe wall thickness

The model calculates the approximate average required thickness of the penstock(s) based on a number of criteria including minimum wall thickness for handling purposes and the wall thickness required to withstand the design maximum water pressure (assuming a 50% water hammer allowance).

## Distance to borrow pits

The user enters the estimated average distance to the nearest suitable borrow pits (e.g. for sand, gravel, clay, fill, etc.) required for the construction of the project. The distance to the borrow pits can be determined from topographic maps and knowledge of the local area. If the distance is unknown, a value of 8 km should be used. This value is not applicable for micro hydro projects.

## Transmission line

The user enters the estimated length, the difficulty of terrain through which the transmission line will be built and the voltage (kV) of the transmission line that is required to connect the site with the nearest existing transmission line of suitable voltage and capacity rating (i.e. large enough to carry the power generated by the small hydro plant).

## Length

The user enters the anticipated length of the required transmission line. The length of the transmission line can be determined from a preliminary layout of the project on a topographic map.

## Difficulty of terrain

The user enters a factor between 1 and 2 representing the difficulty of the terrain over which the transmission line will be constructed. One (1) represents flat terrain and two (2) is used to represent mountainous terrain. This factor is applied directly to the calculated cost of the transmission line.

## Voltage

The user enters the voltage of the transmission line in kV. The voltage of the transmission line will depend on the plant output and the length of the transmission line. The information in the table below can be used as a guideline for determining the suitable transmission line voltage. Intermediate, common voltages (e.g. 13.8 kV and 69 kV) can also be used. Low voltage lines (e.g. 0.6 kV or lower) can be appropriate for some micro hydro projects. The model uses the transmission line voltage in the calculation of the cost of the required transmission line and the substation and transformer.

| Capacity (MW) | Voltage (kV) | Cost/km ($) | Distance (km) |
|---|---|---|---|
| 0 - 2 | 25 | 55,000 | < 50 |
| 2 - 5 | 44 | 65,000 | < 70 |
| > 5 | 115 | 100,000 | > 70 |

**Estimated Transmission Line and Substation Costs**

## Interest rate

The user enters the interest rate (%) for construction financing for the period of construction. This value is used to estimate miscellaneous costs. Interest rates for construction financing are usually at least 2.5% higher than the bank prime rate. Where concessional financing, or grants towards the project cost, are available, a lower equivalent finance cost should be used.

## Initial Costs (Formula Method)

The initial costs associated with the implementation of the project are described in more detail in the Initial Costs detailed method section. In general, major categories include costs for preparing a feasibility study, performing the project development functions, completing the necessary engineering, purchasing and installing the energy equipment, construction of the balance of plant and costs for any other miscellaneous items.

## Feasibility Study

The estimated cost of the required feasibility and environmental studies is calculated by the model.

## Development

The model estimates development costs, which include legal fees, financing and supervision of the project.

## Land rights

The user enters the estimated cost of acquiring the land rights necessary for the construction of the access road, transmission line and project structures.

## Engineering

Most small hydro sites are now built with a water-to-wire contract for both the civil and electromechanical equipment. The estimated cost of engineering and quality control during construction is calculated by the model as a function of the project's plant capacity and gross head and does not include any engineering of the water-to-wire equipment other than the production of specifications.

## Energy Equipment

The model estimates the cost of all electromechanical equipment at the hydro site including the costs of the turbine(s), generator(s), governor and controls based on the type of turbine selected in the *Equipment Data* worksheet.

It is assumed that for central-grid connected projects with individual generator sizes less than 1.5 MW, lower cost induction generators will be used.

# Balance of Plant

The balance of plant for a small hydro project typically includes a number of items, such as access road, transmission line, substation and transformer, penstock, canal, tunnel and other civil works costs.

## Access road

The estimated cost of the required access road is calculated based on the length and difficulty of terrain and whether or not the road will be built as a tote road for construction purposes only. In isolated locations, permanent gravel-surfaced access roads are very expensive and, for mini hydro projects, are normally only selected where the length of road is short (less than about 4 km). Longer roads can be built and re-built every year they are required, depending on the length of the construction schedule and the long-term maintenance requirements.

## Transmission line

The calculation of the estimated transmission line cost is based on its length, difficulty of terrain and voltage. It is assumed that for transmission line voltages less than 69 kV wood pole construction can be used. For the larger voltages a higher cost steel tower line is assumed.

## Substation and transformer

The cost of the substation and transformer is calculated based on the plant capacity and transmission line voltage. The same formula is used for all project classifications.

## Penstock

The cost of the penstock is based on the approximate weight of the penstock(s) assuming steel construction. The model calculates the average required penstock thickness based on the minimum thickness required for both handling and pressure (assuming a 50% water hammer allowance). The same formula is used for all project categories.

## Canal

The cost of the canal is based on the approximate volume of excavation in rock and soil. The same formula is used for all project categories.

## Tunnel

The cost of the tunnel is based on the approximate volumes of rock excavation and tunnel lining required. The model calculates the diameter of the tunnel based on the allowable tunnel headlosses (expressed as a ratio to the gross head). The same formulae are used for small and mini sites. For micro sites, a tunnel cannot be selected.

## Civil works (other)

The balance of the site civil works cost is based on a formula that has different cost coefficients for the size of the turbine runner (i.e. based on the site classification). This is due to the use of more simple designs for micro and mini hydro compared with small hydro. For example, with a mini hydro installation, the dam will usually comprise a simple weir across the river, with no water level or flood controls. For a small hydro plant, the dam will be more extensive, and usually include stoplogs or gates for water level control.

## Miscellaneous

In the "Formula Costing Method," miscellaneous costs include unforeseen costs and interest during construction.

An allowance of 10% of the other project costs (excluding land rights) is included in the calculation of miscellaneous costs to allow for unforeseen costs.

Interest during construction is a function of the cost of money and the time required for construction. For mini and small hydro projects, interest is calculated based on the total cost of the project (including contingencies), the size of the project (defined by the design flow), and the selected interest rate. For micro hydro projects, it has been assumed that construction can be completed within four months and that the construction time is not affected by the size of 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 "Cost (local currency)" column.

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list. The user can input a total cost amount. 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. 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 a total cost amount. Note that the credit item is expressed as a negative value in the "Amount (local currency)" column.

# Initial Costs (Credits)

The detailed costing method allows the user to estimate costs based on estimated quantities and unit costs. The use of this costing method requires the user to estimate the size and layout of the required structures. Some guidelines are provided in the text for estimating quantities and unit costs. Due to the relatively larger scale of small hydro projects, proper use of the detailed costing method will generally require that a preliminary design of the project be completed, a task which is normally part of a more detailed feasibility study.

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

# Feasibility Study

Once a potential cost-effective small hydro project has been identified through the RETScreen pre-feasibility analysis process, a more detailed feasibility analysis study is normally required. Feasibility studies typically include such items as site investigations, a detailed hydrologic assessment, an environmental assessment, a preliminary project design, a detailed cost estimate, a GHG baseline study and monitoring plan and a final report. Feasibility study project management and travel costs are also normally incurred. These costs are detailed in the section below.

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

# Site investigation

Site investigations required as part of a small hydro feasibility study include geotechnical surveys (surface and subsurface investigations in identified problem areas) and preliminary topographic mapping in the area of the proposed structures.

The cost of the site investigations is calculated based on an estimate of the time required by experts to complete the necessary work. The average cost of site investigation services will range between $200 and $800 per person-day.

The time required to complete the required site investigations for a small hydro development depends, to a large extent, on the size of the proposed project. While reducing the scope of the site investigations will necessarily increase the risk of construction difficulties (and hence cost overruns), a small project cannot usually justify the cost of extensive site investigation work. If the scope of the site investigations is reduced, an additional allowance for contingencies/miscellaneous items (under Miscellaneous) should be made to account for the associated added risk. The number of person-days required can range between 10 and 400. As a rule-of-thumb, the cost of site investigations will be about 0.9% of the total project cost.

## Hydrologic assessment

A detailed hydrologic assessment is an integral part of a small hydro feasibility study and is required to estimate the available streamflow for power generation and the probability of extreme conditions (i.e. flooding and droughts) at the small hydro site.

The cost of the hydrologic assessment is calculated based on an estimate of the time required by experts to complete the necessary work. The average cost of hydrologic assessment services will range between $200 and $800 per person-day. The time required to complete the hydrologic assessment will depend primarily on the availability of suitable hydrologic information. Where a site is located near to a suitable streamflow gauge on the same river, the scope of the hydrologic assessment will be significantly less than for a site on a river with no streamflow records. The number of person-days required can range between 5, where streamflow data are available, and up to 100 for large, expensive projects with no available data. As a rule-of-thumb, the cost of the hydrologic assessment should be about 0.3% of the total project cost.

## Environmental assessment

An environmental assessment is an essential part of the feasibility study work. While small hydro can usually be developed in an environmentally acceptable manner (projects can often be designed to enhance environmental conditions), work is required to study the potential environmental impacts of any proposed small hydro project.

The cost of an environmental assessment is calculated based on an estimate of the time required by an expert to complete the necessary work. The average cost of environmental assessment services will range between $200 and $800 per person-day.

The cost of an environmental assessment is site specific and depends on the time required by experts to complete the necessary site investigations, data gathering (e.g. fish surveys, interviews with local residents and/or interest groups, etc.), analysis, preparation of a report with recommended mitigation measures, public consultation and final documentation. As a rule-of-thumb, the cost of the environmental assessment should be about 1% of the total project cost.

## Preliminary design

A preliminary design is required in order to determine the optimum plant capacity, the size and layout of the structures and equipment, and the estimated construction quantities necessary for the cost estimate. As with site investigations, the scope of this task is often reduced for small projects in order to reduce costs. Consequently, additional contingencies should be allowed to account for the resulting additional risk of cost overruns during construction.

The cost of the preliminary design is calculated based on an estimate of the time required by experts to complete the necessary work. The cost of professional services required to complete a preliminary design will range between $200 and $800 per person-day. As with site investigations, the time required to complete the preliminary design will depend, to a large extent on the size of the project and corresponding acceptable level of risk. The number of person-days required can range between 10 and 100. As a rule-of-thumb, the cost of the preliminary design should be about 0.3% of the total project cost.

## Detailed cost estimate

The detailed cost estimate for the proposed small hydro project is based on the results of the preliminary design and other investigations carried out during the feasibility study. The cost of preparing the detailed cost estimate is calculated based on an estimate of the time required by experts to complete the necessary work.

Engineering services for completing a detailed small hydro cost estimate will range between $200 and $800 per person-day. The number of person-days required to complete the cost estimate will range between 5 and 50 depending on the size of the project and acceptable level of risk. As a rule-of-thumb, the cost of the cost estimate should be about 0.3% of the total project cost.

## GHG baseline study and monitoring plan

In order for the greenhouse gas (GHG) emissions reductions generated from a project to be recognised and sold on domestic or international carbon markets, several project documents need to be developed, the key elements of which are a GHG baseline study and a Monitoring Plan (MP). A GHG baseline study identifies and justifies a credible project baseline based on the review of relevant information such as grid expansion plans, dispatch models, fuel use on the margin, current fuel consumption patterns and emissions factors. The GHG baseline study sets a project boundary and identifies all sources of GHG emissions that would have occurred under the baseline scenario, i.e. the scenario most likely to have occurred if the project were not implemented. A Monitoring Plan identifies the data that needs to be collected in order to monitor and verify the emissions reductions resulting from the project and describes a methodology for quantifying these reductions as measured against the project baseline.

An outside consultant or team is often called in to develop the baseline study and monitoring plan. However, as more project examples become available and standardised methodologies are accepted, these studies may be more easily carried out by project proponents. Costs will depend on the complexity of the baseline, the size of the project and the availability of sectoral or regional baselines and standardised monitoring methodologies. Costs for developing baseline studies and monitoring plans for large projects have ranged from $US 30,000- $US 40,000 according to analysis by the Prototype Carbon Fund (PCF).

Requirements for Clean Development Mechanism (CDM) projects are generally more stringent than for Joint Implementation (JI) or other projects. For example, CDM projects must also be monitored for their contribution to sustainable development of the host country. The rules governing baselines and monitoring for CDM can be found at UNFCCC's CDM Website. Note that for small-scale projects (renewable energy electricity projects with a capacity of 15 MW or less), it might not be necessary to carry out a full baseline study as simplified baselines and monitoring methodologies are available.

**Note:** The optional *GHG Analysis* worksheet in RETScreen can be used to help prepare the baseline study.

## Report preparation

A summary report is the final product of the feasibility study and includes the results of the technical and financial analyses of the project. The time required for the report preparation will depend on the extent of the work performed during the feasibility study.

The cost of the report preparation is calculated based on an estimate of the time required by experts to complete the necessary work. Preparing a feasibility study report will involve between 3 and 50 person-days at a rate of between $200 and $800 per person-day. As a rule-of-thumb, the cost of the feasibility study report preparation will be about 0.2% of the total project cost.

## Project management

The project management cost item should cover the estimated costs of managing all phases of the feasibility study for the project, including the time required for stakeholder consultations. Consultations with the stakeholders in a given project are called for in order to build support and collaboration toward the project, and to identify any opposition at the earliest stage of development.

The cost of the management of the feasibility study is calculated based on an estimate of the time required by a professional to complete the necessary work. This component of the work will involve between 5 and 50 person-days at a rate of between $300 and $800 per person-day (travel time must also be added).

## 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 so variable it is advised to contact a travel agent with experience in arranging such travel. Accommodation rates are typically twice the going rate for modest accommodation in populated areas. Typical rates for modest hotel rooms can range from $180 to $250 per day in the more isolated areas.

## Other

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

A cost item may be entered in the grey input cell as "Other." The user then selects "Cost" from the drop-down list in the unit column. The user can input both a quantity amount and unit cost.

This item is provided to allow for project, technology and/or regional differences not specifically covered in the generic information provided.

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

## Development

Once a potential small hydro 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.

Small hydro project development activities typically include costs for such items as power purchase agreement negotiations, permits and approvals, land rights, land surveys, GHG validation and registration, project financing, legal and accounting, project development management and travel costs. These costs are detailed in the section below.

## PPA negotiation

The negotiation of a Power Purchase Agreement (PPA) is one of the first required steps of the project development stage. A PPA will be required if the project is to be owned privately, rather than by a utility and will also involve legal and other professional advice (e.g. finance, accounting). The scope of the work involved in the PPA negotiation will depend on whether or not conditions for the sale of power already exist (e.g. utility policy to purchase private power).

The cost of the negotiation of the PPA is calculated based on an estimate of the time required by an expert to complete the necessary work. The number of person-days required can range between 5 and 200 or more depending on the complexity of the contract. The cost of professional services required for the negotiation of a PPA will range between $300 and $1,500 per person-day.

As a rule-of-thumb, the cost of the PPA negotiation should be about 0.6% of the total project cost.

## Permits and approvals

A number of permits and approvals are required for the construction of the project. These include environmental approvals (e.g. federal/national or state/provincial/regional), authorisations regarding the use of water (e.g. state/provincial/regional), operating agreements (e.g. state/provincial/regional), land lease agreements (e.g. state/provincial/regional), permits for the use of navigable waters (e.g. federal/national), and building permits (e.g. state/provincial/regional or local).

The cost of acquiring the necessary permits and approvals is calculated based on an estimate of the time required by an expert to complete the necessary work. Acquiring the necessary permits and approvals will involve between 5 and 100 person-days at a rate of between $200 and $800 per person-day depending on the complexity, from an approval point of view, of the proposed project. As a rule-of-thumb, the cost of acquiring the necessary permits and approvals should be about 0.5% of the total project cost.

## Land rights

Land rights are required for the land on which the small hydro structures are located, including the access road, transmission line, dam, water conduits and powerhouse. Right-of-way may be granted for the access road and electric lines. The land required for the small hydro plant may have to be leased or purchased.

The user enters, as a lump sum, the estimated cost of purchasing required land that cannot be leased or used under a right-of-way agreement. The cost should include an allowance for legal fees and any required legal surveys. Note that the estimated cost of negotiating any land lease and right-of-way agreements should be included under the "Permits and approvals" section described above. The cost of acquiring the necessary land rights is site specific.

## Land survey

A detailed land survey is required in order to complete the final design of the project. Undertaking a detailed land survey for the purposes of designing the project will involve between 20 and 200 person-days at a rate of between $400 and $600 per person-day. As a rule-of-thumb, the cost of the land survey should be about 0.4% of the total project cost.

## GHG validation and registration

Greenhouse gas (GHG) projects might need to be validated by an independent third party organisation to ensure that the project design documents, including the GHG baseline study and Monitoring Plan, meet the prescribed requirements. Validation includes the confirmation that the emission reductions claimed by the project developer are considered realistic. GHG projects must then be registered through an accredited organisation.

Validation is necessary for Clean Development Mechanism (CDM) projects and must be carried out by an operational entity that has been certified by the United Nations Framework Convention on Climate Change (UNFCCC). See UNFCCC's CDM Website for further details. For other projects, third party validation may provide investors with increased confidence that the estimated emissions reductions will be achieved.

The cost of validation will vary according to the size of the project. For the validation of CDM projects, a prescribed rate of $US 400/day has been set for the staff of designated operational entities or $US 1,200/day for a team of three. The Prototype Carbon Fund (PCF) estimates the cost of validation of large projects at $US 30,000.

CDM projects will also require a registration fee to be paid to the UNFCCC for administration. Registration fees for CDM projects are scaled according to the size of the project as follows:

| *Average Tonnes of $C0_2e$ Reductions/Year* | *Registration Fee in US$* |
|---|---|
| <=15,000 | 5,000 |
| >15,000 and <= 50,000 | 10,000 |
| >50,000 and <= 100,000 | 15,000 |
| >100,000 and <= 200,000 | 20,000 |
| >200,000 | 30,000 |

**Registration Fees for CDM Projects**

## Project financing

The time and effort required to arrange project financing can be significant, even for a small project. Small hydro projects are capital intensive, long-term investments. The cost of financing will be comprised of the effort required by experts to make the arrangements, identify investors and solicit funds. Typical rates for such work are set at a percentage of the financed amount and may include a fixed commencement fee.

The cost of project financing is calculated based on an estimate of the services required to secure both debt and equity commitments. Acquiring the necessary project financing will involve between 5 and 100 person-days at a rate of between $500 and $1,500 per person-day depending on the complexity of the proposed financing structure. As a rule-of-thumb, the cost of acquiring the necessary project financing should be about 1.5% of the total project cost.

## Legal and accounting

Legal and accounting support will be required at different points throughout the development stages of a small hydro project. This cost item allows the user to account for legal and accounting services not included as part of other development cost items such as for establishing a company to develop the project, to prepare monthly and annual financial statements, for project accounting, etc. The requirement for legal support will depend on the arrangements for financing, ownership, insurance, assumption of liability and complexity of contracts and agreements.

The cost of legal and accounting support is calculated based on an estimate of the time required for experts to provide these services throughout the development of the project. Legal and accounting support will involve between 5 and 200 person-days at a rate of between $300 and $1,500 per person-day depending on the complexity and size of the project. As a rule-of-thumb, the cost of legal and accounting support should be about 0.9% of the total project cost.

## Project management

The project management cost item should cover the estimated costs of managing all phases of the development of the project (excluding construction supervision). Public relations are also included as part of the project management cost item. Public relations can be an important element for successful project implementation. The elapsed time for the development of a small hydro project, from feasibility study to final completion, can be up to 5 years. Project management will involve between 0.2 and 2 person-years at a rate of between $130,000 and $180,000 per person-year depending on the size of the project.

As a rule-of-thumb, the cost of project management should be approximately equal to $70,000(Capacity/h^0.3)^0.54, where the capacity is expressed in MW and "h" is the gross head expressed in meters.

## Travel and accommodation

A number of field visits and other trips will be required during the development phase (primarily for meetings). This cost item includes all travel related costs (excluding time) required to develop the project.

## 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 small hydro project design and tenders document preparation, contracting and construction supervision. These costs are detailed below.

## Design and tender documents

The design and tender documents cost item summarises the cost of engineering services required to complete the detailed design for the project and to issue tender documents for the purposes of selecting contractors to undertake the work. Depending on the development approach adopted, this work is either completed by an independent consultant (conventional approach) or by the contractor (turn-key approach).

The preparation of the design and tender documents will involve between 0.6 and 6 person-years at a rate of between $130,000 and $180,000 per person-year depending on the complexity of the project.

As a rule-of-thumb, the cost of design and tender documents should be approximately equal to $200,000(Capacity/h^0.3)^0.54, where the capacity is expressed in MW and "h" is the gross head expressed in meters.

## Contracting

The contracting cost item summarises the estimated costs associated with negotiating and establishing contracts for the completion of the work. Contracting will involve between 5 and 200 person-days at a rate of between $500 and $1,500 per person-day depending on the size of the project and complexity of the construction contracts.

## Construction supervision

The construction supervision cost item summarises the estimated costs associated with ensuring that the project is constructed as designed and is usually carried out by an independent engineering consultant. For larger projects, full-time construction supervision may be justified. For small projects, construction supervision is often reduced to periodic inspection visits as a cost-cutting measure.

Constructions supervision will involve between 0.2 and 2 person-years at a rate of between $130,000 and $180,000 per person-year depending on the duration of the project construction schedule.

As a rule-of-thumb, the cost of construction supervision should be approximately equal to $100,000(Capacity/h^0.3)^0.54, where the capacity is expressed in MW and "h" is the gross head expressed in meters.

## Other

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

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

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

## Energy Equipment

The energy equipment, as defined here, includes all electromechanical equipment at the hydro site including the costs of the turbine(s), generator(s), governor and controls; costs are based on the type of turbine selected in the *Equipment Data* worksheet. 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.

## Turbines/generators, controls

The turbines/generators and controls cost item summarises the cost of purchasing all electromechanical equipment including the turbine-generator(s), governor and controls, electrical protection and control (including remote monitoring system and powerhouse electrical equipment), pumps, gates, powerhouse crane.

The cost of the small hydro turbines/generators, controls and auxiliary equipment varies over a wide range depending on the size and gross head of the project, and the extent of the auxiliary equipment required. For the same capacity, higher head projects will have lower costs per installed kW for this equipment than lower head projects due to the small flow of water used (i.e. smaller turbines).

Costs associated with this cost item can range from a minimum of about $500/kW for a small, higher head scheme requiring minimal auxiliary equipment (e.g. no powerhouse crane or intake gate) to over $4,000/kW for large low head projects which may include requirements for substantial auxiliary equipment and expensive high voltage protection and control systems.

The user may refer to the RETScreen Online Product Database for supplier contact information in order to obtain prices or other information required.

## Equipment installation

A separate cost item is provided to account for the cost of installing the energy equipment and is calculated as a percentage of the estimated cost of the turbine/generators and controls.

The cost of equipment installation can range from 5 to 45% of the purchase cost of the turbines/generators, controls and auxiliary equipment and will depend primarily on the size of the equipment to be installed. Larger equipment has to be transported in sections and assembled on site, which will add considerably to the installation cost for projects in isolated locations.

## Transportation

The transportation cost item summarises the cost of transporting all of the electromechanical equipment to the site and is calculated as a percentage of the estimated cost of the turbine/generators and controls. Transportation costs will vary significantly depending on the size of the shipment, the location of the site and the time of year and can range between 1 to 20% of the cost of the equipment.

## Other

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

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

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

## Balance of Plant

The balance of plant for a small hydro project typically includes a number of items, such as access road, transmission line, substation and transformer, penstock, canal, tunnel and other civil works costs.

## Access road

The cost of constructing the required construction access roads is summarised under the access road cost item. Costs for required access roads can range from $20,000/km to $500,000/km depending on the type of terrain and extent of river crossings required.

## Clearing

The cost of clearing the land on which the small hydro structures will be built is based on the area that has to be cleared and the cost of clearing per area. Clearing costs can range between $20,000/ha to $50,000/ha depending on the type of terrain and vegetation.

## Earth excavation

The cost of earth excavation required to construct the project (excluding canal excavation) is summarised under the earth excavation cost item. Earth excavation can cost between $5/m$^3$ to $15/m$^3$.

## Rock excavation

The cost of rock excavation required to construct the project (excluding canal excavation) is summarised under the rock excavation cost item. Rock excavation can cost between $30/m³ and $70/m³.

## Concrete dam

If the construction of a concrete dam is planned, the associated costs are based on an estimate of the total volume of concrete required. Estimating the volume will require a site visit to determine a suitable dam site and to take measurements of the estimated size of the dam. Advice from an expert specialising in dam construction will likely be required.

Costs for the construction of a concrete dam can range between $400/m³ and $1,600/m³ depending on the quantity (larger quantities will reduce unit costs) and complexity of construction.

## Timber crib dam

If the construction of a timber crib dam is planned, the associated costs are based on an estimate of the total volume of the timber cribs required. Estimating the volume will require a site visit to determine a suitable dam site and to take measurements of the estimated size of the dam. Advice from an expert specialising in dam construction will likely be required.

Costs for the construction of timber crib dams can range between $100/m³, where local timber is available, to over $500/m³ where timber has to be hauled to the site.

## Earthfill dam

If the construction of an earthfill dam is planned, the associated costs are based on an estimate of the total volume of earth fill required. Estimating the volume will require a site visit to determine a suitable dam site and to take measurements of the estimated size of the dam. Advice from an expert specialising in dam construction will likely be required.

Cost for the construction of earthfill dams, including foundation preparation and riprap can range between $30/m³ and $90/m³ depending on the location and distance to suitable borrow pits.

## Dewatering

The cost of dewatering necessary for the construction of a dam is summarised under the dewatering cost item. Dewatering requirements vary from site to site and can involve the construction of extensive temporary diversion structures (cofferdams, bypass channels or tunnels, etc.).

Costs for dewatering can range between 5 and 15% of the cost of the dam plus the cost of any required diversion canals or tunnels (associated with larger dams constructed in rivers with high flows).

## Spillway

The cost of a required spillway is estimated separately from the cost of the dam since each type of dam has different spillway requirements. The estimated cost of a spillway is based on the volume of concrete required. Advice from an expert specialising in dam construction will likely be required.

Costs for the construction of a concrete spillway can range between $400/m$^3$ and $1,600/m$^3$ depending on the quantity (larger quantities will reduce unit costs) and complexity of construction.

## Canal

A canal may form part of a small hydro scheme and will involve the excavation of earth and rock. The cost of a canal is based on the volume of excavation required which depends on the length and cross-sectional area of the canal. The length of the canal can be estimated from detailed topographic maps or on-site measurements. For projects located in cold climates, the cross-sectional area can be estimated assuming a maximum water velocity of about 0.5 m/s (to allow the formation of a suitable ice cover during winter).

Earth excavation costs associated with canal construction can range between $20/m$^3$ and $200/m$^3$. Rock excavation can cost between $40/m$^3$ and $400/m$^3$. Excavation costs depend primarily on the location and volume of excavation (a larger volume will reduce unit costs).

## Intake

An intake is required to direct the water into a penstock or directly into the turbine(s). The cost of the intake is based on an estimate of the volume of concrete required. The volume of concrete required to construct an intake can be estimated as 15 times the design flow. Concrete costs can range between $400/m$^3$ and $1,600/m$^3$ depending on the quantity (larger quantities will reduce unit costs) and complexity of construction.

## Tunnel

A tunnel may also form part of a small hydro scheme. The cost of the tunnel will vary depending on the location, the tunnel diameter and the hardness of the rock being excavated. Advice from an expert specialising in tunnel design may be required. The cost of a tunnel can range from $40/m$^3$ to $150/m$^3$ of material excavated.

## Pipeline/penstock

A pipeline/penstock may form part of a small hydro scheme. The cost of the pipeline/penstock will vary depending on the material selected and the terrain in which it is constructed. Advice from an expert specialising in pipeline/penstock design may be required.

The cost of the pipeline/penstock is site specific due to the variety of materials used and varying complexity of construction. An estimate of the weight of a steel pipeline or penstock can be estimated using the following formula:

$$W = L\,(0.39\,d^2 h_w + 12.3\,d^{2.3} + 92.5\,d)$$

Where:

$W$ = the weight of steel (kg).
$L$ = the pipeline/penstock length (m).
$d$ = the diameter of the pipeline/penstock (m).
$h_w$ = the waterhammer head at the turbine.
= 1.5 times the gross head for reaction turbines.
= 1.25 times the gross head for impulse turbines.

For the purpose of estimating penstock costs, the use of steel can be assumed. Costs for steel penstocks (materials and installation) can range from $5/kg to $10/kg.

## Powerhouse civil

The powerhouse civil costs are based on an estimate of the volume of concrete required. Powerhouse civil costs can range between $400/m³ and $1,600 m³ (assuming concrete construction) depending on the quantity (larger quantities will reduce unit costs) and complexity of construction.

An estimate of the volume of concrete required for the powerhouse foundation can be calculated using the following formula:

$$V_f = k\,(n + 0.5)\,D^{2.3}$$

Where:

$k$ = 140 for vertical axis turbines.
= 90 for horizontal axis turbines.
$D$ = the turbine runner diameter*.
$n$ = the number of units.
$V_f$ = the estimated volume of foundation concrete ($m^3$).

The cost of constructing the powerhouse walls and roof can be approximated by increasing the foundation concrete volume by 15-20%.

* Note: D can be estimated as follows (D = 0.46Q^0.473, where Q is the maximum turbine flow)

## Fishway

A fishway may be required as part of a small hydro scheme. The cost of a fishway can be estimated based on the required lift (i.e. vertical distance between the downstream and upstream water levels). The costs of constructing a fishway can range between $4,000/m lift and $20,000/m lift.

## Transmission line

The transmission line cost is site specific and depends on the type, length, voltage and location of the line and the installed capacity of the power plant being developed. Advice from an expert specialising in transmission line design may be required in order to estimate this cost. The table below presents an indication of the approximate costs involved, assuming reasonable access. These costs should be adjusted based on site conditions.

| Capacity (MW) | Voltage (kV) | Cost/km ($) | Distance (km) |
|---|---|---|---|
| 0 - 2 | 25 | 55,000 | < 50 |
| 2 - 5 | 44 | 65,000 | < 70 |
| > 5 | 115 | 100,000 | > 70 |

**Estimated Transmission Line Costs**

## Substation

The substation cost is site specific and depends mainly on the voltage and the installed capacity of the power plant being developed. The table below presents an indication of the approximate costs involved, assuming reasonable access. These costs should be adjusted based on site conditions.

| Capacity (MW) | Voltage (kV) | Substation ($) |
|---|---|---|
| 0 - 2 | 25 | 250,000 |
| 2 - 5 | 44 | 600,000 |
| > 5 | 115 | 2,000,000 |

**Estimated Substation Costs**

## Transportation

The transportation cost item summarises the cost of transportation associated with the construction of the balance of plant and is calculated as a percentage of the total estimated balance of plant cost (excluding "other costs"). Transportation costs will vary significantly depending on the location of the site and the time of year.

## 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 small hydro projects these costs can include special equipment, contractor's overhead, training, contingencies and interest during construction.

## Special equipment

The user can enter the cost of any special equipment that may be required as part of the small hydro project.

## Contractor's overhead

The costs associated with a contractor's overhead will depend on the remoteness of the small hydro site and the requirements for a construction camp. This cost item should include an allowance for construction insurance and bonding.

Contractor's overhead costs are estimated based on a user-selected percentage of the costs included under balance of plant. Contractor's overhead costs can range between 10 to over 100% of the costs included under balance of plant depending on the remoteness of the site and the requirements for a construction camp, and the portion of this cost already included in the cost estimate (i.e. already part of the unit costs).

## Training

The costs associated with the training of plant operators and maintenance personnel will depend on the size, complexity and remoteness of the installation. For isolated locations, there will be a greater need for local trained technicians in order to avoid lengthy repair delays.

For small hydro plants, one operator/maintenance technician can perform daily operation and maintenance tasks. However, some of the periodic repairs (e.g. bearing replacement) will require specialised labour. Training costs include professional fees. Any travel expenses can be entered in "Travel and accommodation" under the "Development" section. Training will involve between 5 and 100 person-days at a rate of between $200 and $800 per person-day depending on the size and location of the project.

## Contingencies

The allowance made for contingency costs depends on the level of accuracy of the cost estimates. Contingencies are estimated based on a user-selected percentage of the subtotal of all project costs excluding interest during construction. Note that contingencies are incremental in the sense that they are derived from project costs including any credits.

The allowance for contingency items should be based on the level of accuracy associated with the RETScreen pre-feasibility estimate of the project costs. Typically, a pre-feasibility level cost analysis should be accurate within 40 to 50%. However, this accuracy will depend on the expertise of the study team, the scale of the project being considered, the level of effort put forward to complete the pre-feasibility study and the availability of accurate information. It is certainly possible that the RETScreen user experienced with small hydro project developments could estimate costs in the range of 5 to 40% of the total initial project costs.

## Interest during construction

Interest during construction (short-term construction financing) will vary depending on the duration of construction and the cost of money. The user enters the interest rate (%) and the length of construction in months. The interest cost during construction is then calculated assuming the average debt over the project length in months is 50% of the subtotal of all project costs. For example, if $1 million worth of equipment must be financed over 12 months at an annual rate of 10%, the user should enter 10% as the interest rate during construction, the calculated interest cost during construction is: $1,000,000 x 50% x 12 months/12 months/year x 10% / year = $50,000.

The cost of interest during construction can vary between 3 and 15% of the project costs.

## 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.

## Annual Costs (Credits)

There will be a number of annual costs associated with the operation of a small hydro project. These will include land lease, property taxes, water rental, insurance premium, transmission line maintenance, spare parts, O&M labour, GHG monitoring and verification, travel and accommodation and general and administrative expenses. In addition, costs for contingencies will also be incurred. These costs are detailed below.

The financial viability of a small hydro project is particularly sensitive to variations in annual operation and maintenance costs and, therefore, close attention should be given to estimating the individual cost items listed below.

Note that the Annual Costs described here is used for both the "Formula" and the "Detailed" costing methods. As a rule-of-thumb, total costs for operation and maintenance costs will be about 4% of the Initial Costs with the minimum cost being about $50,000.

## O&M

## Land lease

Applicable annual land lease costs are site specific and will depend on the area and value of land that is leased. Annual land lease costs can range from $0 to $2,000 per site.

## Property taxes

This cost item summarises the annual costs of property taxes and is calculated as a percentage of the total estimated initial costs. Property tax might be levied on a small hydro energy project, depending upon the jurisdiction. Applicable property taxes have to be estimated on a site-by-site basis and will depend on the property value of the project and/or the revenue generated by the project.

As a rule-of-thumb, the annual cost of property taxes for a small hydro project represents 0 to 0.6% of the project's initial costs.

## Water rental

An annual charge for the use of the water in the river may be levied by the region in which the small hydro plant is located and will be related to the size of the project. Water rental costs, if applicable, are site specific and will depend on the installed capacity and/or annual energy generation of the small hydro plant. Water rental costs can range from $0/kW to $20/kW of installed small hydro capacity.

## Insurance premium

This cost item summarises the annual insurance premium costs and is calculated as a percentage of the total estimated initial costs. As a minimum, insurance is required for public liability, property damage, equipment failure and business interruption. The annual costs for insurance can be significant for an energy project and should be estimated by contacting an insurance broker.

As a rule-of-thumb, the annual cost of insurance for a small hydro project can range between 0.25 and 1.0% of the project's initial costs.

## Transmission line maintenance

The user enters the percentage of capital costs associated with transmission line maintenance costs. The maintenance of transmission lines associated with a small hydro project will involve periodic clearing of trees (where present) and replacement of parts (e.g. poles, conductor, insulators) that become damaged due to lightning, impact, etc.

The annual cost of transmission line maintenance is estimated based on the capital cost of the transmission line and substation. Annual costs normally range between 3 and 6% of capital costs depending on the location and communication equipment required (i.e. ease of access, presence of trees, VHF radio network, etc.).

## Spare parts

An annual allowance is required for the cost of spare parts and lubricants. An allowance of between 0.5 and 1% of the project's initial costs should be made to estimate the annual cost of spare parts and lubricants.

## O&M labour

The labour cost item summarises the cost of annual labour required for routine and emergency maintenance and operation of the small hydro plant. Operation will include daily monitoring (by remote communication), regular inspection of the equipment (including routine lubrication and adjustments), snow and ice clearing, scheduled maintenance (internal inspection and maintenance of the turbine and water passages), etc.

The cost of labour can range between $40,000 and $80,000 per person-year. The number of person-years of labour can range from 0.2 to 1.0 and will depend on the degree of automation built into the small hydro plant.

## GHG monitoring and verification

Greenhouse gas (GHG) monitoring is generally carried out by project proponents in accordance with the data requirements and methods laid out in the Monitoring Plan. If additional data needs to be collected in order to estimate GHG emissions, the cost of collecting that data and quantifying emissions reductions should be estimated. Note that in the case of Clean Development Mechanism (CDM) projects sustainable development indicators will also need to be monitored. For small-scale CDM projects (15 MW or less), monitoring requirements will be simplified, and therefore the estimated costs should be reduced. (See UNFCCC's CDM Website for details on monitoring requirements for CDM projects.)

Most GHG projects will also require third party verification of emissions reductions on an annual or periodic basis. For Joint Implementation (JI) projects, verification results in an independent confirmation of the actual emissions reductions the project has achieved and the quantification of Emissions Reduction Units (ERUs).

For CDM projects, emissions reductions must be verified and certified by a designated operational entity before Certified Emissions Reductions (CERs) are issued. A prescribed rate of $US 400/day has been set for the staff of designated operational entities or $US 1,200/day for a team of three. For CDM projects, an administration and adaptation fee will be charged by the United Nations Framework Convention on Climate Change (UNFCCC). Some host countries may also require a percentage of the value of CERs to be paid as an administration fee (note this percentage can be entered and accounted for on the *GHG Analysis* worksheet).

It may be decided to bundle and incur GHG monitoring and verification on a periodic (e.g. every two years) rather than on an annual basis, especially for smaller projects. In this case, the user should use the Periodic Costs section at the bottom of the *Cost Analysis* worksheet to do so, and set the same to "0" in the Annual O&M Costs section.

## Travel and accommodation

For small hydro plants in isolated locations, an annual allowance should be made for travel and accommodation costs associated with annual maintenance.

The cost of travel and accommodation will depend on the location of the site (i.e. duration and cost of transportation, duration and cost of accommodation) and can range from $500 (partial day, local site) to over $10,000 (two-week, isolated site) per person-trip. From 2 to 10 person-trips will be required.

## General and administrative

Annual general and administrative costs include the costs of bookkeeping, preparation of annual statements, bank charges, communication, etc. General and administrative costs are project specific and depend on the nature of the business enterprise (e.g. privately-owned with a simple power purchase agreement or utility/publicly owned with individual customers).

General and administrative costs can range between 1 and 20% of the annual costs (excluding other costs and contingencies).

## Other

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

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

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

## Contingencies

A contingency allowance should be included to account for unforeseen annual expenses and will depend on the level of accuracy of the operation and maintenance cost estimate section. This is especially true in the case of project in isolated areas. It is common to carry a contingency allowance for at least the replacement of the most expensive component subject to catastrophic failure. The contingency allowance is calculated based on an estimated percentage of the other operation and maintenance costs. It typically ranges from 10 to 20% of these costs.

## Periodic Costs (Credits)

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

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

The project may also be credited for periodic costs that would have been incurred over the project life of the base case, or conventional, energy system. The periodic credit item is entered in the grey input cell. The user then selects "Credit" from the drop-down list in the unit column. The interval (in years) over which the periodic credit is incurred is entered in the period column. The amount of the credit incurred at each interval is entered in the unit cost column. Note that the credit item is expressed as a negative value in the "Amount" column.

## End of project life

The user enters the value of the project at the end of its life. This amount is also commonly referred to as the salvage value (or disposal value). If the salvage value of the project at the end of its life is positive, then the user selects "Credit" from the drop-down list in the unit column in order to express this item as a negative value. However, if the costs of remediation or decommissioning that must be incurred at the end of the project life exceed the salvage value, then the user must select "Cost" from the drop-down list. The user must enter a positive numerical value in the "Unit Cost" column.

**Note:** At this point, the user should go to the optional *GHG Analysis* worksheet.

# Financial Summary

As part of the RETScreen Clean Energy Project Analysis Software, a *Financial Summary* worksheet is provided for each project evaluated. This common financial analysis worksheet contains five sections: **Annual Energy Balance**, **Financial Parameters**, **Project Costs and Savings**, **Financial Feasibility** and **Yearly Cash Flows**. 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 as to simplify the task of the user in analysing the viability of different projects. This also means the description of each parameter is common for most of the items appearing in the worksheet.

One of the primary benefits of using the RETScreen software is that it **facilitates the project evaluation process for decision-makers**. The *Financial Summary* worksheet, with its financial parameters input items (e.g. avoided cost of energy, discount rate, debt ratio, etc.), and its calculated financial feasibility output items (e.g. IRR, simple payback, NPV etc.), allows the project decision-maker to consider various financial parameters with relative ease. A description of these items, including comments regarding their relevance to the preliminary feasibility analysis, is included below.

## Annual Energy Balance

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

## Project name

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

## Project location

The user-defined project location is entered for reference purposes only in the *Energy Model* worksheet, 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 system. For central-grid applications, all the energy produced is assumed to be absorbed by the grid.

For isolated-grid and off-grid applications, all the energy produced might 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. In this case, the renewable energy delivered equals the renewable energy available less the excess energy available.

## Excess RE available

For "Isolated-grid" and "Off-grid" grid types, the *Energy Model* calculates the excess renewable energy available (MWh), which is the energy from the renewable energy system that is not absorbed by the grid or off-grid load and, therefore, is available as a by-product for heating or other uses.

## Firm RE capacity

The firm RE capacity refers to the "guaranteed" electrical power (kW) that a renewable energy electric power project can deliver. This value is calculated and transferred from the *Energy Model* worksheet. For small hydro projects, the user may enter an "avoided cost of capacity" that is agreed upon with (may need to be negotiated) the local electric utility. This avoided cost of capacity will depend upon the profile of the local electrical demand and renewable energy supply conditions.

## Grid type

The grid type is selected in the *Hydrology & Load* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

## Peak load

For "Isolated-grid" and "Off-grid" grid types, the peak electrical load (kW) of the local electric utility (or application for off-grid systems) is entered in the *Hydrology & Load* worksheet, and it is copied automatically to the *Financial Summary* worksheet. This is the peak load faced during the year.

## Energy demand

The energy demand refers to the annual energy demand (MWh) for isolated-grid and off-grid applications. This value is calculated in the *Hydrology & Load* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

## Net GHG emission reduction - credit duration

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

## Net GHG emission reduction [yr 1 to x (1st period)]

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 project instead of the base case, or baseline, system. This value is calculated in the *GHG Analysis* worksheet, and it is copied automatically to the *Financial Summary* worksheet. For projects in which a change in baseline emission factor has been selected in the GHG Analysis worksheet, the model indicates the net annual average GHG emission reduction for the years preceding the change.

## Net GHG emission reduction - yr x+1 and beyond (2nd period)

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 project instead of the base case, or baseline, system, for the years following the change in baseline emission factor. This value is calculated in the *GHG Analysis* worksheet, and it is copied automatically to the *Financial Summary* worksheet.

## Net GHG emission reduction - project life

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

## Financial Parameters

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

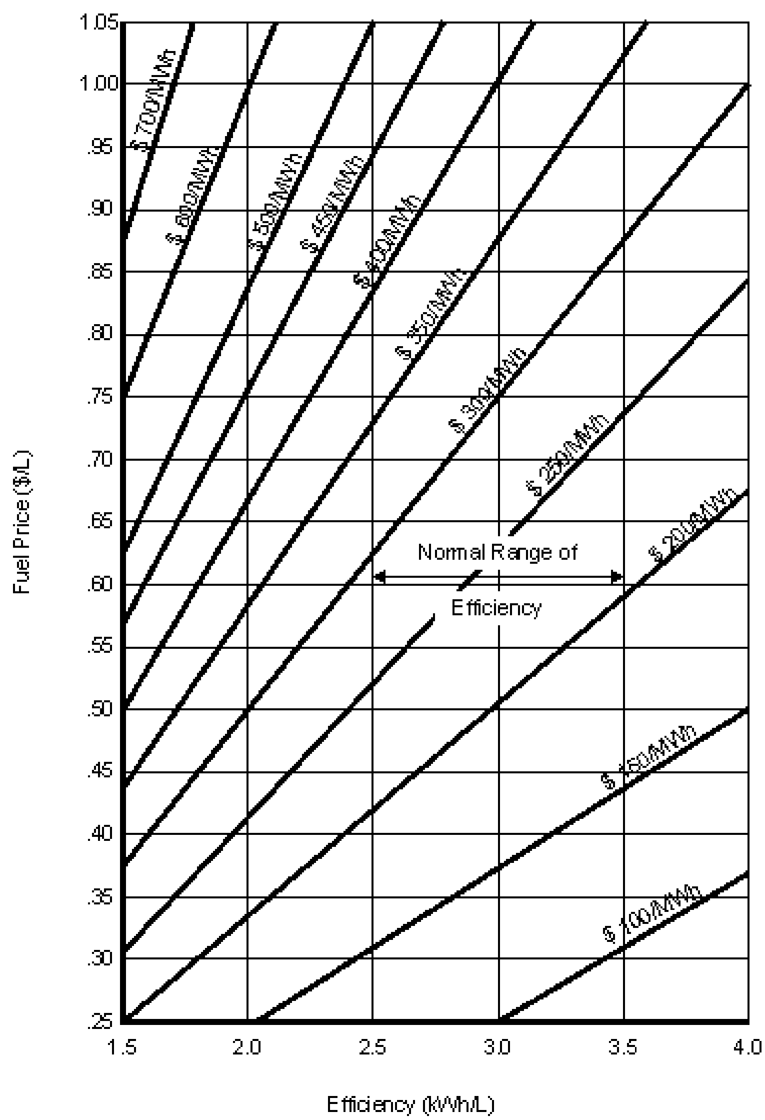
## Avoided cost of energy

The user enters the avoided cost of energy per kWh. This value typically represents either the "average" or the "marginal" unit cost of energy for the base case electricity system and is directly related to the cost of fuel for the base case electricity system. The user is given the flexibility in the model to determine what the base case electricity system is. For example, 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.

Avoided cost of energy calculations for 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 might pay independent power producers (IPP) for electricity produced by the IPP. Utilities might 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 electric power generation will depend upon a number of factors. As an example, for a recently constructed 50 MW hydro project in North America, the local utility pays the IPP approximately 5.84 ¢/kWh ($0.0584/kWh) for electricity sold to the utility for a central-grid application. As another example, a utility located in a remote area of North America is currently paying another IPP more than 20 ¢/kWh ($0.20/kWh) for a hydro project connected to an isolated diesel-grid because the utility faces much higher energy costs due largely to the cost of transporting and storing diesel fuel.

For "Isolated-grid" and "Off-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 this figure includes diesel plant maintenance at 20% of fuel costs. As an example, from this 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.




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

## 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 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.

## 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.

## 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 electric 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 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 avoided cost of energy over the life of the project. This permits the user to apply rates of inflation to energy 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. The model can analyse project life's up to 50 years; the project life of a well designed small hydro project typically falls between 25 and 50 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 an energy project improves. The model uses the debt term in the calculation of the debt payments and the yearly cash flows. The term of the debt normally falls within a 1 to 25 year range. It should not exceed the estimated project life.

## 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 project costs $20,000 to evaluate (feasibility study) and develop, and $80,000 to design (engineering), build, install and commission, the user could enter 80% as the depreciation tax basis in order to depreciate only the engineering, energy equipment, balance of plant and miscellaneous costs while the feasibility and development costs would be fully expensed during year 0.

## Depreciation rate

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

## Depreciation period

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

## Tax holiday available?

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

## Tax holiday duration

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

## Project Costs and Savings

Most of the summary items here are calculated and/or entered in the *Cost Analysis* worksheet and transferred to the *Financial Summary* worksheet. Some calculations are made in the *Financial Summary* worksheet.

## Initial Costs

The total initial costs represent the total investment that must be made to bring a project on line, before it begins to generate savings (or income). The total initial costs are the sum of the estimated feasibility study, development, engineering, energy equipment, balance of plant and miscellaneous costs and are inputs in the calculation of the simple payback, the net present value and the project equity and debt.

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

## Feasibility study

The feasibility study item represents the sum of the costs incurred to assess the feasibility of a project. It is net of any "credits" for not having to develop the base case project. Considerable detail is provided in the *Cost Analysis* worksheet for estimating the sub-costs for feasibility studies. This is done because it will help the project proponent better estimate the costs of the next investment required, which is the investment in a feasibility study. However for smaller projects, 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 is net of any "credits" for not having to develop the base case project.

## Energy equipment

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

## Balance of plant

The balance of plant item represents the sum of the purchasing, construction and installation costs of all the elements of the energy system other than the energy 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 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 and debt payments. Note that the total annual costs include the reimbursement of the "principal" portion of the debt which is not, strictly speaking, a cost but rather an outflow of cash. These costs are described briefly below.

## O&M

The operation and maintenance (O&M) costs are the sum of the annual costs that must be incurred to operate and maintain the energy system, in excess of the O&M cost required by the base case system. The model uses the O&M cost to calculate the total annual costs and the yearly cash flows.

## 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, 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

The annual energy savings are equal to the sum of the product of the "Renewable energy delivered" and "Avoided cost of energy" and, for isolated-grid and off-grid systems, the product of the "Excess RE available" and the "Avoided cost of excess 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 represents 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 credit 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 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 small hydro 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 might 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 0. 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 credits transaction fee, 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 or savings (net cash flows before depreciation, debt payments and income taxes) by debt payments (principal and interest).

The debt service coverage is a ratio used extensively by the potential lenders for a project to judge 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 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 System section provides a description of the emission profile of the baseline system, representing the baseline for the analysis. The Proposed Case System section provides a description of the emission profile of the proposed project. The GHG Emission Reduction Summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections 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. RETScreen allows the user to evaluate proposed projects in both domestic and international markets, including projects that fall under the Kyoto Protocol's Clean Development Mechanism (CDM) and Joint Implementation (JI). The online manual provides information and Website links related to the rules and guidelines that have been developed for CDM and JI projects, in particular those regarding baselines, and the transaction costs associated with these projects. Based on user inputs, RETScreen estimates the quantity of credits that the project may generate and includes the value of these credits in the financial analysis of the project.

One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers. The *GHG Analysis* worksheet, with its emission related input items (e.g. fuel mix, 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.

The RETScreen *GHG Analysis* Worksheet Flow Chart is presented in the following figure.

## 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.

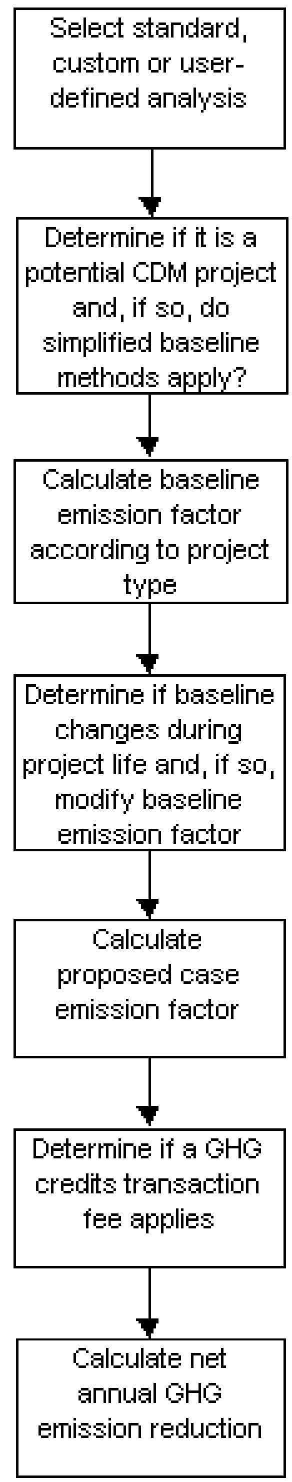
If the user selects "No" from the drop-down list, the user should then go directly to the *Financial Summary* worksheet.

## Type of analysis

The user selects the type of analysis from the three options in the drop-down list: "Standard," "Custom" and "User-defined." "Standard" analysis uses many pre-defined parameters in the calculations whereas "Custom" and "User-defined" analysis require that the user enter these parameters.

## Potential CDM project?

RETScreen has been improved to better take into account the emerging rules for carbon finance under the **Kyoto Protocol**, in collaboration with the United Nations Environment Programme (UNEP) and the Prototype Carbon Fund (PCF) at The World Bank. The Kyoto Protocol is the protocol to the United Nations Framework Convention on Climate Change (UNFCCC) that was adopted in 1997 in Kyoto at the third Conference of the Parties (COP 3). The Kyoto Protocol commits industrialized countries (defined as Annex I countries) to legally binding greenhouse gas (GHG) reduction targets during the period between 2008 and 2012. These commitments are on average 5% below 1990 emissions levels.




***GHG Analysis* Worksheet Flow Chart**

The Kyoto Protocol also established three mechanisms: the **Clean Development Mechanism (CDM), Joint Implementation (JI)**, and **Emissions Trading**, that allow Parties to pursue opportunities to cut emissions, or enhance carbon sinks, abroad. The cost of curbing emissions varies considerably from region to region and therefore makes economic sense to cut emissions, where it is cheapest to do so, given that the impact on the atmosphere is the same.

The user indicates by selecting from the drop-down list whether or not the project is to be evaluated as a potential CDM project. The user should select "Yes" if the **project is located in a developing country** and it has good potential to **meet the requirements for CDM projects**. These requirements are described in brief below and covered in detail at the UNFCCC's CDM Website. The user should select "No" for any other domestic or international GHG reduction projects, including ones that might qualify for Joint Implementation. JI requirements are also described in brief below.

If the user selects "Yes" from the drop-down list, RETScreen automatically assesses, by checking values calculated on other RETScreen worksheets, whether or not the project can be considered as a **small-scale CDM project** (i.e. the capacity of a renewable energy system does not exceed 15 MW or the aggregate energy savings by an energy efficiency improvement project does not exceed the equivalent of 15 GWh per year). If the project fits within the criteria for small-scale CDM projects, then the user may be able to take advantage of the simplified baseline methods and other rules and procedures for small-scale CDM projects.

The basic concept of the Clean Development Mechanism is that industrialized countries (or companies) invest in GHG emission-reduction projects in developing countries and gain credits from these projects that they can then apply to their own GHG reduction commitments as agreed to under the Kyoto Protocol.

Article 12 of the Kyoto Protocol defines the goals of the CDM as:

- to assist developing countries in achieving sustainable development, and in contributing to the ultimate objective of the Convention; and
- to assist industrialised countries in meeting their quantified emission reduction commitments.

The Kyoto Protocol also proscribes that emissions reductions will only be certified if:

- the CDM project has the approval of the host country;
- the project produces real, measurable and long-term GHG benefits; and
- the reductions in emissions are additional to any that would occur in the absence of the certified project activity.

Under the Kyoto Protocol an Executive Board (EB) has been established to oversee and monitor the CDM. The Executive Board is responsible for accrediting Designated Operational Entities (DOE) that validate CDM projects and verify and certify emissions reductions. Credits generated and certified from CDM projects are known as "Certified Emissions Reductions," or CERs. A

CER is equal to one metric tonne of carbon dioxide ($CO_2$) equivalent and must be certified by a Designated Operational Entity.

In November 2001, at COP 7 in Marrakech, Morocco, the parties reached an agreement on the legal text needed to implement the Kyoto Protocol. A key outcome of Marrakech was agreement on the basic rules and regulations governing the CDM. These rules are covered in a section of the Marrakech Accord known as "Modalities and Procedures for a Clean Development Mechanism." Specific issues agreed to in Marrakech include the baseline approaches that will be permitted for CDM projects, the procedures for approving baseline methodologies, and the format of the Project Design Document (PDD). Marrakech also allowed for simplified procedures for small-scale projects and identified the types of projects that could be considered small scale.

All CDM projects must be "additional to any that would occur in the absence of the proposed project activity" in order to be eligible for credits. This qualification is called "**additionality**." All CDM projects, therefore, require the estimation or measurement of "baseline" emissions - those that would have occurred without the project - and actual emissions that occur after a project has been implemented. Guidelines are available at the UNFCCC's CDM Website on how to demonstrate additionality.

A **baseline approach** is the basis for defining a baseline methodology. The Conference of the Parties have agreed to the following three approaches for CDM project activities.

1. Existing actual or historical emissions, as applicable.
2. Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment.
3. The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category.

The RETScreen GHG Analysis worksheet can be used for each of these approaches.

Note that although the Executive Board has approved these three baseline approaches, they are simply guidelines. In order to register a CDM project the baseline must be developed using an approved methodology.

A **baseline methodology** is an application of one of the allowable baseline approaches, as defined to an individual project activity, reflecting aspects such as sector and region. Baseline methodologies for CDM projects must be approved by the Executive Board. If project proponents wish to use a new methodology they may submit it for approval. Details of approved methodologies are provided at the UNFCCC's CDM Website.

Joint Implementation projects, on the other hand, occur in Annex 1 countries, that is, countries that have agreed to emissions targets under the Kyoto Protocol. Like the CDM, the basic concept of JI is that industrialised countries (or companies) invest in GHG emission-reduction projects in other Annex 1 countries where reductions are cheaper than in their own country and gain credits from these projects that can then applied to their own GHG reduction commitments as agreed to under Kyoto. In practice, Joint Implementation projects are more likely to take place in Economies-In-Transition or EITs, where there tends to be more scope for cutting emissions at lower costs.

Joint Implementation projects must have the approval of all Parties involved, and must lead to emission reductions or removals that are additional to any that would have occurred without the project. An ERU is an Emission Reduction Unit generated from a JI project. An ERU is equal to one metric tonne of carbon dioxide ($CO_2$) equivalent.

Projects starting from the year 2000 that meet the above rules may be listed as Joint Implementation projects. However, ERUs may only be issued after 2008[1].

## Use simplified baseline methods?

RETScreen automatically assesses, by checking values calculated on other RETScreen worksheets, whether or not the project can be considered as a **small-scale CDM project** (i.e. the capacity of a renewable energy system does not exceed 15 MW or the aggregate energy savings by an energy efficiency improvement project does not exceed the equivalent of 15 GWh per year). Note that this option will automatically be hidden in RETScreen for non-CDM projects, or for potential CDM projects that exceed the small-scale CDM project size limits.
Simplified rules and procedures are available for small-scale CDM projects if it can be demonstrated that one of the barriers identified by the UNFCCC has been overcome in order to implement the project. These simplifications will allow the use of standardized baselines, streamlined monitoring procedures, a simpler Project Design Document, and reduced registration fees - all of which reduce transaction costs so that small-scale projects can offer CERs at more competitive prices. The user should select "Yes" from the drop-down list to indicate that the simplified methods will be used for developing the baseline for the potential small-scale CDM project.

The RETScreen GHG Analysis worksheet can be used to calculate the baseline for a small-scale CDM project directly in conjunction with Appendix B of the document “Simplified modalities and procedures for small-scale CDM project activities”, which is available at the UNFCCC's CDM Website. This appendix contains indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories, including recommendations for determining the project boundary, leakage, baseline and monitoring. Note that small-scale CDM projects should not be debundled components of larger project activities, as described in Appendix C.

In accordance with the simplified modalities and procedures for small-scale CDM project activities, a simplified baseline and monitoring methodology listed in the appendix may be used for a small-scale CDM project activity if project participants are able to demonstrate to a

[1] Portions of this text were adapted from the UNFCCC's document, *Guide to the Climate Convention and its Kyoto Protocol*, available at UNFCCC's Website.

designated operational entity that the project activity would otherwise not be implemented due to the existence of one or more barrier(s) listed below.

(a) Investment barrier: a financially more viable alternative to the project activity would have led to higher emissions.

(b) Technological barrier: a less technologically advanced alternative to the project activity involves lower risks due to the performance uncertainty or low market share of the new technology adopted for the project activity and so would have led to higher emissions.

(c) Barrier due to prevailing practice: prevailing practice or existing regulatory or policy requirements would have led to implementation of a technology with higher emissions.

(d) Other barriers: without the project activity, for another specific reason identified by the participant, such as institutional barriers or limited information, managerial resources, organisational capacity, financial resources, or capacity to absorb new technologies, emissions would have been higher.

As an example of how RETScreen can be used with Appendix B of the document "Simplified modalities and procedures for small-scale CDM project activities," under paragraph 28 of this document concerning a system where all fossil fuel fired generating units use fuel oil or diesel fuel, the baseline is the annual kWh generated by the renewable unit times an emission coefficient for a modern diesel generating unit of the relevant capacity operating at optimal load as given in the following table.[2]

| Type of Grid | Mini-grid with 24-hour Service | i)Mini-grid with 4- to 6-hour Service<br>ii) Productive applications<br>iii) Water pumps | Mini-grid with Storage |
|---|---|---|---|
| ***Load Factor*** | ***25%*** | ***50%*** | ***100%*** |
| <15 kW | 2.4 | 1.4 | 1.2 |
| >=15 to <35 kW | 1.9 | 1.3 | 1.1 |
| >=35 to <135 kW | 1.3 | 1.0 | 1.0 |
| >=135 to <200 kW | 0.9 | 0.8 | 0.8 |
| >=200 kW *** | 0.8 | 0.8 | 0.8 |

**Emission Factors for Diesel Generator Systems (in kg$CO_2$equ/kWh *)**
**for Three Different Levels of Load Factor****

*) A conversion factor of 3.2 kg $CO_2$ per kg of diesel has been used (following revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories).

**) Figures are derived from fuel curves in the online manual of RETScreen International's PV 2000 Model.

***) Default values.

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2 Portions of this text were adapted from Appendix B of the document, *Simplified modalities and procedures for small-scale CDM project activities*, available at the UNFCCC's CDM Website.

In this example, the user would select "User-defined" type of analysis at the top of the RETScreen GHG Analysis Worksheet and enter "diesel mini-grid" as the electricity system under the Base Case Electricity System (Baseline) section, and then enter the appropriate GHG coefficient as selected from the table above. Note that the UNFCCC used RETScreen to help calculate the emission factors at different load levels for the table provided above.

# Background Information

## Project name

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

## Project location

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

## Project capacity

The project capacity is calculated in the *Energy Model* worksheet and it is copied automatically to the *GHG Analysis* worksheet.

## Grid type

The grid type is selected in the *Hydrology & Load* worksheet, and it is copied automatically to the *GHG Analysis* worksheet.

## Global Warming Potential of GHG

The model indicates the global warming potential of methane ($CH_4$) and nitrous oxide ($N_2O$). If the user selects the "Custom" type of analysis, different values from the default values provided may be entered by the user. Researchers have assigned Global Warming Potentials (GWPs) to greenhouse gases to allow for comparisons of their relative heat-trapping effect. The higher the global warming potential of a gas the greater the contribution to the greenhouse effect. For example nitrous oxide is 310 times more effective than carbon dioxide at trapping heat in the atmosphere.

GWPs of gases are defined as a unit multiple of that given to carbon dioxide ($CO_2$), which is assigned a reference value of 1 (i.e. the GWP of $CO_2$ is 1 and the GWP of $N_2O$ is 310). The default values are those defined by the Revised Intergovernmental Panel on Climate Change (IPCC) Guidelines for Greenhouse Gas Inventories, 1996.

# Base Case Electricity System (Baseline)

To perform the RETScreen GHG emission reduction analysis for the project, the user needs to define the baseline (also called base case or reference case) electricity system.

For example, in North America when preparing a GHG emission reduction analysis for a small hydro 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 needs only to select "Natural gas" as the fuel type with a 100% fuel mix and use the default "T & D losses" of 8%. For the case of an isolated-grid or an off-grid application, 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 grid-connected 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. Note that this methodology can be used for small-scale CDM renewable energy projects that are connected to a grid that includes generating units other than diesel or fuel oil.

Some users may prefer to perform a much more detailed analysis of the GHG reduction potential of the project (e.g. an economist working for a public utility commission). The model allows for a more detailed analysis regarding 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

*(Custom or Standard analysis)*

The user selects the fuel type from the options in the drop-down list. The RETScreen software can model the GHG emissions of any electricity supply system. The fuel type is the fuel(s) or power plant(s) which will be displaced by the proposed project. If the user selects one of the fuel types from the drop-down list, default emission factor and fuel conversion efficiency values will be inserted into the row inputs of the table. The default emission factors and conversion efficiencies of various fuel types are given in the following table [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 the following 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 type

*(User-defined analysis)*

The user enters the type of fuel of the base case electricity system in the grey input cell.

## Fuel mix

The user enters the fuel mix (%) of the base case electricity system for each fuel type. Units are given as percentages of total electricity supplied. Note that the user should verify that the sum of all fuel types listed in the fuel mix column equals 100%.

## $CO_2$, $CH_4$ and $N_2O$ emission factors

*(Custom analysis)*

The user enters the $CO_2$, $CH_4$ and $N_2O$ emission factors for the different fuel types. They represent the mass of greenhouse gas emitted per unit of energy. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants. For grid-connected projects, the user should enter factors representative of large generating plants. On the electricity mix row at the bottom of the table, the model calculates the equivalent emission factors for the global electricity mix and per unit of electricity delivered. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T & D losses of the different fuel types.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ). For the global electricity mix shown on the bottom row of the table, units are given in kilograms of gas emitted per gigajoule of end-use electricity delivered.

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. $CO_2$ emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. $CH_4$ and $N_2O$ emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual. In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

## $CO_2$, $CH_4$ and $N_2O$ emission factors

*(Standard analysis)*

The model provides the $CO_2$, $CH_4$ and $N_2O$ emission factors which represent the mass of greenhouse gas emitted per unit of energy. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants. The default factors provided are those which are representative of large power plants that feed a central electricity grid. On the electricity mix row at the bottom of the table, the model calculates the equivalent emission factors for the total electricity mix and per unit of electricity delivered. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T & D losses of the different fuel types.

For each fuel type selected, units are given in kilograms of gas emitted per gigajoule of heat energy generated (kg/GJ). For the total electricity mix shown on the bottom row of the table, units are given in kilograms of gas emitted per gigajoule of end-use electricity delivered.

For more information on determining GHG emission factors, see the revised IPCC Guidelines for National Greenhouse Gas Inventories. $CO_2$ emission factors for many fuels are included on page 1.13 of the IPCC Reference Manual. $CH_4$ and $N_2O$ emission factors for a number of fuels are included on pages 1.35 and 1.36 of the IPCC Reference Manual. In addition, refer to the National Communications at the UNFCCC Website to see if more relevant emission factors are available for the country being considered.

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

## Fuel conversion efficiency

*(Custom analysis)*

The user enters the fuel conversion efficiency for the selected fuel type. The fuel conversion efficiency is the efficiency of energy conversion from primary heat potential to actual power plant output. This value is used to calculate, for each fuel type, the aggregate GHG emission factor and therefore is only relevant for fuel types which actually produce greenhouse gases (i.e. with non-zero $CO_2$, $CH_4$ and $N_2O$ emission factors).

For example, a typical coal-fired power plant could have a fuel conversion efficiency of 35%, which indicates that 35% of the heat content of the coal is transformed into electricity fed to the grid.

Units are given as a percentage of primary heat potential (gigajoules of heat) to actual power plant output (gigajoules of electricity). Fuel types which emit no GHGs (e.g. solar) have a default value of 100%.

## Fuel conversion efficiency

*(Standard analysis)*

The model provides the fuel conversion efficiency for the selected fuel type. The fuel conversion efficiency is the efficiency of energy conversion from primary heat potential to actual power plant output. This value is used to calculate, for each fuel type, the aggregate GHG emission factor and therefore is only relevant for fuel types which actually produce greenhouse gases (i.e. with non-zero $CO_2$, $CH_4$ and $N_2O$ emission factors).

For example, a typical coal-fired power plant could have a fuel conversion efficiency of 35%, which indicates that 35% of the heat content of the coal is transformed into electricity fed to the grid.

Units are given as a percentage of primary heat potential (gigajoules of heat) to actual power plant output (gigajoules of electricity). Fuel types which emit no GHGs (e.g. solar) have a default value of 100%.

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

## Transmission and distribution losses

The user enters the transmission and distribution (T & D) losses (%) of the base case electricity system, which includes all energy losses between the power plant and the end-user. This value will vary based on the voltage of transport lines, the distance from the site of energy production to the point of use, peak energy demands, ambient temperature and electricity theft. In addition, T & D system type (e.g. AC vs. DC) and quality may also influence losses. The model calculates the weighted average of the T & D losses of the global electricity mix on the bottom row of the table.

Units are given as a percentage of all electricity losses to electricity generated. 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

*(Custom or Standard analysis)*

The model calculates the GHG emission factor for each reference fuel type. Values are calculated based on the individual emission factors, the fuel conversion efficiency and the T & D losses. The weighted GHG emission factor for the total electricity mix is calculated on the bottom row of the table.

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

## GHG emission factor

*(User-defined analysis)*

The user enters the GHG emission factor for the base case electricity system specified.

**Units switch:** The user can choose to express the emission factor in $kg_{CO2}$ / kWh or in $t_{CO2}$ / MWh (which are equivalent).

## Base case GHG emission factor

The model calculates the GHG emission factor for the electricity system specified. The value is calculated based on the GHG emission factor and the T & D losses entered by the user.

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

## Does baseline change during project life?

The user indicates by selecting from the drop-down menu whether or not the baseline changes during the project life. The project baseline might not stay constant throughout the life of the project, due to factors such as changes in regulations in the electricity sectors, the planned addition of new generation units on the grid (e.g. large-scale hydroelectric project), or decommissioning of existing units.

The model allows for one change in the baseline during the project life that the user enters as a percentage increase or decrease in the initial baseline. The baseline emissions will thus be scaled accordingly for the year in which the change occurs as well as each year following the change.

## Change in GHG emission factor

The user enters the percentage by which baseline emissions will increase (positive percentage) or decrease (negative percentage) because of the change in the baseline.

For example, if a new hydro plant already under construction will decrease emissions by 10% in year 5, then the user enters negative 10%. The model will then reduce baseline emissions by 10% for year 5 and all subsequent years.

## Year of change

The user enters the year in which the change in the baseline occurs.

For example, if a new hydro plant is scheduled to be added to the electricty grid during the fifth year after this proposed project begins, the user enters 5.

## GHG emission factor year x and beyond

The model calculates the GHG emission factor for the years following the change in baseline. Values are calculated by applying the specified change in emission factor to the weighted GHG emission factor of the electricity mix.

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

## Reason/event for baseline change

The user enters the reason for the baseline change, i.e. the event that triggers the change in the baseline. This information is given for reference purposes only.

For example, if the addition of a new hydro plant is the reason for the change in the baseline, the user would enter something like "Addition of new hydro plant already planned."

## Proposed Case Electricity System (Small Hydro Project)

The proposed case electricity system, or mitigation system, is the proposed project. The GHG emissions for the proposed project are assumed to be equal to zero.

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

## Fuel type

The fuel type of the proposed project is assumed to be an emission free source.

## Fuel mix

The fuel mix of the proposed project is set to 100%.

## $CO_2$, $CH_4$ and $N_2O$ emission factors

*(Custom analysis)*

The user enters the $CO_2$, $CH_4$ and $N_2O$ emission factors corresponding to the fuel type, i.e. the proposed project.

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

## $CO_2$, $CH_4$ and $N_2O$ emission factors

*(Standard analysis)*

The model provides the $CO_2$, $CH_4$ and $N_2O$ emission factors corresponding to the fuel type, i.e. the proposed project. These values are assumed to be zero in all cases.

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

## Fuel conversion efficiency

If the user selects the "Standard" type of analysis, the fuel conversion efficiency is set to 100% for the proposed project. For "Custom" type of analysis, the user enters the fuel conversion efficiency.

This value is used in conjunction with the $CO_2$, $CH_4$ and $N_2O$ emission factors and the transmission and distribution losses 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 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 proposed project. Values are calculated based on the individual emission factors and the fuel conversion efficiency.

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

## Proposed case GHG emission factor

The user enters the GHG emission factor for the proposed project.

**Units switch:** The user can choose to express the emission factor in $kg_{CO2}$ / kWh or in $t_{CO2}$ / MWh (which are equivalent).

## GHG Emission Reduction Summary

Based on the GHG emission data entered, the model calculates the annual reduction in GHG emissions when the base case system is displaced with the proposed case system.

If the baseline changes during the project life, then the model calculates the annual GHG reduction for both periods of the base case, that is, for the years before the change in baseline and for the years following the change in baseline.

## Years of occurence

If the user has entered that the project baseline does change, the model indicates the year numbers for the first period GHG emission factors and for the second period GHG emission factors.

## Base case GHG emission factor

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

**Units switch:** The user can choose to express the emission factor in $kg_{CO2}$ / kWh or in $t_{CO2}$ / MWh (which are equivalent).

## Proposed case GHG emission factor

The model transfers the proposed case GHG emission factor calculated (or entered by the user) in the Proposed Case Electricity System section.

**Units switch:** The user can choose to express the emission factor in $kg_{CO2}$ / kWh or in $t_{CO2}$ / MWh (which are equivalent).

## End-use annual energy delivered

The model calculates the end-use annual energy delivered by the proposed project, which is the amount of energy delivered to the electricity grid (or load for off-grid systems), as calculated in the *Energy Model* worksheet, minus the T & D losses for the grid vis-à-vis the proposed project.

Units are given in megawatt-hours of electricity delivered (MWh).

## Gross annual GHG emission reduction

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

Units are given in equivalent tonnes of $CO_2$ emissions per year ($t_{CO2}$/yr).

## GHG credits transaction fee

The user enters the percentage of credits that will have to be paid annually as a transaction fee. In order to obtain credits for a GHG project, a portion of the credits might have to be subtracted as a transaction fee, to be paid each year to the crediting agency (e.g. the UNFCCC) and/or the host country.

For CDM projects 2% of the CERs generated by each project will be paid into an *Adaptation fund* to help particularly vulnerable developing countries adapt to climate change. Note that projects in least developed countries are exempt from this part of the levy in order to promote the equitable distribution of projects.

The CDM Executive Board, as well as a number of host countries, also require that they receive a percentage of the credits to help cover their administrative costs (e.g. for project approval etc.). The user might wish to check the UNFCCC's CDM Website and with the host country's Designated National Authority to find out if they require a percentage of credits to be paid.[3]

The model then reduces the annual GHG credits by this percentage before it calculates the total GHG credits and the value of these credits.

[3] A list of Designated National Authorities, is available at the UNFCCC's CDM Website.

## Net annual GHG emission reduction

The model calculates the net annual reduction in GHG emissions estimated to occur if the proposed project is implemented. The calculation is based on the gross annual GHG emission reduction and the GHG credits transaction fee.

Units are given in equivalent tonnes of $CO_2$ emissions 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 MWh 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 $30,000,000 means that the initial costs could take any value between $27,000,000 and $33,000,000. Since $30,000,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

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

## Annual costs

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

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

For example, a range of 10% for an annual cost of $80,000 means that the annual cost could take any value between $72,000 and $88,000. Since $80,000 is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

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

## Debt ratio

The debt ratio is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt ratio range. The range is a percentage corresponding to the uncertainty associated with the estimated debt ratio value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0% and the lowest percentage such that the debt ratio will always fall between 0 and 100%. The range determines the limits of the interval of possible values that the debt ratio could take.

For example, a range of 10% for a debt ratio of 70% means that the debt ratio could take any value between 63 and 77%. Since 70% is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt ratio is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Debt interest rate

The debt interest rate is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

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

For example, a range of 10% for a debt interest rate of 20% means that the debt interest rate could take any value between 18 and 22%. Since 20% is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt interest rate is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## Debt term

The debt term is automatically transferred from the *Financial Summary* worksheet to the *Sensitivity* worksheet.

The user enters the debt term range. The range is a percentage corresponding to the uncertainty associated with the estimated debt term value. The higher the percentage, the greater the uncertainty. The range specified by the user must be a percentage value between 0% and the lowest percentage such that the debt term will always fall between 1 year and the project life. The range determines the limits of the interval of possible values that the debt term could take.

For example, a range of 10% for a debt term of 20 years means that the debt term could take any value between 18 and 22 years. Since 20 years is the estimated value, the risk analysis will consider this value as being the most probable and the minimum and maximum values as being the least probable, based on a normal distribution.

If the debt term is known exactly by the user (no uncertainty), the user should enter a range of 0%.

## GHG emission reduction credit

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

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

For example, a range of 10% for a GHG emission reduction credit of $\$5/t_{CO2}$ 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 "tornedo 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 "Turbine type" selected by the user in the *Equipment Data* worksheet. From the dialogue box the user selects the Region followed by the Supplier. The suppliers name can be pasted from the dialogue box to the spreadsheets by clicking on the "Paste Data" button. Only data that are in **bold** are pasted to the spreadsheets; all other data are provided for reference purposes only. Data entered using the product database may be **overwritten**; i.e. the user may prefer to use other data and can manually enter values into the spreadsheets. "Other information," such as product weight and/or dimensions, is provided to help the user prepare the study. The product database contains a link to the Websites of some product suppliers. In the case where the Website link cannot be activated the user should try using another browser or can contact the supplier by other means (email, fax, etc.).

**Note:** To see all the suppliers listed in the product database and their contact information, the user can choose "Any" from the "Turbine 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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Natural Resources Canada
1615 Lionel-Boulet, P.O. Box 4800
Varennes, Quebec, CANADA J3X 1S6

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Fax: +1-450-652-5177
E-mail: rets-pdb@nrcan.gc.ca

# Weather (Hydrology) Data

The RETScreen Small Hydro Project Model can be used for any location in the world. For projects in Canada, the user can use Canadian hydrology data included in the online weather (Hydrology) database. For other project locations around the world, hydrology data from other sources can be entered directly into the worksheet.

This database currently includes some of the hydrological data required in the model for projects located in **Canada**. In addition, maps are also provided to help the user with the analysis. To access the weather database the user may refer to "Data and Help Access."

From the dialogue box, the user selects a "Region" (i.e. N. & Central America), then a "Country" (i.e. Canada), then "Map or Province/State" and finally a "Flow-Duration Curve (FDC) Type/Proxy Gauge Number." If the "Flow-Duration Curve Map" option is chosen, rather than the province, then the FDC type must be in the same region as the small hydro site. From the dialogue box the flow-duration curve data can be pasted to the spreadsheets by clicking on the "Paste Data" button. Only data that are in **bold** are pasted to the spreadsheets; all other data are for reference purposes only. Data entered using the weather database may be **overwritten**; i.e. the user may prefer to use other data and can manually enter values into the spreadsheets.

The following source of hydrological data has been used to calculate the new flow-duration curve dataset found in RETScreen: HYDAT (Hydrological Database) available from Environment Canada. Contact these organisations to purchase hydrological data where more detailed site information is required. Alternatively, for Canadian gauging stations not included in the RETScreen Database, individual datasets for particular stations can also be purchased from Environment Canada's National Water Data Archive.

Flow-duration curve data, that are required to run the model, are available for a large number of streamflow gauging stations. For example, streamflow data for the United Kingdom and Spain are available from the Centre for Hydrology and Ecology via a database called HYDATA.

In addition, data might be available from the International Small-Hydro Atlas website which can be accessed via the "Visit IEA Small-Hydro Atlas" button in the dialogue box.

CETC-Varennes is interested in adding hydrological data to the RETScreen Online Weather Database for other regions of the world. Please contact RETScreen International if you have data that you would like added to the database.

# 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/.

# Terms of Use

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# Bibliography


Acres International Limited, Hydrologic Design Methodologies for Small-Scale Hydro at Ungauged Sites - Phase I, prepared for: Environment Canada, Inland Waters Directorate, executed for Energy, Mines and Resources Canada, 1984.

Bennett, K., Small Hydro in Canada: An Overview. Prepared for Industry, Science and Technology Canada, Aboriginal Economic Programs, 1990.

The Danish Energy Agency, Engerstatistics 1995, 1999.

Energy, Mines and Resources Canada (EMR), Small power production in remote communities: a shared opportunity, 1988.

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

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

Gordon, J. L., What we must not forget, 1991.

Gordon, J. L., Black boxing hydro costs, 1989.

Gulliver, J.S., Arndt, E.A., Hydropower Engineering Handbook, 1991.

Johansson et al., Renewable Energy - Sources for Fuels and Electricity, Island Press, 1993.

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

Leng, G., J. Martin, Distributed Photovoltaic Demand-Side Generation: An Economic Evaluation For Electric Utilities, IEEE First World Conference On Photovoltaic Energy Conversion, December 1994.

Leng, G., Distributed Photovoltaic Demand-Side Generation: An Economic Evaluation For Electric Utilities - Master Degree Thesis, University of Massachusetts Lowell, November 1993.

Leopold, L.B., Water: A Primer, 1974.

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

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

Sigma Engineering Ltd, Energy Overview Study of Remote Communities in Canada, prepared for the Remote Community Demonstration Program, Energy Mines and Resources Canada, March 1985.

United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) Executive Board, Annex B - Indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories, December 2002.

# Website Addresses

Canada's Clean Development Mechanism (CDM): http://www.dfait-maeci.gc.ca/cdm-ji/cleandev-en.asp

Canada's Geographical Names: http://geonames.nrcan.gc.ca/

Canada's Joint Implementation (JI): http://www.dfait-maeci.gc.ca/cdm-ji/joint-en.asp

Canadian Topographic Maps: http://maps.nrcan.gc.ca/topographic.html

Engineering News Record: http://www.enr.com/

Environment Canada - HYDAT CD-ROM:
http://www.msc-smc.ec.gc.ca/wsc/products/hydat/main_e.cfm?cname=hydat_e.cfm.htm

Environment Canada - National Water Data Archive:
http://www.msc-smc.ec.gc.ca/wsc/products/hydat/main_e.cfm?cname=archive_e.cfm

Institute of Hydrology - Centre for Ecology and Hydrology: http://www.nwl.ac.uk/ih/

Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories:
http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

International Energy Agency - International Small-Hydro Atlas: http://small-hydro.com/

IPCC Reference Manual: http://www.ipcc-nggip.iges.or.jp/public/gl/invs6a.htm

NASA Surface meteorology and Solar Energy Data Set: http://eosweb.larc.nasa.gov/sse/RETScreen/

Prototype Carbon Fund (PCF) at World Bank: http://prototypecarbonfund.org/

RETScreen: www.retscreen.net

RETScreen Development Team: www.retscreen.net/e/partners/

RETScreen Software License Agreement: www.retscreen.net/license.html/

RETScreen Training & Support: www.retscreen.net/e/training/

United Nations Environment Programme (UNEP): http://www.unepie.org/energy/

United Nations Framework Convention on Climate Change (UNFCCC): http://unfccc.int/

UNFCCC Clean Development Mechanism (CDM): http://cdm.unfccc.int/

U.S. Environmental Protection Agency - Emissions and Generation Resource Integrated Database:
http://www.epa.gov/cleanenergy/egrid/index.html

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## NOTES:

www.retscreen.net