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. In the Nineties, hydroelectric power accounted for 34% of the total energy produced in Lombardy, 80% in Piedmont, 99% in Trentino, and practically 100% in Valle d’Aosta, compared to 22% of the overall national total.

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).

Ice: is it an inexorable resource?

With only very few exceptions, glaciers all over the world are in a retreating phase, that began at the start of the last century and was interrupted for a short period of time with a small advance in the Alpine area around the Eighties. This endangers not only the existence of the glaciers but also of an important renewable source of energy. Ice and the water deriving from it therefore seem destined to turn into a source that is becoming exhausted and that is not renewed any more as is the case of fossil fuels. In fact the mass of most of the Italian glaciers shows a negative trend. In summer more ice is melted than what is formed during the cold season, hence the mass of the glaciers decreases.

Unlike the fossil fuels that are exploited according to the will of man, and that can be planned and programmed to a certain extent, by storing "strategic" reserves if necessary, the amount of water produced from melting glaciers can be used only when it is available. This source of energy depends on meteorological characteristics and in the course of the years, on fluctuations in the climate that are also influenced by man’s activities. For example, the torrid summer of 2003, that was hot and dry above average, favoured the output of a large amount of melted water that was not completely exploited for the production of energy. In fact the artificial reservoir that has been built, contains only a limited volume of water and the technical characteristics of the plants are designed to produce a fixed maximum quantity of energy even though the available resource is present in excess.

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

The state of the glaciers in Italy

In Italy there are approximately 800 glaciers, that cover a surface of approximately 550 km$^2$, equal to 1/5 of the overall surface covered by the glaciers of the Alpine mountain range.

According to data of the Comitato Glaciologico Italiano (the Italian Glacier Committee) in 1999, 89% of the Italian glaciers
was retreating, this condition was more marked for the glaciers in Lombardy, less in the Triveneto area and in the Piedmont-Valle d’Aosta regions. The retreating trend began after 1860, the year that is considered as the end of the last cold period, the so-called Little Ice Age. Beginning from the mid Nineteenth Century, 40% of the surface of the Italian glaciers has been lost, while the snow-line has risen 100 m. In the past 20 years Italian glaciers have lost 10 to 20% of their volume of ice. These data are troubling: if the present trend does not meet with any variations, most of the Italian glaciers will disappear in a few decades, and with them also an important source of energy.

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.

**Is it a really clean energy?**

Anything associated with water, including hydroelectric power, gives us the idea of a clean, eco-compatible and, especially, a renewable source of energy. The impact of a large dam and its reservoir, or a hydroelectric power plant on the landscape certainly cannot be disregarded, and it is not only a matter of visual impact. An artificial reservoir (some can contain hundreds of millions of m³ of water) has very strong geological and hydro-geological repercussions. Deep water and superficial water circulation is upset, and a large number of areas are created that can generate problems with regard to stability, with consequent landslide phenomena. The network of intake channels that are necessary to transport the water from the reservoirs and from the areas in which water is collected to the power plants is often created underground, and dug inside the mountain, changing the water circulation underground, with consequences that are difficult to foresee, particularly in the karst areas. Also for large power plants there are problems connected with the environmental impact: aesthetical aspects, electromagnetic pollution and overload on the ground. The power stations in the caves, built underground, partly eliminate the aesthetical problem but the problem of the disposal of the excavation material remains, and their realization may influence underground water circulation. Intake of water decreases the quantity of water in the torrents and rivers downstream from the power plant and upsets the river ecosystems, thus causing severe damages in the heritage of fish and nature. By law, it is foreseen that the water intake must not exceed a percentage of the natural capacity and what is considered a "vital minimum" must be guaranteed, so that the life of the water course and its ecosystems is protected. Actually in periods of drought, long tracts of the water courses are left practically dry, with the consequent damages to the environment. The negative effects are not limited to parts of the river downstream from the plants but are felt along the entire water-network. A decreased flow of water in the water courses provokes a greater concentration of polluting substances in the water courses and also in the water tables that these supply.

Furthermore it must be added that the plants are built in mountain areas at high levels, and often these are to be found in Parks and Natural Reserves – areas that are particularly vulnerable and that require a particular protection of the environment. In Italy, in the Alps, approximately 90% of the water courses are altered due to intake-structures for hydroelectric purposes, and only 10% of the Alpine torrents is left to flow in its "natural" state. It is easy to imagine how the utilization of a source of energy that is apparently "clean" can be transformed into a source of severe environmental damage, if it is not managed in a responsible and careful manner.

**Small plants, small impact**

In order to face the problem of safeguarding the environment when constructing hydroelectric plants in particularly vulnerable and sensitive areas, the trend in the past years was to progressively abandon the construction of large plants that can cause a heavy environmental impact, in favour of small hydroelectric plants, the micro-hydro plants that are small hydroelectric power plants producing a power below 100 kW. These plants are built without the need to create reservoirs or collection basins, and they exploit drops in level of few metres, and can produce energy also in isolated areas, that usually are not served by the Italian national energy network, as for example isolated housing units, farms and shelters. In this way the use of the source of water offers the mountain communities that are concerned, the possibility of a direct control over the management and use of the plant. The energy produced is exploited in the area
with immediate advantages for the local populations and without necessarily having to build large electricity pylons. In the case of plants whose power is limited the intake of water is very limited and modification in the course and capacity of the water supply are small, and the water that is utilized is immediately returned downstream of the plant itself. The characteristics of these plants seem more suited for a capillary exploitation of the potentiality offered by water courses fed by glacier melt waters in isolated mountain areas that are poorly served by the Italian national network. At present a bill is being studied to allow micro-hydro plants to be added to the net metering network, the system that has been created in order to enable an exchange with the Italian national electricity network, through which it is possible to yield energy when there is an over-production and request the same when it is not sufficient. At present this method is applied only in the case of power produced by private photovoltaic plants.