Solar knowledge

What it is

The energy carried by sunrays as a consequence of nuclear reactions (hydrogen fusion) and transmitted to the Earth as electromagnetic radiation is called solar energy. Electromagnetic radiations are made of photons. A photon is a neutral particle that spreads into the air at a speed of 300,000 km/sec, with an energy that depends on its frequency and a mass that is considered as void when at rests (when it is not moving). The intensity of solar radiations that arrive every year to the earth's surface amounts to 80 thousand billion tons of oil equivalent (the so-called TOE, that indicates a quantity of energy that equals the energy produced by a ton of oil). This quantity is infinetisimal if compared to the energy produced by the Sun thanks to nuclear reactions. But it is also a very large quantity, if you only consider that the world energy demand amounts to 8 billion TOE a year. From the flow of solar energy, the following are derived: biomass energy, through the photosynthesis process; hydraulic energy (the Sun, in fact, is the motor of the water cycle); wind energy from which, in turn, wave energy derives. Anything, starting from what we eat every day, is directly or indirectly linked to it. Even fossil fuels, which derive from chemical-physical alterations of prehistoric living organisms, contain solar energy. Solar radiations, although they only reach a maximum power of 1 kilowatt per square meter (soil irradiation in a clear day, sunny, at midday), are the most abundant and clean energy source on the Earth.

The sun

The Sun is the closest star, which makes life on Earth possible. The sun is a sphere with a 1.4 million km diameter (109 times as much as the earth's diameter) and has a mass approximately 300.000 times greater than the earth's mass. 75% of it is hydrogen, 23% is helium and only 2% is formed by heavier elements. It produces its heat by transforming hydrogen into helium in its inner core, where the temperature reaches 15 million °C (the surface temperature is around 6000°C). The transformation reaction is called nuclear fusion and joins together 4 nuclei of hydrogen (protons) to create a helium nucleus, freeing a large quantity of energy, which, as photons, is irradiated towards the space.
A solar constant is the radiation that perpendicularly hits a unit surface positioned at the top limit of the atmosphere and amounts to 1350 watts per square metre. This heat, multiplied by the surface of the earth's section (the squared earth's average radius multiplied by pi Greco) calculates the quantity of energy the earth receives from the sun every second, i.e. 173,000 TW.

The energy balance of the Earth

A sunray reaches the earth's surface after travelling for 150 million kilometres in 8 minutes. The solar energy received by the earth amounts to 170,000 TW approximately (the unit of measurement equivalent to 1012 watts, used to measure solar energy). 50,000 TW are reflected by the top layers of the atmosphere, 30,000 are absorbed by the atmosphere and 90,000 TW reach the earth's surface.
A big part of them is reflected (by water, for example) or absorbed. A small part is transformed. 400 TW make seawater evaporate and transform it into clouds, 370 TW activate the wind and 80 TW are transformed by the plant's photosynthesis into chemical energy.
The 30,000 TW absorbed by the atmosphere and 90,000 reaching the earth's surface are transformed into infrared radiations towards the space. Thus, the energy balance remains constant, like the temperature of the earth's atmosphere and surface. The greenhouse effect, i.e. the natural phenomenon heating the bottom layers of the atmosphere, which normally makes human existence possible, has been lately increasing due to certain human activities often leading to catastrophic effects (i.e. climate changes).

Distribution of solar radiations

The sun will illuminate and heat the Earth until its hydrogen reserves are depleted, i.e. in approximately 5 billion years. The sun's radiation reaches the earth in a non-homogeneous way because of its interaction with the atmosphere and the

angle of incidence of sunrays. The angle of incidence varies according to two factors: the earth's rotation around its axis, which is very important for the alternation of day and night, and the inclination of the earth's axis as compared to the plane of its orbit, leading to a seasonal variation of the maximum height of the sun on the horizon.
When the sun is perpendicular to the earth's surface, the maximum concentration of sunrays on the ground is obtained. On the other hand, if the sunrays reach the earth's surface with a certain inclination, the same amount of energy is dispersed over a larger surface. Therefore solar energy can be highly exploited only within a belt included between 45° latitude south and north.

Useful radiation

Only a part of the huge energy flows that gets from the Sun to the Earth can be transformed into useful energy. The quantity of solar energy that arrives to the earth's surface and that can be usefully "collected" depends on irradiation on the area. Irradiation is the quantity of solar energy that arrives at a surface within a determined time interval, typically one day (it is measured in kWh by square metre by day). Instead, the value of solar radiation that arrives on the surface unit (at a determined moment) is called radiance (it is measured in kW/m2). Irradiation is influenced by local climatic conditions (clouds, mist, etc) and depends on the latitude: as it is well known, it increases when it gets closer to the equator. In Italy mean annual solar radiation ranges from 3.6 kWh per square metre per day in the Po river plain area, to 4.7 kWh per square metre per day in Central-Southern Italy, to 5.4 kWh per square metre per day in Sicily. In some favourable spots it is possible to collect every year around 2,000 kilowatts for each square metre, which corresponds to 1.5 barrels of oil for a square metre.

A bit of history

Mankind has always known what happens when a sunray hits a body. If this is light-coloured or is a mirror, the energy of the sun is reflected. If it is dark-coloured, the sun's radiation is absorbed and the body heats up. The first solar collector is based on this principle. It was invented in 1767 by the Swiss Horace de Saussure: a "black pot" used by the first American pioneers to heat water and cook while they were travelling west. In 1891, Clarence Kemp patented the first solar energy water heater. It was a success, but human beings already knew cheaper and easier ways to heat water. Only after 80 years, following the energy crisis of 1973 and the consequent increase in the oil prices, did Kemp's water heater develop into a more modern form, becoming the solar panel that today is enjoying growing success. Besides the thermal effect, human beings recently learned how to exploit the electromagnetic effect of the sun's radiation. The problem is converting sunrays into electric energy by means of ad hoc devices. The process, known as photovoltaic conversion or photovoltaic effect, was discovered in 1839 by the physicist Bequerel, but its first commercial implementation took place only in 1954 in the U.S., when the Bell laboratories developed the first photovoltaic cell in single-crystal silicon, reaching a 6% efficiency. The first steps of the photovoltaic conversion took place in the semiconductor and IT sectors. The first of such implementations dates back to 1958. Today the main implementations take place on earth and the industrial production of photovoltaic cells has increased from the 1960s to date, with the consequent impact on production prices. Remarkable efficiency was achieved, up to 10-13%, which may render the exploitation of solar energy to produce electricity increasingly competitive. Remarkable yields, of up to 20%, have been obtained, which will make exploitation of solar energy increasingly competitive, for the production of electricity. This means that if the solar energy that strikes a photovoltaic panel is 100, the panel will transform 20% of this energy into useful energy, more specifically into electric energy.

Some figures: worldwide

Photovoltaic capacity installed in the world in 2015 reached 227 GW, due to 50 GW installed during the year. In 2015, Italy held the 5th place for installed power, after China, Germany and in front of the USA. In analyzing the data, the extension of the various States being compared must be born in mind, and it is significant that a small country like Italy can compete with a giant like China and the USA.
If we analyze the data of the different geographic areas of the world, it can be observed that Europe has always been a

pioneer in this sector, and it now has the leading position, with the greatest amount of installed power amounting to 95 GW (42% of the world's installed power) versus 25.6 GW in the USA. Due to this difference, it is quite probable that Europe will continue for a long time to be a leader in the photovoltaic sector. Japan is one of the countries that are emerging in this field, and starting from 2007-2008 there have been significant increases also in the rest of the world. With regard to solar thermal power, the technologies used to heat water with the help of solar energy are spreading to many countries: China, USA, Turkey and Germany have been the protagonist countries in the solar thermal market in 2015. In particular in 2015, China increased its solar thermal capacity and reached 71% of global capacity. In 2015, 21 thermal Gigawatts (GWth) were installed around the world and the total installed power reached 456 (GW_{th}).
(*Source: Renewables 2016 Global Status Report*)

Some figures in Italy

Italy is the country of sunshine, not only in its popular songs and in the image of Italy that all the tourists have, but also from the point of view of energy. In Italy, mean annual solar radiation ranges from 3.6 kWh per square metre per day in the Po river plain area, to 4.7 kWh per square metre per day in Central-Southern Italy, to 5.4 kWh per square metre per day in Sicily: as a consequence some regions have a very high production potential, even though the entire national territory actually has very favourable conditions for the installation of solar energy production plants. Italy is one of the leading countries for the production of solar energy, and it is in the vanguard also in the sector of research and technological innovation.
Starting from 2007, the year in which a boom in solar energy was recorded in Italy, growth has never stopped. In 2015 in fact, a 1.6% increase in installed power, compared to 2014, was recorded. According to GSE – Gestore dei Servizi Energetici (the Italian company for electric services) there were 688,398 solar power plants operating in Italy in 2015 (+6.2% compared to 2014) with an installed power equal to 18,892 MW.
In particular, out of the 688,398 plants, the 58% has power ranging from 3 to 20 kW. In 2015, the small sized plants (<3 kW) were 192,252, with an installed power equal to **627** MW. The average sized plants, from 20 kW and 1 MW, reached 10,566 units, for a total installed capacity amounted to 7,266 MW, while the large plants, with power over 1 MW, reached 1,127 units, for a total installed capacity amounted to 4,126 MW.
In 2015, the Lombardy region was reconfirmed in the leading position for the number of plants (101,403 units) followed by the Veneto region (93,168 units) and the Emilia Romagna region (56,951 units). The regions that showed the greatest growth rates in terms of number of plants, were the Liguria region (+8.8%) and the Lazio and Emilia Romagna region (+8.3%). In terms of power, instead, the leading region is the Puglia region (2,600 MW), followed by the Lombardy region (2,109 MW) and the Emilia Romagna region (1,898 MW). The most relevant variations, compared to the previous year, with regard to the installed power were recorded in the Liguria region (+5.4%) and in Campania (+2.9%). (NOTE: the largest number of photovoltaic plants recorded in the Northern and Central regions is to be attributed to the high density of the inhabitants in these regions).
44% of the installed capacity is in the North, 37% is in the South, and 19% is in the Central part of Italy. In particular the Puglia region, with 13.8% has the largest amount of installed power, followed by Lombardy (11.2%) and Emilia Romagna (10%). The map of the provinces showing the percentage distribution of the power, highlights the substantial contribution of some Provinces in the North: Cuneo, Brescia, Ravenna and Turin with 2.9%, 2.2% and 2% respectively of the total 18,892 MW. In Southern Italy, Lecce with 3.6% supplies the largest amounts on a national scale. In the Regions in Central Italy, the provinces that stand out are Rome and Viterbo with 2.2% and 2% respectively.
However, an analysis of the numbers, alone, is not sufficient to illustrate the photovoltaic sector in Italy and to identify the more "virtuous" and "sunny" regions. Observing the data, we must bear in mind the population density in the regions, which is very high in Lombardy and very low in regions such as Trentino Alto Adige, Valle d'Aosta, Basilicata and Molise. GSE periodically publishes the data of the photovoltaic plants in Italy and an atlas which indicates all the photovoltaic power plants in Italy (ATLASOLE).
(Source: GSE, Rapporto statistico "Energia da Fonti Rinnovabili in Italia – 2015")