Electricity: energy

Origin of daily energy

The modern world is characterized by extraordinary technological development. For this reason, we do not pay enough attention to daily situations like flicking a button to light up a room, or turning a control to produce a flame on a burner.

Why is the room lit up or why is the burner started?

A lightbulb glows thanks to the electric current that flows through its wires, and this current comes from power plants. Some of them are the following:

Nuclear power plant

Radioactive materials are used to produce electric current.

Steam power plant

Coal or oil products are used to produce electric current.

Hydroelectric power station

The speed of a water flow is used to produce electric current.

Wind farm

The speed of the wind is used to produce electric current.

Solar farm

The sunlight is used to produce electric current.

As for gas, it arrives to our country in ships called gas tankers, which load it in ports of countries that have gas fields.

Gas is transported from gas fields to ports through special pipes called gas-pipelines.

Therefore, we have studied the origin of two of the main utilities we use in our homes: electricity, which allows us to light and operate electrical appliances, and gas, which allows us to cook, heat up the house we live in and the water we use to have a shower, etc.

The electric current which flows through cables, heat emitted from burning gas, the movement of a washing machine, the light from a lightbulb, etc., are different types of energy.

Forms of energy

Energy is understood as a capacity. For example, we say that electric current has energy because it has the capacity to turn on a lightbulb or make an electrical appliance operate. Gas has energy because, when burnt, it can heat up water, air, and other materials.

We will now look at some of the most usual examples of this capacity, which we call *energy*. We are talking about **types of energy**.

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Types of energy

Kinetic energy

This is the energy of an object due to its movement. A moving car has the capacity to knock over a street light. The kinetic energy of an object depends on its mass and velocity. It is calculated like this:

$$E_K = \frac{1}{2} m \cdot v^2$$

Wind turbines capture the kinetic energy of the wind and transform it into electric current.

Gravitational potential energy

This is the energy of an object due to its height above the ground. An object that falls from the roof of a building has the capacity to crack the paving on the street below. The potential energy of an object depends on its mass and its height above the ground. It is calculated like this:

$$E_g = m \cdot g \cdot h$$

Reservoirs capture the gravitational potential energy of accumulated water, which can be turned into an electric current. The energy is measured in joules (J) in the International System of Units.

Thermal or caloric energy

This is the energy of an object due to its temperature. For example, a hot object has the capacity to move air or heat up another object. As we will see, thermal energy is a key stage in the production of an electric current in many power plants.

Chemical energy

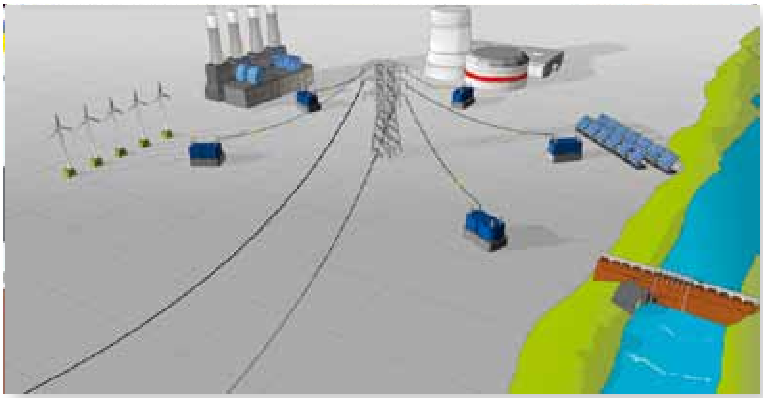
This is the energy of an object due to its chemical structure. When this structure changes, the energy is released, often in the form of heat. This is what happens when we burn a fuel such as firewood, coal, or petroleum derivative.

The chemical energy that is released from fuel is the first step in the production of an electric current in many power plants.

Electric energy

The energy possessed by an electric current. As you know, a current is simply a flow of electrons. The movement of these electrons has the capacity to make lightbulbs and electrical appliances work.

Electric energy is the final product of power plants.



Light energy

The energy of light. The light of the sun, as you know, has the capacity to heat up an object that is exposed to its rays for enough time.

The energy of sunlight is used to produce an electric current in photovoltaic solar panels and to heat water in solar collectors.

Sound energy

The energy of sound. Sound is a vibration in the environment that transports energy. An intense sound has the capacity to damage our eardrums, and a high-pitched sound can even break glass.

Energy souces

We have been looking at how the energy we use in our everyday lives is produced in different ways. In some power plants, fuels derived from petroleum are used; in wind farms, the wind is used, etc.

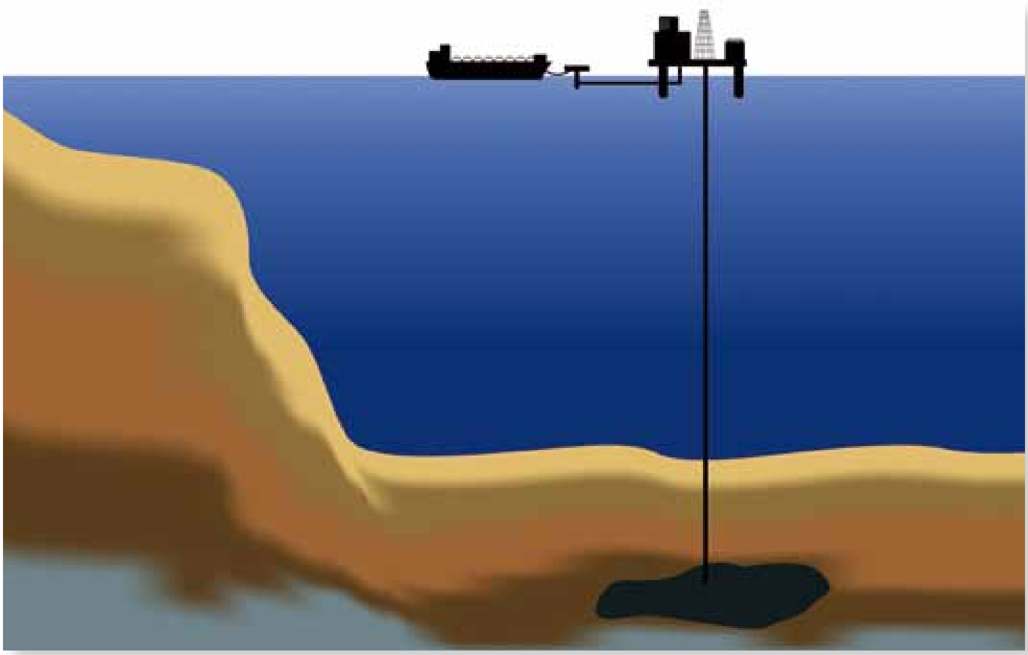
All of the elements containing energy that can be captured and transformed are known as **energy sources**: petroleum, sun, wind, coal, firewood, gasoline, gas, uranium, the heat inside the earth, the waves of the sea, tides, electric current, etc.

Fossil fuels

Some of the energy sources mentioned before (petroleum derivatives, coal, and gas) have something in common: they come from organic material (animal and vegetable) that has undergone a process of fossilization. For this reason, and because they release energy when burned, they are called **fossil fuels**.
As we will see, the fossilization process takes millions of years, and our current rate of consumption of these fossil fuels is so high that reserves are running out.

Petroleum formation

Petroleum is formed on a marine environment rich in plankton and other organisms. When these organisms die, they are deposited on the seabed. Due to the pressure and heat exerted over 500 million years, they are converted into petroleum.



Petroleum deposit on the seabed

Coal formation

Coal is formed on a land environment rich in trees and plants. The remains of these vegetables are buried. Due to the pressure and heat exerted over 500 million years, they are converted into coal.
Gas is usually formed near petroleum and coal fields. It is also a consequence of the fossilization process of dead organic material.

Primary and secondary

Energy sources are classified as primary and secondary:

• Primary energy sources

They are found in nature: Sun, wind, coal, petroleum, gas, waves, heat of earth, tides, firewood, uranium.

• Secondary energy sources

They are not found in nature; they are produced using primary sources by means of a technological process: gasoline, electricity, hydrogen.

Renewable and non-renewable

You have probably noticed another important distinction that can be made between energy sources such as petroleum, gas, wind, and Sun. You must have heard that petroleum and gas supplies are running out, whereas the Sun and wind never will.

Whether an energy source will run out depends on two factors:

- The rate at which the energy source is generated.
- The rate at which the energy source is consumed.

Now that we know all this, we can define renewable and non-renewable energy sources in the following way:

• Renewable energy sources

Sources for which the rate of consumption is lower than the rate of production: Sun, wind, waves, tides, biomass, water, earth heat.

• Non-renewable energy sources

Sources for which the rate of consumption is higher than the rate of production: uranium, coal, gas, and petroleum.

Origin of energy sources

Next we will learn about the origin of all these sources:

Firewood

Firewood is an organic material. Organic materials grow using energy from the Sun. Therefore, the energy we get from firewood comes from the Sun.

Petroleum

Petroleum comes from fossilized organic material. This organic material originally grew using energy from the Sun. Animals obtain energy from plants. Therefore, the energy in petroleum comes from the Sun.

Gas tanker

Coal

Coal is made from fossilized organic material. This organic material originally grew using energy from the Sun. Therefore, the energy in coal comes from the Sun.

Gas

Gas is made from fossilized organic material. This organic material originally grew using energy from the Sun. Animals obtain energy from plants. Therefore, the energy in gas comes from the Sun.

Sun

Obviously, solar energy comes from the Sun.

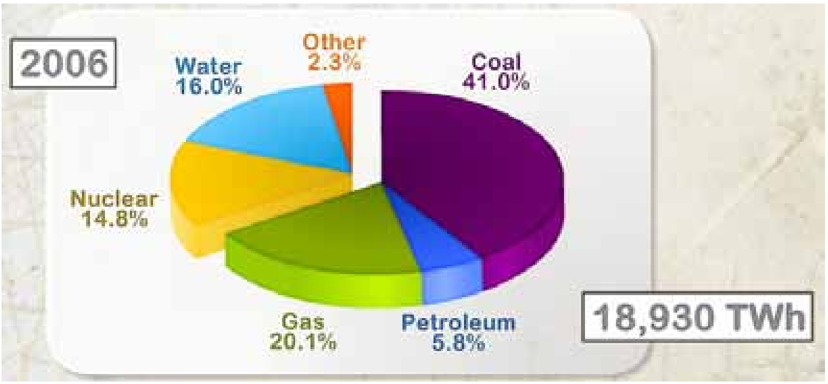
Wind
The wind is air that moves due to differences in temperature caused by the Sun's rays. Therefore, the energy in the wind comes from the Sun.
Waves
Waves are movements in water caused by the wind. Therefore, since wind energy comes from the Sun, wave energy must do too.
Water
Water in reservoirs comes from the rain. Rain occurs because the heat of the Sun evaporates water from rivers and the sea. Therefore, water energy comes from the Sun.
Earth's heat
The Earth's heat is generated beneath the Earth's crust.
Tides
The movement of water caused by the variation in the gravitational attraction of the Moon over a large body of terrestrial water results in the formation of tides.
Therefore, most of the energy that is available in our planet comes from the Sun.

Electricity

Current electrical system

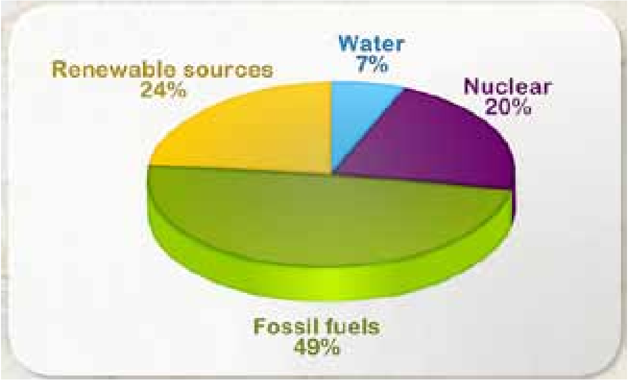
There are international, national, and regional organizations dedicated to the study of the used energy sources. The International Energy Agency came up with the following data:
In the year 2006, 18,930 TWh of electric energy were globally produced. This number is so high that it is difficult to comprehend. More interesting than the amount itself is how this electric energy was generated.

Statistics on electricity



If we combine the usage of coal, petroleum, and gas, we see that 66.9% of all electricity produced came from fossil fuels. Of the rest, 14.8% was produced by nuclear power plants and 18.3% from renewable sources.

The prefix T means 1012 and Wh is an energy unit which is equal to 3,600 J. Therefore, 18,930 TWh are 68,148,1015 J or 68,148 PJ.



According to the Spanish Electricity Network, organization responsible for studying energy at a national level, in the year 2008, the electric energy produced in Spain corresponds to the percentages presented in this chart:

Therefore, in Spain, 49% of electricity was produced using fossil fuels, 31% using renewable sources, and the remaining 20% using nuclear energy.

Conclusions

In general terms, electricity production is highly reliant on fossil fuels. Nuclear energy and renewable sources play a similar role.

Since they have been used for a longer time, fossil fuels, uranium and water are known as **traditional or conventional energy sources**.

We will now see how electricity is obtained from these materials.

Conventional power plants

Most electricity that we consume is produced in big installations called **power plants**.

In power plants, electric energy is produced, which is sent to the consumption points through the electricity network. This network connects the generation and consumption points with wires.

Conventional power plant

Thermal power plants

Thermal power plants were the first to be used to generate electricity on an industrial scale.

They take their name from the thermal energy released from the burning of certain materials.

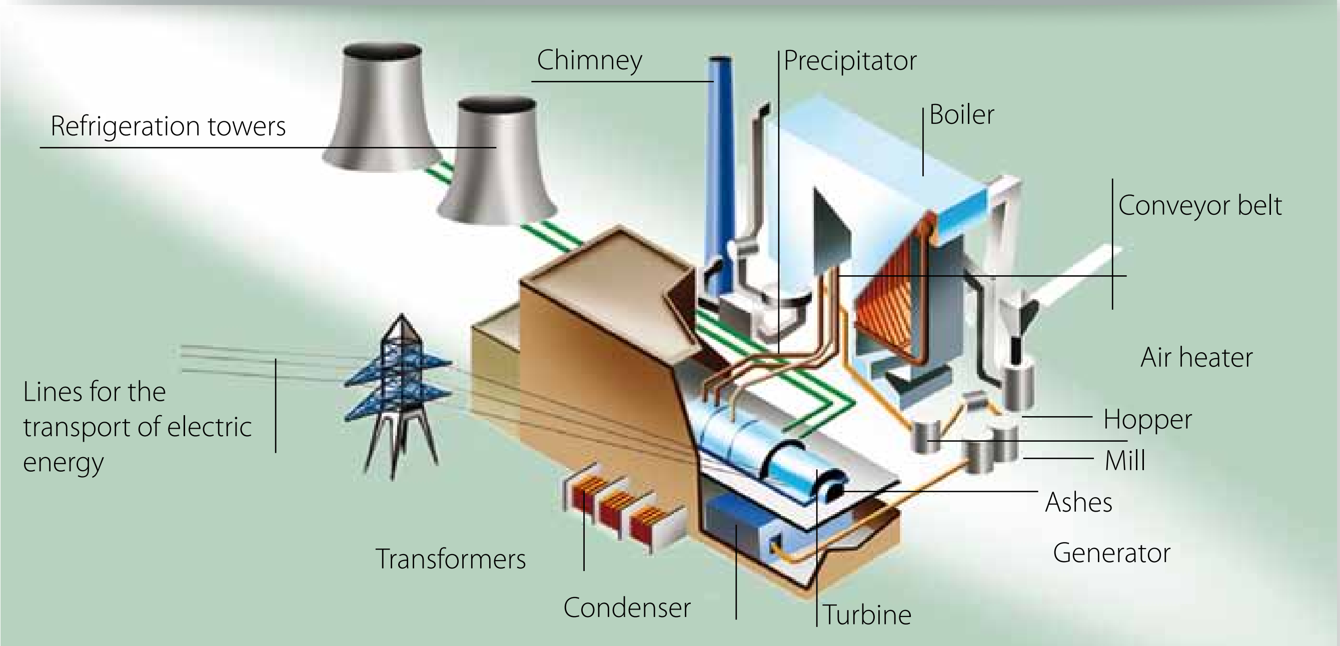
Design and functioning

The steps followed in the electricity production process are the following:

1. The fuel is put in the boiler.
2. The heat produced by the burning of the fuel is used to heat the water that flows through pipes inside the boiler. This water then evaporates into steam.
3. The gases produced by the combustion process are released through a chimney.
4. The steam, moving quickly thanks to the pressure and temperature reached, makes a turbine turn.
5. On leaving the turbine, the steam cools down in the condenser, turning back into a liquid, and flowing back into the boiler.

6. To cool the steam in the condenser, cold water is piped in from the refrigeration tower, and piped back as steam or hot water (depending on the plant). This steam or hot water is released from the plant via a chimney or pipes.
7. The turbine is connected to an electrical device called a generator, which, when it turns, produces electricity.
8. A transformer adapts the characteristics of the current produced to the ones of the electrical grid, so that it can be distributed.

Diagram of a thermal power plant



Fuels used and efficiency

Fossil fuels (coal, gas or petroleum derivatives) are used in thermal power plants.
The process is 30% efficient. In other words, of all the thermal energy that is released in combustion 30% ends up being transformed into electricity. The rest is released as hot water or steam.

Combined cycle power plants

Technology has been used to improve the efficiency of thermal power plants for many years. The most advanced are called combined cycle power plants. Their name is based on the way they produce electricity using two turbines, one powered by gas and the other by steam.
These plants work in the following way: gas is burnt and the gases released are used to power a turbine that generates electricity.
When they leave the turbine, these hot gases are used to produce steam which powers a second electricity-generating turbine.
Thus, the performance of these plants can reach 50%.
The first combined cycle power plant was installed in Spain in 2002.

Hydroelectric power plants

Water power has been in use for thousands of years. For example, it has been used to power small water mills that grind wheat.

In the nineteenth century, water power from reservoirs was harnessed to power turbines connected to electric generators. This innovation led to the modern hydroelectric power plants.
The first of these was constructed at the end of the nineteenth century at Niagara Falls thanks to some machines invented by Nikola Tesla.

Design and functioning

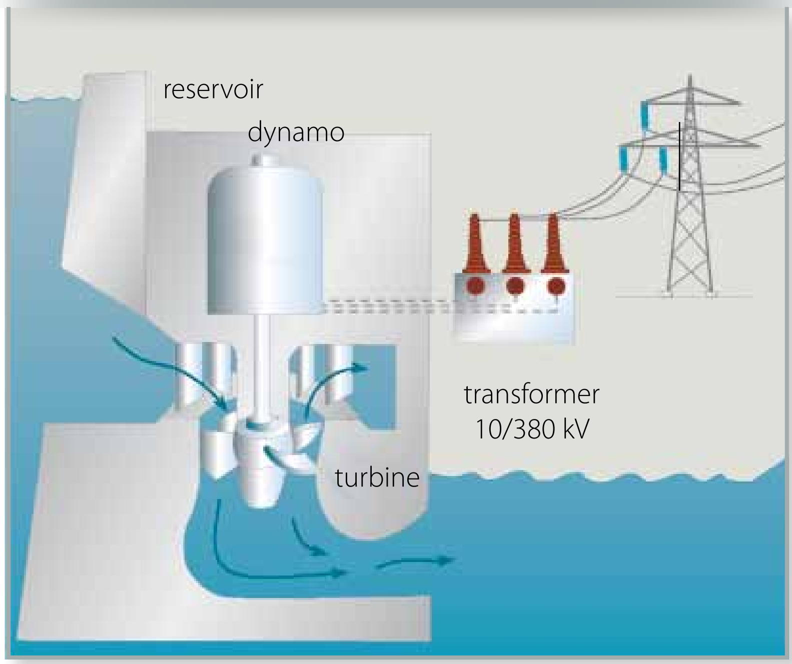
There are many kinds of hydroelectric power plants. There are some that use the diverted flow of the rivers; some that use natural waterfalls, such as those of Niagara; and others that require the construction of a reservoir to store water and to be able to use it to produce electricity when it is most convenient.
Following are the steps followed by a hydroelectric power plant to produce electricity:

1. Water stored at a certain height has potential energy.
2. When the floodgate is opened, the water flows out through a pipe, building up speed as it goes.
3. When the water reaches the turbine it makes it turn, and then flows back to its natural course.
4. When the turbine turns, it powers the generator, which in turn produces an electric current.
5. The transformer adapts the characteristics of the current produced to the ones of the electrical grid, so that it can be distributed.

Renewable hydroelectric plants?

Hydroelectric power plants use the water cycle to generate electricity. The Sun evaporates water from seas and lakes to form clouds that rise and rain on higher land areas. This rain returns to the sea or lake via rivers and streams.
This natural cycle is driven by the energy of the Sun, so, strictly speaking, water is a renewable energy source. However, large hydroelectric power plants that use reservoirs have a significant environmental impact. We must only consider as renewable hydroelectric energy the one produced in small hydroelectric power plants, generating a moderate environmental impact.

Hydroelectric power plant



Nuclear plants

Nuclear power plants are a special kind of thermal power plant. They are thermal because they use heat to produce a vapor that powers a turbine connected to a generator. What makes them special is that this heat is produced by a nuclear reaction.
Thanks to advances in atomic and nuclear physics at the start of the twentieth century, we can now produce controlled nuclear reactions that release a large amount of heat.
Nuclear technology has also been used in warfare, for example in the bombs dropped on Hiroshima and Nagasaki in 1945 during the Second World War. They caused the deaths of more than 200,000 people.


Nuclear power plant

Nuclear reactions

In nuclear power stations, heat is produced by splitting the atoms of radioactive materials such as uranium.
This kind of reaction is called **nuclear fission**.
The reaction is produced by bombarding atoms of uranium with neutrons. The atoms of uranium split up, releasing more neutrons that are able to heat and split up other uranium atoms, and so on. This is known as a **chain reaction** because the same splitting process is repeated, over and over again.

Radioactive waste

As well as useful heat energy, nuclear fission also releases radiation that is dangerous for living beings. For this reason, the reactor core where fission takes place is protected and isolated by metal and concrete walls. Furthermore, in the rest of the power plant, strict security measures are taken to guarantee that there are no leaks of radioactive waste.
After its use in fission, the uranium is transformed into a waste produce that continues to emit dangerous radiation for thousands of years. The disposal of this waste is one of the main problems with nuclear technology. Currently, the waste is stored for a few years in the power plants themselves, and then moved to special storage facilities.

Design and functioning

Some radioactive waste products can be used to make nuclear bombs. This makes their safe, secure storage particularly important.
We will now see the process followed by nuclear power plants to produce electric energy:

1. The reactor is located in a chamber 50 meters high with concrete walls more than a meter thick.
2. The nuclear fission reaction takes place inside the nuclear reactor.
3. A mix of water and other liquids enter the reactor core, are heated by the energy released by the fission, and evaporate.
4. The steam passes through a tank of cold water, which heats up and evaporates. The first vapor stream condenses and flows back to the reactor core.
5. The steam builds up speed under pressure and makes the turbine turn. It then cools down and condenses, returning back to the tank.
6. The turbine turns and powers the generator, which produces the electric current.
7. Finally, a transformer allows the current to be sent out to the electrical grid and, ultimately, to the point of use.

Distribution of electric energy

We have seen how most of the electricity we use is produced in large installations. Once generated, the electricity needs to be transported to the point of use: buildings in towns and cities, factories and businesses, and transport networks.

The transport of electricity from power plants to the consumer is done via conductive wires in a particular way.
The network of wires and cables that carries electricity from wherever it is generated to the point of use is known as the **electrical grid**.

Losses

The main problem with transporting electricity to points of use that are located far away from power stations is that energy is lost along the way.

Remember that an electric current is just electrons moving within a conductive material. These moving electrons hit the atoms of the conductor and in doing so lose energy in the form of heat.

This effect can easily be seen in your own home. Turn on any electrical appliance and touch the cable that feeds it. After a while it will warm up noticeably.

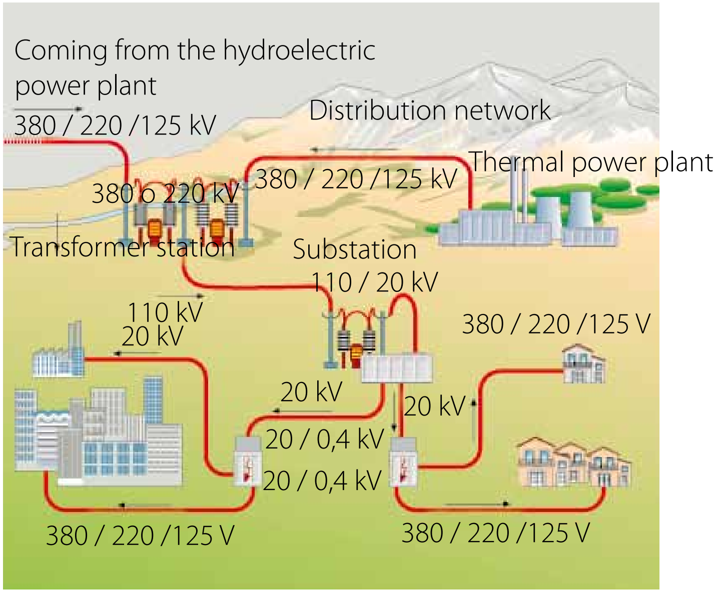
The process by which an electric current flowing through a conductive material loses energy in the form of heat is called **Joule effect**.

Voltage and intensity

Electric current is characterized by two quantities: the voltage (V), which is measured in volts (V) in the SI, and intensity (I) which is measured in amperes (A) in the SI.

Energy losses of the electric current in the form of heat depend on intensity. The greater the intensity, the greater the energy loss.

Therefore, in order to reduce losses in the transport of electricity, the solution is to reduce the current intensity. But if we only do this, the energy of the current being transported is also reduced. The solution is to increase the voltage of the transported current. The voltage is also called **tension**, **potential difference** or **simply potential**.



Electrical distribution network

Power

The power of an electric current, that is, the energy transported per unit of time, is calculated as follows:

$$P = VI$$

Therefore, if we want to reduce energy loss without lowering the power transported, we have to raise the voltage.

However, a high voltage is dangerous. Therefore, the voltage is reduced as it nears points of use in order to guarantee the security of people.

Process for the distribution of electric energy

1. 1. A current of about 26,000 volts is produced in power plants.
2. A transformer raises the voltage of this current to between 138,000 and 765,000 volts. Here we find the current in a state of high tension.
3. Electricity pylons (also known as high tension towers) conduct the electricity through high tension wires.
4. As the wires near points of use, substations lower the voltage of the current to the appropriate level for different consumers.
5. Heavy industry uses a current of about 33,000 volts.

6. Transport networks such as trains and metro systems use a current of between 15,000 and 25,000 volts.
7. Light industry uses a current of between 380 and 415 volts.
8. In our homes we use a current of between 220 and 240 volts.

Electric energy consumption

Electric bill

Electric energy has a price, as for producing and transporting it, power plants, transformers, towers and cables have to be built, and the salaries of all people working in these installations have to be paid.

In the electric bill, there are two main concepts: the **contracted power** and the **consumption**.

Contracted power

This concept refers to the maximum amount of electric energy that can be used in any given moment. If we contract more power, we can connect more appliances and use them at the same time.

The level of power contracted is paid for at a fixed price, depending on the level. In most homes, the power contracted is a few kW (4.4 or 5.5, etc.). In industry, factories, and sports centers, it is obviously necessary to contract much higher levels.

Consumption

Consumption depends on the amount of electricity that you use. If you plug in more appliances, and keep them running, obviously you will use more electricity and receive a higher bill.

The energy consumed by an appliance can be calculated by multiplying the power it needs to function by the amount of time it is switched on:

$$E = P \cdot t$$

Since power is expressed in watts (W), or kilowatts (kW), and the consumption time in hours (h), the consumption of an electrical appliance is usually expressed in watt hours (wh) or kilowatt hours (kWh).

One kWh is an energy unit which is equivalent to $3.6 \cdot 10^6$ J

Energy saving and efficiency

The current electrical system is based on non-renewable energy sources such as fossil fuels and nuclear energy. The reserves of these energy sources are scarcer and scarcer and, besides, when they are used, they provoke pollution problems (smokes and gases coming from the burning of fossil fuels) or problems with regard to the management of radioactive waste.

The more energy we consume, the further these sources are exhausted and the more pollution is produced.

Therefore, it is important to consume only the energy that we need and not more. To do so, we have to take into account two criteria that can be applied in our daily lives: **saving** and **efficiency**.

Saving

Saving is simply not using energy we don't need; not leaving the lights or television on in an empty room, and not using a half-empty washing machine, for example. All of these things need to be borne in mind in order to avoid using electricity unnecessarily. The energy used by one lightbulb or television set might not seem like much, but if there is one left on in every house, it soon adds up to a lot of wasted energy.

Saving energy means we cannot only save money on our electric bills, but also significantly reduce pollution and prolong our supply of non-renewable energy sources.

A megawatt is equivalent to a million watts. Just as important is the concept of the "negawatt". This is a megawatt not used due to a saving effort.

Efficiency

Efficiency means using appliances that consume less energy to perform the same function. Like energy saving, this strategy saves energy and money, and reduces pollution.

One of the clearest examples of energy efficiency in action is energy saving lightbulbs. They are capable of producing the same amount of light using only 25% of the energy of traditional lightbulbs.

There are other domestic appliances which are energy efficient. You will recognize them by their labels indicating this efficiency. Using domestic appliances like these is another way of saving energy and money, and reducing pollution.

Impact and deficiencies of the current electrical system

Until now we have seen that our current energy system is based on non-renewable energy sources that run out and produce waste products, which pollute the environment or need to be managed very cautiously.

A further problem is that the system relies on a small number of large electricity-producing installations. This means that electricity, once generated, has to travel large distances before reaching the point of use.

Both the form of this system and the used energy sources make it a system with a series of deficiencies.

We will now see what these deficiencies are about.

- Due to the use of non-renewable energy sources, we cannot guarantee the energy supply in the future, as these sources run out.
- The fact that these sources are essentially fossil and nuclear fuels provokes an immediate pollution and the accumulation of toxic radioactive materials for thousands of years.
- The production of energy in great power plants far away from the points of use generates energy losses during transport that reach 10% of all the energy produced, that is, of all the electricity leaving power plants, 10% is lost on the way in the form of heat, and does not reach the consumer. This means a generation of more energy than the amount needed, a greater consumption of resources and a greater pollution.

Centralization

The fact that the electrical grid is centralized and that there are few points of generation that must supply many consumption points, make the electrical system very fragile. What happens when there is a problem in a power plant, or damage to an electricity line or substation? Many consumers are left without electricity. This electricity is crucial to the daily running of shops, businesses, factories, sports centers, etc.

In the summer of 2007, for example, a fault in a substation in Barcelona left more than 350,000 people without electricity, and caused the loss of more than 60 million Euros.

Questions

Is there any way of resolving these problems?

Could a cleaner and more secure electrical system be built?

Would it cost a lot to make the current system cleaner and more secure?

Next, we will analyze other ways of generating electricity, some of which are already in common use. This will help us with the answer to these and other questions.

Renewable energy sources

What are renewable sources?

We have said already that renewable energy sources are those for which the rate of consumption is lower than the rate of production.

Now we will look in depth at how renewable energy sources such as the sun and wind can be harnessed to generate electricity.

Some renewable energy sources, such as water and wind, have been used by humans for thousands of years.

Wheat has been ground by mills powered by both river currents and the wind.

For centuries, the wind has also powered sailboats across seas and oceans.

Solar energy

The Sun is without a doubt the most abundant renewable energy source. As we have seen, it is also the point of origin of the energy found in the wind, waves, firewood, and many other sources. Every day the Sun beams down more energy than is consumed by the Earth's inhabitants. Let's see how this energy can be harnessed.

Solar thermal power

I am sure at some time or another you have left something in the sun and noticed how it warmed up.
This is one of the simplest ways to harness solar energy.
This is called solar thermal energy because it produces heat from the energy in sunlight.
One of its main applications is in the production of hot water for domestic use.

Design and functioning

There are two key elements in the production of solar thermal energy: the solar collector and the tank. The steps of this process are the following:

There are two key elements in the production of solar thermal energy: the solar collector and the tank. The steps of this process are the following:

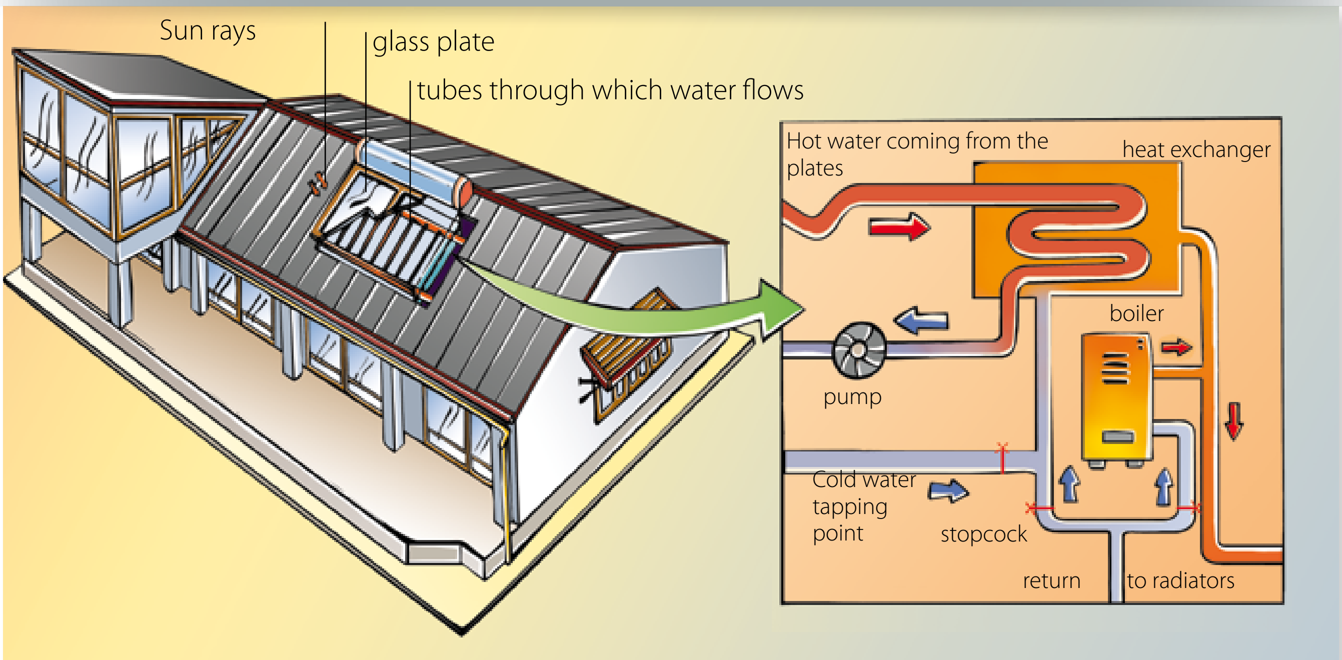
1. The cold water enters the collector.
2. The solar radiation heats the inside of the collector, which can exceed 70ºC.
3. The cold water flows through the collector and comes out hot.
4. The hot water that flows out of the collector is stored in a thermally insulated tank. This prevents it from cool ing so that it can be used when needed.

Because solar radiation does not always hit the same spot on Earth at the same intensity, the collectors have to be placed so that the capture of radiation is as efficient as possible. The most efficient positioning is for the rays of sunlight to hit the collector perpendicularly. To achieve this, the following general criteria are used:

- The sun is highest in the sky at the equator. This means that at higher latitudes, collectors need to be inclined at a steeper angle.
- In winter, the sun is lower in the sky than in summer. This means that collectors need to be inclined at a steeper angle during the winter.

Solar thermal systems can be used in an individual household, in which a few people live (with one or two collectors), or in larger buildings, such as hotels or sports centers . (We just have to install more collectors).
Throughout the year, these installations cover, habitually, between 60% and 70% of the needs of sanitary hot water (shower, hand washing, dishes, etc.).

Domestic heating with solar panels



At a moderate latitude like ours (40° N), a collector of 2 m^2 provides this percentage when covering the needs of two people.
As solar thermal energy systems do not cover 100% of our hot water needs, it is also necessary to install another heating system, which is usually a gas boiler or a deposit with an electric heating system.

Other applications

Apart from the production of sanitary hot water, there are other applications of solar thermal energy:

- Low temperature solar ovens can heat water up to 100ºC, allowing us to cook a variety of vegetables.
- Solar parabolic cookers concentrate solar radiation in a small spot, allowing us to cook all kinds of dishes, even paella.
- High temperature solar ovens concentrate solar radiation and can reach temperatures of up to 4,000ºC. They are mainly used for scientific research.

Solar photovoltaic power

Another way of harnessing the energy of the Sun is to transform it directly into electric energy.
This can be done with photovoltaic cells. These devices are made from semiconductors that generate an electric current when light hits them. This process is called the photovoltaic effect, and, as its name indicates, it is the source of photovoltaic solar energy.

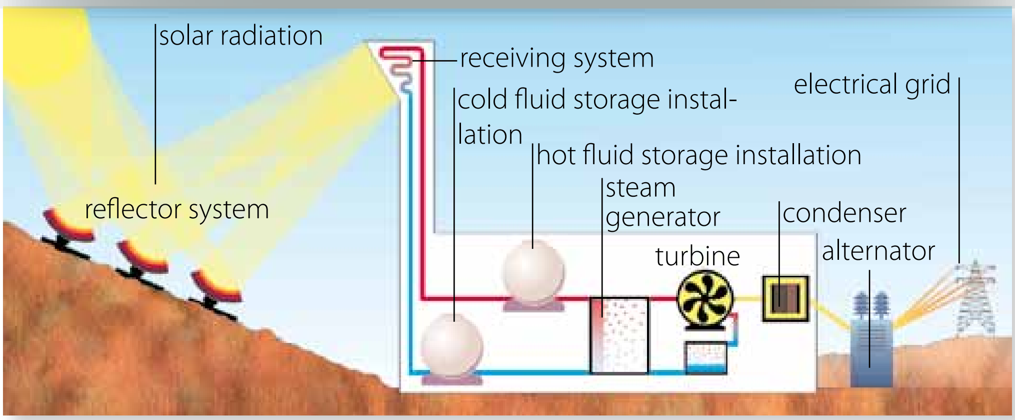
Solar installations

As one photovoltaic cell produces a little current, some cells are connected together to form the so-called **photovoltaic panels** or **modules**.
Like solar collectors, photovoltaic panels can be connected together to achieve the energy level required.
Currently, there are small installations of a few kilowatts and large installations with many megawatts of power. The latter are called s**olar farms**.

The electric energy produced in photovoltaic installations can be used directly on the electrical grid, and be consumed at another point, or it can be stored in batteries to be consumed at the point of production when there is no sunlight.

If the installation is located close to the network, it is usually connected directly to it. Only when the installation is isolated (in mountains, islands, rural areas, on satellites, etc.) are batteries installed to store the energy produced. These two types of installations are called **isolated solar installations** and **grid-connected solar installations**.

Solar energy plant



Design and functioning

We will now see how grid-connected and isolated solar installations operate, and which their main components are:

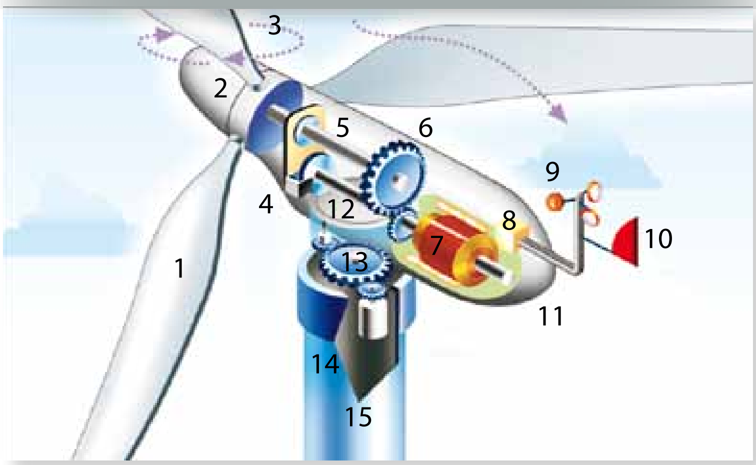
Photovoltaic installation connected to an electrical grid

1. When the solar radiation hits the panels, a continuous electric current is produced..
2. The inverter transforms the continuous electric current generated by the panels and batteries into an alternating current so that it can be used by the electrical grid of the building.
3. The protection switchboard regulates the exchange of electric energy between the installation and the electrical grid.

Isolated photovoltaic installation

1. When the solar radiation hits the panels, a continuous electric current is produced.
2. The regulator detects whether there is demand for electricity in the building. When there is demand, it sends the electric current from the panels to the inverter; when there is no demand, it sends the current to the batteries.
3. Batteries store electric energy so that it can be used when needed.
4. The inverter transforms the continuous electric current generated by the panels and batteries into an alternating current so that it can be used by the electrical grid of the building.

Parts of a wind turbine



1) Blade 2) Rotor 3) Inclination of the blades 4) Brake 5) Transmission for a low speed 6) Gear box 7) Generator 8) Controller 9) Anemometer 10) Weather vane 11) Case 12) Transmission for high speed 13) Guidance traction 14) Guidance engine 15) Tower

Solar thermal energy

Solar energy can also be used to produce electricity in a similar way to traditional thermal power plants. The only difference is that the steam is produced by heat from the Sun.

Since a lot of water needs to be heated up in order to produce enough steam to move the turbine, the solar radiation needs to be highly concentrated. This is usually achieved with a field of mirrors that directs the rays of sunlight to the top of a tower.

Wind power

Wind energy has been used for many years to power boats and windmills. While windmills are still in use in some places, nowadays the most important use of wind energy is in the production of electricity. The transformation of the kinetic energy of the wind into electricity is done by **wind turbines.**

Wind turbines

Modern wind turbines are machines capable of producing many megawatts of electrical power. They are towers over 80 meters in height, with a generator and three rotor blades of around 40 meters in length.

Installing a wind turbine of such large dimensions is not easy. It is therefore crucial to establish the optimal location for wind capture before installation.

The ideal conditions are where the wind blows constantly, without gusts, at a speed above 6 m/s.

To decide which location is suitable for installing wind turbines, wind is measured for years.

Design and functioning

We will now study the process for transforming wind energy into electric energy:

1. The foundations of the wind turbine support all of its weight, which can exceed 300 tons. They give stability to the structure.
2. The tower supports the generator and the rotor blades at a height where the wind conditions are optimal.
3. The generator contains the elements which are necessary to transform the rotational energy of the rotor blades into electric energy.
4. When the wind blows, the rotor blades turn perpendicularly to the direction of the wind.
5. The rotation of the blades turns at an axis inside the generator.
6. The multiplier is a system of gears that multiplies the speed of the rotation of the axis by 60.
7. The generator produces an electric current from the rotation.
8. The electric current produced by the generator travels down the tower through a wire.
9. A transformer adapts the properties of the current so that it can flow to the electrical grid.

Installations

When it is decided that a location meets the required wind conditions, and there is enough space, wind turbines are installed in large groups. These groups of wind turbines are called **wind farms**. There are wind farms with hundreds of wind turbines and others with as little as ten, depending on the space available.

Wind farms are usually located on plains, on the peaks of mountains, or near the sea. In some countries in the north of Europe there are wind turbines at sea. These are known as offshore wind farms.

Wind energy is one of the most commonly used renewable energy sources in the entire world. However, the proliferation of wind farms is also criticized. Wind farms alter the landscape and sometimes affect bird populations.

Although large wind turbines are the most common, they are also produced in smaller sizes. Small wind turbines can be installed on roofs and boats, and larger turbines can be used to produce enough power for a group of households.
These wind turbines are usually connected to a battery that stores the electric energy produced so that it can be used when it is most convenient for the consumer.

Biomass

Firewood has always been used by humankind for energy. In many communities in Africa, for example, there are people who spend the whole morning collecting firewood to be able to cook for the rest of the day.

What is it?

In many other parts of the world, products which are similar to firewood are used with energetic finalities, both for the production of thermal and electric energy. This kind of energy is known as biomass.
The term biomass refers not only to firewood and vegetable matter. In the world of energy, biomass may refer to:

- **Agricultural waste**

Crop remains and products of livestock farming, such as farm slurry (a mixture of water, urine, and pig excrements).

- **Forest waste**

Tree prunings and fallen branches.

- **Energy crops**

Crops grown specifically for energy production.

- **Urban waste**

Organic waste from homes, restaurants, etc.

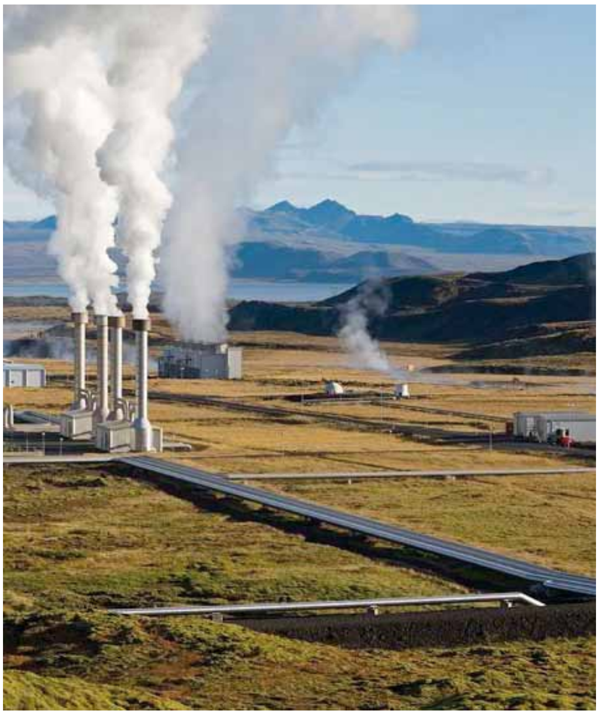
Uses

However, none of these sources are directly used to generate energy. Beforehand, they must be processed and converted into more appropriate materials.

These final materials, which may be liquids, solids or gases, may be used to produce energy.
One of the most common uses of these final products is as fuel in thermal power plants specifically designed to produce electricity from the combustion of these products.
These plants function in a very similar way to conventional thermal power plants.
The most important difference is the fuel used.
If finally the biomass ends up being used in thermal power plants, we can ask ourselves if it can really be classified as a renewable energy source.
In the case of waste products, the answer is clear: yes. This is because if they were not used as biomass energy, they would be thrown away. In the case of wood and crops cultivated especially for biomass energy, we can only classify them as a renewable source as long as the rate of consumption remains equal to or lower than the rate of production.

Geothermal energy

In some beaches in New Zealand, you can feel the heat from the Earth's core by making a shallow hole in the sand. As you know, the inside of the Earth is made up of a mantle of melted rock at temperatures of over 3,500ºC. In some places of the planet, such as New Zealand, this mantle is closer to the surface and we can take advantage of its heat.



How do we take advantage of its heat?

The energy from inside the Earth is called geothermal energy. The two most habitual ways of taking advantage of **geothermal energy** are:

- Using it to heat water and produce steam to move a turbine connected to an alternator, with the purpose of generating electricity in the so-called geothermal power plants.
- The heat is also used to directly heat water in central heating systems for both individual houses and entire cities.

Design and functioning

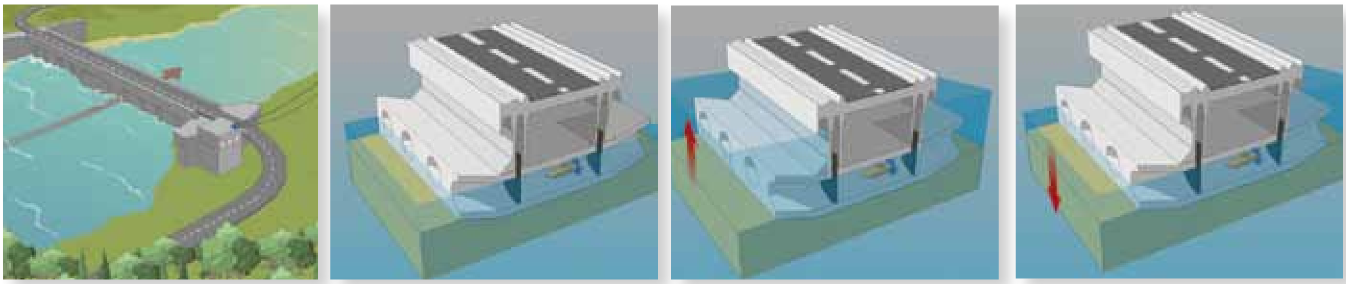
We will now study the steps that have to be followed to transform geothermal energy into electric energy:

1. The water flows through a pipe embedded in the hot earth.
2. Due to the heat, water transforms into steam.
3. The steam makes the turbine move.
4. The turbine moves the generator which produces an electric current.
5. The transformer adapts the properties of the generated current to those of the electrical grid.
6. The steam cools down in the condenser and returns to a liquid state.
7. The liquid water cools down in the refrigeration tower.

Tidal power

If you have visited the coast of a great ocean, such as the Atlantic or the Pacific, you must have observed that at a certain moment the water level starts to rise and, after a few hours, it goes down again. This phenomenon is called the tide and, as you know, it is caused by the gravitational attraction that the Moon exerts over large water masses on Earth.

You can also take advantage of the tides to produce energy!



Operation of the tidal power

How?

Essentially, the tide is just a mass of water that rises and falls. When the tide reaches its highest point, there is a great quantity of water at a certain height. Therefore, this water has potential energy that you can use, the same as with potential energy of water in reservoirs, to produce electric energy in hydroelectric power plants.

Design and functioning

A We will now study how the energy from tides is transformed into electric energy:

1. When the tide rises, the water enters the dike.
2. When the tide reaches its highest point, the doors of the dike are closed.
3. When the tide falls to its lowest point, the floodgates are opened and the water rushes out through the tur bines.
4. The speed of the water makes the turbines turn. This powers a generator that produces electric current.

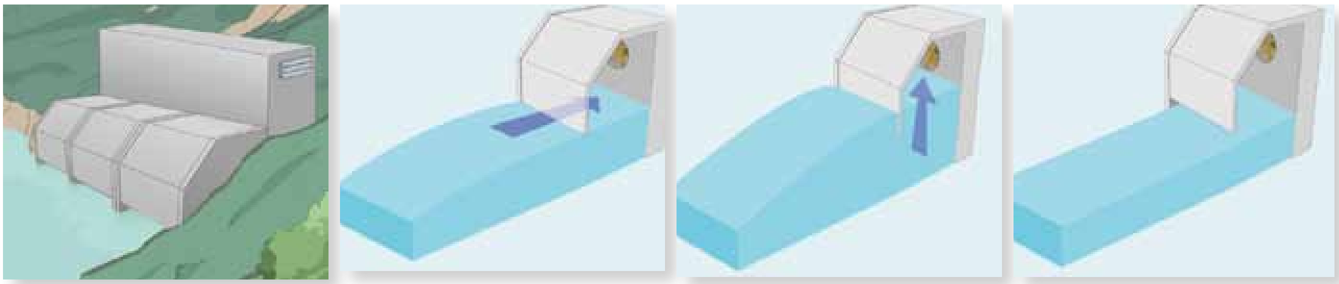
Wave energy

If we looked at the ocean from a bird's-eye view, we would notice waves advancing towards the coast, where they break against its shore. Hundreds of waves a day pass across any fixed point in the ocean's surface. When observed from a fixed point on the ocean's surface, a wave is just water rising and falling. For this reason, we can harness wave energy!

Design and functioning

We will now study how wave energy is transformed into electric energy:

1. Wave water enters the air chamber.
2. As the water level rises, air is pushed upwards and flows through a turbine, making it turn. A generator connected to the turbine produces electricity.
3. As the wave falls, the water level is reduced and the chamber fills up with air again.



Operation of the wave energy

Conclusions

As we have seen, renewable energy sources do overcome some of the disadvantages of the current energy system.

Firstly, as they are renewable sources, the supply is infinite, unlike that of fossil fuels and nuclear materials.

Secondly, because they are not based on fossil or nuclear fuels, they do not cause atmospheric pollution or leave behind dangerous waste products.

Furthermore, many energy installations (e.g., solar and wind) can be as small as individual installations. This makes it possible, with these sources, to construct a decentralized energy system, that is, with many points of production of a small power interconnected by the electrical grid. First of all, this decentralization would save losses during the transport of electricity, because the points of production would be closer to the points of generation.

Additionally, the electric system would be more robust, as a fault in one or different points of generation would not affect so many users.

Renewable energy sources also have limitations. The sun is not always shining, the wind is not always blowing, there are not always waves, etc. The advantage is that there are many different sources that can combine, some of them overcoming the limitations of the other ones.

To achieve a cleaner, safer and more sustainable energy system (one which can last forever), we have to bet on renewable energy sources, decentralization, saving and efficiency in the production sites.