SolarTool

Generating solar radiation at inclined planes

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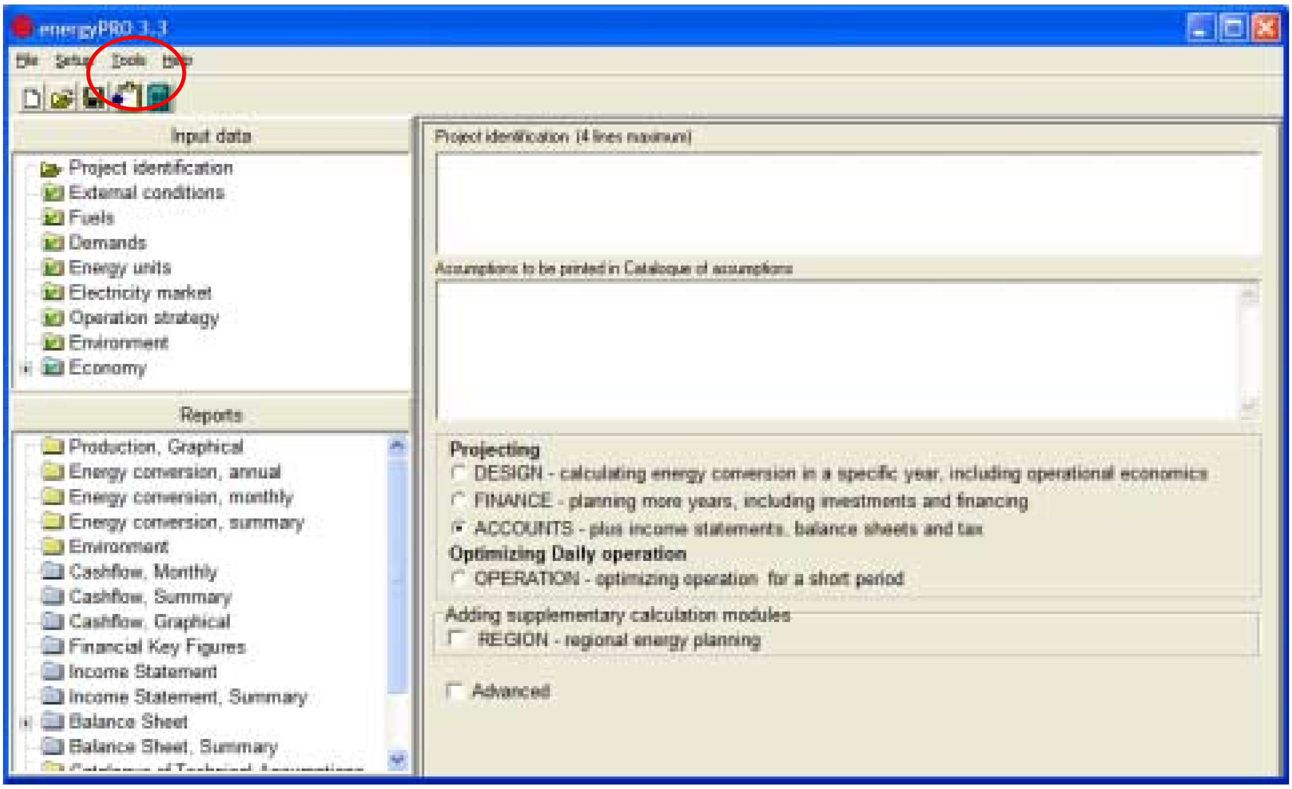
1. Introduction

With SolarTool you can create a time series with solar radiation on an inclined plane, typically to be used for solar collectors and photovoltaic.

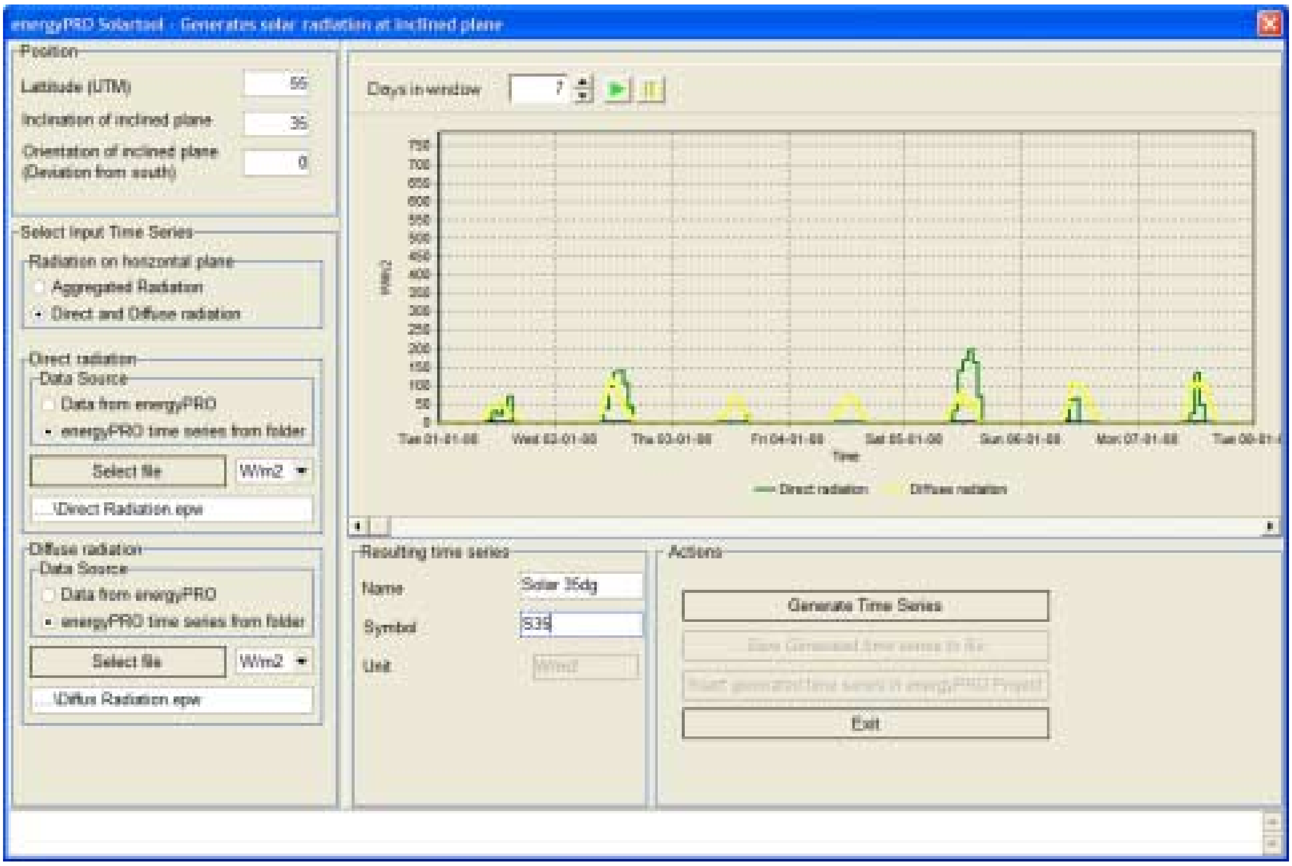
Al you need is a few input data and one or two time series with solar radiation on a horizontal surface.

2. User interface

You get access to the SolarTool by selecting Tools and ”Generate solar radiation at inclined plane”



The SolarTool has the following interface:



In the box “Position” you specify the latitude, inclination and orientation of the plane (solar collector or photo voltaic).

In the box “Select Input Time Series” you select your time series with the solar radiation on horizontal.

If the radiation comes as one time series choose “Aggregated Radiation”. If the radiation comes as two time series with beam radiation and diffuse radiation, respectively, choose “Direct and Diffuse radiation”.

You can select your time series in two ways. By selecting a time series in the present energyPRO-project file or by selecting a time series located in a folder on your computer or network.

The time series have to be formatted as an energyPRO file. At present, the values have to be in W/m^2.

Next, you give the resulting time series a proper name and symbol.

A click on “Generate Time Series” generates the resulting time series with aggregated radiation on the inclined plane. You can choose to save the generated time series to a file or to insert it in the open energyPRO project.

3. Method of calculation

3.1 Definitions

ϕ	[°]	Latitude
δ	[°]	Solar declination angel
γ	[°]	Orientation of inclined plane, south = 0°, west = 90°
θ	[°]	Angel of incidence of beam radiation on inclined plane
ω	[°]	Hour angel
ρ	[]	Reflection factor
θ_z	[°]	Solar zenith angle (Angel of incidence of beam radiation on horizontal)
I	[W/m^2]	Total radiation on a horizontal plane
I_b	[W/m^2]	Beam radiation on a horizontal plane
I_d	[W/m^2]	Diffuse radiation on a horizontal plane
I_{diff}	[W/m^2]	Diffuse radiation on an inclined plane
I_{dir}	[W/m^2]	Beam radiation on an inclined plane
I_o	[W/m^2]	Extraterrestrial radiation on a horizontal plane
I_{ref}	[W/m^2]	Ground reflected radiation on an inclined plane
I_s	[W/m2]	Total radiation on an inclined plane
I_{sc}	[W/m2]	Solar constant, 1367 W/m^2
K_T	[]	Ratio of total radiation on a horizontal plane to extraterrestrial radiation
n	[]	Day of year
R_b	[]	Ratio of beam radiation on an inclined plane to beam on horizontal
R_d	[]	Ratio of diffuse radiation on an inclined plane to diffuse on horizontal
R_r	[]	Ratio of reflected radiation on an inclined plane to total radiation on horizontal
s	[°]	Inclination of surface

3.2 External conditions

External time series are needed to calculate the solar radiation on an inclined plane in energyPRO. These time series include solar radiation. Optimally, the solar radiation is divided into beam radiation, I_b and diffuse radiation, I_d. Alternately, the solar radiation comes as total radiation, I.

If the solar radiation comes as total radiation the diffuse and the beam radiation can be calculated as follows (Reindl, D.T, et al., ”Diffuse Fraction Correlations” Solar Energy, vol. 31, No 5, October 1990):

Interval: $0 \le K_T \le 0,3$, Constraint: $I_d/I \le 1,0$

$$I_d / I = 1{,}020 - 0{,}254 * K_T + 0{,}0123 * \sin\alpha$$

Interval: $0,3 < K_T < 0,78$, Constraint: $0,1 \le I_d/I \le 0,97$

$$I_d / I = 1{,}400 - 1{,}749 * K_T + 0{,}177 * \sin\alpha$$

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Interval: $0,78 \le K_T$, Constraint: $0,1 \le I_d/I$
$I_d / I = 0,486 * K_T + 0,182 * \sin\alpha$

Where K_T is the ratio of total radiation on a horizontal plane to extraterrestrial radiation:

$$K_T = \frac{I}{I_o}$$

I_o is defined as:

$$I_o = I_{sc} * \cos\theta_z$$

where I_{sc} is the solar constant, 1367 w/m^2
θ_z is the solar zenith angle, described in section 3.3.1.

The beam radiation is

$$I_b = I - I_d$$

3.3 SolarTool

To make a time series with solar radiation on an inclined plane you need the following:

- Time series with total solar radiation (I) on horizonal plane <u>or</u>
- Time series with beam radiation (I_b) <u>and</u> time series with diffuse radiation (I_d)
- Inclination of surface (solar collector or photo voltaic) (s, [degrees])
- Orientation of surface (deviation from south) (γ, [degrees]).
- Latitude of location (ϕ).

3.3.1 Beam radiation

The relation between the beam radiation on an inclined plane and the beam radiation on horizontal is giving by the factor R_b.

$$R_b = \frac{\cos\theta}{\cos\theta_z}$$

where θ_z Angel of incidence of beam radiation on horizontal.

Angel of incidence of beam radiation on horizontal is specified by the formula:

$$\cos\theta_z = \sin\delta * \sin\phi + \cos\delta * \cos\phi * \cos\omega$$

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where δ is the solar declination angel
ϕ is the latitude
ω is the hour angel

The solar declination angel is approximately specified by:

$$\delta = 23{,}45 * \sin\left(360 * \frac{284 + n}{365}\right)$$

where n is the day of the year.

The hour angel is identified by (”European simplified methods for active solar system design”, Bernard Bourges, July 1990):

$$\omega = 15 * (h - 12)$$

The beam radiation on an inclined plane is found by the following formula:

$$\begin{aligned}\cos\theta = {} & \sin\delta * \sin\phi * \cos s - \sin\delta * \cos\phi * \sin s * \cos\gamma \\ & + \cos\delta * \cos\phi * \cos s * \cos\omega \\ & + \cos\delta * \sin\phi * \sin s * \cos\gamma * \cos\omega \\ & + \cos\delta * \sin s * \sin\gamma * \sin\omega\end{aligned}$$

where s is the inclination of the plane
γ is the plane's orientation.

The beam radiation on an inclined plane:

$$I_{dir} = I_b * R_b$$

3.3.2 Diffuse radiation

The ratio between the diffuse radiation on an inclined plane and horizontal is given by

$$R_d = 0{,}5 * (1 + \cos s)$$

Hereby the diffuse radiation on the inclined plane:

$$I_{diff} = I_d * R_d$$

3.3.3 Reflected radiation

The contribution from radiation reflected from the ground is defined as follows:

$$R_r = 0,5 * (1 - \cos s) * \rho$$

where ρ is the reflection factor

ρ depends on local conditions, a typical value is 0.2, equal to ground covered by grass.

Hereby the reflected radiation becomes

$$I_{ref} = I * R_r$$

3.3.4 Total radiation

The total radiation on the inclined surface is the sum of the beam, diffuse and reflected radiation:

$$I_s = I_{dir} + I_{diff} + I_{ref}$$

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