2.2. Solar radiation.

Solar radiation refers to the electromagnetic radiation that reaches the Earth from the sun. More energy from sunlight strikes the Earth in an hour (4.3 × 10^{20} Joules) than all the energy consumed on the planet in a year (4.1 × 10^{20} Joules), and in a year there is about 10 times more sunlight energy reaching the Earth than all of its reserves of coal, oil, natural gas and uranium combined.

Standard irradiation on a PV panel arises from three sources
(1) Directly from the sun.
(2) Indirectly, from radiation scattered in the atmosphere.
(3) Indirectly, through the medium of clouds.

We will consider the energy and frequency characteristics of illumination arising from these three sources.

The amount of solar radiation on average is as follows [SR1]

Illuminescence type	Percentage
Reflected back into space	35.0
Absorbed by atmosphere	17.5
Scattered to Earth from blue sky	10.5
Scattered to Earth from clouds	14.5
Radiation going directly to Earth's surface	22.5

The outer atmosphere of Earth receives approximately 1367 W/m² of solar radiation [World Meteorological Organisation], [SR2]. The radiation varies by around ±2% due to fluctuations in emissions from the sun itself as well as by ±3.5% due to seasonal variations in distance and solar altitude.

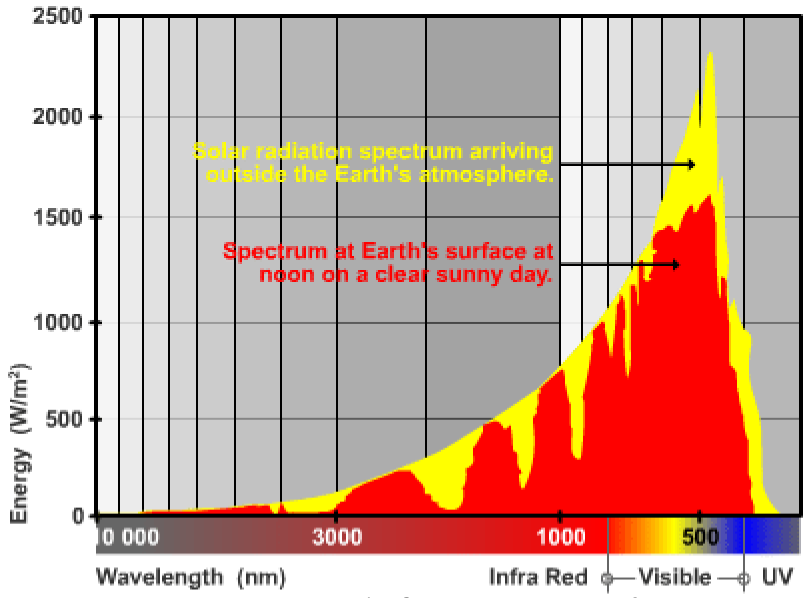

Figure 1 - Spectral content of incident solar radiation.

Figure 1 shows that the majority of solar radiation occurs in the short-wave visible and ultraviolet portions of the electromagnetic spectrum. There is a long-wave component of infrared. However, large bands of this are absorbed by gasses and particles within the upper atmosphere. [SR2].

By Wien's displacement law, the greater the temperature of a star, the shorter will be the wavelength of its radiant emissions. Solar radiation is spread over a wide frequency range. The sun's rays contain electromagnetic wavelengths as short as 0.2 mm (ultraviolet) with maximum energy centred at around 0.4 mm (visible blue light).

Ultraviolet (UV) radiation makes up a very small part of the total energy content of solar radiation, roughly 8% – 9%. The visible range, with a wavelength of 0.35 mm to 0.78 mm, represents only 46% – 47% of the total energy received from the sun. The final 45% of the sun's total energy is in the near-infrared range of 0.78 mm to 5 mm. In addition to the spectrum of solar radiation there is a spectrum of terrestrial radiation that fills out the far-infrared range spanning from 3 to 75 mm. These are basically the heat radiating from the surfaces of materials that have been warmed by the sun.

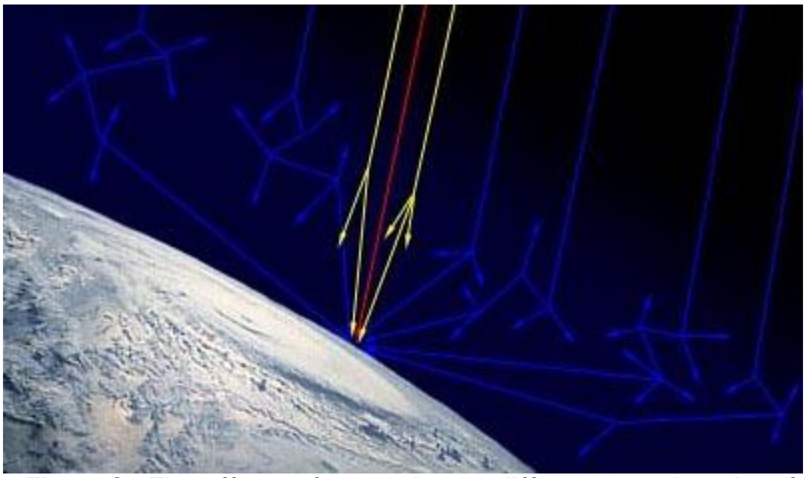

Figure 2 - The effects of scattering on different wavelengths of light. Blue light arrives from all directions after scattering, whilst red and yellow light arrives almost directly from the sun.

You will notice significant differences between the spectral content of the radiation reaching the outer atmosphere and that actually reaching us on the surface. This is due to the absorption of some of the radiation when a gas molecule or particle retains some of this energy as heat. There are noticeable dips in the solar spectrum that coincide with the absorption characteristics of different gasses. Whilst some of this absorbed heat finds its way to the surface as long-wave radiation, the vast majority is simply re-radiated back out into space.

[SPV]. Whilst a cloudy sky can increase the amount of *diffuse* solar radiation, a heavy rain cloud can reduce the *direct* component to almost zero. On clear days, a surface receiving solar energy will capture mainly direct radiation, but on cloudy days mainly diffuse radiation. As there is generally an increase in cloud activity during the colder or wetter months, these factors combine to produce a significant seasonal variation in available solar radiation.