Hydroelectric

Introduction

Water is one of the oldest sources for energy production. It is a renewable, abundant and clean source. Hydroelectric power is the main source of non-fossil energy generation. For many countries, hydroelectric power is an important source of electricity production: in Norway it accounts for 96% of electricity production, in Venezuela 68.3%, in Brazil 63.2%, and in Canada 58.3%. Every year, in various parts of the world, there are continuous and growing works of modernisation or construction from scratch of dams and barriers on the main waterways and water basins in order to collect, convey and exploit water availability for energy production. Most of the increase in the generation of hydroelectric power is taking place in emerging countries, especially in China, India and Brazil.
Worldwide, there are as many as 45,000 dams over 15 m high. These barriers are distributed in 150 countries, but 22,000 of them have been built in China and approx. 4,000 in India. Only five percent of dams exceed 80m, and only one percent is over 150m high. If we also count barriers and dykes less than 15 m, there are an unspecified number of million dams.

(*Data source: International Energy Agency (IEA) – Key World Energy Statistics 2016*)

Hydroelectric kwowledge

What is it

The water cycle, triggered by the evaporation of the Earth's water, the formation of clouds and rain, provides mankind with the most extraordinary renewable energy source, the second after biomass. Its origin is once again the sun, the radiation of which causes evaporation. Although only 0.33% of solar energy received by the Earth leads to rainfall, it is still a remarkable amount of energy.
Water includes two types of energy: potential and kinetic.

Potential energy

Both when it falls down as rain and when it comes out of a spring, water is forced to go “downwards” due to force of gravity. We all can see the energy of a waterfall; the higher the jump, the more energy will be produced by the water when it falls. Therefore, the higher the water is located with respect to the point of arrival, the more the energy that can be potentially developed. Potential energy is therefore the energy of the water mass at rest, according to the initial position of water and its point of arrival. It corresponds to the energy contained in the glaciers and natural or artificial basins located at high altitude.

Kinetic energy

Water kinetic energy is the energy of a moving water mass and corresponds to the energy contained in the water of rivers, water streams and the sea. It depends on the speed and the volume of the moving water. Hydraulic machines transform water movement into mechanic energy. It is simple to convert mechanic energy into electric energy.

How to obtain energy

Two procedures are available to obtain energy from fresh water: water wheels and hydroelectric power plants. The former produce mechanic energy, the latter electricity. Water is a source of energy marked by numerous advantages known by mankind. That is why it has been used for 4,000 years. It is a relatively abundant source, more or less free, renewable and environmentally friendly. Moreover, its efficiency in the production of electric energy can exceed 80%.
Energy can be obtained from seawater too, by exploiting its movements (waves, tides and currents) and its thermal energy (water heating) by creating artificial basins and equipment exploiting temperature difference. However, such technologies still need further development and sometimes only lead to experimental applications.

Potential development

In terms of large plants, in Italy the development of hydroelectric production has reached its peak. After having been the main source of electric energy until the 1960s (82% of the total amount), its share has decreased progressively whereas the quantity produced has remained constant (approximately 40/50 billion kW/h). During the ‘80s the share of hydroelectric energy had already decreased to 25%, whereas the thermoelectric production passed from 14 to 70% during the same period. The hydroelectric sector, if compared to the other renewable resources, has already reached a high value of resource exploitation. All the big hydroelectric plants have been built by now. The way to go in the future is based on small plants for isolated users, who have the chance to exploit the nearby water resources. The further contribution of those plants would be limited to 15 billion kW/h a year, a modest amount as compared to the energy needs of the country. Today, in Italy, hydroelectric operating power plants total approximately 21 MW which, in 1999, produced over 51 billion kW/h, i.e. approximately 19% of the total energy production (over 210 billion kW/h!).
Estimates at global level calculate a potential of 180,000 MW that could supply 75% of the current electric energy demand, as compared to the 47,000 MW currently installed. In general industrialized countries are characterized by large plants and there is scope for mini-hydroelectric plants. In many developing countries hydroelectric energy can represent an interesting source of energy supply, both through large hydroelectric plants and mini-hydroelectric ones. The European Union aims at moving from the current 9,500 MW of installed power to 14,000 MW of installed power by 2010.

Where it is

Water energy turned into hydroelectric energy a little more than a century ago and it has undergone a very rapid development which is still continuing in industrialised countries and developing countries of Asia and Latin America, potentially rich in resources. Also in terms of exploitation of available hydroelectric resources, Western Europe and the United States are the world leaders and use almost all the available resources. The use of hydroelectric energy is much more limited in Eastern and developing countries, where the energy produced by hydroelectric power plants could be increased remarkably. The installed capacity of Africa is remarkably low as compared to the huge potential of the continent. In this respect, a dam on the Congo river alone would allow the production of as much energy as it is produced in Italy in one year. In terms of installed capacity and energy efficiency, hydroelectric energy remains one of the most widely exploited resources to produce electric energy. In 2014 hydroelectric energy accounts for over 16,7% of the world production of electric energy, although only 10% of the technically viable water resources are exploited.
(*Source: International Energy Agency (IEA) – Key World Energy Statistics 2016*)

Hydroelectric power in Italy

In Italy 42% of energy produced in 2015 by renewable sources comes from hydroelectric. According to the data of GSE (Gestore dei Servizi Elettrici), at the end of 2015, the hydroelectric power produced in Italy amounted to 45,537 GWh. In Italy in 1938, 14.6 GWh out of 15.5 GWh total energy produced, was hydroelectric power. This source contributed to the start of Italian industrialization in the 19th-20th Century. After being the main source of electric power up to the 60s (82% of the total), the percentage of this renewable source progressively decreased, while the quantity produced remained constant. In the 80s, the percentage of hydroelectric power had dropped to 25%, while thermoelectric power production, during the same period increased from 14 to 70%.
It has been calculated that the hydroelectric potentiality of the Italian territory could be approximately 65 TW. When compared with the amount of energy produced, this indicates that the potential of the hydroelectric resources in Italy is exploited to about 90% and the maximum limit of possible exploitation has been reached. It therefore does not seem to be a sector that can expand further.
The fact that more favourable and convenient sites, from a technical and economical point of view, are already being utilized, contributes to the “closing” of this sector, and a number of technical, environmental and economic obstacles have arisen with regard to the realization of new high-capacity and high-output power stations. Consequently the future of hydroelectricity in Italy seems to consist in the realization of only the low-output.

A bit of history

Thousands of years ago mankind learned how to exploit the mechanic energy produced by falling water. The Greeks and Romans already used water mills to grind wheat. In Barbegal, France, and near Arles, an important port supplying Rome with wheat, 8-wheel water mills were found exploiting the same river at the same time (310 A.D.).
However, in Europe the exploitation of water power to obtain mechanic work was to become more common only during the 12th and 13th century. The main use was in the agricultural sector, i.e. grinding cereals, olives, salt and other minerals by means of water mills. Other machines powered by canals were developed between 1500 and 1600, although they were less common than water mills. One of the best manufacturers of this kind of machines was Leonardo da Vinci.
During the Middle Ages the water wheel invented by the Greeks became very popular. It was a sort of mill used to lift water and was used to reclaim swamp areas, to irrigate and in the mining field. The water wheel coupled with a camshaft (part of a machine that, fixed to a rotating axis, transmits a continuous rotating movement to another part of the machine by making it alternatively lift and lower) also allowed the production of an alternated vertical movement, similar to a hammer. It was used to print textiles and operate bellows, leading to a further development of the metal industry.
Great technical progress was achieved following the evolution of the water wheel into the turbine, i.e. an equipment capable of transforming mechanic energy into electric energy. The creation of the hydraulic turbine dates back to the end of the 1800s. Since then the turbine has been further developed and its current total efficiency in state-of-the-art plants exceeds 80%.

Hydroelectric plants

Different types of plants

The main concept hydroelectric plants are based on is to transform the potential energy of resting mass of water and/or the kinetic energy of a water current into mechanic energy. Subsequently this energy will be converted into electric energy. Hydroelectric plants are subdivided into: big hydroelectric plants (or simply hydroelectric plants) and minor hydroelectric plants (or mini-hydroelectric plants). This subdivision depends on the power installed inside the plant and can take 10 MW as a reference value (actually in Italy minor hydroelectric refers to a maximum power of 3 MW).
This subdivision is usually reflected on different types of plants: while large hydroelectric plants usually require wide surfaces to be submerged, with a significant environmental and social impact, small hydroelectric plants perfectly integrate with the local ecosystem (it directly exploits the river current).
Hydroelectric power plants are also marked by great flexibility of use. Thanks to the modern automation systems, a few minutes are enough to make the power plant pass from the stand-by to the full power state. Thanks to this peculiarity, hydroelectric power plants are faster than thermoelectric power plants in increasing their production of electric energy during peak consumption hours.
Therefore, the hydroelectric production process is convenient not only from the economic and environmental viewpoint, but also from the viewpoint of operating efficiency.
Hydroelectric plants can also be defined according to the type of plant, i.e. regulated flow plants or flowing water.

Regulated outflow power plants

These plants are natural water basins (lakes) or artificial lakes (like many tanks) and sometimes the capacity of water basins increases by means of barriers (many times barriers are dams that are tens of metres high). It is possible to modify the quantity of water used by the power plant.
Today these are the most powerful and exploited plants, although they have an environmental impact. They can be used as energy “accumulators” during peak hours by pumping water at night. In general these plants have more than 10 MW power and reach an extremely high power: for example, Itaipu plant in Brazil has a basin of 1,460 square Km extension (4 times as much as Garda lake).

Flowing-water power plants

Flowing-water power plants were much more used at the beginning of the last century, above all to activate machine tools in some workshops. The potential of these plants today is less exploited than it could be. Moreover the environmental impact of these plants can be limited. The flow into these plants cannot be regulated, therefore the maximum capacity coincides with the watercourse capacity (except a portion, called minimum vital flow, that is needed to safeguard the ecosystem). Therefore the turbine produces energy according to the watercourse availability: if the watercourse is dry and the water flow diminishes under a certain level, the electric energy production stops.
In Switzerland flowing-water power plants satisfy the basic need for electric power.

How is a plant made

A hydroelectric plant usually includes five elements: a water collection system, a penstock a turbine transforming potential energy into mechanic energy, a generator converting mechanic energy into electric energy and a control system regulating the water flow. After being used, water is returned to its natural flow without undergoing any transformation from the viewpoint of its chemical and physical properties.
The collection system is mainly a barrage or a dam. It has to comply with very rigorous building and operating principles regulated by the law and, in the case of larger plants, monitored by the National Dam Service. The surface levelling hoses and the bottom outlet ensure a controlled management of the water in the basin. According to the characteristics of the area where the barrage is built, different types of batters (small size barrages) or dams apply. After it has been collected, the water is conveyed into a turbine through pipes. These pipes start from the place where the water is collected and take the water to the plant where electric energy is produced. They are inclined and consist of round steel tubes (they also have valves on the head and foot that allow them to block the water passage).
The variables determining its capacity are the available head and the rate of flow. The first is the difference between the level at which the water is before entering the collection system and the outlet level. The rate of flow is the volume (measured in cubic metres) of water passing through a section in one second’s time.
In order to calculate the hydroelectric potential of a site, it is necessary to know the flow variation during the year and the available gross head. Sometimes the hydrographic services install a measurement unit and collect the data about the previous flowing rates. Should the hydro-geological data be unknown, it will be necessary to measure the flow rate for one year. Each turbine contains a water intake and distribution device leading it to an impeller where the potential energy is transformed into mechanic energy. Moreover, turbines can be divided into impulse turbines and reaction turbines. In the former the whole transformation takes place inside the water distribution device and therefore they are preferred when the available head is higher (up to 1,000 metres) and the rate of flow is limited.
If the available head is lower (up to 200 metres) and the rate of flow greater, a reaction turbine is preferable to exploit the action of the impeller as well.
Solidly fixed to the turbine shaft, a generator transforms mechanic energy into electric energy. Each generator includes a moving rotor, upon which a magnet is installed, and stator, a fixed component. The magnetic field generated by the rotor transmits a electromagnetic power – electricity – to the copper coils in the stator.
Through suitably dimensioned copper cables, the electric energy, which is originally characterised by a 5,000 volts voltage, goes from the generator to the transformer. Here the voltage is increased up to 150,000 volts before the electricity is conveyed into the distribution network. The whole hydroelectric system is governed, controlled and protected by electronic devices monitoring the production process and intervening in case of failure and/or anomalous operation, stopping the plant immediately. Over the last years, thanks to I.T. and telecommunications, almost all plants are remotely operated from a limited number of control centres supervising all the necessary operations to allow the plants to work correctly.

Barrages

Barrages intercept the watercourse in a specific area. There can be two different types of barrages which differ according to their dimensions: dams or weirs.

Dams

Dams are high works that, as well as intercepting the watercourse, create a tank that is useful to regulate the flow rate. They can be hundreds of metres high. Dams can be made of concrete or melted materials.

Weirs

Weirs are modest height works that usually retain the high water within the river bed. Their maximum height is ten metres. They can be fixed or mobile, according to the bed configuration, the maximum flow rate and the need to avoid, during floods, excessive overflowing which would be dangerous in the area above the weir. Fixed weirs are made of masonry or reinforced concrete and are bound to be overcome by water during floods or flow rates that are higher than what the plant can bear. This is why they are usually shaped to avoid erosion. Mobile weirs have a fixed part, made of masonry or reinforced concrete, and a mobile part (called bulkhead) usually made of steel.

Small plants, small impact

In order to overcome the problems regarding the protection of the environment which the realization of hydroelectric power plants in areas that are particularly vulnerable and sensitive involve, the trend of the past years has been to progressively abandon the construction of large plants with a heavy impact on the environment, in favour of small sized hydroelectric power plants, the microhydro plants, which are small hydroelectric power plants with powers that are less than 100kW. These power plants are built without storage tanks or water collection areas , and can exploit differences in levels of only a few metres, enabling the production of energy even in isolated areas that are normally not served by the national energy supply network, as for example isolated inhabited locations, farms and shelters. This type of water resource offers the concerned mountain communities the possibility of a direct control of its management and use. The energy that is produced is exploited on site with immediate advantages for the local populations and without necessarily setting up imposing electricity power lines. For plants with a limited power, the intake of water is quite limited, changes in the course and the flow rate are negligible and the water that is used is returned immediately downstream of the hydroelectric power plant. The characteristics of these plants seem to be most suited to exploit the potential of the streams that are fed by waters from melting ice in a capillary manner, in isolated mountain areas that are not well served by the national network. At present a law proposal is being examined, which will also allow the inclusion of micro-hydro power plants in the net metering network, which is an exchange system with the Italian national electricity network, which enables the input of energy when one's production has an excess and to draw energy when one's production is not sufficient. At present this method is applied only in the case of energy produced by private photovoltaic plants.

Energy from the glaciers

A resource of energy

Most of the mountain regions in areas with a humid and temperate climate, including Italy, have a high production of hydroelectric power. This is an important item in the national energy accounts.

The water of the mountain torrents flows down great drops, which determine an optimum energetic potential, but generally the outputs of the torrents are too variable to be exploited continually. Glacier melt waters guarantee a supply of large quantities of water in the summer season, when the other courses of water have run dry. It is sufficient to compare, with equal precipitation, the summer output of water courses in the Alps and in Central and Southern Italy, to realize the importance of the existence of glacier bodies in the surface water regimen.

For this reason many hydroelectric plants in the mountain areas are fed by ice melt waters, and in very many cases water is tapped directly from the torrents that form from the glaciers. Countries like Switzerland, Austria, Italy and New Zealand were among the first to exploit the productive potentiality of ice waters. At the start of the Seventies, 64% of the energy requirement in Switzerland was covered by the production of the hydroelectric power plants, that were mostly fed directly or indirectly by water melting from the glaciers. In the Italian Alps, there are a number of examples in the mountain regions in the north, in the regions of Piedmont, Valle d'Aosta, Trentino-Alto Adige and Lombardy, where the presence of glaciers enables an intensive use of water as a source of energy.

One of the most imposing examples of exploitation of the water resources of the Alpine glaciers is the gravity dam in Dixence in Val des Dix in Switzerland. With its 285 m wall, it is the highest in the Alpine range and one of the highest in the world, supporting a reservoir with a capacity of 400 million m^3. With a network of over 100 km of underground galleries and channel shunts , it collects the waters of the Cheilon Glacier and the glaciers coming from Mount Rosa and the Matterhorn, with plants that cover an overall surface area of 357 km^2, half of which are covered by glaciers (data : Smiraglia, 1992).

The state of the glaciers

With only very few exceptions, glaciers around the world are receding, a phase which began at the beginning of the last century and briefly interrupted by a small advance of the alpine area around the 1980s. This puts at risk not only the existence of glaciers, but also an important renewable energy resource. Also the resulting ice and water therefore seem to be transformed into a source that is running out and is no longer renewed, as is the case with fossil fuels. In fact, the mass of most Italian glaciers is negative: summer melts more ice than is formed during the cold season and the mass of the glaciers decreases.

Unlike fossil fuels, whose exploitation depends on man and can be to some extent planned and programmed, possibly setting aside "strategic" reserves, the water produced by melting glaciers can only be used when it is available. This energy source depends on the weather conditions and, over the years, on climatic fluctuations, also influenced by human activity. For example, the torrid summer of 2003, hotter and dryer than average, facilitated the release of large quantities of melting water that was not fully exploited for energy production. Indeed, an artificial basin is constructed to contain only a limited amount of water and the technical characteristics of the plants are designed to produce that particular maximum amount of energy, even in the presence of an excess of the available resource.

Water resources from glaciers are therefore difficult to manage: the only certainty they offer is their availability during the summer months. For how many years will it still be possible to exploit this resource?

The state of the glaciers in Italy

The intense reduction of the area of glaciers in the Italian mountains, which has been accelerating in recent decades, is reflected in all the other sectors of the Alps and in other mountain ranges on the Earth and is certainly one of the clearest and most obvious signs in nature of the climate changes in progress and in particular of the increase in average air temperature. In addition to being the most reliable climatic indicators, glaciers represent an important water, energy, landscape and tourist resource.

According to the New Land registry of Italian Glaciers in Italy (published in 2015), there are 903 glacial bodies in Italy, covering a total area of 370 km^2, equal to that of Lake Garda, present in 6 Italian regions, of which only one, Abruzzo, is not alpine. Making a comparison with the previous national glacier land registry, which was completed at the end of the 1950s by the Italian Glaciological Committee in collaboration with the National Research Council, it can be seen that the number of glaciers has increased from 835 to 903. What may appear to be a contradiction is actually not because the numerical increase is to attributed to the intense fragmentation of existing glacial units. The glacial surface area has indeed recorded a loss of 30% (157 km^2), comparable to the area of Lake Como, from 527 km^2 to the current 370 km^2 (approx. 3 km^2 lost per year). There are therefore numerous Italian glaciers, albeit fragmented and of small dimensions (an average area of 0.4 km^2 can be estimated) with the exception of three glaciers with a surface area of over 10 km^2: the Forni, in Lombardy (National Park of Stelvio), the Miage, Valle d'Aosta (Mont Blanc Group), and the Adamello-Mandrone complex, in Lombardy and Trentino (Adamello Park); the latter can be defined as the largest glacier in Italy, having been classified as a large unitary glacial unit due to its unusual shape, similar to that of the large Scandinavian glaciers, characterised by a plateau with many tongues.

Advantages of power from glaciers

There are many advantages in using glacier melt waters for the production of hydroelectric power. Glaciers are a source of water that is constant and sure during the summer months, unlike the water of rivers and torrents whose capacity is subjected to remarkable variations depending on precipitation. Consequently, in the summer months, when most of the water courses on the surface suffer a lack of water, the water courses fed by the glaciers instead, are rich in this precious resource. The energy obtained from glaciers can therefore be used in the periods in which the other water resources register minimum levels and due to the melting water of the glaciers it is possible to face situations of energetic emergency such as the recent summer black-outs.

The costs for the realization of a large hydroelectric power plants with all the connected structures (reservoirs, dams, channels, pipes, power plants and long distance power lines) are very high, but as most of these are plants that date back many years, the costs have partly been amortized and consequently the cost of hydroelectric power is relatively low. At present, due to economic and environmental reasons there is a preference for the construction of micro-plants that satisfy the power requirements of small local communities and are less costly and more ecological. It is a “clean” energy, as the production does not produce any polluting substances even though there are some repercussions on the environment.

Problems and solutions

Apart from the problem of having almost reached the maximum limit in the exploitation of this resource, a fact that has already been mentioned, the utilization of glacier melt waters for the production of hydroelectric power involves some technical problems, which have important economic repercussions.

One of the most important technical problems concerns the solid load that is normally transported by glacier melt waters, that is generally very high. The waters that flow from a glacier always have a characteristic milky grey colour, due to the large quantities of very fine material that are carried in suspension. This characteristic does not make the melted waters particularly suited to be used for hydroelectric purposes. In fact the reservoirs and channels in which these waters flow and are collected are subjected to the deposits of the suspended material. So that the plants can operate efficiently and so that the capacity of the reservoirs is not modified, cleaning interventions are required, and the deposits must constantly be removed. These operations are costly and technically they are not easy. The progressive accumulation of material on the bottom of the reservoirs (known as silting process) gradually decreases their capacity and also the productive potentiality, because the utilization times are decreased and also the plant’s operative life.

The waters that are rich with material in suspension also create another severe technical problem : the particles hit the mechanical parts of the turbines at a high speed and with great force and provoke a rapid wear of the same. For this reason these waters must be subjected to a filtering process before they enter the plant. The filtering operations are difficult and they lead to the subsequent problem of the disposal of large quantities of limey mud and clay, without creating damages to the environment.

Another problem that is becoming more and more serious each year is tied to the progressive retreat of the glaciers’ front. Many intake or input units, including some large reservoirs, are located near the glacier fronts in order to collect the largest possible amount of water, and to avoid any dispersion in the detrital deposit. The progressive retreat of the fonts requires the adaptation of the intake units, thus requiring a continuous modernization of the structures and their adaptation to the changing position of the new front. This leads to an increase in the costs and the environmental problems connected with the realization of new structures.

As an experiment, plants which take water directly within the glacier have been realized. These structures are mainly used for research and are generally associated with laboratories to study glacier dynamics. The most famous endoglacial laboratory is in Engabreen in Norway, and has been installed in the intake tunnel dug inside the glacier.

Also the example of the Argentière glacier located on the French slopes of the Mont Blanc group of mountains, is famous. In the Sixties tunnels were dug in the ice, under the front, in order to capture the melting waters for hydroelectric purposes. A characteristic of the sub-glacial torrents, however, is to continually change their course, with sudden variations in their direction, therefore the galleries soon became useless and were transformed into underground laboratories to study basal erosion.

Energy from the sea

Energy from the waves

Theoretically it is possible to convert at least five types of energy that are present in the sea: the current, the waves, the tides and the thermal gradient (temperature difference) between the surface and the floor.
At the moment there is only one power plant that exploits tides in France, while experiments are being made to exploit wave energy potential in the UK, in Norway and Japan and the thermal gradient in the United States. The European Union has just concluded a study that identifies almost 100 sites that could be used to produce electric energy from sea tides. In Italy the strait of Messina has been defined as one of the most promising sites.

Energy from the waves

The idea of exploiting the waves to obtain electric energy, although it creates some problems, stimulates engineers' fantasy. Researchers are trying to concentrate the waves in order to increase their height and their potential conversion into electric energy.
Other attempts try to use pressure variations that occur under the sea; some others use floats that “replicate” the wave motion and convey it to the generators by means of hydraulic pistons.

Energy of tides

We all know the strong pull of the Moon on water. From the regular raising and lowering of water mass it is possible to obtain energy. In order to build a tide-based power plant the estuary is barred towards the sea with an artificial damn. The energy technique exploits the difference in height between high and low tide: the so-called amplitude of tide. Obviously the amplitude of the tide has to be sufficient, as it happens in Northern France, close to Saint Malo, where the difference between the minimum level and the maximum level of the water is 12-13 metres. Right from Saint Malo to Dinard, on the Channel, at the mouth of the Rance River, the world's first tide-based power plant has been active since 1966. It is the Rance Tidal Power Station, which has a power of 240 MW.

Sea current and tide energy

Tidal power is one of the most interesting and unexplored sources of renewable energy. It must be noted that in Europe alone, the availability of this type of energy is equal to approximately 75 gigawatt (75 million kilowatt). As it is known, besides the power, what is important is the estimate of the energy that can be exploited: in Europe this amounts to approximately 50 terawatt (terawatt hour equivalent to 50 billion kilowatt hour).
In 2003, for the first time a project was realized for the exploitation of this energy in Hammerfest, a town on the northern coast of Norway. The inhabitants of this remote town, who do not see the sun for long periods of the year, and whose geographic position is not so suited for connections to the traditional sources of energy, seem to have solved the problem. The blades of the turbine are 10 metres long and turn when the tide rises in the Kvalsund strait, and stop when the seawater reaches its maximum level. They then start moving in the opposite direction when the tide begins to fall. According to estimates, approximately 700,000 kilowatt hour of non-polluted power should be generated per year (even though production costs are higher), which is enough to guarantee light and heating to about thirty homes.
The turbines to exploit the sea currents can be (as in the case of wind technologies) either horizontal-axis or vertical-axis turbines. Horizontal axis turbines are more suited in the case of constant sea currents, as in the Mediterranean, while vertical axis turbines are more suited for sea currents, because they can change direction by approximately 180 degrees a number of times in a day.

Energy from thermal gradient

The first power plant for the conversion of ocean thermal energy was created in 1996 offshore the Hawaii islands and produces energy exploiting the temperature difference between the different layers of the ocean. The solar energy absorbed by the sea surface heats it, creating a temperature difference between the surface water, whose temperature is around 25-28°C, and deeper water, up to 600 m depth, and whose temperature does not exceed 6-7°C.
Superficial water, which is warmer, lets substances like ammonia and fluoride evaporate. High-pressure vapours activate a turbine and an electricity generator; they pass into a condenser, go back to a liquid state and are cooled down by the water, which is sucked from the bottom. A 20°C difference is sufficient to guarantee the production of an economically exploitable quantity of energy. At the moment there is a power of 50 kW/h, but it will probably be possible to reach 2 MW even though the costs are very high. (Many abandoned sea platforms for the extraction of hydrocarbons could be converted for the application of this technology).

Environment and territory

The advantages of hydroelectric energy

Just like other types of renewable sources, hydroelectric energy is characterised by remarkable advantages as compared to the production of electric energy from fossil fuels. To begin with, it is a renewable and endless source.
Secondly, emissions of polluting substances into the air and water are virtually absent, since no combustion process is involved. In particular, carbon dioxide ($CO2$) emissions are reduced by 670 grams for each kW/h of energy output. Other advantages are: a low dependence on ester energy sources, source diversification and the regional re-organization of energy production.
Moreover, mini-electric plants, in many cases, thanks to their hydraulic arrangement, create many advantages to the watercourse (in particular to the regulation of floods in water streams, especially on the mountains characterized by soil deterioration), and can efficiently contribute to the protection and safeguarding of the territory.
In some cases, the artificial lake that forms as a consequence of a weir o dam can improve the surrounding area, by allowing the development of tourist, sports and productive activities that can coexist together with hydroelectric exploitation. The chance to accumulate water and then regulate its flow downhill can also contribute to reduce floods and encourage a better use of water resources, which are becoming more and more precious and rare.

Really clean energy ?

Hydroelectric power suggests, in our mind, the idea of a clean source of energy, that is eco-compatible and especially a source of energy that is renewable. Actually, a large power plant has problems in connection with the environmental impact, problems of an aesthetical nature, electromagnetic pollution and overload of the ground.
Water intake decreases the amount of water in the streams and rivers downstream from the power plant and provokes disorders in the river ecosystems with severe damage for the fish- and naturalistic heritage. According to the law, water intake must not exceed a percentage of the natural flow, and what is called the “ minimum vital flow” must be guaranteed, in order to protect life and the ecosystems of the river or stream. Actually during the periods of draught, long stretches of the waterways become quite dry, with consequent damages to the environment. The negative effects are not only limited to parts of the river downstream of the power plants, but may be noted in the entire water supply network, a decrease in the flow rate of the waterways consequently leads to a greater concentration of the pollutants in the water and also in the underground water table that they supply water to.
With regard to the future development of hydroelectric power, in Italy, as in most of Europe, this type of resource has been almost completely exploited, i.e. the hydroelectric power plants have been built in almost all the locations where there were ideal conditions to exploit the kinetic energy of water precipitating towards the valleys from the mountains. It is therefore difficult to increase the number and the power of the existing park of hydroelectric power plants. In other large

regions of the world, this form of energy is available in large amounts, and still has not been exploited.
It is the case of Africa, where as a result of the low consumption of energy per person and the low level of wellbeing, this type of energy can become precious and important to support the economic development of these populations .
A second limit of the hydroelectric power plants are the vast areas of territory that are often occupied and flooded by very large dams, which are built for the purpose of accumulating the water that is necessary to move the turbines constantly. It is therefore necessary to modify the original plan of the territory and the natural flow rate of the rivers and streams, which, in some cases, causes environmental impacts on the ecosystems and economic impacts on other agricultural or industrial activities.
Therefore large hydroelectric plants with a reservoir require opportune assessments with regard to the impact on the environment, in order to guarantee the absence of interference with the natural environment. Underground Hydroelectric Power plants partly eliminate the aesthetical problem, however there is the problem of the disposal of the excavation materials, and these plants can influence underground water circulation.

Visual impact

With reference to the visual impact of large hydroelectric plants, they are difficult to hide and quite eye-catching. This is why it is necessary to carry out a careful assessment of the plant on the territory, by also making an aesthetical assessment. Any element in a plant (bars, intakes, power plant, restoration works, electrical substation) can determine a change in the site visual impact. In order to reduce the impact, some elements can be disguised with the vegetation; it is possible to use colours that better integrate with the landscape and build a part of the installations underground (i.e. the power plant).
Acoustic pollution provoked by a power plant is usually generated by turbines and turn multiplication mechanisms. At present the noise can be reduced up to 70 decibels inside the power plant, to imperceptibles levels from the outside. For example in Fiskbey 1 power plant in Norrkoping, Sweden, there is a maximum internal noise of 80 decibels and 40 decibels outside, at 100 m distance. This is a totally acceptable value. Noise is therefore easy to sort out.

Relation with the ecosystems

The relation with the ecosystems is fundamental when designing a hydroelectric power plant. Two aspects are strictly linked to the collection of superficial water and can provoke two different impacts:

- Impact related to the variation (reduction) of the water quantity, with possible consequences for the users, that could argue about the use of water and impact on aquatic fauna;
- Impact related to the change in the water quality as a consequence of quantity variation (i.e. higher concentration of pollutants) and as a consequence of vegetation change on river banks.

If a dam for a basin power plant is built, the consequences will be the following ones: above the barrier a reservoir will form and therefore there will be running water (lothic water) moving in still water (lenthic water), with a longer time needed to exchange water and a possible impact on the ecosystem. Underneath the barrier, until the area where the water used by the plant is released, the watercourse may be dry for some periods of time unless a continuous release is guaranteed so that the river has a suitable minimum flow rate. The minimum flow rate (to be guaranteed according to the law), that ensures the natural development of all biological and physical processes, is called “minimum vital outflow”. All these aspects have to be taken into consideration during the impact assessment. This is why some choices are made during the design phase and precise precautions are taken to avoid any type of damage to the ecosystem. The reduction in water flow rate does not have to be excessive, and it is necessary to respect the minimum vital outflow value, since otherwise it is possible to damage the deposit, incubation, growth and transit of fish. With regard to the latter aspect, it is necessary to take into consideration the movement of fish that go up the current and the fish that go down the current, by building the adequate passages, installing the most suitable nets to prevent the fish from entering into the intake areas and get into the turbine (some types of turbines can kill the fish). When a dam is built to supply a hydroelectric plant, it is necessary to think about the different ways water can be used: drinking water, agricultural water or industrial water. The size and management of the dam must be compatible with all these needs, by optimising the use of water as a resource, since in some regions water is not sufficient to satisfy all these needs.

Dams and the local climate

The presence of a dam influences the microclimate of the territories all around due to the large mass of water that collects upstream of the dam. In fact water has a high thermal capacity, a parameter that indicates the quantity of heat required to raise the temperature of a body 1°C, which means that water absorbs a great amount of heat, which it takes from the atmosphere, in order to warm up. In summer therefore the water absorbs great quantities of heat from the air thus mitigating the atmospheric temperature. The opposite takes place in winter, when the water cools, releasing a large amount of heat in the atmosphere. Near artificial reservoirs, in summer the atmospheric temperature is lower than in the surrounding areas, because the water takes away the heat from the air. In winter the microclimate in the lake area will be warmer than in the surrounding area, because the lake gives off the heat it has stored to the atmosphere which becomes warmer. The extension of the area concerned depends on the volume of water that the dam can hold back.