European Educational Concept in Environmental-, Nature and Climate protection to safeguard cross-border Sustainable Development

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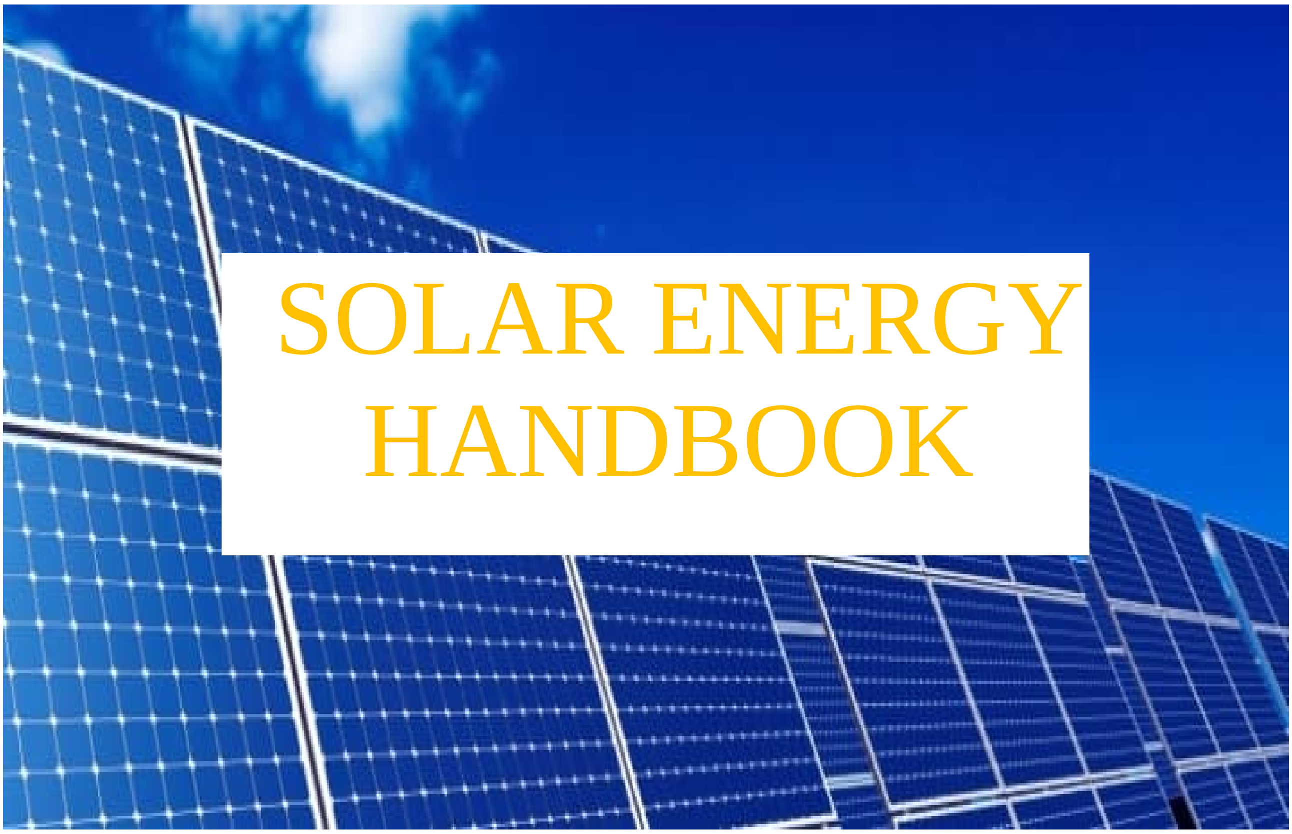
SOLAR ENERGY HANDBOOK



ORADEA 2018

1. The suns energy. Understanding how the Sun works

1.1 Heat and light

The sun (Fig. 1) is an immense fusion reactor. "Fusion" simply means that hydrogen atoms are combined to make helium. This occurs on the sun because it is very hot. The sun is very hot because fusion releases a great quantity of heat. That is why fusion is called a chain reaction.The energy source is provideb by fusion reactions of the hydrogen into helium primarily through proton-proton (pp) cycle (Severino G., 2017).

The sun’s nuclear fusion process converts 508 million tons of hydrogen into 504 million tons of helium every second. The remaining 4 million tons of matter are converted to energy, making the core temperature of the sun extremely hot. As Albert Einstein found, a very small amount of matter converts to a very large amount of energy. In fact, one ounce of matter converted to energy by fusion could supply all the energy your home and car would need for a year -- plus five-thousand other people’s homes and cars as well.

The energy the sun radiates is preferable to other sources of energy because solar radiation is abundant and will be for many more millions of years (West M., 1993).

What is the source of the sun's energy? It's a crucial question, because light and heat from the sun are the basis of (almost) all life on earth. Sunlight drives plant life via photosynthesis, and animals survive by eating plants. Almost all microscopic forms of life (bacteria, protozoa, etc.) survive by using the energy of sunlight.

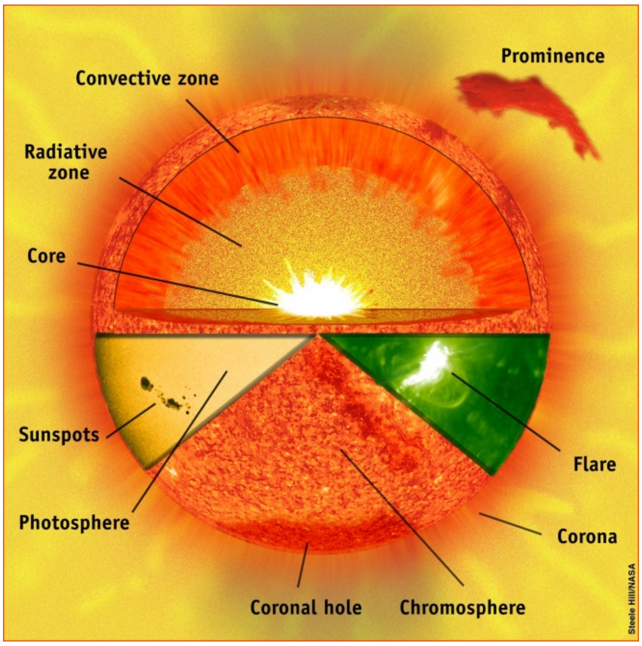


Fig. 1 Structure of the Sun
(source, http://www.thesuntoday.org/the-sun/solar-structure)

1.2 Surface temperature

We know that the sun is a sphere of diameter 1,400,000 km, that its outer regions are hot gases, mostly hydrogen and helium, and that its surface temperature is about 6,000 degrees Celsius (about 11,000 degrees Fahrenheit). Any surface at that temperature will generate heat and light. The burners of an electric stove or a toaster oven, for example, are not at 6,000 C., but when they're turned on they are "red hot"; they emit heat and light and the light is red. If we could raise the temperature to 6,000 C. they would become "white hot", and emit light very much like the sun's. Similarly, a fire is a region of gases at a temperature high enough to generate heat and light (Goga N., 2010)

So the question becomes not so much why is there heat and light, but where does the energy come from to keep the surface temperature of the sun at 6,000 degrees?

To a scientist living in the 18th or 19th century, before electrical appliances, the most likely approach to understanding the sun's energy would be to make the analogy to a fire. When something burns there is a chemical reaction between the material and the oxygen in air. Not knowing what the chemicals in the sun are, one could still assume there is some chemical reaction going on that produces heat, and keeps the sun hot. The problem is, how long would it be before the burning chemicals are all used up and the fire goes out, just as logs burning in a fireplace will all turn to ash within a few hours?

1.3 The sun's lifetime

It is not difficult to arrive at a rough answer to that question, since we know the sun's mass. The mass is calculated using the law of universal gravitation, and the known orbits of the planets. Assuming the mass is all something like carbon, one can calculate the sun's lifetime to be about 50,000 years. Any chemical burning will lead to a lifetime in that general range (Bland P., 2004).

But nineteenth century geologists believed that the age of the earth was 100 million years or more. These calculations were approximate, but based on reasonable assumptions about how salt is deposited into the sea, and how marine sediment is deposited onto what are now the continents. (For example, if we assume that all the salt in the oceans got there by being deposited by rivers, and we can measure the current rate of deposition by rivers, we can then calculate the number of years it would take to reach the salt levels found in oceans today.) Since the earth orbits the sun, it is hard to imagine how the earth could be older than the sun. Thus the model of the sun as a chemical fire was not tenable (http://academic.brooklyn.cuny.edu/physics/sobel/Nucphys/sun.html)

1.4 Gravitational energy

About 1850, the physicist Hermann von Helmholtz proposed that the source of the sun's energy could be gravitation - that is, the universal gravitational force that every piece of the sun exerts on every other piece (Cahan D., 2004). We can see that gravity can produce energy by just thinking of releasing an object, say a baseball, and letting it fall to the ground. Energy of motion (kinetic energy) is produced, as the ball accelerates downward. If we think of the sun as a huge sphere of gases, each atom in the gas feels a net attraction to the center of the sphere, and so all the atoms have a tendency to "fall" in toward the center. As this happens they collide with other atoms, and so their motion is energetic, but randomized. Rapid random motion of atoms in a gas means higher temperatures. Given the known rate at which the sun produces energy, Helmholtz was able to estimate how long the sun, given its mass, could continue producing energy this way. His conclusion was about 20 million years, much longer than the estimate based on chemical burning, and closer to estimates at that time of the earth's age.

Billions of years Nevertheless, millions of years is not long enough. The best value today for the age of the solar system, the sun and the planets, is 4.6 billion years. We know from radioactive dating that there are rocks which solidified about 4 billion years ago, and that early microorganisms existed close to 3.5 billion years ago. So gravitation cannot be the explanation for where the sun gets its energy.

1.5 Nuclear reactions

Things came together finally in the early twentieth century with the discovery of the atomic nucleus (1911), the exploration of *nuclear reactions* (the 1920s), and Einstein's

theory of *relativity* (1905). In a typical nuclear reaction, several sub-atomic particles come together, interact, and several (possibly different) particles emerge. There are a series of reactions going on in the sun, but the net result is the following combination of particles.
Hydrogen burning

$$4\,{}^{1}_{1}H + 4e \longrightarrow {}^{4}_{2}He + 2e \qquad (1)$$

The left side of this reaction shows four protons and four electrons, basically four hydrogen atoms. Hydrogen is the natural starting point, since most of the matter in the sun (and also the stars) is hydrogen gas. Hydrogen is the simplest element, so it's reasonable to expect that in a primitive state much of the universe would be hydrogen. The endpoint is helium, known to be the second most abundant element in the sun. It is often referred to as "hydrogen burning" to helium, and hydrogen is often called "fuel", but one must understand that the reaction is not burning in the sense of a chemical reaction between a fuel, such as coal or wood, and oxygen. It is a nuclear reaction (Green S. F., Jones M. H., 2004).

1.6 Mass converted to energy

Energy is generated when this reaction occurs because the total mass of the particles on the right side is less than that on the left side. It is not just that there are fewer electrons on the right. The most important difference is that the mass of the helium nucleus (${}^{4}{}_{2}He$) is substantially less than the total mass of the four protons on the left. This is an example of *binding energy*: The ${}^{4}{}_{2}He$ consists of two protons and two neutrons, but its mass is less than the total mass of two protons and two neutrons.

Since the mass on the left side is greater than that on the right, we end up with energy produced when the reaction occurs, energy equal to the mass difference times c^2. This energy is in two forms: energy of motion of the particles in the sun, and *gamma rays*.

1.7 The proton-proton cycle

Equation (1) is actually the net product of a series of more fundamental reactions. The process of Equ. (1) is called the proton-proton cycle, since it begins with the interaction of two protons.

Building up from small nuclei to larger ones is called fusion, and the sequence that takes place in the sun is similar (but not identical) to the *fusion reactions* being studied as a possible source of electrical energy on earth (Severino G., 2017).

1.8 The binding energy of the alpha particle

Why does nature (the sun and the stars) go to so much trouble to make ${}^{4}{}_{2}He$'s? The answer is that among the various small nuclei that are involved in the proton-proton cycle, the ${}^{4}{}_{2}He$ is the most strongly bound. Its binding energy is relatively very large, and that means that if nature creates a ${}^{4}{}_{2}He$, a large amount of energy is released. Some energy is released in each part of the cycle, but most is released in the last step, where ${}^{4}{}_{2}He$ is created.

1.9 Gravitational collapse

The model we have for the origin of the sun is a cloud of hydrogen gas that begins to collapse under its own self-gravitation (as in the thinking of Helmholtz), and begins to get hot. Although this cannot be the mechanism for the sun's generating energy for billions of years, it can be a triggering or ignition mechanism (O'Keefe M., Pike K., 2004).

1.10 A hot plasma

Thus the cloud collapses, and at high temperature the gas becomes a plasma. The hydrogen atoms separate into protons and electrons, and these particles move about randomly. The temperature is hottest in the center of the cloud, and there the protons move so energetically that the reaction in Equ. begins to occur, and the proton-proton cycle starts.

1.11 Equilibrium

These processes continue in the center of the cloud, bringing the temperature up to around 10,000,000 degrees. At this temperature the sun reaches an equilibrium, where outward pressure from these "burning" gases balances the gravitational force pulling the matter inward. The energy produced in the center continually works its way outward, keeping the whole sun hot. The outer regions are much cooler than the center, but they are hot enough so that energy is radiated out into space, in the form of the heat and light that bathe the earth (Green S. F., Jones M. H., 2004).

1.12 The sun's lifetime

The sun can stay in this balanced state for a total of about 10 billion years. Given the sun's age as about 4.6 billion years, one can assume we have 5 billion years or so to go. Eventually most of the hydrogen in the center will get used up, and the sun will enter a dying phase.

The stars The proton-proton cycle powers not only the sun, but most of the stars in the medium to small range of masses. Stars larger than the sun produce energy via a more complicated set of reactions, but the net effect is also that in Equ. (1), hydrogen burning to helium (Tyson N., 2017).

1.13 Solar radiation

Often called the solar resource, is a general term for the electromagnetic radiation emitted by the sun. Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. However, the technical feasibility and economical operation of these technologies at a specific location depends on the available solar resource (https://www.energy.gov/eere/solar/articles/solar-radiation-basics).

Every location on Earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one spot on the Earth's surface varies according to:

i. Geographic location
ii. Time of day
iii. Season
iv. Local landscape
v. Local weather

Because the Earth is round, the sun strikes the surface at different angles, ranging from 0° (just above the horizon) to 90° (directly overhead). When the sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse. Because the Earth is round, the frigid polar regions never get a high sun, and because of the tilted axis of rotation, these areas receive no sun at all during part of the year.

The Earth revolves around the sun in an elliptical orbit and is closer to the sun during part of the year. When the sun is nearer the Earth, the Earth's surface receives a little more solar energy. The Earth is nearer the sun when it is summer in the southern hemisphere and winter in the northern hemisphere. However, the presence of vast oceans moderates the hotter summers and colder winters one would expect to see in the southern hemisphere as a result of this difference.

The 23.5° tilt in the Earth's axis of rotation is a more significant factor in determining the amount of sunlight striking the Earth at a particular location. Tilting results in longer days in the northern hemisphere from the spring (vernal) equinox to the fall (autumnal) equinox and longer days in the southern hemisphere during the other 6 months. Days and nights are both exactly 12 hours long on the equinoxes, which occur each year on or around March 23 and September 22.

The sun is responsible for all of the earth energy. Plants use the sun's light to make food. Decaying plants hundreds of millions of years ago produced the coal, oil and natural gas that we use today. Solar energy is most commonly collected by using solar cells. Of course solar energy can be put to use to heat or light up a room by simply having well placed windows and skylights. We can also use solar energy to dry our clothes in the sun. To use solar energy to power electrical appliances solar cells are used (https://www.energy.gov/eere/solar/articles/solar-radiation-basics).

1.14 Solar energy - basic principles

Solar energy is created by light and heat which is emitted by the sun, in the form of electromagnetic radiation.

With today's technology, we are able to capture this radiation and turn it into usable forms of solar energy - such as heating or electricity.

Solar energy is the sun's nuclear fusion reactions within the continuous energy generated. Earth's orbit, the average solar radiation intensity is 1367kw/m2. Circumference of the Earth's equator is 40000km, thus we can calculate the energy the earth gets is up to 173,000 TW. At sea level on the standard peak intensity is 1kw/m2, a point on the earth's surface 24h of the annual average radiation intensity is 0.20kw/m2, or roughly 102,000 TW of energy. Humans rely on solar energy to survive, including all other forms of renewable energy (except for geothermal resources) Although the total amount of solar energy resources is ten thousand times of the energy used by humans, but the solar energy density is low, and it is influenced by location, season, which is a major problem of development and utilization of solar energy (Tiwari G, 2005).

The pressure upon this sector of renewable energy sources is more and more increasing because of the development of world economy and of population increase. Fig. 2 shows the forecast of electric energy gained from renewable sources until 2030 (Maican E., 2015).

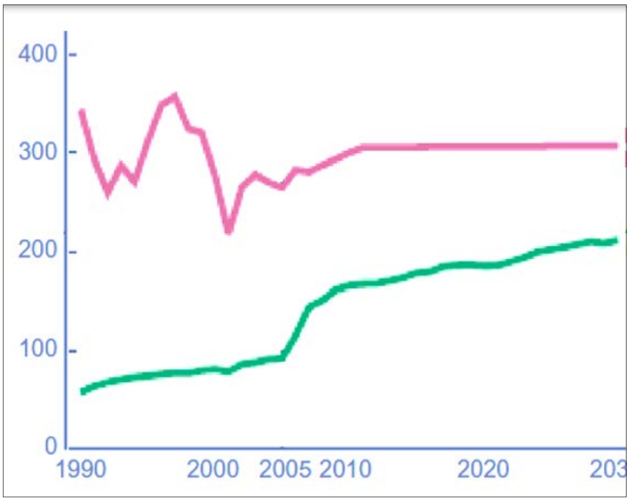


Fig. 2 The evolution tendency of energy from renewable sources up to 2013, in bil. KWHS, red line – hydropower energy, green line – renewable energy, (source, Maican E., 2015)

1.14.1 Available Solar Resource

It is difficult that there war ever a time that humans did not understand and appreciate the contribution that the Sun makes to the survival of the human race. (Newton D.E., 2015).

The technical feasibility and economical viability of using solar energy depends on the amount of available sunlight (solar radiation) in the area where you intend to place solar heaters or solar panels.This is sometimes referred to as the available solar resource.

Every part of Earth is provided with sunlight during at least one part of the year. "part of the year" refers to the fact that the north and south polar caps are each in total darkness for a few months of the year. The amount of sunlight available is one factor to take into account when considering using solar energy.

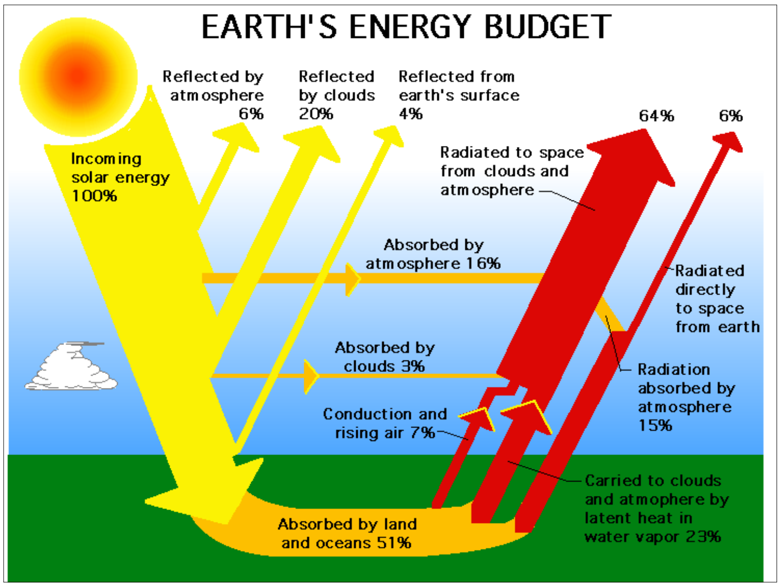


Fig. 3 Earth s energy budget
(source, https://marine.rutgers.edu/cool/education/class/yuri/erb.html)

There are a few other factors, however, which need to be looked at when determining the viability of solar energy in any given location. These are as follows:

Day and night is due to the Earth's rotation generated, but the season is due to the Earth's rotation axis and the Earth's orbit around the sun's axis was 23 °27'angle and generated. the Earth rotate around the "axis" which through its own north and south poles a circuit from west to east every day. Per revolution of the earth cause day and night, so the Earth's rotation per hour is 15 °.In addition, the Earth goes through a small eccentricity elliptical orbit around the sun per circuit per year. The Earth's axis of rotation and revolution has always been 23.5° with the earth orbit. The Earth's revolution remain unchanged when the direction of spin axis always points to the Earth's north pole. Therefore, the Earth's orbit at a different location when the sunlight is projected onto the direction of the earth is different, so it cause the formation of the Earth's seasons changes. Noon of each day, the sun's height is always the highest. In the tropical low-latitude regions (in the equatorial north and south latitude 23 ° 27 'between the regions), sunlight of each year, there are two vertical incidences at higher latitudes, the sun is always close to the equator direction. In the Arctic and Antarctic regions (in the northern and southern hemispheres are greater than 90 ° ~ 23 ° 27 '), in winter the sun below the horizon for a long time.

1.15 Diffuse and Direct Sunlight

As sunlight passes through Earth's atmosphere, some of it is absorbed, scattered, and reflected.

Sunlight is composed of two parts - direct sunlight and diffuse sunlight. Solar radiation goes through the atmosphere and reaches the ground, due to the atmosphere air molecules, water vapor and dust, such as solar radiation absorption, reflection and scattering, not only reduction of the intensity of radiation, but also to change the direction of radiation and radiation of the spectral distribution. Therefore, the actual solar radiation reaching the ground is usually caused by direct and diffusion of two parts. Direct sunlight is the radiation directly from the sun and the direction of the radiation has not been changed; diffusion is the reflection and scattering by the atmosphere changed after the direction of the solar radiation, which consists of three parts: the sun around the scattering (surface of the sun around the sky light), horizon circle scattering (horizon circle around the sky light or dark light), and other sky diffuse radiation. In addition, the non-horizontal plane also receives the reflection of radiation from the ground. Direct sunlight, diffuse and reflected sunlight shall be the sum of the total radio or global sunlight. It can rely on the lens or reflector to focus on direct sunlight. If the condenser rate is high, you can get high energy density, but loss of diffuse sunlight. If the condenser rate is low it can also condense parts of the solar diffuse sunlight . Diffuse sunlight has a big range of variation, and when it’s cloudless, the diffuse sunlight is 10% of the total sunlight. But when the sky is covered with dark clouds and the sun can not be seen, the total sunlight is equal to the diffuse sunlight. Therefore, poly-type collector is collecting the energy usually far higher than the non-poly-type collector. Reflected sunlight is generally weak, but when there is snow-covered ground, the vertical reflection sunlight can be up to 40% of the total sunlight (https://www.energy.gov/eere/solar/articles/solar-radiation-basics).

1.16 Measuring Sunlight and Solar Energy

Scientists measure the amount of sunlight available in specific locations during the different times of year. They are then able to estimate the amount of sunlight which falls on similar regions at the same latitude with similar climates and conditions.

Measurements of solar energy are normally expressed as "total radiation on a horizontal surface", or as "total amount of radiation on a surface tracking the sun". In the latter case, the assumption is that one is using a solar panel that automatically tracks the sun. In other words, the solar panel would be mounted on a tracking device so that the panel would remain at right angles to the sun throughout the day. This system is primarily used for industrial setups, when it is used at all.

1.16.1 Solar Energy Measurements

Radiation data (the amount of solar energy available at a given location) for solar electric (photovoltaic) systems is often represented as kilowatt-hours per square meter (kWh/m2). Direct estimates of solar energy may be expressed as "watts per square meter" (W/m2) (https://www.energy.gov/eere/solar/articles/solar-radiation-basics).

Radiation data for solar water heating and space heating systems is usually represented in British thermal units per square foot (Btu/ft2).

2. SOLAR PANELS

A solar panel is a device that collects and converts solar energy into electricity or heat. Solar photovoltaic panels can be made so that the sun's energy excites the atoms in a silicon layer between two protector panels. Electrons from these excited atoms form an electric current, which can be used by external devices. Solar panels were in use over one hundred years ago for water heating in homes. Solar panels can also be made with a specially shaped mirror that concentrates light onto a tube of oil. The oil then heats up, and travels through a vat of water, instantly boiling it. The steam is created and then it turns a turbine for power.

2.1 How solar panels work

The basic element of solar panels is pure silicon. When stripped of impurities, silicon makes an ideal neutral platform for transmission of electrons. In silicon's natural state, it carries four electrons, but has room for eight. Therefore silicon has room for four more electrons. If a silicon atom comes in contact with another silicon atom, each receives the other atom's four electrons. Eight electrons satisfy the atoms' needs, this creates a strong bond, but there is no positive or negative charge. This material is used on the plates of solar panels. Combining silicon with other elements that have a positive or negative charge can also create solar panels.

For example, phosphorus has five electrons to offer to other atoms. If silicon and phosphorus are combined chemically, the results are a stable eight electrons with an additional free electron. The silicon does not need the free electron, but it can not leave because it is bonded to the other phosphorous atom. Therefore, this silicon and phosphorus plate is considered to be negatively charged.

A positive charge must also be created in order for electricity to flow. Combining silicon with an element such as boron, which only has three electrons to offer, creates a positive charge. A silicon and boron plate still has one spot available for another electron. Therefore, the plate has a positive charge. The two plates are sandwiched together to make solar panels, with conductive wires running between them (http://www.articlesbase.com/technology-articles/solar-energy-basic-principles-6 49460.html).

Photons bombard the silicon/phosphorus atoms when the negative plates of solar cells are pointed at the sun. Eventually, the 9th electron is knocked off the outer ring. Since the positive silicon/boron plate draws it into the open spot on its own outer band, this electron does not remain free for long. As the sun's photons break off more electrons, electricity is then generated. When all of the conductive wires draw the free electrons away from the plates, there is enough electricity to power low amperage motors or other electronics, although the electricity generated by one solar cell is not very impressive by itself. When electrons are not used or lost to the air they are returned to the negative plate and the entire process begins again.

2.2 Solar thermal energy

Solar thermal energy (or STE) is a technology for harnessing solar energy for heat. Solar thermal collectors are characterized by the US Energy Information Agency as low, medium, or high temperature collectors. Low temperature collectors are flat plates generally used to heat swimming pools. Medium-temperature collectors are also usually flat plates but are used for creating hot water for residential and commercial use. High temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production. This is different from solar photovoltaic which converts solar energy directly into electricity.

2.2.1 Low-temperature collector

Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal typically copper or aluminum because the metal is a good heat conductor. Copper is more expensive, but it is a better conductor and less prone to corrosion than aluminum. In locations with average available solar energy, flat plate collectors are sized approximately one-half- to one-square foot per gallon of one-day's hot water use.

The main use of this technology is in residential buildings where the demand for hot water has a large impact on energy bills. This generally means a situation with a large family, or a situation in which the hot water demand is excessive due to frequent laundry washing.

Commercial applications include car washes, military laundry facilities and eating establishments. The technology can also be used for space heating if the building is located off-grid or if utility power is subject to frequent outages. Solar water heating systems are most likely to be cost-effective for facilities with water heating systems that are expensive to operate, or with operations such as laundries or kitchens that require large quantities of hot water.

Unglazed liquid collectors are commonly used to heat water for swimming pools. Because these collectors need not withstand high temperatures, they can use less expensive materials such as plastic or rubber. They also do not require freeze-proofing because swimming pools are generally used only in warm weather or can be drained easily during cold weather.

While solar collectors are most cost-effective in sunny, temperate areas, they can be cost-effective virtually anywhere in the country so should be considered.

2.2.2 High-temperature collector

In order to reduce the Flat-plate collector heat loss and to improve the collect temperature, the international community in the 70s had a successful development of vacuum tube, its heat-absorbing body is enclosed in a high vacuum inside the glass vacuum tube, greatly improving the thermal performance. The number of branch vacuum tube assembly together, shall constitute a vacuum tube collector, the collection in order to increase the amount of sunlight, some in the vacuum tube in the back is also fitted with reflectors. Vacuum collector tube can be roughly divided into two: all-glass evacuated collector tubes (glass-U-tube vacuum collector tubes), and Metal heat-pipe vacuum tubes (straight-through vacuum collector tubes and stored thermal vacuum collector tube).

Condenser collector mainly by the condenser, absorber and tracking system has three major components. Accordance with the principle of distinction between condenser, condenser collector can be divided into reflection and refraction condenser two categories, each category in accordance with the condenser can be divided into a number of different kinds. In order to meet the requirements of solar energy utilization like simplify tracking agencies, improve reliability, reduce costs, by development of condenser collector in this century, there are many kinds of condenser collectors, but the promotion of condenser collector is less than flat-plate collector, and lower degree of commercialization. In the reflective concentrator collectors, rotating parabolic mirror condenser (point focus) and the parabolic troughlike mirror condenser (line focus) is more applied. The former can get hot, but two-dimensional tracking; the latter can get the temperature, as long as for onedimensional tracking. The two condenser collectors are applied at the beginning of this century and after decades to carry out a number of improvements, such as reflective surfaces to improve machining accuracy, development of high reflective materials, development of high-reliability tracking agencies, at present, these two kinds of parabolic trough collectors are fully capable to meet a variety of high-temperature solar energy utilization requirements, but the high cost of these two kinds of parabolic trough collectors limits their wider application.

In the 1970's, "compound parabolic concentrator mirror collector" (CPC) appeared into the international market. It consists of two parabolic mirrors, CPC do not need to track the sun,they only need to make adjustments according to the season change then it can collect the sunlight and get a higher temperature. The rate of condense is below 10 normally, when the condense rate is below 3 it can be fixed to install, no need for adjustment. At that time, many people give high evaluation to CPC, and even think it is a big breakthrough to solar thermal utilization technologies and it will be widely applied. However, decades later, CPC has been applied to only a small number of demonstration projects, and did not like the flat-plate collector and vacuum tube collector be widely used.

Other reflective mirror concentrators are conical, spherical mirrors, bar mirrors, bucket-type trough mirrors, flat and Parabolic mirror concentrators, etc.. In addition, there is an application in a tower solar power plant called heliostat. Heliostats consist of a number of flat mirrors or curved mirrors, under the computer control these mirrors reflect the sun's rays to the same absorber, the absorber can reach very high temperatures,and get powerful energy.

According to the principle of the use of refraction of light, the refraction-type condenser can be made. Some people use a set of lenses and flat mirrors to assemble a high-temperature solar boiler. Clearly, the glass lens is too heavy, manufacturing process complex and high cost, so it is difficult to make it big. Therefore, the refraction-type condenser is no long-term development. In the 1970s, the international development of large Fresnel lens was an attempt for the production of solar concentrating collectors. Fresnel lens is a plane of the condenser lens, light weight, low prices, and also has bit focus type or line focus points type , generally made of plexiglass or other transparent plastic, but also useful for glass production, mainly for solar concentrators power generation systems. The optical fiber condenser, which consists of fiber-optic lenses and optical fiber connected to the composition of the sun through the optical lens focusing the use of office after the fiber spread. The other is the fluorescence condenser, which is actually a fluorescent pigment to add a transparent plate (usually PMMA), it can absorb sunlight and fluorescent wavelength of the same part of the absorption band, and then a longer wavelength than the absorption band emit fluorescence. Emit fluorescent has total internal reflection within the plate-driven flat-panel edge face due to plate and the surrounding medium differences. The rate of condense depends on the ratio of flat area and the edge area, it is easy to reach 10 100, this flat-panel can absorb the sunlight from different directions, but it also can absorb the scattered light and does not need to track the sun.

2.3 System designs

During the day the sun has different positions. If the mirrors or lenses do not move, then the focus of the mirrors or lenses changes. Therefore it seems unavoidable that there needs to be a tracking system that follows the position of the sun (for solar photovoltaics a solar tracker is only optional). The tracking system increases the cost. With this in mind, different designs can be distinguished in how they concentrate the light and track the position of the sun.

Sketch of a parabolic trough design. A change of position of the sun parallel to the receiver does not require adjustment of the mirrors.

2.3.1 Thermal energy storage

2.3.1.1 Sensible heat storage

The use of sensible heat energy storage materials is the easiest method of storage. In practice, water, sand, gravel, soil, etc. can be considered as materials for energy storage, in which the largest heat capacity of water, so water is used more often. In the 70's and 80's, the use of water and soil for cross-seasonal storage of solar energy was reported. But the material's sensible heat is low, and it limits energy storage.

2.3.1.2 Latent heat-storage

Latent heat-storage units are storing thermal energy in latent (= hidden, dormant) mode by changing the state of aggregation of the storage medium. Applicable storage media are called "phase change materials" (PCM).. Commonly salts crystal is used in low-temperature storage, such as sodium sulfate decahydrate / calcium chloride, sodium hydrogen phosphate 12-water. However, we must solve the cooling and layering issues in order to ensure the operating temperature and service life. Medium solar storage temperature is generally higher than 100 ℃ but unc
Suitable for medium temperature storage of materials are: high-pressure hot water, organic fluids, eutectic salt. Solar heat storage temperature is generally above 500 ℃, the materials currently being tested are: metal sodium and molten salt. Extremely high temperature above 1000 ℃ storage, fire-resistant ball alumina and germanium oxide can be used.

2.3.2 Chemical, thermal energy storage

Thermal energy storage is making the use of chemical reaction to store heat. It has the advantage of large amount in heat, small in volume, light in weight. The product of chemical reaction can be stored separately for a long time. It occurs exothermic reaction when it is needed. it has to meet the needs of below conditions to use chemical reaction in heat reserve: good in reaction reversibility, no secondary reaction, rapid reaction, easy to separate the resultant and reserve it stably. Reactant and resultant are innoxious ,uninflammable, large in heat of reaction and low price of reactant. Now some of the chemical endothermic reaction could meet the needs of above conditions. Like pyrolysis reaction of Ca(OH)2, Using the above endothermic reaction to store heat and release the heat when it is necessary. But the dehydration reaction temperature in high atmospheric pressure is higher than 500 degrees. I t is difficult to use solar energy to complete dehydration reaction. We can use catalyst to decrease the reaction temperature, but still very high. So it is still in testing time of heat reserve in chemistry.

2.3.3. Plastic crystal thermal energy storage

In 1984, the U.S. market launched plastic crystal materials for home heating. Plastic crystal's scientific name is Neopentyl Glycol (NPG), it and the liquid crystal are similar to three-dimensional periodic crystals, but the mechanical properties are like plastic. It can store and release thermal energy in the constant temperature, but not to rely on solid-liquid phase change to store thermal energy, it stores the energy through the plastic crystalline molecular structure occurring solid - solid phase change. When plastic crystals are at constant temperature 44c, it absorbs solar energy and stores heat during the day, and releases the heat during the night.

2.3.4 Solar thermal energy storage tank

Solar pond is a kind of a certain salt concentration gradient of salt ponds, and it can be used for acquisition and storage of solar energy. Because of its simple, low cost, and it is suit to large-scale applied so it has attracted people's attention. After the 60’s, many countries have started study on solar pond, Israel has also built three solar pond power plants.

2.4 Levelized cost

Since a solar power plant does not use any fuel, the cost consists mostly of capital cost with minor operational and maintenance cost. If the lifetime of the plant and the interest rate is known, then the cost per kWh can be calculated. This is called the levelized cost.

The first step in the calculation is to determine the investment for the production of 1 kWh in a year. For example, the fact sheet of the Andasol 1 project shows a total investment of 310 million euros for a production of 179 GWh a year. Since 179 GWh is 179 million kWh, the investment per kWh a year production is 310 / 179 = 1.73 euro. Another example is Cloncurry solar power station in Australia. It produces 30 million kWh a year for an investment of 31 million Australian dollars. So, this price is 1.03 Australian dollars for the production of 1 kWh in a year. This is significantly cheaper than Andasol 1, which can partially be explained by the higher radiation in Cloncurry over Spain. The investment per kwh cost for one year should not be confused with the cost per kwh over the complete lifetime of such a plant .

In most cases the capacity is specified for a power plant (for instance Andasol 1 has a capacity of 50MW). This number is not suitable for comparison, because the capacity factor can differ. If a solar power plant has heat storage, then it can also produce output after sunset, but that will not change the capacity factor, it simply displaces the output. The average capacity factor for a solar power plant, which is a function of tracking, shading and location, is about 20%, meaning that a 50MW capacity power plant will typically provide a yearly output of 50 MW x 24 hrs x 365 days x 20% = 87,600 MWh/year, or 87.6 GWh/yr.
Although the investment for one kWh year production is suitable for comparing the price of different solar power plants, it doesn't give the price per kWh yet. The way of financing has a great influence on the final price. If the technology is proven, an interest rate of 7% should be possible. However, for a new technology investors want a much higher rate to compensate for the higher risk. This has a significant negative effect on the price per kWh. Independent of the way of financing, there is always a linear relation between the investment per kWh production in a year and the price for 1 kWh (before adding operational and maintenance cost). In other words, if by enhancements of the technology the investments drop by 20%, then the price per kWh also drops by 20%.

If a way of financing is assumed where the money is borrowed and repaid every year, in such way that the debt and interest decreases, then the following formula can be used to calculate the division factor: (1 - (1 + interest / 100) ^ -lifetime) / (interest / 100). For a lifetime of 25 years and an interest rate of 7%, the division number is 11.65. For example, the investment of Andasol 1 was 1.73 euro, divided by 11.65 results in a price of 0.15 euro per kWh. If one cent operation and maintenance cost is added, then the levelized cost is 0.16 euro. Other ways of financing, different way of debt repayment, different lifetime expectation, different interest rate, may lead to a significantly different number.

If the cost per kWh may follow the inflation, then the inflation rate can be added to the interest rate. If an investor puts his money on the bank for 7%, then he is not compensated for inflation. However, if the cost per kWh is raised with inflation, then he is compensated and he can add 2% (a normal inflation rate) to his return. The Andasol 1 plant has a guaranteed feed-in tariff of 0.21 euro for 25 years. If this number is fixed, it should be realized that after 25 years with 2% inflation, 0.21 euro will have a value comparable with 0.13 euro now.

Finally, there is some gap between the first investment and the first production of electricity. This increases the investment with the interest over the period that the plant is not active yet. The modular solar dish (but also solar photovoltaic and wind power) have the advantage that electricity production starts after first construction.

Given the fact that solar thermal power is reliable, can deliver peak load and does not cause pollution, a price of US$0.10 per kWh starts to become competitive. Although a price of US$0.06 has been claimed with some operational cost a simple target is 1 dollar (or lower) investment for 1 kWh production in a year.

2.5 Types of Solar Panels

Several decades of research, work, and development have lead to the wide range of different types of solar panels now available on the market for solar panels.

To give a broader overview, GreenMatch has put together some helpful information about the most common and special types of solar panels.

Solar Cell Type	Efficiency-Rate	Advantages	Disadvantages
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimised for commercial use; high life-time value	Expensive
Polycrystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	shorter warranties & lifespan
Concentrated PV Cell (CVP)	~41%	Very high performance & efficiency rate	Solar tracker & cooling system needed (to reach high efficiency rate)

Tab. 1 Types of solar panels
(source, https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels

2.5.1 How to Categorise the Different Types of Solar Panels

Given that sunlight can be used differently whether on Earth or in space points to the fact that location, itself, is a significant factor when it comes to choosing one of the types of solar panels over another.

Distinguishing between different types of solar panels often means differentiating between single-junctions and multi-junctions solar panels—or first, second, or third generations. Single-junction and multi-junctions differ in the number of layers on the solar panel that will observe the sunlight, whereas the classification by generation focusses on the materials and efficiency of the different types of solar panels.

The 1st Generation Solar Panels are the traditional types of solar panels made of monocrystalline silicon or polysilicon and are most commonly used in conventional surroundings.

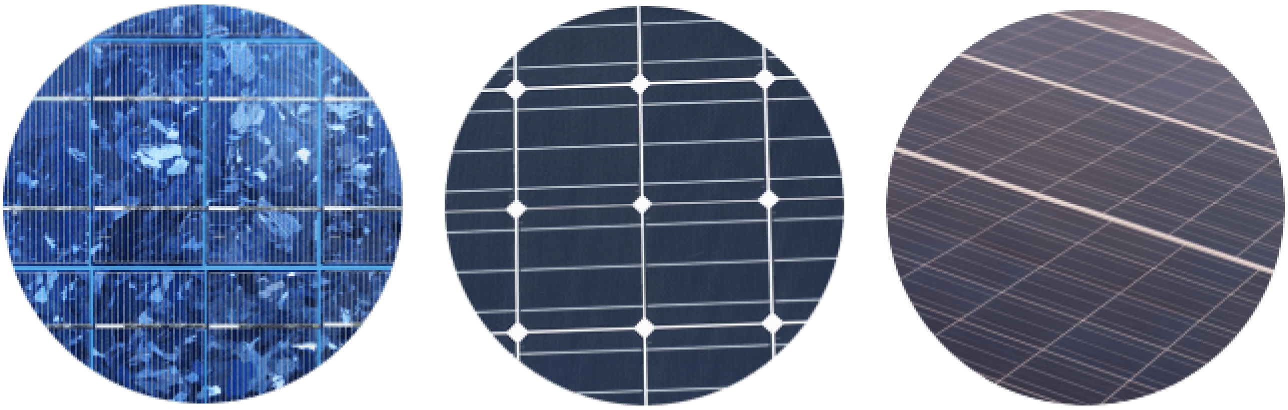


Fig.4 Types of solar panes
Monocrystalline (left), Polycrystalline (center), Thin-Film Solar Cells (right)
(source, https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels)

Monocrystalline Solar Panels (Mono-SI)

This type of solar panels (made of monocrystalline silicon) is the purest one. You can easily recognise them from the uniform dark look and the rounded edges. The silicon's high purity causes this type of solar panel has one of the highest efficiency rates, with the newest ones reaching above 20%.

Monocrystalline panels have a high power output, occupy less space, and last the longest. Of course, that also means they are the most expensive of the bunch. Another advantage to consider is that they tend to be slightly less affected by high temperatures compared to polycrystalline panels.

Polycrystalline Solar Panels (Poly-SI)

You can quickly distinguish these panels because this type of solar panels has squares, its angles are not cut, and it has a blue, speckled look. They are made by melting raw silicon, which is a faster and cheaper process than that used for monocrystalline panels.

This leads to a lower final price but also lower efficiency (around 15%), lower space efficiency, and a shorter lifespan since they are affected by hot temperatures to a greater degree. However, the differences between mono- and polycrystalline types of solar panels are not so significant and the choice will strongly depend on your specific situation. The first option offers a slightly higher space efficiency at a slightly higher price but power outputs are basically the same.

2nd Generation Solar Panels

These cells are different types of thin film solar cells and are mainly used for photovoltaic power stations, integrated in buildings or smaller solar power systems.

Thin-Film Solar Cells (TFSC)

If you are looking for a less expensive option, you might want to look into thin-film. Thin-film solar panels are manufactured by placing one or more films of photovoltaic material (such as silicon, cadmium or copper) onto a substrate. These types of solar panels are the easiest to produce and economies of scale make them cheaper than the alternatives due to less material being needed for its production.

They are also flexible—which opens a lot of opportunities for alternative applications—and is less affected by high temperatures. The main issue is that they take up a lot of space, generally making them unsuitable for residential installations. Moreover, they carry the shortest warranties because their lifespan is shorter than the mono- and polycrystalline types of solar panels. However, they can be a good option to choose among the different types of solar panels where a lot of space is available.

Amorphous Silicon Solar Cell (A-Si)

Have you ever used a solar powered pocket calculator? Yes? Then you have definitely seen these types of solar panels before. The amorphous silicon solar cell is among the different types of solar panels, the one that is used mainly in such pocket calculators. This type of solar panel uses a triple layered technology, which is the best of the thin film variety.

Just to give a brief impression of what “thin” means, in this case, we’re talking about a thickness of 1 micrometre (one millionth of a metre). With only 7% efficiency rate, these cells are less effective than crystalline silicon ones—that have an efficiency rate of circa 18%—but the advantage is the fact that the A-Si-Cells are relatively low in cost.

3rd Generation Solar Panels

3rd generation solar panels include a variety of thin film technologies but most of them are still in the research or development phase. Some of them generate electricity by using organic materials, others use inorganic substances (CdTe for instance).

Biohybrid Solar Cell

The Biohybrid solar cell is one of the types of solar panels, that is still in the research phase. It has been discovered by an expert team at Vanderbilt University. The idea behind the new technology is to take advantage of the photosystem 1 and thus emulate the natural process of photosynthesis. It explains more detailed how these cells work. Many of the materials being used in this cell are similar to the traditional methods, but only by combining the multiple layers of photosystem 1, the conversion from chemical to electrical energy becomes much more effective (up to 1000 times more efficient than 1st generation types of solar panels).

Cadmium Telluride Solar Cell (CdTe)

Among the collection of different types of solar panels, this photovoltaic technique uses Cadmium Telluride, which enables the production of solar cells at relatively low cost and thus a shorter payback time (less than a year). Of all solar energy technologies, this is the one requiring the least amount of water for production. Keeping the short energy payback time in mind, CdTe solar cells will keep your carbon footprint as low as possible.

The only disadvantage of using Cadmium Telluride is its characteristic of being toxic, if ingested or inhaled. In Europe especially, this is one of the greatest barriers to overcome, as many people are very concerned about using the technology behind this type of solar panel (https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels).

Concentrated PV Cell (CVP and HCVP)

Concentrated PV cells generate electrical energy just as conventional photovoltaic systems do. Those multi-junction types of solar panels have an efficiency rate up to 41%, which, among all photovoltaic systems, is the highest so far.

The name of such CVP cells is related to what makes them so efficient, compared to other types of solar panels: curved mirror surfaces, lenses and sometimes even cooling systems are used to bundle the sun rays and thus increase their efficiency.

By this means, CVP cells have become one of the most efficient types of solar panels, with a high performance and efficiency rate of up to 41%. What remains is the fact, that such CVP solar panels can only be as efficient if the y face the sun in a perfect angle. In order to reach such high efficiency rates, a solar tracker inside the solar panel is responsible for following the sun (Misak S., Prokop L., 2016).

3. Solar energy uses

Solar energy, solar power derived from the sun through the use of solar panels, is just one of the newest initiatives the "Going Green" movement has presented to us, in an effort to build and maintain renewable and sustainable power sources. As with any new addition to your home, there is always the initial cost of the components and installation cost to get it up and running (https://www.thespruce.com/top-solar-energy-uses-1152263).

3.1 Solar Powered Ventilation

Photo 1 Solar power ventilation
(source, Peter Starman/Photographer's Choice RF/Getty Images

How would you like the sun's power to run bath fans, floor fans, and ceiling fans in your home? Fans are widely used throughout the home to move air around for comfort, moisture, and smell control. Think are heating and cooling within your home and cut down on the utility bills. Think about how many ceiling fans run in your home each day. Now, think about how many bath fans run throughout the day, How about floor fans and fans above the stove? I think you'll agree, we all use fans...MORE to either keep us cool, circulate the air or discard unwanted air. With solar powered fans, you can optimize

3.2 Heat Your Swimming Pool With Solar Energy

Photo 2 Swimming pool heating
(source, BraunS/Getty Images)

Swimming pools are one of the greatest joys of summer for children and parents alike. Everyone is excited the first day the pool is opened, except when the pool is just too cold to jump into it. To fix that problem, you can add a solar blanket that will warm the water, much to everyone's delight. This heating works directly through the blanket and no other installations are needed. However, if you'd like to get a little more high tech, simply install a solar hot water heating. This utilizes solar hot water heating panels that are mounted on your roof to collect the sun's heat and then is circulated to the pool. As the water is slowly pumped from the pool, heated and then returned from the panels, the pool temperature is increased.

3.3 Solar Energy Can Heat Your Water

Photo 3 Water Heaters
(source, Getty Images)

Have you considered the possibility of solar energy heating your water instead of using gas or conventional electric water heaters? I know you may say that you'll have to buy all of these pieces to get this option to work. There will installation that you may or may not be able to do. And the cost, well maybe you should just stick to the one you have now, right?

Not so fast! If you think about it, it's no different than changing out an outdated furnace, water heater, or air conditioning unit. You may increase the efficiency by 15-30% by replacing the unit, but there is an up-front cost associated with that change as well. Although the change will save you money over the years, so that should be considered over a period of time.

3.4 Solar energy heating system heating system

Photo 4 Roof solar heating system
(souce, Antonis Liokouras/Getty Images)

Solar heating is referred to as passive space heating and in this example, I'm going to try and explain how this works. One way is to use hot water heat in your home that can be created by using sun-heated tubes of water on your roof and pumping it into your water heater (https://www.thespruce.com/top-solar-energy-uses-1152263).

With the addition of a sunroom, we'll refer to it as a solar room, for example, the all glass room allows the daylight hour sunshine to filter in and warm the room through a collector called a transparent covering in the glass. Now, if we add plants and rocks for a nice visual, the rocks will actually store the heat of the sun and that energy can be used when the sun goes down to heat the room. Stored energy is great and has a lot of uses, like batteries for instance.

3.5 Power pumps with solar energy

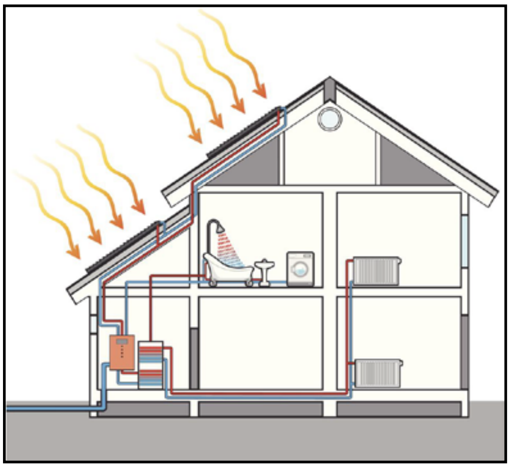


Fig. 5 Solar pump
(source, chuvipro/Getty Images)

In the two illustrations previous, water was used for heating water and your home. To accomplish that task, you'll need to have a pump to circulate the water around. This pump would normally connect to your home's power supply, but let me give you this nice tip. You can use solar energy to run a DC motor that will slowly circulate the water throughout your home or in and out of your water heater. This way, the cost of the system is minimized further. Now, the skeptics will say great, but what do we do when there is no sun? One way is to have normal power run a pump when there is no sun. You can also have a battery backup system that can run the pump and the battery could be connected to a solar battery charger.

3.6 Solar energy for battery charging

Have you considered solar energy for charging batteries? These could be used to power sump pumps, hot water pumps, ceiling fans in your home, or lighting that id of DC nature. battery chargers are used in homes to charge all of those batteries used for video games and such as well. But most likely, if you have a reserve battery bank that is charged through the day while sunlight is present and is used for the nighttime hours, you can see the benefits of that, right?

3.7 Use solar energy to power your home

Yes, you heard me right, solar energy can power your home. The system needed isn't that complex when you examine the devices needed. Simply add solar panels to collect sunlight and convert it into electricity. DC power (direct current) is then sent to an inverter, which converts DC power into Ac power, which now runs your home. Through the use of transfer switches and other safety devices, your clean, renewable power source is capable of powering your home, camper, cabin, tool shed, other building for that matter.

3.8 Solar energy for cooking

Photo 5 Solar cooker
(source, Getty Images)

Oh yes, we can all relate to this one. After all, we all have to eat. When you consider the energy and resources that are used to cook alone, the utility bills may surprise you. Cooking with the use of solar energy is much easier than you think. We call it thinking outside the box, or in this case, cooking within a box. Imagine cooking inside a solar oven instead of your conventional one at home. Building one of these is a recipe for successful cooking on sunny days! With a box, pan, aluminum foil, a cooking bag, duct tape (man's best friend), styrofoam insulation, and a thermometer, you'll be cooking in no time at all.

3.9 Solar Energy for Indoor Lighting

Photo 6 Indoor lightning
(source, BanksPhotos/Getty Images)

Lighting in your home is something we all use. With the invention of LEDs (light emitting diodes) lighting, your home can now have optimal lighting with minimal power consumption. These small, electronic light or set of lights can be connected through a battery-charged system that is powered by sunlight through the day and batteries through the night. When the sun is available, the battery charger charges the backup battery and runs the lighting. Then at night, the batteries kick in and supply...MORE the lighting while the sun is not visible.

3.10 Solar energy used for outdoor lighting

Photo 7. Outdoor lightning
(source, Getty Images)

If you're like me, you like to come home at night to some sort of security light and walkway lighting present. Not only does it aid in a clear view of the walkway area, a clear view of keys and the entrance door, but also it serves as a deterrent to unwanted guests. As in the case of a pole light, your whole yard can be lit and best of all for free! Yes, with the use of solar lighting, the solar panel charges the batteries during the day and the batteries run the light at night.

4. Disadvantages of solar energy

With the cost of electricity rising 3%-5% each year, you may be considering alternative sources of energy, such as solar. But before you go and install a solar system on your house, some major disadvantages need to be weighed in.

With solar power having the highest initial costs than any other renewable energy source, you would think it would be pretty good. But in reality, solar panels have low efficiency.

If you’re in a prime location you will be lucky to get more than a 22% conversion rate, with the best and most expensive technology available.

Then there is the potential of the solar panels being damaged by storms. On top of the cost of replacing the solar panels, the damaged ones have to be handled and disposed of properly due to the toxic compounds used inside.

This article will discuss the major disadvantages of solar energy that should be taken into consideration before deciding on whether or not to go solar (https://www.nachi.org/disadvantages-solar-energy.htm?loadbetadesign=0).

4.1 Location and sunlight availability

Your latitude is one of the main factors in determining the efficacy of solar power. Not all locations get the same amount of annual sunlight, with the efficacy of solar power dropping dramatically the farther you get from the equator.

This means residents in places like Canada and Russia are at a solar disadvantage. However, in places like Hawaii where they average 277 days per year of rain and clouds, their location to the equator is irrelevant because they just don't have enough unclouded sunlight reaching the ground (http://waldenlabs.com/disadvantages-solar-energy).

Solar efficacy is also determined by the season. In the summer you can generate more electricity than you need because the sun is tilted closer to your location. While in the winter, the sun is tilted farther from your location making it so you can't generate enough electricity to supply your needs.

Like everything else that is left in the sun, solar panels will undergo deterioration from ultra-violet rays. Things like wind, hail, snow, dirt and temperature fluctuations are also serious threats to solar panels.

4.2 Installation Area

For homeowners that want to install solar panels, the installation area is not going to be that big of a deal, especially when most of the time they are installed on the roof. However, big companies that want to produce a lot of power are going to need a very large installation area to provide electricity on a consistent basis.

The largest solar field is located in Spain and sits on about 173 acres and provides power to nearly 12,000 households. That's 173 acres of land that cannot be used for anything else, like grazing animals (https://www.nachi.org/disadvantages-solar-energy.htm?loadbetadesign=0).

4.3 Reliability

Since solar energy relies on the sun, electricity cannot be generated during the night, requiring you to either store excess energy made during the day, or connect to an alternate power source such as the local utility grid. This means that you will have to pay more on top of the high cost of the solar panels.

Clouds and storms also restrict the amount of energy you can produce by blocking light rays that would have otherwise been absorbed by the solar panel.

4.4 Inefficiency

According to the Qualitative Reasoning Group with Northwestern University, most solar panels on people's houses convert only 14% of their available energy into power. Even today's most efficient solar panels convert only 22% of their available energy into power.

According to the second law of thermodynamics, solar cells will never reach 100% efficiency. The highest theoretical maximum efficiency is 85%, and that's with mirrors and motors to follow the sun.

For a system that does not track the sun, the highest theoretical maximum efficiency is only 55%. The same is true for systems that track the sun on cloudy days.

Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops. Solar panels are dependent on sunlight to effectively gather solar energy. Therefore, a few cloudy, rainy days can have a noticeable effect on the energy system. You should also take into account that solar energy cannot be collected during the night. On the other hand, if you also require your water heating solution to work at night or during wintertime, thermodynamic panels are an alternative to consider.

4.5 Pollution and environmental impact

Solar Energy Effectors and Potential Effects on the Environment Effectors may be temporally categorized over the lifetime of a photovoltaic (PV) or concentrating solar power (CSP) installation, from construction through decommissioning and may have one or more potential effects on the environment with multiple potential ecological responses. Additionally, the technology, size, and location of solar energy infrastructure may impact biota and the environment in different ways. For example, integrated solar energy is that which has zero land-use and land-cover change impacts beyond those associated with raw materials acquisition and manufacturing. Thus, it has minimal to zero adverse effects on the biosphere (beyond life-cycle emissions), resources (e.g., cultural), and legal entitlements - e.g., religious rights of indigenous communities. Integrated solar energy is cohesively constructed into elements of the built environment in urban and suburban areas (e.g., commercial and residential building rooftops, parking garages, and carports) relatively close to consumers. Although geographically diffuse, integrated solar energy offers high levels of solar energy potential it has been estimated that 20%–27% of all residential rooftop space and 60%–65% of commercial rooftops in the United States are conducive to photovoltaic and solar thermal systems. In contrast, displacive solar energy is that which incurs additional land-use or land-cover change and therefore reduces biophysical capacity or facilitates the loss of other resources of value (e.g., cultural) across the Earth's surface. These installations are typically groundmounted and large in capacity They are often geographically far from demand loads and preexisting transmission, and have large land area requirements (i.e., installed capacity increases concomitantly with land area) (Murphy-Mariscal Michelle L. et. al., 2018).

4.6 Land Requirements

To meet projected 2040 energy consumption demands, it is estimated that approximately 800 000 km2 of additional land (with spacing), an area two times that of the state of California, would be affected by carbon-intensive and renewable energy development. Ground-mounted solar energy requires relatively large expanses of land to support power plant infrastructure, mirrors and towers (e.g., CSP), and panels (e.g., PV), and therefore, such installations are often sited far from urban population centers where most electricity is consumed. This may necessitate additional transmission infrastructure (i.e., power line corridors, roads, and substations) to transport electricity, expanding impacts beyond the immediate footprint of facilities themselves (Murphy-Mariscal Michelle L. et. al., 2018).

The environmental impacts associated with solar power are land and water use and pollution, habitat loss, and use of highly hazardous materials in the manufacturing process.

Thinking back to installation area, land use by solar fields can be massive, and unlike with wind power, sharing the land for agriculture uses is not an option. Solar power also affects land use when it comes to mining and production of materials needed to produce photovoltaics.

Among the compounds found in solar panels is cadmium and lead, extremely toxic metals. There are a number of other toxic and hazardous materials used in the production of solar panels including gallium arsenide, copper-indium-gallium-diselenide, hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone.

In the United States, manufactures are required to make sure these high value substances are recycled rather than disposed of. However in other countries such as China, Malaysia, the Philippines, and Taiwan, where over half of photovoltaics are manufactured, these hazardous materials are being irresponsibly disposed of in fields, polluting the air, water, and soil.

4.7 Expensive energy storage

Most consider storing large amounts of electrical energy as the single biggest obstacle in producing solar power on industrial scale. Currently, the battery storage system options for storing solar energy as electrical energy are very expensive.

Tesla has created the Powerwall battery to store solar energy for later use. However, with one 14kWh battery costing around $7,100 with installation, these batteries are very expensive. If you wanted to have one day’s worth of back-up energy for a four bedroom house, you would need three Tesla batteries, coming to a whopping total of $18,300.

4.8 High initial cost

It cost between $15,000 and $29,000 for average sized systems that produce between 4kW and 8Kw of power. These costs include the solar panels, inverter, mounting hardware and wiring, installation, permits, repairs, monitoring and maintenance costs, and additional operation and overhead costs.

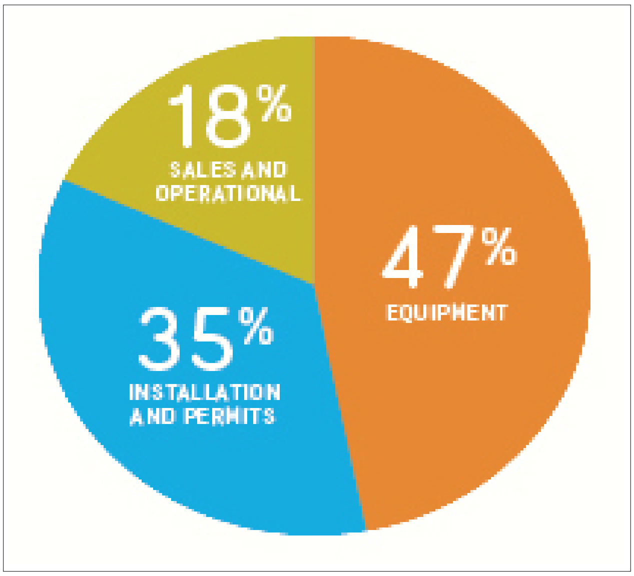


Fig. 6 Percentages of measured costs of solar panels acquisition (source, https://www.sunrun.com/solar-lease/cost-of-solar)

Solar panels are measured in watts and are often priced in dollars-per-watt. Not all panels are created equal, and they're priced accordingly. Equipment costs consits of solar panels, inverter, mounting hardware and wiring; Installation and permits consists of solar installation, supply chain, permitting and interconnection; Sales and operational consists of monitoring and maintenance costs, repairs, additional operational and overhead.

You may notice this does not include a battery storage system, which is an additional cost. Battery storage systems are not required, if you plan on supplementing your energy needs by connecting to the local energy grid.

If you factor in the cost of a battery storage system as described previously, you're looking at a potential total cost of between $33,300 and $47,300 to reliably supply enough energy, day and night, for the average four bedroom household. Even then depending on the climate and your location, you may have to reduce usage and be more frugal with how you use your energy.

Another factor to consider when looking at the initial cost is the payback period. For an $18,000 system, you are looking at 20 years before you make the money back from the savings created by solar power. That is not very reasonable for most people and their finances.

4.9 Economic Disadvantages

The main disadvantage of solar power is the economics. Semiconductor material from which the solar cells are made are prohibitively expensive to manufacture. Even as advances in material science and manufacturing methods are discovered, the fundamental techniques are highly cost prohibitive. There are cheaper solar panel material used in consumer electronics but they do not generate as much power as the classic photovoltaic cell.

Some recent discoveries allow for more of the solar spectrum to be used to generate power, but these experimental materials use the same expensive crystal growth and doping methods. Manufacturing improvements are still decades away.

For the past few decades, solar power generation stations have been operating under government sponsorship and have proven that generating electricity from the sun's energy is technically feasible but economically not viable, as least not yet. These installations are located in sparsely populated, arid deserts that receive sunshine almost all year. Large amounts of inexpensive land is required to accommodate the solar panels and mirrors which relegates these power plants to be located far from where the power is actually used. Expensive transmission towers need to span these distant power sources to energy-consuming, urban centers.

Despite the current disadvantages of solar power, harnessing the free energy of the sun still seems promising. As scientific advances and manufacturing techniques help make solar cells more efficient and cheaper to make, solar power will become an important energy source for residential homes in the future.

4.10 Conclusions

While solar energy is considered and inexhaustible renewable resource, the way we currently harness that energy has many disadvantages from being unaffordable to inefficient. However, solar technology is still in its infancy and many good ideas are beginning to surface.

For example, research on energy storage issues has found two different methods that could be used to store electrical energy in the future.

Finding inspiration in existing technology, scientists are creating flow batteries that use small organic molecules that help rhubarb plants store energy, called quinones, rather than the toxic and very expensive metal vanadium ions. Researchers predict this technology could take the present cost from $0.02 per kilowatt-hour down to $0.0025 per kilowatt-hour.

The other method, which is really quite ingenious, takes the solar energy produced to create methanol from carbon-dioxide instead of electricity. The plan is that a plant would burn the methanol as fuel, which would convert it back to carbon-dioxide that would be re-captured and stored. The goal is to reduce emissions by recycling carbon, instead of letting escape into the atmosphere.

One thing is for sure though. Solar energy still has a long ways to go before it is affordable, efficient, and environmentally friendly.

5. Case study - Osorhei Photovoltaic Power Plant (CEF Osorhei)

Realization of the Osorhei Photovoltaic Power Plant (CEF Osorhei) intended to use the renewable solar energy for producing green energy by achieving a power generation capacity of 0.6 MW on solar panels in Oşorhei.

Fig. 7 Location of Osorhei commune
(source, dgtat-dgtatamd.opendata.arcgis.com/)

Romania provides the necessary context for producers of electricity using sunlight. Areas of special interest for electric power applications of solar energy in Romania are: - the Romanian Plain, the West Plain, Banat and part of the highlands of Transilvania and Moldova.

These areas have streams of solar energy with an annual average between 1700 and 2050 hours of sunshine per year, and areas such as Dobrogea, Romanian coast of the Black Sea and the Danube Delta, presents special features, with an average annual solar flux extremely favorable reaching a number of over 2,200 hours of sunshine a year (Clima Romaniei, 2008).

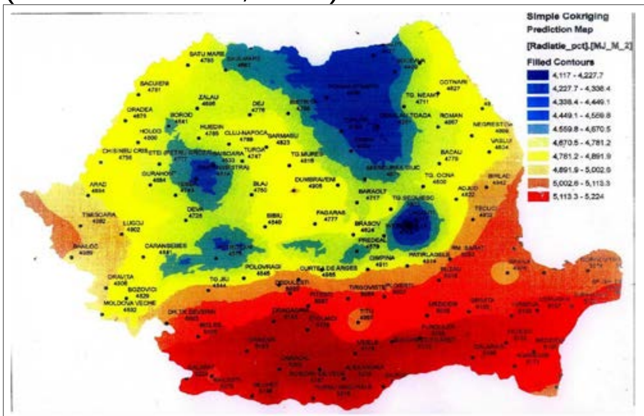
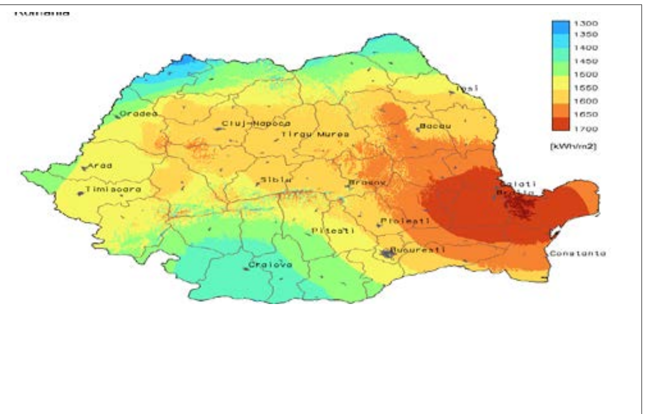
	

Fig.8 Solar energy potential of Romania (Clima Romaniei, 2008)	Fig.9 Yearly sum of global irradiation received by optimally-inclined Pv modules (source, Clima Romaniei, 2008)

The region in which it is located (county of Bihor) the electricity generation capacity based on photovoltaic solar panels, have favorable characteristics to achieve its objectives. According to the study "Climate and topoclimatele of Oradea" developed by Aurelia Florina Dumiter in 2007, summarized the climate data of the Bihor County, with an average annual solar radiation of 2990.0 Wh / m2. If we refer to the maximum and the minimum potential of solar radiation in Bihor County, in a year, will be as follows: 5659.2 Wh / m2 in June and 626.4 Wh / m2 in January.

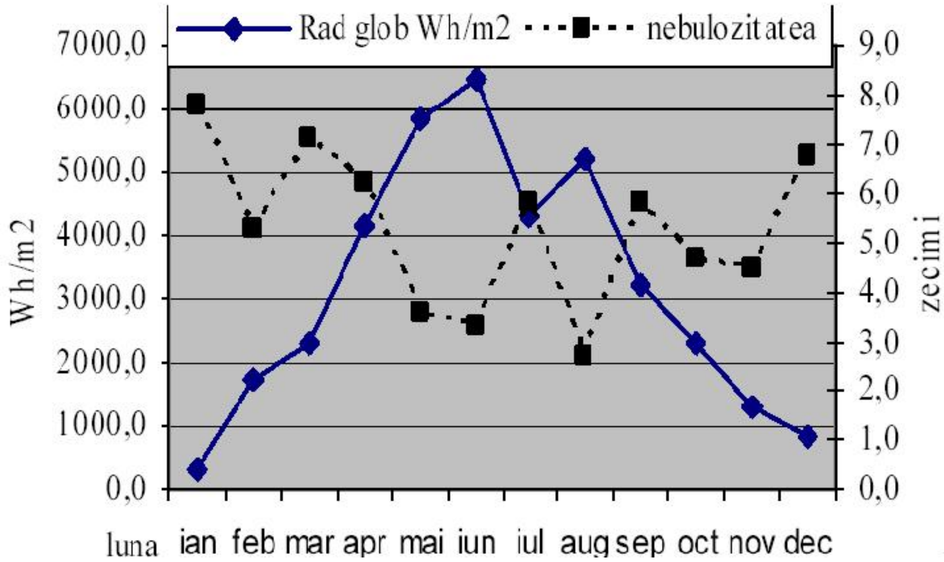


Fig 10. Correlation between cloudiness and total global radiation in temperate zone, area includes Bihor county (Source, Dumiter A., 2007)

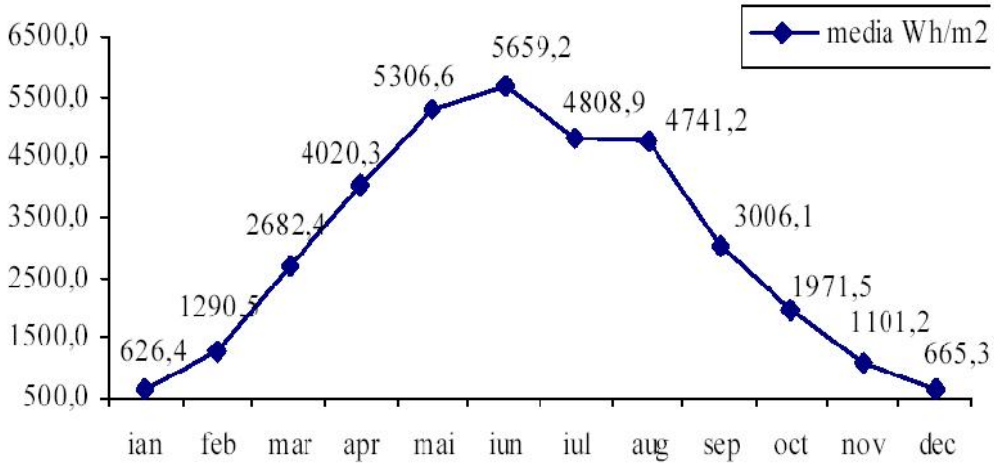


Fig 11 Walking annual global solar radiation in Oradea (source, Dumiter A., 2007)

The Fughiu town of Bihor is where the plant based on solar photovoltaic panels was carried out, with a production capacity of 0.6 MW of electricity. The solar energy potential that it offers the Bihor county is harnessed through the solar production of electricity, which is connected to the National Power Grid downstream of the point of separation (where users' installations are separated as property plant operator network). The land for this facility was chosen in Fughiu town because it has a large enough area for this project, and is positioned at a distance from any buildings, forests or other issues that may create shadows to the installation. The capture of solar radiation on the ground it take place under optimum conditions.

With reference to the favorable situation in terms of solar radiation of the areas where the solar system is located, this enables capturing the full potential of solar radiation in Bihor County, in a year, 5659.2 Wh / m2.

In this way solar energy flows reach annual average between 1700 and 2050 hours of sunshine a year, which can generate a real electrical current production of 650,000 kWh / year for that installation of 0.6 MW.

The solar power photovoltaic thin film panels were chosen being the most viable for that production area, having a higher current than the system based on polycrystalline panels, because it works properly in days with low solar radiation. Basically a thin film PV system can be built to any size, taking into account the energy that you have to produce. Additionally it can be enlarged or moved, given the context.

The Thin film photovoltaic technologyhas brought a great advantage for further development of this field, by removing the expensive silicon of the cost equation. It uses a semiconductor material such as Copper, Indium, Gallium and Selenium to produce photovoltaic panels capable of converting sunlight into electricity. In addition, the silicon free panels are much lighter and more flexible, and no longer requires rigid and solid frame. Thus, the solar panels can be used in more and more areas.

The photovoltaic system with connection to a power grid is characterized by the production of electricity through its 3 main elements:

vi. Photovoltaic panels
Iinverter
vii. Power line network

These ar completed with a series of ancillary equipment such as various protection against surges or energy meters.

Photovoltaic panels forming a photovoltaic generator have the purpose to receive sunlight and convert it into electricity. The energy generated by the panels we refer to as direct current (DC), which will by introduced in thea electrical distribution network, being converted into alternating current (AC) by an inverter. The inverter will convert the DC produced in AC, making it suitable for delivery to the electrical network.
The installation also incorporates a series of counters, in order to obtain a measurement of the energy generated.

The power grid will receive the energy generated and through it will be distributed to the points of consumption that is the beneficiary the City of Oşorhei.
In this way, at the end of the process, will have a solar photovoltaic installation connected to the low or medium voltage network.

The photovoltaic panel used for this facility is a panel with thin film technology (silicon as cadmium tellurium) with a rated output of 75 W.

Thin film photovoltaic panels are durable and flexible, being packed in isolation systems against infiltrations, also having self-cleaning polymers. These plates can be used even as roof shingles, or any other creative contexts that exploit flexibility.
Thin film photovoltaic panel provides high energy yields (high performance) regardless of season or weather conditions, with excellent response in low light or low temperatures. They are very strong, robust and resistant to vandalism.

They contain inferior robust laminate frames, at very best, thin film photovoltaic panels can be easily recycled at the end of use without damaging the structure of the panels. The panels used meet the standards of quality and environmental management ISO 9001/2000 and ISO 24001/2004.

Most photovoltaic products have a life of 30 years. Modules of any kind, including the integrated thin film products, have a life of 20 years, twice more durable than crystal or glass plates laminated witch have a life of 10 years. Another component of the system is the inverter. The inverters used for the instalation ar of two kinds of values: 18 KW and 3.3 KW.

DC photovoltaic modules generate irradiation proportional to the incident intensity. For the photovoltaic systems to operate in parallel with the existing network, it is necessary to convert DC into AC, which have the same characteristics available in the power grid. The device in charge of this process is called an inverter DC/AC.

Power line network

From each series of panels a cable is driven to an inverter, which is located in a place as close as possible to them to avoid losses in the current (DC).

Maximum drop in the DC voltage is 1.5% and in the CA's 2%. Operating voltage starts at maximum power point.

Positives and negatives of each group of modules ar conducted separately and ar protected in accordance with current standards. All DC cable ar double isolated and its proper for use in bad weather conditions, on the surface or in the ground.

By this method it is carried aut, at a power of 0.6 Mw, an annual production of 0,650 MWh, which is about 12% higher than what occurs in polycrystalline technology, and therefore revenue, it is biger.

That's also the economic aspect taken in consideration for the total cost of the investment (construction and operation) versus the total operating income.

The solar photovoltaic thin film works best in low sunlight conditions, as compared to polycrystalline panels that require direct sunlight. The thin film photovoltaic yield is obviously higher than that of the polycrystalline, total amount of energy produced in the same installed capacity, is at least 12% higher with thin film photovoltaic panels.

Another advantage is the guaranteed period of operation panels, which means the number of years for which ensure a capacity of 98% of the nominal power installed; thin film photovoltaic panels are guaranteed 5-10 years longer than the polycrystalline technology.

The support structure of the modules ar fixed on the ground with a inclination of the modules at 33 ° and the south orientation of 0 °, being kept a distance between rows of modules of 7.25 m. The structure is made of steel, cement and aluminum.

It was chosen an inclined bench configuration, made of galvanized steel, to obtain a high structural strength and durability in all weather conditions. The columns structure of standard steel profiles are fixed on the ground in a cylinder foundation of diameter 500 mm and depth 900 mm made by cement.

Over these steel profile are positioned cement cross beams, 100x170 mm section, supporting profiles of aluminum, which fits over the modules. Aluminum profiles are 60x60 mm with a thickness of 2 mm. Each row of 8 thin film modules is supported by two aluminum profiles.

They are used galvanized fasteners to anchor the modules, thus ensuring a good electrical contact between modules and supporting profiles, providing security against the possible isolation loss to the generator and against the effects induced by atmospheric discharges.

In the structure ar mounted 9480 of the modules with a power rating of 75 W which require 30 inverters at 18 KW and 18 inverters at 3.3 KW to convert the direct current produced by the panels into alternating current, which is transported to the National Power Grid.

The 9480 modules ar arranged in 6 identical groups of 99.9kW of generated power, and 118.5 kWp installed power. Each group contains 1580 modules, of which 1400 modules are wired to 5 inverters of 18 KW, and 140 modules are wired to 3 inverters of 3.3 KW.

The structure supports overloading of wind and snow, according to the Building Technical Code, in addition to its own weight. Frame structure was calculated according to the rules, ensuring a good anchoring of the panels, in order to suport the modules own weight and to overload caused by earthquake, wind or snow.

All frame structures ar connected to the ground to reduce the risks associated with the accumulation of static charge.

Electrical installation and cabling

The electric system and the wiring efficiency was calculated from the maximum possible, paying particular attention to the installation and execution of both safety and its low voltage drop between the inverter and fotovotaic field, which should be less than 1,5% entry into transformer.

Wiring DC (from modules to inverters) and AC (from inverters to CGP's located in box counters) it is also grounded.

The Transformation Center is formed of a small prefabricated cement precint, which includes in its interior a compact medium voltage equipment, a transformer, a low voltage setting and appropriate interconnections and auxiliary elements.

The conductors are of copper and have the appropriate section to prevent power surges and overheating. All DC and AC cables are double insulated and suitable for use in case of bad weather, being arranged in tubes on the surface or buried in the ground.

Independent of the photovoltaic installation it is instaled a CA line with appropriate protections dedicated for the inverter power use.

Inverter has a line of communication made with multimode optical fiber, which unite the inverter with the control of each module of photovoltaic power plant unit. This line ends at the control center of the plant, which monitor the most important variables of each module unit.

The connection to the National Power System

In order to be connected to the grid the plant do not operate in isolation, for this, the inverter performs a process of continuous monitoring network voltage and frequency, disconnecting himselves from when the parameters that are outside the regulatory thresholds for electrical installations in Romania.

Connection module is triphasic, guaranteeing high quality of the generated signal. The inverter has a harmonic distortion less than 3% and has a minimum power factor of 0.99 of the nominal power itself.

Connection to the National Power Grid is made at 20 kV, which is 100 meters from the solar system.

Functional Description

Operation of the solar system in subject is carried out through the following process: solar energy is taken up by photovoltaic panels, inside them it takes place the conversion of solar energy into direct current; The resulting direct current is sent to the inverter that performs the transformation of direct current into alternating current. The alternating current produced is distributed through the Power Grid to be used by recipients. The following chart is exemplified operation of the solar system.

Technological description

Thin Film Photovoltaic Panel

The photovoltaic panel for this unit is a panel with thin film technology (silicon cadmium tellurium) with a rated output of 75 W.

Thin film photovoltaic panel is a panel made based on thin wafer consisting of 116 cells.

Panel sizes are 1.2 m long x 0.6 m wide. Panel weight is 12 kg. The panel features a lower laminate frame and robust and recyclable .

All photovoltaic panels have two layers of semiconductors, one positively and one negatively charged. When the sun shines on the semiconductor, the electric field of the junction of these layers produce energy → the greater the intensity of the sun, the more energy is produced.

Inverter

These inverters are technologically very advanced, satisfying the technical safety required for low voltage network interconnection and also the Community directives on electrical safety and electromagnetic compatibility.

the most relevant Technical characteristics, of inverters:

- It allows a perfect fit of the vectors to achieve maximum energy production
- It contains a detection system maximum power point
- It offers fast and accurate control of the process which it performs
- Improves the electric current efficiency by up to 20%, even in unfavorable climatic conditions
- Increases kilowatt output of the photovoltaic panels.
- Provides a wide range of operations along the photovoltaic cell technology
- High dynamic performance in cloudy days
- It operates at a wide range of temperatures from -20 degrees to 85 degrees celsius
- Resistant to high levels of air pollution and high humidity
- Modular components its services effective
- It has dual cooling fans
- Designed in accordance with the seismic April
- Built switches for DC and AC disconnect
- They contain isolation transformer
- Link and match the resulting voltage of the inverter photovoltaic power system
- Self-isolation for the supervision of the operation of the network voltage and frequency synchronize with the output voltage of the alternator voltage to its own network.
- Funcţionament fully automatic, virtually no losses during idle periods.
- It works as a source of power, and is able at any time to extract maximum power that can provide photovoltaic generator by further automatic maximum power point, which will present a rank variable input power.
- Protection against voltage and frequency variation contactor with the network connection.
- Protection against short-circuit AC
- Overvoltage protection
- Protection against disturbances present in the network such as micro switches, pulse cycles failures, interruption and recovery network
- Reverse polarity protection
- Galvanic isolation transformer
- The containment CC
- Protective packaging over current connections exposed
- With all components incorporated in one compartment, invertorarele are easy to install, operate and maintain
- Easy access to all components
- Designed specifically for the external environment
- galvanized insulation

The inverter have a monitoring system able to register and manage the following variables:

viii. Voltage and current input
ix. Active power output
x. temperature and radiation inside panels, and the ambient temperature
xi. device status
xii. Status of output contactors

xiii. Alarms (when supply voltage falls, network frequency, derivations, insufficient voltage panels, communication errors)

Data stored by the monitoring system is managed by a customized software which facilitates communication within the solar installation through which the parameters of each element are monitored and adjusted. Additional monitoring system incorporates guided communication and alarm management with GSM communications.

Transformer

The 630 kVA transformer with the necessary protections, has the following characteristics:

xiv. Three-phase transformer, mono voltage 420 V (no load) / 20 kV
xv. Waterproof full within the rules
xvi. Designated power 630 kVA
xvii. 24 kV insulation level
xviii. Group Dyn 11 connection
xix. The short circuit impedance at 75 ° C 4%
xx. Current goal 2.3%
xxi. 59 dB Sound Pressure

Equipment Center Transformation

Inside and over the connection is mounted the electrical equipment, type MB, composed of the following elements:

xxii. A shelf bracket
xxiii. Lifting System
xxiv. MT gear unit compact, fully insulated in SF 6, GCM kind Cosmos 2 - LP
xxv. BT gear unit. Frame with low voltage protection function and control
xxvi. Distribution transformer unit MT / BT 160 kVA entirely filled with oil / 24 kV, in compliance with the standards SEE
xxvii. Direct interconnections with MT and BT cables
xxviii. Circuit fixation on earth
xxix. Lighting and auxiliary services

Monitoring system

The photovoltaic system have a bidirectional electronic three-phase counter of low voltage and an indirect measure of energy whitch measure the energy produced by the photovoltaic system and the consumption of the photovoltaic installation.

Essential characteristics of the measurement equipment are:

xxx. Capable of measuring the active power (bi-directional) and reactive (4 quadrants)
xxxi. Availability for 3 counters
xxxii. Computing power, maximum demand, and excess power
xxxiii. Communication ports, local and remote reading
xxxiv. Availability of 4 free power contacts to transmit signals to an external device
xxxv. LCD viewer

The theoretical annual production is made in concordance with the technical code requirements for photovoltaic installations network connection available at European level, as follows:

xxxvi. Ep (kWh / day) = Gdm (a, ß). PM PMP. PR / GCEM
xxxvii. Ep = energy produced by generator
xxxviii. PMP = peak power generator
xxxix. GCEM = 1KW / m2

xl. PR = Ratio of performance is the energy efficiency of the plant under the conditions of the actual work.
xli. Consider: dependence between efficiency and temperature; the effectiveness of the wiring; losses due to impurity, scattering parameters, mistakes in maximum power point tracking; energy efficiency inverter.
xlii. Gdm (α, β) = monthly and annual average daily irradiation of the plan generator in kWh / m2 / day, taking into account the inclination and azimuth of the plant.
xliii. Data collated calculations were obtained from various official sources are:
xliv. Join European reasearch centers (European Comisson/European Commission)
xlv. PV - GIS Geografical Assesment of Solar Energy Resource

Month	**Gdm (0) [KW · h (m 2 · day)]**	**Gdm (a = 0, SS = 37) [KW · h (m 2 · day)]**	**Ep [KW · h / day]**	**Ep [KW · h / month]**
January	1105	1874	203	6294
February	1989	3108	332	9307
March	3228	4238	441	13678
April	4474	4992	503	15101
May	5719	5722	563	17452
June	5965	5663	550	16510
July	6135	5988	579	17 964
August	5360	5778	562	17416
September	3945	4966	497	14855
October	2592	3907	400	12413
November	1298	2136	225	5759
December	827	1366	148	4574
Mediate	3553	4145	417	12610
Total	42 637	49738	5003	151 323

Tab. 2 Values of radiation on the inclined surface (kWh / m2) considering orientation and tilt (source of data, Dumitreanu M., 2017)

Month	**theoretical production** kW / h	**PR**	**Produtos Real** kW / h
January	6294	0.77	4846
February	9307	0.77	7166
March	13678	0.77	10532
April	15101	0.77	11628
May	17452	0.77	13438
June	16510	0.77	12 713
July	17 964	0.77	13832
August	17416	0.77	13410
September	14855	0.77	11438
October	12413	0.77	9558
November	5759	0.77	4434
December	4574	0.77	3522
Mediate	12610	0.77	9710
Total	151 323	0.77	116 519

Tab. 3 Theoretical power generation estimated by the facility's 151 323 kWh/year for an inverter (source of data, Dumitreanu M., 2017)

According to the table, we can state that the generation of electricity, estimated real installation is of 116.519 kWh / year for an inverter.

Thin film photovoltaic module values and assessments STC1		**Numerical values of the panel**
Name Denominations	**Abbreviations used**	
Power (+/- 5%)	PMPP (W)	75
Voltage PMAX	VMPP (W)	68.2
Current PMAX	IMPP (A)	1.10
Open Circuit Voltage	VOC (V)	89.6
Short Circuit Current	ISC (A)	1.23
The maximum system voltage	VSYS (V)	1000
Temperature Coefficient PMPP	TK (PMPP)	-0.25% / ° C
Temperature Coefficient VOC, high temperature (> 25 ° C)	TK (VOC, high temp)	-0.25% / ° C
Temperature Coefficient VOC, low temp (-40 ° C to 25 ° C)	TK (VOC, low temp)	-0.25% / ° C
ISC temperature coefficient	TK (ISC)	+ 0.04% / ° C
Limiting reverse curentului2	IR (A)	2
Safety maximum source circuit	ICF (A)	10 (2 IEC617303)

Tab. 4 Thin film photovoltaic module technical parameters
(source of data, Dumitreanu M., 2017)

The datasheet thin film photovoltaic module 75 W.

Thin film photovoltaic module values and assessments 800W / m2, 45 ° C, AM 1.5		**Numerical values of the panel**
Name Denominations	**Abbreviations used**	
Power (+/- 5%)	PMPP (W)	56.3
Voltage PMAX	VMPP (W)	63.9
Current PMAX	IMPP (A)	0.88
Open Circuit Voltage	VOC (V)	83.3
Short Circuit Current	ISC (A)	1.01

Description Mechanics			
Length	1200 mm	Thickness	6.8 mm
Width	600 mm	Area	0.72 m2
Weight	12 kg	cable Order	3.2 mm 2, 610 mm

Tab. 5 Thin film photovoltaic module 75 W technical parameters
(source of data, Dumitreanu M., 2017)

The datasheet for 18 KW inverter with AC protection.

Inputs	
CC Maximum Power	22500 W
Beach Voltage DC	335 V - 800 V

The nominal voltage (UFV, nom)	335 V
Maximum MPP voltage (UMPP, max)	560 V
The maximum DC voltage (UCC max)	800 V
Max. entrance (IFV, max)	23
CC distortion factor (UPP)	<10%
Maximum number of layers (parallel)	4
connection CC	Hooks (MC or Tyco)
The thermal control varistors	Yes
Monitoring laying on the ground	Yes
Reversed polarity protection	Short circuit diode
Output values	
Maximum power CA (PCA max)	19800 W
Rated AC (PCA nom)	18000 W
Max. output (ICA max)	31
Coefficient of distortion nealinear from current network	<4%
Rated voltage AC (UCA, nom)	380 V - 400 V
Rated frequency AC (FCA, nom)	50 Hz / 60 Hz
Power factor (cos)	1
Short-circuit resistance	Yes, current control
Network Connection	Terminals CA
Output factor	
The maximum yield coefficient	96%
European efficiency factor	95.3%
Power Electronics	
Concept circuit	Power Transformer
Network monitoring	surveillance grid
number of phases	3 (three-phase star connection)
housing	
DIN EN 60529	IP 65
Cooling concept	Opti Cool
Permissible ambient temperature	between - 25 ° C and + 60 ° C
Weight & Dimensions	
Weight	210 Kg
Width / Height / Fund (mm)	2000/1000/300
Characteristics	
Communication	Radio
Display	display options 2 or more lines
Guarantee	5 years - 10 years

Tab. 6 The 18 KW inverter technical parameters
(source of data, Dumitreanu M., 2017)

The datasheet for the 3.3 KW inverter incorporated in the plant protection AC

Inputs	
Maximum DC power, DC voltage Rank	3820 W
The nominal voltage (UFV, nom)	500 V
Photovoltaic MPPT voltage range (UMPP)	200-500 V
Max. Entrance (IFV, max)	20
CC distortion factor (UPP)	<10%
Max. layers (parallel)	3

DC separator device	ESS connector
The thermal control varistors	Yes
Monitoring laying on the ground	Yes
Reversed polarity protection	Short circuit diode
Output values	
Maximum power CA (PCA max)	3600 W
Rated AC (PCA nom)	3300 W
Coeficinet distortion, nealinear from current network	<4%
Rated voltage AC (UCA, nom)	220-240 V
Rated frequency AC (FCA, nom)	50 Hz / 60 Hz
Power factor (cos)	1
Short-circuit resistance	Yes, regulation
Network Connection	connector CA
Output factor	
The maximum yield coefficient	95.2%
European efficiency factor	94.4%
Degree of protection DIN EN 60529	IP 65
mechanical parameters	
Width / Height / Fund (mm)	450/352/236
Weight	41 Kg

Tab. 7 The 3.3 KW inverter technical parameters
(source of data, Dumitreanu M., 2017)

Operating costs are as follows:

- Expenditure on staff required for current maintenance consisting of panel cleaning and vegetation removal - about 5200 euro / year
- Expenditure on staff required for production management with two components technical component - service and configuration of equipment - about 24.000 euro / year
  economic component - record production, putting it in value, - about 6500 euro / year

How to build a solar water heater step by step

The proposed solar water heater is one of the simpliest methods to build such a device and it doesnt any special technical skills so it can be build by anyone with minimum financial investment. The size is the ”standard” size (2×1) for devices wchich can be purchased on the market.

Neccesary materials:

– cooper pipes 15×07 – 30 meters (10 pipes x 3 meters)
– 30 pieces of ”T” shape cooper joints
– 5 pieces of ”MM” cooper jacks
– wooden planks for the box: 8 pieces of 2 meter lenght (5 pieces for the botom, 2 pieces placed on lenght, one piece cut in half) , 20 cm wide, 2 cm thick (standard size) = 8 pieces *2 lenghts 0.2 widht *0.02 thick = 0.064 cubic meters of wood planks
– 15 pieces of wood screws
– 0.6 cm thick glass sheet for the box cover
– angle profile (metal, aluminium or plastic) for the glass sheet fixing, 6 meters
– glass wool with aluminium foil for insulation
– one tube of polyurethanic foam
– 2 sanitary universal sylicon tubes
– metal sheet of 1.25 cm thickness
– 42 pieces of metal clips
– 1 piece of angle metal profile x 6m length for the metal frame of the box + 2x square metal bars of 6 m length to support the box (if the box will be fixed on the roof this metal part is nor necessary)
– 2-3 sacks of cement
– green paint, about 2 liters, for the wood box + black paint for the metal sheet
– cooper pipe cutting device
– gas tank and torch for welding the copper pipes with the joints and jacks

SPEP 1 Building the wood box

The wood plancks must be dry in order to avoid cracks during the process of drying. The corners of the box are strengthened with wood screws and the whole interior must be painted in order to avoid humidity absorbtion and damagind in time.

Photo 8 The painted wood box (source, http://www.douamaini.ro/)

The eventual crakcs and the joints of the wooden planks are sealed with polyutethanic foam in order to prevent any water i inside the wood box.

–

Photo 9 The isoloation of the wood box with polyurethanic foam
(source, http://www.douamaini.ro/)

Step 2 The construction of the cooper pype system

The first step is to fit the "T" shape cooper joints with the cooper jacks. At this stage the coooper pype cutting tool is a very useful device because it allows precise cuttings. One must be notice that at this stage of fitting together all these parts, any measuring error will be multiplied at every step of the welding process. For example a cutting error of one milimeter at the first cutting will end at an error of 10 cm at the and of the pype system.

Photo 10 The welding process of the cooper joints and jacks
(source, http://www.douamaini.ro/)

After the cooper joints and jacks are welded, the next sper is to insert the cooper pype and to weld all the cooper parts together. One must notice that the most difficult part of this step is not twist the pypes into the joints in order to avoid cracks because this could led to fluid loss and subsequently to system failure.

Photo 11 The cooper pypes (source, http://www.douamaini.ro/)

After all the cooper pypes are welded together, the next step is to fix the cooper pype system on the metal plate. Before fixing the cooper system, the metal plate must be painted in black. In order to obtain the best heat transfer from the plate to the pypes, the whole cooper system must be fitted at both ends and at the middle with metal clips.

Photo 12 The cooper pype system (source, http://www.douamaini.ro/)

Sper 3 Mounting the glass wool isolation

Before installing the cooper pype system into the box, it must be isolated. One of the best solutions is to use glass wool with aluminium foil. The use of glass wool is recommended because it has excellent isolation coefficient, it is simpe to use and to handle. One must notice that the best isolation results are obtained if the glass wool is not pressed because the isolation is made by the air trapped within the glass wool fibres, eliminating the air may led to isolation coefficient failure. The side of the glass wool with the aluminium foil must be fixed towards the metal plate.

The role of the aluminium is to reflect the heat back to the metal plate and the cooper pype system thus increasing the heat coefficient. The glass wool can be fixed with glue or using special clips.

Photo 13 The glass wools used for isolation (source, http://www.douamaini.ro/)

After fixing the isolation, the cooper pype system can be instaled into the wood box with the use of screws.

Step 4 Mounting the glass sheet on the wood box

After all the inner components are mounted together, the next step is to mount the glass sheet. If the upper part of the side board is cut at an angle, the glass sheet can be directly inserted into the profile of the wood box. If not, the easiest way is to use an angle profile (iron, aluminium or plastic) which is fixed with screws on the side of the wood box. In both cases, the glass sheet is is sealed using universal sylicon. This step is very important one because this side will be the upper part of the system, the correct sealin will prevent any further water infiltration.

Photo 14 Sylicon sealing (source, http://www.douamaini.ro/)

The cooper pype exhausts must be also sealed with sylicon preventing water to infiltrate from lateral and also preventing heat escape from the box.

Step 5 Fixing the heating system to its final position and connection to water supply system

After all the elements are fixed into the wood box, the system can be fixed to its final position. If the position of the system will be a permanent one, it is recommended to fix the system in concrete, using a mix of concrete, sand and lime.

The whole system is fixed using metal angle profiles and are tilled at an inclination between 25° - 45° facinc sothward (http://www.panourisolare-online.ro/pdf).

After fixing in the final position, the system can be fitted to water supply system.

Photo 15 The system in ist final position (source, http://www.douamaini.ro/)

This proposal is one of the easiest to do, anyone can do it with a minimum of financial inverstments. The calculations made taking into considerations all the necessary materials shows a price between 150-180 euros, the depreciation of the invertment being within 4-6 months.

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