ENERGY FROM THE SUN

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Introduction

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).

Energy production

The definition passive solar systems refers to the systems in which solar energy is used directly. For example, greenhouses are glass structures that allow the Sun to enter, but do not let the heat escape. In this way they are able to maintain temperatures inside the structure that are higher than those outside. Then there are the solar distillers, in which in a closed space, covered by transparent panels that are exposed to the Sun, sea water evaporates and condenses and forms water that has no salts, and therefore that can be reutilised.
In the active solar systems instead, solar energy is collected and transformed into thermal or electric energy before it is utilized. This type of system includes solar thermal power systems, solar concentrator systems used for the production of thermal energy and solar photovoltaic panels for the production of electric energy. The best technologies also enable the cogeneration of different types of energy, and it is possible to accumulate thermal energy in many ways and for different uses.

Thermal solar panels

Solar panels catch the energy of the sun and use it to produce hot water (up to 60/70°C) which collected in an ad hoc tank, can be used both for household (i.e. for household and water heating) and industrial purposes, as well as for the production of electric energy on a large scale through thermoelectric solar plants:

- plate panels;
- concentration collectors;
- vacuum-pipe collectors;

Plate panels

A solar panel system includes two elements: the actual solar panel and the accumulation tank. The first includes a solar heat accumulator, i.e. a steel or copper panel crossed by the pipes in which the fluid to be heated by the sun flows: generally antifreeze is added to the water in order to tolerate winter temperature. Above the absorber there is a glass panel that lets the incoming sunrays in but does not them out, so that the environment underneath remains hot. The tank includes a heat exchanger that allows the transmission of the heat from the heated liquid inside the absorber to the water of the house hydraulic system. Thermal solar panels are installed in a fixed position, if possible south-oriented, in order to receive the maximum amount of radiation. A square metre of solar collector can heat between 40 and 300 litres of water every day, at 45-60 degrees. The efficiency varies according to climatic conditions and the type of collector by 30-80%. Efficiency ranges from 30% to 80% depending on the climatic conditions and the type of collector. The yield of the solar panels has increased about 30% in the past decade. This means that if the energy from the Sun is equal to 100, the useful energy supplied by a solar panel is equal to 30.

Concentration collectors

Concentration collectors are thermal solar panels that use a mirror system that reflects the sunrays and makes them concentrate on a receiver. Collectors can be linear, when they concentrate sunrays on a segment of a straight line, or they can concentrate sunrays on a single point, heating the out-flowing fluid of the panel at more than 100°C. The thermal energy produced can be directly sent to the users.

Or the heat produced by the various solar concentrators can activate the motors that are activated by the heat at a medium-high temperature (i.e. to pump water or other mechanic applications).
The thermal energy can also be transformed into electric energy thanks to solar thermoelectric power plants. In those plants, the thermal energy captured by the collectors is used to transform water into steam which, in its turn, operates a turbine connected to an electric energy generator (see image). These power plants are environmentally friendly, with a very limited environmental impact as compared to fossil fuels plants, since the only substance to be emitted into the atmosphere is steam.

Vacuum-pipe collectors

Some thermal solar panels are called vacuum-pipe collectors as they are made of special glass vacuum pipes, covered by a layer that transforms the sun light into heat. In this case the heat absorber has a round shape and is hosted inside the pipe vacuum cavity: in this way the fluid that carries the heat evaporates, and by transmitting the heat to the top part of the pipe, it condenses and goes back to the bottom. Differently from plate panels, this type of vacuum collectors does not carry the heat (as air is the best insulator), therefore there is no loss and its performance is higher. These collectors need a smaller exposure surface with respect to the other panels and are able to retain the accumulated heat also in very tough weather conditions, guaranteeing a high and constant performance during the whole year. For these reasons they can be used also with a medium-low sun or under particularly tough weather conditions in winter, like on high mountains or in northern countries.

Thermo-solar energy accumulators

Just like the other renewable sources, solar energy is not constantly available. As a consequence, accumulation systems are extremely important for the evolution and development of technologies.
The energy produced by thermo-solar plants does not have to be limited to sunny hours nor have to

be hampered by clouds. For this reason, two techniques have been tested. They also allow a better use of the installation and therefore a lower cost for the production of electric energy:

- accumulation of thermal energy: the heat is used to warm a medium from which, on a specific moment, heat is extracted to produce electric energy. These devices are quite cheap, highly efficient and allow to keep the installation working during peak periods and night hours. They also have the advantage to eliminate, in many cases, fluctuations due to clouds;
- solar-methane hybrid systems: during prolonged periods where solar heat is absent, the methane can provide the missing energy, with a reduction of costs. A hybrid system can be economically convenient also for the supply of modest solar power.

Photovoltaic solar panels

Photovoltaic technology allows the direct transformation of solar energy into electric energy by exploiting the photovoltaic effect. The photovoltaic effect is based on the characteristics of certain semiconductor materials such as silicon which, after being ad hoc processed, generates electric energy after being hit by the solar radiation.
Photovoltaic cells are the most basic device capable of carrying out the conversion. Each cell produces around 1.5 watts in standard conditions, i.e. the temperature is 25 °C and it is subject to a radiation power of 100 watts per square meter. The outgoing power in standard conditions is called "peak power" (Wp): it expresses the electric power supplied by a photovoltaic generator with 1,000 watt/square meter irradiation, 25°C system temperature and 1.5 air mass. Actually the electric energy produced is lower than the peak value due to higher temperatures and the lower values of the irradiation. Many cells assembled and connected together into a single structure form a photovoltaic module. The traditional module is made up of 36 cells, with an outgoing power of 50 watts, but at the moment, especially due to architectonic needs, modules with a higher number of cells can be bought, reaching a power of up to 200 watts for each system. In order to increase the electric power it is necessary to connect different modules: several modules form a panel, and several panels form a string.

Solar plants

Solar towers. Concentration collectors include solar towers, which consist of a system of mirrors (called heliostats) that follows the movement of the Sun and that reflects the solar energy on a receptor located on the top of a central tower. The solar heat is collected by a fluid (a melted salt) that has the task to accumulate energy. With the heat accumulated on melted salts, vapour is produced (565°C), in order to make an electric turbo-generator turn.
Linear parabolic mirrors. Linear parabolic mirrors are called SEGS (Solar Electric Generating System): they are used to concentrate sunrays on a long receiving pipe positioned on the concentrator line. A heat-carrier, i.e. oil, pumped by receiving pipes, supplies a plant. The solar heat is transformed into vapour in order to activate an electric turbo-generator. The typical operational temperature is 390 °C. These installations today work with 30-80 electric megawatts and also burn a certain quantity of

fossil fuel (sometimes natural gas) in order to produce energy when the solar energy is not sufficient.

Photovoltaic plants

The photovoltaic system includes different mechanical, electrical and electronic components that attract the solar energy, transform it into electric energy until the user can use it.
There are two types of photovoltaic systems: the systems with accumulation and those without accumulation. The former is equipped with lead batteries to accumulate electric energy while the sun shines and use it when the sun is not present.

Solar systems

These systems are not connected to the national electric network and directly supply some equipment. They also have a battery system that guarantees the supply of power even during poor light hours or in the dark. These systems are technically and economically advantageous in those cases where the electric network is absent or difficult to reach. They are particularly popular in developing countries for rural users who also employ them to pump water. In Italy many photovoltaic systems have been created in order to produce electric power in rural and mountain areas, especially in the South of Italy, on the islands and on the Alps.
At the moment the most spread devices are used to supply:

- equipment for water pumping;
- radio relays, survey stations and data transmission centres (weather and seismic), telephone sets;
- refrigeration systems, especially for the transport of medicines;
- lighting systems;
- road, port and airport signs;
- supply of utilities on camper vans;
- advertising systems, etc.

Systems connected to a network

These systems are permanently connected to the national electric grid. When the photovoltaic generator is not able to produce the electric energy needed to satisfy the demand for electricity, the network provides the requested energy. Instead, if the photovoltaic system produces more energy than needed, the surplus is transferred to the network. These systems do not need any battery, as the distribution network supplies electric power when solar irradiation is absent.
Centralized plants for the production of high-power photovoltaic electric energy have been built. Actually at the moment small systems are becoming more and more important, especially thanks to state incentives that do not exceed 20 kilowatts (peak power). The most popular plants have 1.5-3 kilowatt power. These plants are installed on building roofs or fronts and contribute to satisfy the users’ demand for electric power.

Installations integrated in buildings

They are among the most promising applications of photovoltaic systems. These systems are installed on civil or industrial buildings in order to be connected to the national electric network. The power generated by photovoltaic modules is supplied to the internal network of the user building and, at the same time, to the public distribution network. In this way, according to the needs, it can be used by local users or supplied to the network.

Photovoltaic modules can be used to cover buildings as a replacement of traditional components. With this objective, the photovoltaic and the building industry have created some architectonic modules that can be integrated with the building structure. They are more and more used on building fronts and to cover buildings. The possibility to integrate photovoltaic modules into architectures and transform them into building components has widened the range of application of the photovoltaic and architectural sector, that exploit this type of energy.

A particularly interesting use consists of "photovoltaic fronts". The modules for each front are made up of two glass sheets with silicon cells between them and connected by resin sheets.

The dimension of these modules can vary from 50x50 cm to 210x350 cm. Moreover, as the lower is the temperature of photovoltaic modules during solar irradiation, the higher the energy performance, photovoltaic fronts can be better used on "cold" areas of building fronts (parapets, lifts, and other matt surfaces) provided they are oriented towards the South-East or South-West and are not located on shady areas. The use of photovoltaic modules can be extremely useful as sunblind or to create shade on wide areas if they be used as a cover, i.e. as a cover for bus shelters.

Where to position a plant

In order to obtain the maximum energy production, when designing a plant, it is necessary to study the area irradiation and the sun exposure. In this way it will be possible to make decisions on the inclination and orientation of the receiving device. Considering the latitude of our Country, the best position for the panel surface is on top of the building, oriented towards the South and with an inclination angle of 20-30°C with respect to the horizontal plane. But the front covering gets very good results, too. It is obviously very important to position the panel in order to avoid any shade area.

Thermo-photovoltaic systems

Thermo-photovoltaic co-generation systems include thermo-solar technologies for the production of hot and cold water and thermo-solar systems for the production of electric energy.

An example of these systems are those panels where a thermo-solar collectors and photovoltaic cells are integrated and where the primary energy is the direct solar energy. It is a very interesting system, especially when the thermal fluid is able to regulate the temperature of photovoltaic cells, which are usually more efficient at 20-25°C. A solar thermo-photovoltaic panel is able to produce the same quantity of hot water as a traditional panel, as well as being able to supply 175 watts of electric power on a sunny day.

Thermodynamic solar power

In the thermodynamic solar power process, electric power is obtained by using solar energy to heat water, which is then transformed into steam, which in turn moves the turbines analogously to the traditional thermoelectric power plants. In this case, combustion of fossil fuels to produce steam is not required, the energy to heat the water comes directly from the sun. Since the power plant operates at high temperatures, obviously, standard solar heating panels cannot be used, but particular devices are required to concentrate solar energy in precise restricted points, so that the required high temperatures are reached, similarly to when one wants to light a fire with a magnifying glass and a ray of sunlight! The intermediary is a fluid known as the “thermovector” which has an excellent heat-exchange capacity. The thermovector receives solar energy transformed into thermal energy that it then releases in the water, which, converted into steam, activates the turbines of the power plant producing electric energy. Many of the large power plants that are currently being designed all over the world are of this type. The advantages, when compared with the production of energy using the photovoltaic method, are a greater yield and a smaller surface area occupied by the power plant.

Research in this field is aimed at improving the technologies and the structures to concentrate the solar energy, and studies are carried out to find the best arrangements of the various elements. As a consequence, power plants of various types have been developed:

- power plants with a field of mirrors and a central tower (Solar Tower), where solar radiation is concentrated by means of concave mirrors, known as heliostats, on a receiver on top of a tower, that is about a hundred metres high: here the thermovector fluid is heated to temperatures reaching hundreds of degrees, which then feeds a traditional thermodynamic cycle for the production of energy. The heliostats rotate so that the amount of solar energy that is concentrated on the receiver remains constant;
- power plants with linear parabolic collectors (Parabolic Troughs): in which there is an alignment of linear parabolic mirrors that do not concentrate the radiations in a single point, but on a receiver-tube that is filled with thermovector fluid;
- power plants with a circular parabolic collector or parabolic solar dish (Dish Stirling): a large parabolic mirror, with a diameter of a few meters, that concentrates solar energy onto a collector placed in the focal point of the mirror, where a thermovector gas flows. The thermal energy is transformed into electric energy by means of a Sirling engine. The parabolic dishes can be connected to one another in clusters of hundreds of units, thus forming solar farms;
- power plants with Fresnel linear collectors: in this case the heliostats are linear and are arranged horizontally near the ground. They reflect the solar radiation onto a receiver-tube that is positioned about ten metres from the ground. Of all the systems, the Fresnel reflectors are those with the lowest costs.

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