SunSim 8.0 – User manual

Introduction

The program *SunSim 8.0* has been devised and developed to calculate in a simple, quick and reliable way the amount of solar radiation available for the photovoltaic systems, both stationary and sun-tracking, but the program can be used also for different types of solar system as those thermal.

Having the aim of obtaining the necessary characteristics of speed and ease of use, it was decided to limit to a minimum the use of the keyboard, instead favouring the introduction of data using the mouse. Simply scrolling the cursor on the sun-path diagram is thus possible to orientate the solar PV array, while buttons or drop-down menus may easily select the different options related to the operation.

Calculation method

SunSim 8.0 is a simulation program that works in the time domain. Results are therefore obtained by tracking the solar paths during the year, thus evaluating the effects on the site in the sampled points and finally by properly adding all those the partial results.

The simulation approach allow taking into account the various factors that affect the result, firstly the shadings and the atmospheric turbidity. On the other hand, this method requires a huge amount of calculations (one may consider that with a 10 minutes time step, as that adopted by *SunSim 8.0*, a single result need to calculate the solar radiation in about 600 different conditions). However, modern PCs do not present any difficulty to keep up with these demands calculation and therefore results are obtained almost instantaneously.

The program is completely written in C/C++ language.

Minimum system requirements

The program *SunSim 8.0* can work on every PC commercially available with operating system Windows Vista or higher and a minimum screen resolution of 1280×720.

The resources needed by *SunSim 8.0* are anyway very low, because the program does not need the installation of specific drivers, does not use its own DLL libraries and can work without an installation procedure, because it can run from any folder contained in a fixed or movable device such as, for example, a CD or a memory stick.

From the website www.sunsim.it however, one can download a test version of the program, named SunSimTest.exe. You may want to try this preliminary test version on your PC in order to verify that all requirements are met. In Annexes the problems that have been detected an a few cases are also reported.

Installation
SunSim 8.0 does not need any installation procedure and can run from any folder contained in a fixed or movable device simply by double-clicking on the program icon.
Firstly, it is advisable to copy the executable file on the Desktop and, by means of the right mouse button, activate the command "Add to Start Menu".

Protection
SunSim 8.0 is protected by means of a code of 3 characters that are notified at delivery time and that shall be inserted in the specific editable field named *Insert Code* →.
If the 3 characters are right, the editable field disappear and at its place the text *Code accepted* will appear. Otherwise, an error message will appear and the program terminates its execution.
Every copy of *SunSim 8.0* distributed under licence is customized, because in the main window the name of the owner is properly marked as it is in the user licence.

Operation description

The program *SunSim 8.0* consists essentially of a main dialogue window through which is possible to control all the main parameters involved in the calculations. However, a few of them, for reasons of space, need to be introduced by means of proper dialog windows. These parameters are basically represented by the horizon profile and the albedo.
Every part of the main window and the sub-windows that is possible to open will be described hereafter.
From the main window, it is possible to find the areas, which contain the main commands for the program:

- *Solar data-base – Meteo station*
- *Shading & Albedo*
- *MJ/kWh*
- *Limit angle*
- *Tracking area*

Moreover, there is an operation area with the solar paths:

- *View from North to South*

Finally, an area that reports the results and an area that help to understand the array orientation by means of a simple animation are also present:

- *PV array – View from South to North*
- *Average daily radiation*

In the next figure an example of main window is shown.
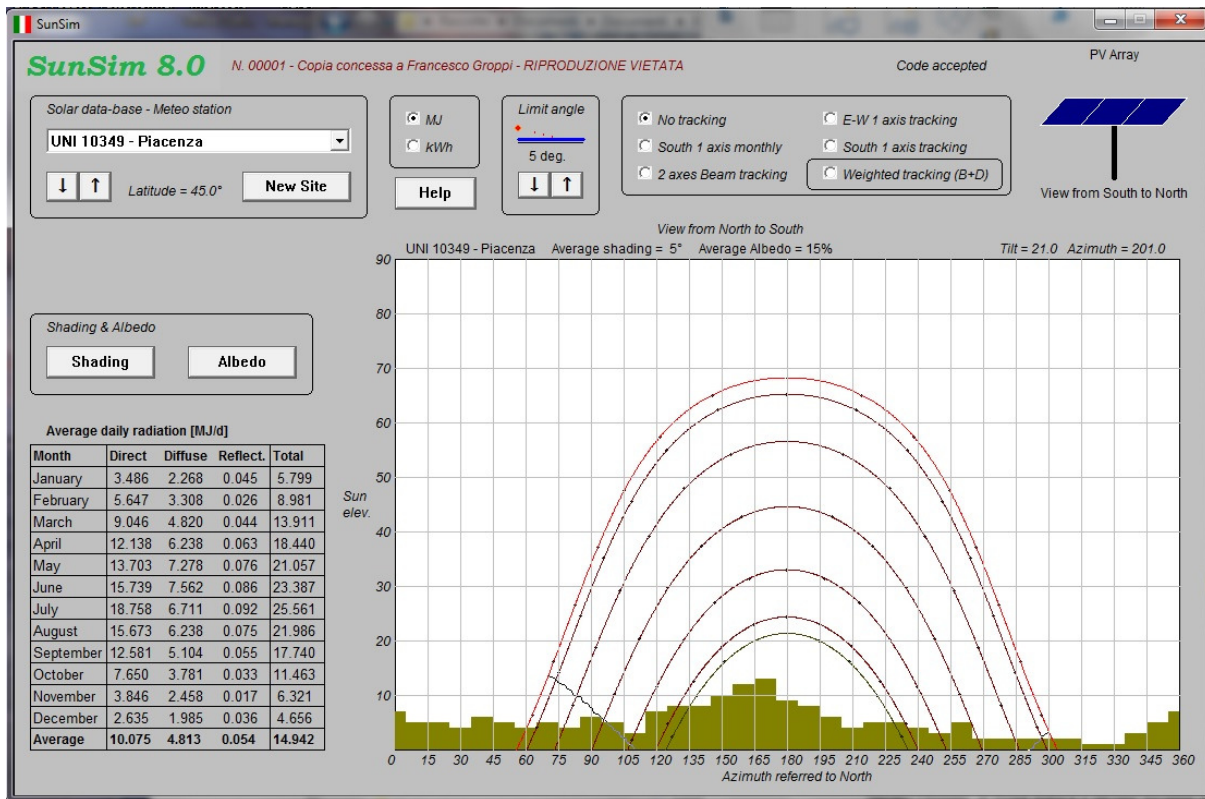
Solar data-base – Meteo station

By using the drop-down menu, it is possible to select the data of direct and diffuse radiation on a horizontal plane for the chosen site. These data refers to those reported in the standard UNI 10349 for the Italian sites and to the calculation methods used by Ispra Joint Research Centre (JRC) for the Europe, Middle East and North Africa as well as for a number of representative Italian sites. Information available on PVGIS are of public domain and can be found on the JRC website.

Data, which refer to the standard UNI 10349, concern the following 101 Italian provinces.

Agrigento	Genova	Pistoia
Alessandria	Gorizia	Pavia
Ancona	Grosseto	Potenza
Aosta	Imperia	Ravenna
Ascoli Piceno	Isernia	Reggio di Calabria
L'Aquila	Crotone	Reggio nell'Emilia
Arezzo	La Spezia	Ragusa
Asti	Lecco	Rieti
Avellino	Lodi	Roma
Bari	Lecce	Rimini
Bergamo	Livorno	Rovigo
Belluno	Latina	Salerno
Benevento	Lucca	Siena
Bologna	Macerata	Sondrio
Brindisi	Messina	Siracusa
Brescia	Milano	Sassari
Bolzano	Mantova	Savona
Cagliari	Modena	Taranto

Campobasso	Massa-Carrara	Teramo
Caserta	Matera	Trento
Chieti	Napoli	Torino
Caltanissetta	Novara	Trapani
Cuneo	Nuoro	Terni
Como	Oristano	Trieste
Cremona	Palermo	Treviso
Cosenza	Padova	Udine
Catania	Parma	Varese
Catanzaro	Perugia	Verbania
Enna	Pescara	Vercelli
Ferrara	Piacenza	Venezia
Foggia	Pisa	Vicenza
Firenze	Pordenone	Verona
Forlì	Prato	Viterbo
Frosinone	Pesaro e Urbino	

Data, which refer to the calculation methods, adopted by the Joint Research Centre, concern the categories Classic PVGIS, PVGIS-Helioclim and Climate-SAF PVGIS.
The 88 sites listed here below have been selected by referring to the Classic PVGIS method.

Belfast (UK)	Hamburg (D)	Roma (I)
Birmingham (UK)	Munchen (D)	Campobasso (I)
Edinburgh (UK)	Warszawa (PL)	Napoli (I)
London (UK)	Praha (CZ)	Potenza (I)
Manchester (UK)	Bern (CH)	Bari (I)
Dublin (IRL)	Innsbruck (A)	Lecce (I)
Reykjavik (IS)	Wien (A)	Cosenza (I)
Oslo (N)	Budapest (H)	Reggio Calabria (I)
Stockholm (S)	Barcelona (E)	Palermo (I)
Helsinki (SF)	Bilbao (E)	Catania (I)
Kobenhavn (DK)	Granada (E)	Ragusa (I)
Vilnius (LT)	Madrid (E)	Sassari (I)
Riga (LV)	Sevilla (E)	Cagliari ()
Tallin (EST)	Zaragoza (E)	Ljubliana (SLO)
Moskva (RU)	Lisboa (P)	Zadar (HR)
Minsk (BY)	Porto (P)	Beograd (SRB)
Kiev (UA)	Aosta (I)	Bucaresti (R)
Bordeaux (F)	Bolzano (I)	Sofija (BG)
Lyon (F)	Torino (I)	Tirana (AL)
Marseille (F)	Milano (I)	Athina (GR)
Nice (F)	Padova (I)	Thessaloniki (GR)
Paris (F)	Udine (I)	Istanbul (TR)
Rennes (F)	Genova (I)	Valletta (M)
Strasbourg (F)	Bologna (I)	Nicosia (CY)
Bruxelles (B)	Firenze (I)	Casablanca (MA)
Amsterdam (NL)	Ancona (I)	Algier (DZ)
Luxembourg (L)	Perugia (I)	Tunis (TN)
Berlin (D)	Grosseto (I)	Tripoli (LAR)
Frankfurt (D)	Pescara (I)	Cairo (ET)
Freiburg (D)		

For the following 3 sites the reference is represented instead by the calculation method PVGIS-Helioclim.

Doha (Q)   Dubai (UAE)   Riyad (KSA)

Finally, for the following 26 sites in Italy the calculation method Climate-SAF PVGIS was also used.

Aosta	Bolzano	Torino
Milano	Padova	Udine
Genova	Bologna	Firenze
Ancona	Perugia	Grosseto
Pescara	Roma	Campobasso
Napoli	Potenza	Bari
Lecce	Cosenza	Reggio Calabria
Palermo	Catania	Ragusa
Sassari	Cagliari	

As one can see, a number of Italian sites are recallable both from UNI 10349 and from JRC. In this way it is possible to understand how different solar data can affect results.

By means of a first pair of buttons marked with the arrows ↓ and ↑ it is possible to modify the latitude of the site from 0° N to 90° N by initiating from that of the chosen site. The use of these buttons for minor corrections does not cause any problem. However, if large variations are needed one should always keep in mind that the radiation data loaded for that site could not be compatible with the new latitude, especially shifting northward. Thus in these cases it is always necessary to verify the correctness of the radiation data and modify them when needed.

The last one of the sites in the list is indicated as <New site>. It is a site for which it is possible to introduce solar radiation data from an existing site.

The button *New Site* allows the personalization of the direct and diffuse solar radiation by means of a specific dialog window as shown in the following figure.
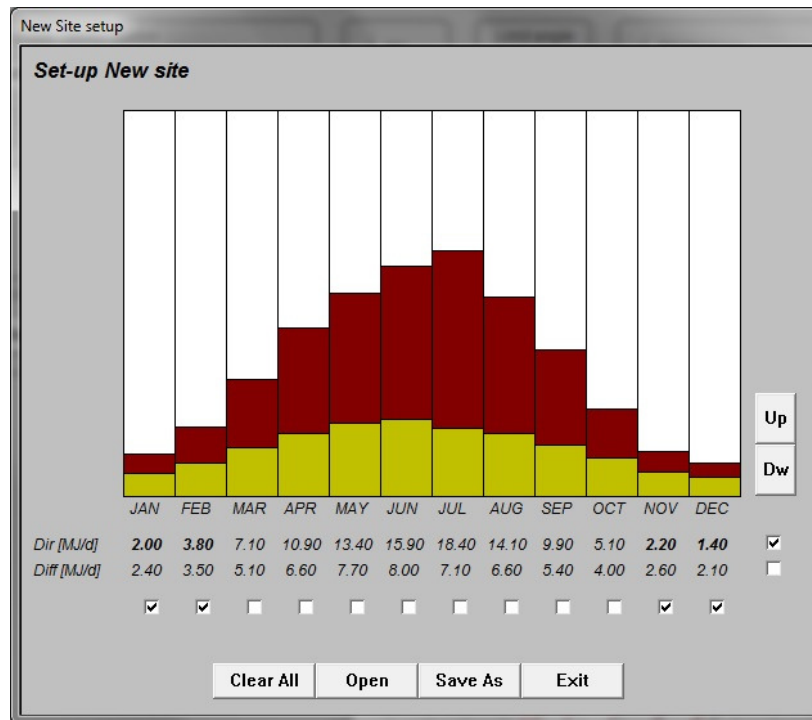
By means of the buttons Up and Dw it is possible to increase or decrease the values of direct and diffuse daily average solar radiation per month. The values to modify are chosen by means of a selection grid made by means of checkboxes placed in correspondence of the months of the year and of the direct and diffuse radiation. By this method it is possible to modify several values at the same time.

As an example, in the figure the direct and diffuse solar radiation for the months of January, February, November and December have been selected. By pressing the buttons Up and Dw it is thus possible to change all the selected values at the same time.

The window allow to save the new set values in a proper file .SIT and to open the existing files to load the data previously saved.

Shading

The profile of the shadings on the site is introduced by means of a proper window, where a smaller solar-path diagram is newly proposed, and it is made clicking the left button of the mouse inside the diagram, in correspondence with the position and height of the solar obstructions.
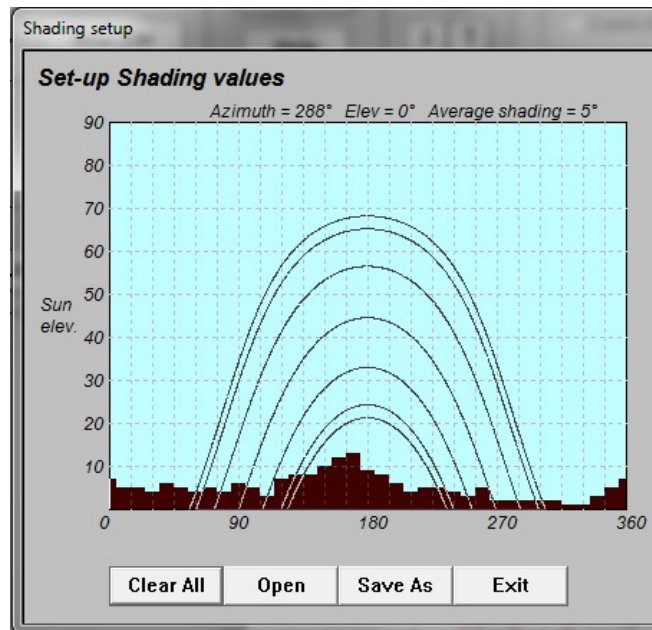
In this window it is possible to save the new set values in files .HOR and to open the existing ones in order to use the previously saved data.

Albedo

The program *SunSim 8.0* takes into account the radiation reflected by the ground or by the surrounding objects by means of proper albedo coefficients.

The conditions of albedo here considered are those contained in the previous standard UNI 8477. As these conditions may change seasonally, and furthermore we may have more than one present at the same time, the data input is made by opening a specific window that presents a matrix of possible conditions and allow a large choice of combinations among them. By selecting one or more conditions, the corresponding albedo value is equal to the arithmetic average of the selected values.

In short, a specific albedo coefficient ρ is associated to each month, whose value ranges from 0.00 and 1.00, equal to the arithmetic average of the coefficients selected in the window.
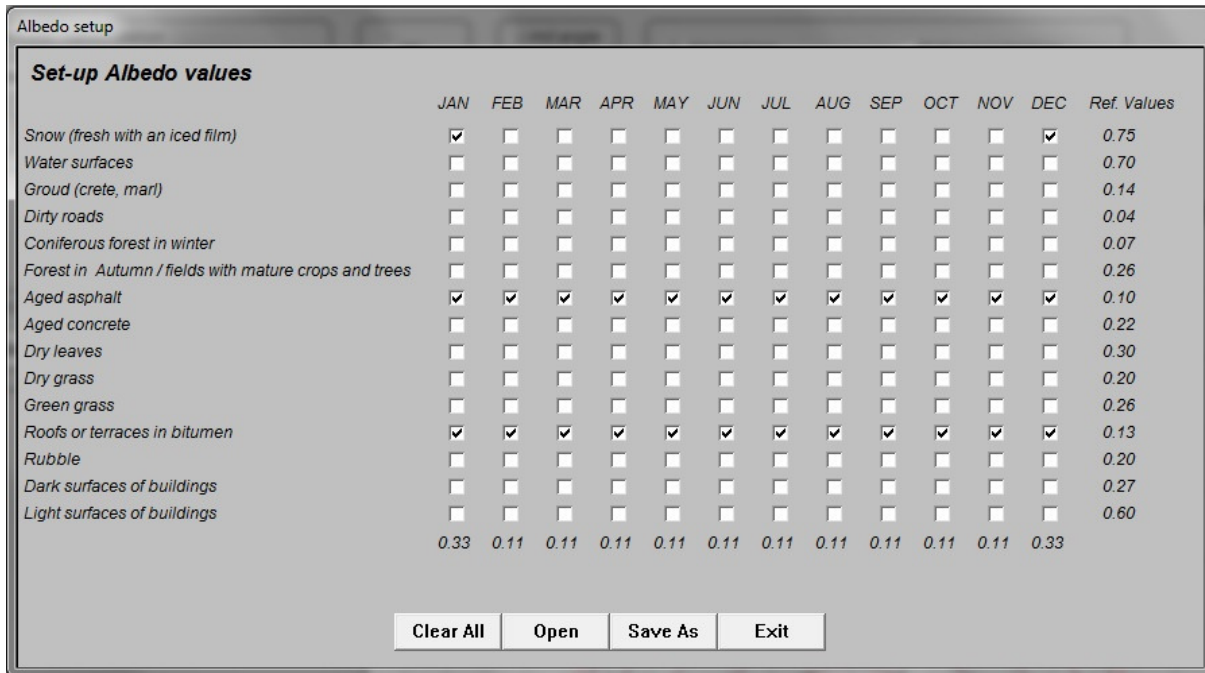
The window allow to save the new set values in the files .ALB and to open the existing files in order to recall the data previously saved.

MJ/kWh

The values of solar radiation calculated and highlighted in the dialog window correspond to the monthly and yearly energies intercepted by the solar system. These values can be made available and calculated as MJ or kWh, by selecting the corresponding button.

Limit angle

The parameter defined as limit angle allow taking into account the lower incidence of the solar radiation on the photovoltaic cells when the angle between the direct solar radiation and the solar PV array plane decreases below a given value.

For low values of this angle, the front glass has a tendency to reflect the solar radiation instead of let it pass through, and this is valid for the surface of the cells as well. This behaviour has induced a few PV modules producers to texture the surface of the cells and front glass, for instance with a pyramidal pattern, such as the solar radiation, however oriented, may strike always on surfaces not excessively inclined.

Thin films tend to be more opaque and are less affected by this phenomenon, especially if cells are externally protected by plastic transparent material or with a suitably treated glass.

As regards the choice of the limit angle, *SunSim 8.0* suggests a value of 5°, giving the possibility to change such a value in the range between 0° and 25°.

Help

This button open a window that contains information on the use of commands by keyword and by mouse buttons.

It is specified that by using the arrows one can move in the working area of the solar diagram, obtaining therefore the same effect of the mouse but with the possibility of making more precise displacements.

The left button of the mouse or the key *Return* of the keyboard allow the generation of the file of results and copy the solar diagram in the clipboard.

Tracking area

In the so-called Tracking area, it is possible to move from the calculation of the solar radiation collected on a surface with a steady tilt and orientation to the simulation of a few types of solar tracking systems.

I must be stated that the simulations of the tracking systems do not take into account in detail of their mutual shading, because these calculations would require the knowledge of the actual shape of the supporting structures in use. Furthermore, the use of monthly average values of solar radiation, instead of hourly values, could induce errors in calculations difficult to evaluate. The results obtained from the simulations of tracking systems give therefore indicative results and should be further refined at design stage.

The possibilities of solar tracking that one can select by using *SunSim 8.0* are the followings:

No tracking	Normal operation without tracking (default choice)
E-W 1 axis tracking	Sun-tracking with a single-axis structure that can be oriented East-West, therefore rotating the solar PV array on the North-South axis
South 1 axis monthly	Single-axis tracking with a Southward orientation of the solar PV array and a tilt that changes monthly and corresponds to the solar height at noon
South 1 axis tracking	Single-axis tracking with a Southward orientation of the solar PV array and a tilt that change according to the solar height. In those periods when the sun would be on the back of the solar PV array, the latter assumes a horizontal deployment
2 axes beam tracking	Two-axes tracking that keeps perpendicular the direct solar radiation on the solar PV array

The button *Weighted tracking* can be used along with every tracking possibility and allow to take into account the diffuse radiation by reducing the inclination of the PV module plane as a function of the average monthly ratio between the diffuse radiation and the direct radiation.

View from North to South

The solar diagram represents the fundamental part of the program *SunSim 8.0*. It is composed by a working area with a white background, that reports a x-scale from 0° to 360°, which correspond to the solar azimuth with respect to North with an increase clockwise, and a y-scale from 0 to 90°, which corresponds to the solar elevation. The following figure gives an example of this diagram.
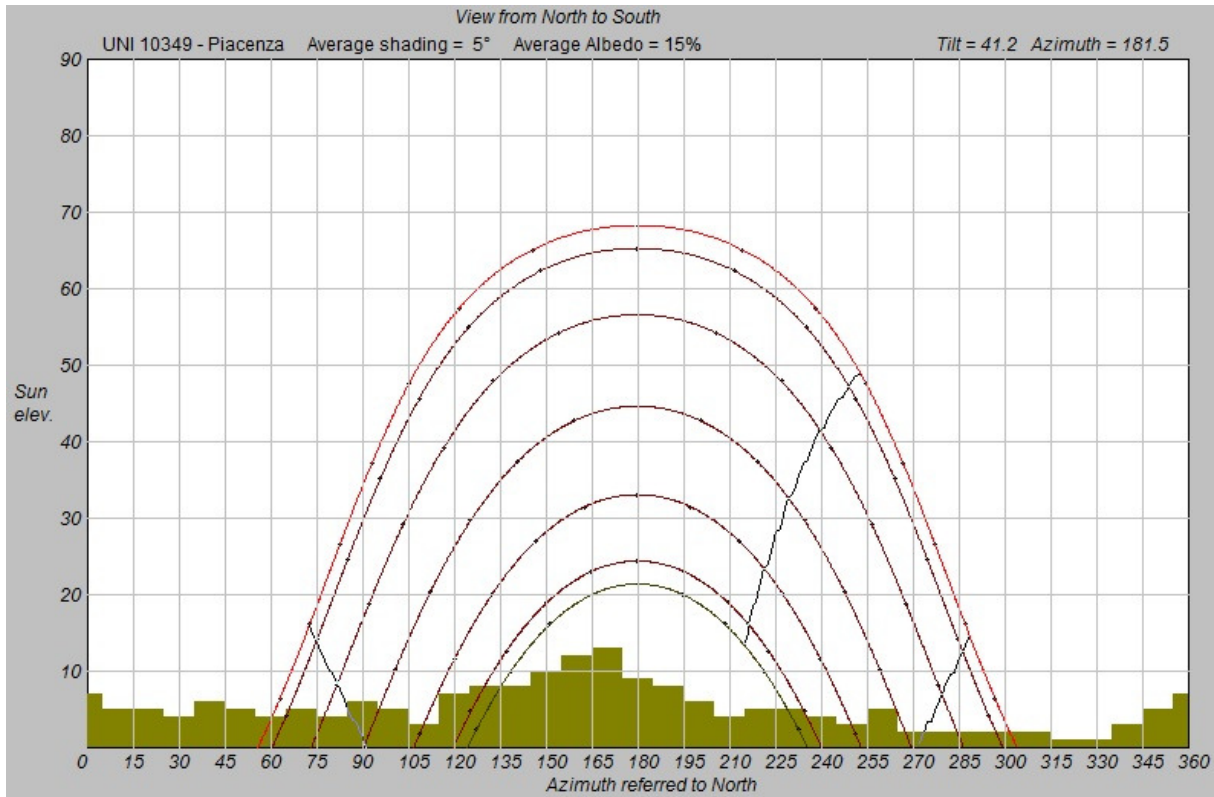
Solar paths and shading diagram

In the working area, the solar paths related to the latitude of the selected site (or to a different latitude if it was decided to change it) are plotted.

Throughout the solar diagrams are 7. In most cases the lower one refers to 21 December and the higher one (having a different colour) refers to 21 June. However, in case of low values of latitude (tropical sites) this order may vary.

The 5 intermediate paths are related to the pairs of months November-January, October-February, September-March, August-April and July-May.

The values of the solar elevation θ_h and of the azimuth angle θ_a are obtained from the latitude Φ e the declination δ (different curves have different declinations). Each curve is therefore obtained by varying the hour angle ω in the following formulas.

$$\cos\theta_h = \sin\delta \cdot \sin\Phi + \cos\delta \cdot \cos\Phi \cdot \cos\omega$$

$$\cos\theta_a = \frac{\sin\theta_h \cdot \sin\Phi - \sin\delta}{\cos\theta_h \cdot \cos\Phi}$$

Where:

$$\delta = 23{,}45 \cdot \sin\left(360 \cdot \frac{284 + n}{365}\right) \qquad (n \text{ is the day of the year calculated from the 1}^{\text{st}} \text{ of January})$$

$$\omega = 15 \cdot t + \Delta\omega - 180 \qquad (t \text{ is the time in hours and } \Delta\omega \text{ depends from the longitude})$$

In the working area the shading diagram is also represented, when is needed, in order to point out the periods of the year and the hours of the day when the solar paths are shaded.

Orientation of the solar PV array

The innovation introduced by the program *SunSim 8.0* (also present in the previous releases) consists in using the same working area containing the solar paths and shadings for the orientation of the solar PV array.

In this case, the cursor, represented as a cross-hair, point out the orientation of the perpendicular line (or the normal) to the solar PV array. In other words, the solar PV array is exactly oriented in the direction indicated by the cursor.

This process is quite intuitive but one should consider that the PV module tilt is not that read on the solar elevation scale, it is instead its complement to 90°. Conversely, as regards the azimuth angle there are not variations.

However, to avoid misunderstandings, just above the working area the tilt and azimuth values of the PV module plane are reported.

In the heading of the working area, the sentence *View from North to South* recall that when pointing the solar PV array one should figure to be behind the plane itself and look at the sun paths. The figure placed on the top right corner moves accordingly and represent the solar PV array seen by an observer placed in front of it, and therefore the note below reports the sentence *View from South to North*.

When the mouse cursor is placed inside the working area or when it is moved inside of it, *SunSim 8.0* calculates the values of direct, diffuse and reflected solar radiation for the solar PV plane oriented according the cursor position.

The possible values for the tilt β vary from 0° to 90°, and those for the azimuth α vary from 0° e 360° (that is from -180° and +180° with respect to South). This possibility to operate on all the diagram allow to simulate also solar PV arrays tilted northward.

In the working area, a pair of curves, overlapped to the solar paths, represent the limits of the solar diagram over that the direct solar radiation cannot be seen by the front of the solar PV array because of its tilt and azimuth. One can easily verify that if the solar PV array is horizontal these curves disappear and instead, if it is vertical these curves have the appearance of vertical segments that exclude all the space region on the rear of the module plane. For intermediate conditions, these curves have a shape more or less accentuate according to the tilt, while their symmetry depends from the difference to South of the azimuth angle. However, one can observe that there are combinations of tilt and azimuth that do not allow to fully plot these limits for the direct radiation.

Behaviour when one of the solar tracking mode is selected

The above consideration on the use of the working area are obviously valid for the steady PV systems (function *No tracking* selected). Conversely, in case of one of the possible tracking mode is selected, it is not possible to choose the solar PV array orientation and therefore the working area, however visible, does not allow any operation.

However, the values of solar radiation on the solar PV array are calculated only when the cursor s placed on the working area.

By selecting one of the solar tracking modes, the figure on the top-right part of the window start to move autonomously and show the different orientation of the solar PV array during the day and in each different month of the year.

Calculation of the direct solar radiation

The calculation of the direct solar radiation is made by examining separately the solar paths referred to different months. Each solar path is thus considered as composed by a number of points, whose

radiation with respect to the solar PV array is calculated for each of them on the basis of the following factors:

- Solar radiation data
- θ angle between the path of the direct radiation and the normal to the plane of the module array
- Turbidity of the atmosphere

The solar radiation data are those prevoiously loaded on the site, while the θ angle is calculated according to the following expression:

$$\cos\theta = \sin\delta \cdot \sin\Phi - \sin\delta \cdot \cos\Phi \cdot \sin\beta \cdot \cos\alpha$$
$$+ \cos\delta \cdot \cos\Phi \cdot \cos\beta \cdot \cos\omega + \cos\delta \cdot \sin\Phi \cdot \sin\beta \cdot \cos\alpha \cdot \cos\omega$$
$$+ \cos\delta \cdot \sin\beta \cdot \sin\alpha \cdot \sin\omega$$

The turbidity of the atmosphere is calculated by means of the Linke formula:

$$I_B = I_0 \cdot e^{-\delta_{CDA} \cdot T_L \cdot am}$$

The Linke formula therefore may allow the calculation of the value of the direct solar radiation on ground I_B from the extra-atmospheric one I_0. The formula uses the value of the Air mass am, set to $1/\sin\theta_h$, and the Linke turbidity coefficient, which may vary according to the site and the season of the year, but for sake of simplicity has been set constant and equal to 3, considering this last as an average value commonly used.

As concerns the paramenter δ_{CDA} a number of expressions may be used. Among these, that proposed by Kasten was chosen, which is valid in a wide interval of am:

$$\delta_{CDA} = \frac{1}{9,4 + 0,9 \cdot am}$$

From a geometric point of view, as already pointed out, the points of the paths that compose the monthly values of the direct solar radiation are considered in calculations only if they do not intersect the shading diagram, otherwise their contribution is set to zero.

Calculation of the diffuse solar radiation

The calculation of the diffuse solar radiation on the solar PV array I_D takes into account the inclination β of the solar PV array with respect to the horizontal plane and uses the expression:

$$I_D = I_{D0} \cdot \frac{1 + \cos\beta}{2}$$

However, it is necessary to take into account the effect of the objects, which surround the site, namely the shadings, because these decrease the portion of sky that the PV module array can see. For this purpose, the space surrounding the site has been divided in 2 portion, each of them having an azimuthal amplitude of 180°.

In the first of these, namely the portion in front of the solar PV array, the presence of obstacles reduces always the diffuse radiation, because the energy collecting surface is in any case oriented in such direction.

As regards the second portion, namely that relative to the backward space of the PV module array, the presence of the obstacles is felt only if their angular height β_h is greater than the tilt β, and in this case the effect is due solely to the portion of sky above the space delimited by the tilt β.

This way, for instance, one can take into account the solar PV arrays placed on vertical surfaces, typically represented by sunblind, which, in most cases, have a $\beta_h = 90°$ for an azimuthal angle of 180°, correspondent to all the space placed on the rear of the solar PV array.

Calculation of the reflected radiation

The calculation of the reflected solar radiation on the solar PV array I_R takes into account the inclination β of the solar PV array with respect to the horizontal plane and uses the expression:

$$I_R = \rho \cdot (I_B + I_D) \cdot \frac{1 - \cos \beta}{2}$$

The values of the albedo coefficients ρ, of the direct solar radiation I_B and of the diffuse solar radiation I_D change monthly, while the tilt β of the solar PV array is kept constant during calculations.

Average daily radiation

The table Average daily radiation appears when the mouse come into the working area and reports the daily averages on a monhly basis of the solar radiation divided into its three components: direct, diffuse and reflected.

In the following figure one can see an example of this table with the column of the totals and the row of the yearly averages. In the example the energy measurement unit *kWh* has been selected.

Average daily radiation [kWh/d]				
Month	Direct	Diffuse	Reflect.	Total
January	1.362	0.606	0.026	1.994
February	1.773	0.884	0.014	2.671
March	2.702	1.288	0.023	4.014
April	3.433	1.667	0.034	5.133
May	3.726	1.945	0.040	5.711
June	4.325	2.021	0.047	6.392
July	5.099	1.793	0.049	6.941
August	4.429	1.667	0.040	6.136
September	3.755	1.364	0.029	5.148
October	2.595	1.010	0.018	3.624
November	1.485	0.657	0.010	2.151
December	1.122	0.530	0.021	1.674
Average	**2.984**	**1.286**	**0.029**	**4.299**

Reports

SunSim 8.0 allows to obtain a number of reports that can be used by word processors and spreadsheets, because it can produce files .RTF (Rich Text Format) and .CSV (Comma-Separated Values).

If the left mouse button or the <Return> key are pressed in the working area, the following window is shown.
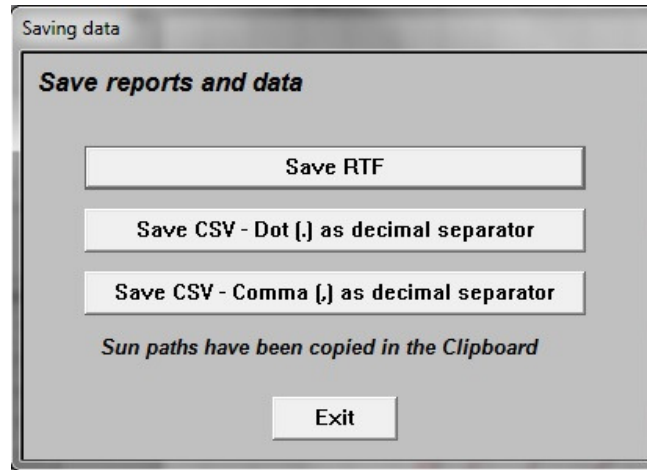
By means of the window *Save Reports and Data* it is possible to generate the reports of interest, that is:

Save RTF	File readable by every word processor
Save CSV - Dot (.) as decimal separator	File readable by every spreadsheet with a dot between the decimal and the integer part of the values and those separated from one another by a comma (English standard)
Save CSV - Comma (,) as decimal separator	File readable by every spreadsheet with a comma between the decimal and the integer part of the values and those separated from one another by a dot (Italian standard)

At the same time, the working area is saved in the clipboard, as shown in the following figure.
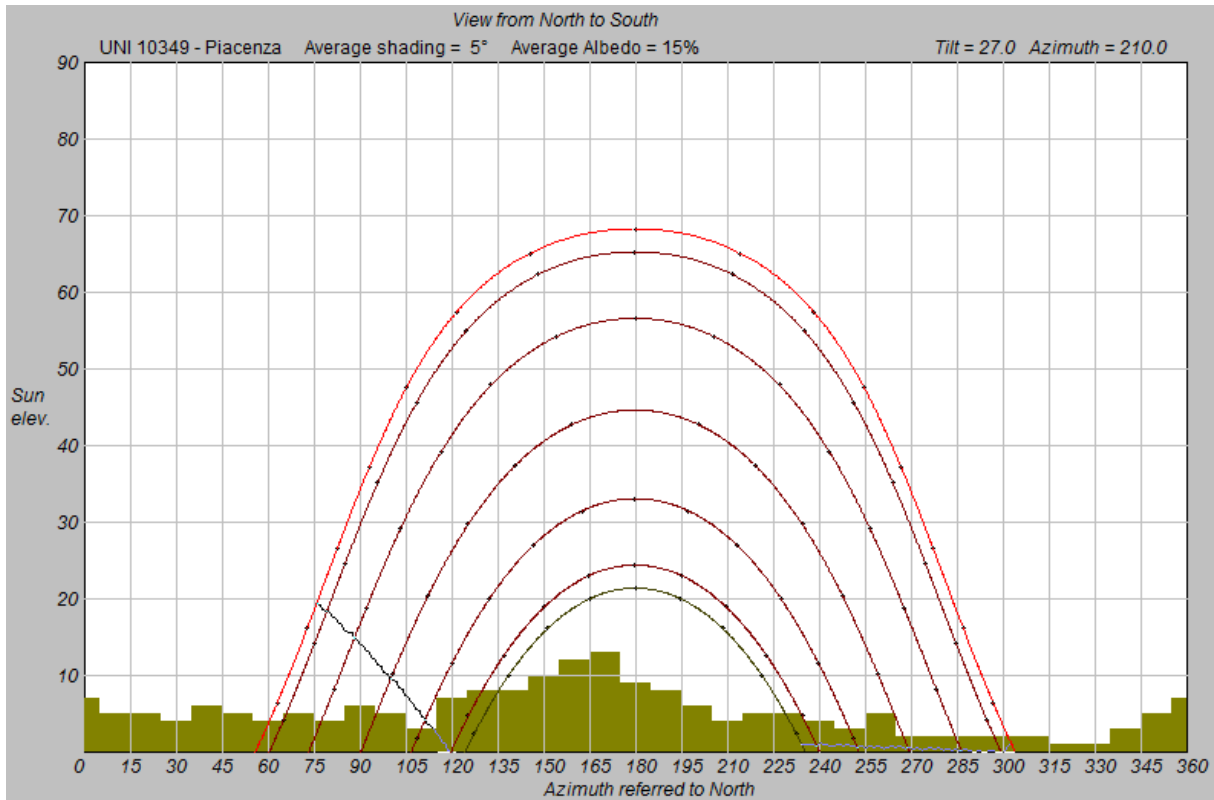
The file .RTF contains the data used by *SunSim 8.0* and the table of the resulting monthly average values of the solar radiation as in the following example.

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SUNSIM 8.0 - Simulation report

Input data of the site

Sun data: UNI 10349 - Piacenza

Latitude: 45.0° N

Average shading: 5°

Average albedo: 15 %

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Dir [MJ/d]	2.000	3.800	7.100	10.900	13.400	15.900	18.400	14.100	9.900	5.100	2.200	1.400
Diff [MJ/d]	2.400	3.500	5.100	6.600	7.700	8.000	7.100	6.600	5.400	4.000	2.600	2.100

Azimuth [°]	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
Shading [°]	7	5	5	4	6	5	4	5	4	6	5	3	7	8	8	10	12	13

Azimuth [°]	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
Shading [°]	9	8	6	4	5	5	4	3	5	2	2	2	2	2	1	1	3	5

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Albedo	0.33	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.33

Input data of the PV array

Tilt: 27.0° N
Azimuth: 220.0°
Limit angle: 5.0°

Calculated average radiation per day [MJ/d]

Month	Beam [MJ/d]	Diffuse [MJ/d]	Reflected [MJ/d]	Total [MJ/d]
January	3.490	2.208	0.074	5.772
February	5.570	3.220	0.043	8.833
March	8.884	4.692	0.072	13.648
April	11.868	6.071	0.104	18.043
May	13.344	7.083	0.125	20.553
June	15.321	7.359	0.141	22.822
July	18.265	6.531	0.151	24.947
August	15.322	6.071	0.123	21.516
September	12.354	4.968	0.091	17.412
October	7.550	3.680	0.054	11.283
November	3.844	2.392	0.028	6.264
December	2.650	1.932	0.059	4.641
Average	**9.872**	**4.684**	**0.089**	**14.645**

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The file .CSV contains the data used by *SunSim 8.0,* the table of the resulting monthly average values of the solar radiation and the hourly average values of the solar radiation in their components: direct, diffuse and reflected.
Here below an example of this table is shown, where, for reasons of space, the row of the radiation values has been clipped.
In the example, an orientation of +40° to South (azimuth = 220°) has been intentionally introduced. This westward displacement affects the hourly values of higher direct solar radiation that consequently show a tendency to shift in the afternoon.

SUNSIM 8.0 - Simulation report

Input data of the site

Sun data: UNI 10349 - Piacenza
Latitude: 45 °
Average shading: 5 °
Average albedo: 15

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Direct [kWh/d]	0,556	1,056	1,972	3,028	3,722	4,417	5,111	3,917	2,75	1,417	0,611	0,389
Diffuse [kWh/d]	0,667	0,972	1,417	1,833	2,139	2,222	1,972	1,833	1,5	1,111	0,722	0,583

Azimuth [°]	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230
Shading [°]	7	5	5	4	6	5	4	5	4	6	5	3	7	8	8	10	12	13	9	8	6	4	5	5

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Albedo	0,33	0,11	0,11	0,11	0,11	0,11	0,11	0,11	0,11	0,11	0,11	0,33

Input data of the PV Array
Tilt: 27 °
Azimuth: 240 °
Limit Angle: 5 °

Calculated average radiation per day [kWh/d]

Month	Beam [kWh/d]	Diffuse [kWh/d]	Reflected [kWh/d]	Total [kWh/d]
January	0,808	0,614	0,021	1,442
February	1,348	0,895	0,012	2,254
March	2,251	1,304	0,02	3,575
April	3,131	1,687	0,029	4,847
May	3,623	1,968	0,035	5,626
June	4,201	2,045	0,039	6,286
July	4,963	1,815	0,042	6,82
August	4,045	1,687	0,034	5,766
September	3,132	1,38	0,025	4,538
October	1,823	1,023	0,015	2,861
November	0,887	0,665	0,008	1,56
December	0,603	0,537	0,016	1,156

Hourly values of the direct radiation [kWh]

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January	0	0	0	0	0	0	0	0	0	0,038	0,088	0,132	0,158	0,161	0,137	0,085	0,007	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0,011	0,076	0,142	0,197	0,231	0,238	0,215	0,161	0,078	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0,047	0,139	0,226	0,298	0,343	0,355	0,332	0,272	0,179	0,061	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0,007	0,1	0,204	0,302	0,38	0,431	0,447	0,425	0,367	0,274	0,157	0,037	0	0	0	0	0
May	0	0	0	0	0	0	0	0,029	0,135	0,241	0,338	0,417	0,467	0,484	0,465	0,41	0,323	0,212	0,094	0,009	0	0	0	0
June	0	0	0	0	0	0	0	0,046	0,164	0,28	0,388	0,473	0,529	0,548	0,527	0,468	0,375	0,255	0,127	0,021	0	0	0	0
July	0	0	0	0	0	0	0	0,04	0,185	0,33	0,463	0,57	0,639	0,662	0,635	0,561	0,442	0,292	0,131	0,013	0	0	0	0
August	0	0	0	0	0	0	0	0,009	0,129	0,264	0,39	0,491	0,556	0,576	0,549	0,473	0,355	0,204	0,049	0	0	0	0	0
September	0	0	0	0	0	0	0	0,066	0,194	0,315	0,413	0,476	0,493	0,461	0,378	0,249	0,086	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0,014	0,101	0,192	0,267	0,314	0,324	0,292	0,217	0,103	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0,042	0,098	0,146	0,176	0,179	0,152	0,094	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0,024	0,067	0,104	0,126	0,127	0,104	0,051	0	0	0	0	0	0	0	0	0

Hourly values of the diffuse radiation [kWh]

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January	0	0	0	0	0	0	0	0,003	0,033	0,065	0,088	0,1	0,102	0,093	0,073	0,045	0,01	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0,024	0,062	0,094	0,117	0,13	0,132	0,122	0,102	0,073	0,037	0,003	0	0	0	0	0	0
March	0	0	0	0	0	0	0,014	0,058	0,098	0,131	0,155	0,168	0,17	0,161	0,14	0,109	0,072	0,029	0	0	0	0	0	0
April	0	0	0	0	0	0,008	0,048	0,09	0,128	0,159	0,182	0,195	0,197	0,188	0,168	0,139	0,103	0,062	0,019	0	0	0	0	0
May	0	0	0	0	0,001	0,03	0,071	0,111	0,147	0,177	0,199	0,211	0,213	0,204	0,185	0,158	0,124	0,085	0,044	0,007	0	0	0	0
June	0	0	0	0	0	0,005	0,039	0,078	0,117	0,152	0,18	0,201	0,213	0,215	0,206	0,188	0,162	0,129	0,091	0,052	0,014	0	0	0
July	0	0	0	0	0,001	0,029	0,066	0,102	0,136	0,163	0,183	0,194	0,196	0,188	0,171	0,145	0,114	0,078	0,041	0,007	0	0	0	0
August	0	0	0	0	0	0,009	0,048	0,09	0,128	0,159	0,182	0,195	0,197	0,188	0,168	0,139	0,103	0,062	0,02	0	0	0	0	0
September	0	0	0	0	0	0	0,015	0,061	0,103	0,138	0,164	0,178	0,18	0,17	0,148	0,116	0,076	0,031	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0,026	0,07	0,107	0,134	0,149	0,151	0,14	0,117	0,083	0,041	0,003	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0,003	0,036	0,07	0,095	0,109	0,111	0,101	0,08	0,048	0,011	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0,023	0,056	0,08	0,093	0,095	0,085	0,065	0,035	0,004	0	0	0	0	0	0	0

Hourly values of the reflected radiation [kWh]

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January	0	0	0	0	0	0	0	0,001	0,002	0,003	0,003	0,003	0,003	0,003	0,002	0,001	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0,001	0,001	0,002	0,002	0,002	0,002	0,002	0,001	0,001	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0,001	0,002	0,002	0,002	0,003	0,003	0,002	0,002	0,002	0,001	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0,001	0,002	0,002	0,003	0,003	0,003	0,003	0,003	0,002	0,002	0,001	0	0	0	0	0	0
May	0	0	0	0	0	0,001	0,001	0,002	0,003	0,003	0,004	0,004	0,004	0,004	0,003	0,003	0,002	0,001	0,001	0	0	0	0	0
June	0	0	0	0	0	0,001	0,002	0,002	0,003	0,004	0,004	0,004	0,004	0,004	0,004	0,003	0,002	0,002	0,001	0	0	0	0	0
July	0	0	0	0	0	0,001	0,002	0,002	0,003	0,004	0,004	0,005	0,005	0,004	0,004	0,003	0,003	0,002	0,001	0	0	0	0	0
August	0	0	0	0	0	0	0,001	0,002	0,003	0,003	0,004	0,004	0,004	0,004	0,003	0,003	0,002	0,001	0	0	0	0	0	0
September	0	0	0	0	0	0	0,001	0,002	0,003	0,003	0,003	0,003	0,003	0,003	0,002	0,001	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0,001	0,002	0,002	0,002	0,002	0,002	0,002	0,001	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0,001	0,002	0,003	0,003	0,003	0,003	0,002	0,001	0	0	0	0	0	0	0	0

Hourly values of the total radiation [kWh]

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January	0	0	0	0	0	0	0	0,003	0,035	0,105	0,179	0,236	0,264	0,257	0,213	0,131	0,018	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0,024	0,073	0,17	0,26	0,328	0,364	0,362	0,319	0,235	0,116	0,003	0	0	0	0	0	0
March	0	0	0	0	0	0	0,015	0,059	0,146	0,272	0,384	0,468	0,515	0,518	0,474	0,383	0,251	0,09	0	0	0	0	0	0
April	0	0	0	0	0	0,008	0,049	0,098	0,23	0,366	0,487	0,579	0,631	0,638	0,596	0,508	0,379	0,22	0,057	0	0	0	0	0
May	0	0	0	0	0,001	0,031	0,072	0,142	0,284	0,421	0,541	0,632	0,684	0,692	0,653	0,57	0,448	0,298	0,139	0,016	0	0	0	0
June	0	0	0	0	0	0,005	0,04	0,08	0,165	0,318	0,464	0,593	0,691	0,748	0,758	0,719	0,633	0,506	0,349	0,18	0,035	0	0	0
July	0	0	0	0	0,002	0,029	0,068	0,145	0,324	0,497	0,65	0,769	0,839	0,854	0,81	0,709	0,559	0,372	0,173	0,02	0	0	0	0
August	0	0	0	0	0	0,009	0,049	0,098	0,165	0,26	0,426	0,575	0,69	0,756	0,768	0,72	0,615	0,46	0,268	0,069	0	0	0	0
September	0	0	0	0	0	0	0,016	0,063	0,171	0,335	0,482	0,595	0,659	0,666	0,611	0,496	0,327	0,118	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0,026	0,085	0,21	0,328	0,418	0,467	0,466	0,411	0,301	0,144	0,003	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0,003	0,036	0,113	0,194	0,257	0,289	0,282	0,233	0,142	0,011	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0,024	0,082	0,149	0,2	0,224	0,215	0,171	0,087	0,004	0	0	0	0	0	0	0

Annex

Files managed by SunSim 8.0

\<filename\>.SIT	File containing the latitude and the values of solar radiation data as monthly averages for a given site not included in the list proposed by the program
\<filename\>.HOR	File containing the values of the angles of the obstacles to the solar paths related to a given point of observation
\<filename\>.ALB	File containing the albedo coefficients to use for the calculation of the reflected radiation on a monthly basis
\<filename\>.RTF	Report file readable by a un word processor
\<filename\>.CSV	Report file readable by a spreadsheet

Files included in the software package

SunSim.exe	Executable program
Protection.txt	File containing the 3 characters to digit in order to enable the operation of the program
Licence.PDF	User licence of the program
SunSim_Manual.PDF	User manual of *SunSim 8.0*

Possible problems of use in a few PC

Although SunSim 8.0 was made with the aim of having the widest possible diffusion on different PCs and versions of the Microsoft Windows operating system, in a few cases some compatibility problems have been detected as listed hereafter.

Windows 8.0 e Windows 8.1

In some installations of these versions of Windows the library msvcr100.dll is not present, although C-written programs, as SunSim 8.0, often use it. In these cases, one can fix this problem by adding the proper file in the system folder or by installing Microsoft Visual C++ 2010 (free).

Windows XP

On this version of Windows, no working problems have been reported, but the icon of the program is not always properly read and in these case Widows shows the default symbol for unknown icons.