SOLAR RADIATION - 1

SOLAR CONSTANT
1352 W/m²

GLOBAL IRRADIATION
800 - 1000 W/m²
Solar radiation spectrum of at an average solar constant of $I_0 = 1353$ kWh/m²
Source: http://www.howtopowertheworld.com
SOLAR RADIATION - 4

The diagram illustrates the direct normal irradiance across different wavelengths, categorized into UV, visible, and infrared regions. Various gases and molecules, such as O$_3$, H$_2$O, and CO$_2$, are indicated at specific wavelengths.
SOLAR RADIATION - 3

- Atmospheric scattering
- Absorbed
- Diffuse
- Reflected
- Direct
- Ground-reflected
**SOLAR RADIATION - 2**

Global irradiance and diffuse fraction, depending on the cloud conditions

<table>
<thead>
<tr>
<th></th>
<th>Clear, blue sky</th>
<th>Scattered clouds</th>
<th>Overcast sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar irradiance [W/m²]</td>
<td>600 - 1000</td>
<td>200 - 400</td>
<td>50 - 150</td>
</tr>
<tr>
<td>Diffuse fraction [%]</td>
<td>10 - 20</td>
<td>20 - 80</td>
<td>80 - 100</td>
</tr>
</tbody>
</table>
SOLAR RADIATION - 2

Cloudy Sky

Clear Sky, Sun

Mainly Diffuse Radiation

Mainly Direct Radiation

0  200  400  600  800  1000

Irradiation W/m²
1000 – 1200 kWh/m² a

Yearly sum of Global Horizontal Irradiation (GHI)

Source: Meteonorm 7.0 (www.meteonorm.com); uncertainty 8%
Period: 1986 - 2005; grid cell size: 0.25°
Depending on the geographic location the yearly global insolation on a horizontal surface may vary between 1000 and 2200 kWh/m².
Global radiation on the horizontal and a 45° inclined surface for two clear days, latitude 47°.
SOLAR RADIATION DATA

http://www.meteotest.ch

http://www.retscreen.net
MEASURING INSTRUMENTS

Campbell- Stokes
Sunshine Recorder

It consists of a solid glass sphere as a lens that produces an image of the sun on the opposite surface of the sphere. A strip of inflammable paper is mounted around the appropriate part of the sphere, and the solar image burns a mark on the paper whenever the beam radiation is above a critical level. If the sun is covered by clouds, the line on the paper is interrupted. The lengths of the burned portions of the paper gives an index of the duration of bright sunshine.
Pyranometer

Pyranometers are instruments for measuring global radiation (direct and diffuse). The detectors of these instruments must have a response independent of the wavelength of radiation over the solar energy spectrum. The detectors convert the solar radiation into an electrical voltage, which is an indicator for the solar radiation.
Black and White Pyranometer

The black and white pyranometer consist of star-shaped white and black thermal elements. The temperature differences between white and black surfaces result in thermal stress, which is the indicator for the solar radiation.
Measurements of diffuse radiation can be made with pyranometers by shading the instrument from the direct (beam) radiation. This is done by means of a shading ring. Adjustments need to be made for changing declination.
A pyrheliometer is an instrument using a collimated detector for measuring solar radiation from the sun and a small proportion of the sky around the sun at normal incidence. It is used for measuring the beam radiation.

Pyrheliometer
Solar Radiation on Tilted Surface

\[ \bar{H}_T = \bar{H}_s \bar{R}_b + \bar{H}_d \left( \frac{1 + \cos \beta}{2} \right) + \bar{H} \rho_\varepsilon \left( \frac{1 - \cos \beta}{2} \right) \]

\[ \frac{\bar{H}_d}{\bar{H}} = 1.391 - 3.560 \bar{K}_T + 4.189 \bar{K}_T^2 - 2.137 \bar{K}_T^3 \]

\[ \frac{\bar{H}_d}{\bar{H}} = 1.311 - 3.022 \bar{K}_T + 3.427 \bar{K}_T^2 - 1.821 \bar{K}_T^3 \]

\[ \bar{H}_b = \bar{H} - \bar{H}_d \]

See Page 27 of the manual
As a general rule, the optimum angle of tilt is equal to the degree of latitude of the site.

<table>
<thead>
<tr>
<th>Latitude [degree]</th>
<th>June</th>
<th>Orientation</th>
<th>Sept./March</th>
<th>Orientation</th>
<th>December</th>
<th>Orientation</th>
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</thead>
<tbody>
<tr>
<td>50 N</td>
<td>26.5</td>
<td>S</td>
<td>50</td>
<td>S</td>
<td>73.5</td>
<td>S</td>
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<tr>
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<td>16.5</td>
<td>S</td>
<td>40</td>
<td>S</td>
<td>63.5</td>
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<tr>
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<td>20</td>
<td>S</td>
<td>43.5</td>
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<tr>
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<td>8.5</td>
<td>N</td>
<td>15</td>
<td>S</td>
<td>38.5</td>
<td>S</td>
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<tr>
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<td>N</td>
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<td>S</td>
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<td><strong>N</strong></td>
<td><strong>0</strong></td>
<td><strong>-</strong></td>
<td><strong>23.5</strong></td>
<td><strong>S</strong></td>
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Tilt and orientation of the collector

Tracking systems ???
Thank you for your attention