ENERGY FROM THE EARTH

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Introduction

The Earth has its own internal energy, that is responsible for the dynamics of our planet, and volcanic activity is its most evident example, however, this energy also spreads silently and continuously towards the surface in the form of heat: this occurs in every spot of the Earth, even in those areas which do not seem to have any volcanic or geologic activity.

Geothermal plants

Deeper and deeper into the subsoil, the rock temperatures increase with a gradient of 1°C every 33 m in depth on average, even though there are areas which are particularly active, where the temperature increase is more consistent (as for example in volcanic areas): in these particular areas, the so called geothermal fields, the energy found deep in the Earth is exploited to produce electric power. However, this requires very high temperatures, so it is possible only in some fields, called high enthalpy fields (or high temperature fields). The Earth's internal heat can be exploited also when the temperatures are not very high, not for the production of electricity but to obtain heat for domestic heating or for other industrial uses (refer to the special report on geothermal energy). If special devices such as heat pumps are connected to the process to "capture" endogenous heat, an "indirect" use of thermal energy of the Earth becomes possible, and much lower temperatures of "direct" geothermal energy can be exploited: and therefore there is the possibility of a greater diffusion of this use of geothermal energy also in areas without the particular geological conditions of the geothermal fields.

Geothermoeletric plants

Geothermal electricity power plants can be of different types; "back pressure system" if the steam, after being exploited, is freed into the atmosphere; "condensing system", if the utilized steam is condensed and newly injected into the subsoil, through an injection well. "Flash" power plants are installed in areas dominated by water and are equipped with separators that separate the steam sent to the turbine, from the water that is then eliminated.

Geothermal power plants exploit geothermal heat. The flow of steam that comes from the subsoil either freely or channeled in deep geologic wells, produces a force that moves the turbine. The mechanical energy of the turbine is transformed into electricity by alternators. In the geothermal systems dominated by steam, geothermal energy can be utilized to produce electric energy, by forwarding the steam through steam-pipes to a turbine that is connected to a generator that produces electric current. If the fluid does not reach a sufficiently high temperature, the hot water may be used for the production of heat, as for example in teleheating plants.

Besides the "Direct Steam" technology, there is also another called "Binary Cycle" in which the heat of the geothermal fluid is exchanged with another fluid that activates the turbines. The Binary Cycle is a choice that is technically suited when the energy value of the fluid is low (temperatures below

180°C), while the “Direct Stream” is the more efficient choice in the presence of higher temperature geothermal fluid.
With equal fluid characteristics, the “Direct Stream” plant has significant advantages: the environmental impact is less, thanks to the lesser amount of fluid required to produce the same amount of energy (and therefore less wells to drill and less pipelines to be built), the structure is more compact and therefore occupies less territory and is less noisy than the Binary Cycle technology due to the reduced number of cooling towers and related fans. Lastly, both technologies do not have significant differences in the emissions in the atmosphere, as, also in the Binary Cycle, the gases that are separated from the liquid phase are treated.

Air conditioning plants

With geothermal power it is possible to supply our houses with air-conditioning. Small geothermal plants are built for small buildings, medium-sized and big buildings. A heat well is made by drilling with an adequate drill and using some coating tubes deep underground in order to prevent the land from sliding down (it can be done in a small space like a garden and small courtyard). The heat well can be built in any area, on any kind of land and regardless of the height of the aquifer. Once the drilling as been concluded, and the final depth has been reached, heat exchangers are introduced in the hole and connected to an external collector that balances the heat flow that comes from the soil and directs it to heat pump inside the building. Later the hole is filled with a mixture of cement and bentonite in order to avoid any form of pollution. In winter the heat exchanger allows to take the free heat from underground and, through the heat pump, use it to warm up the buildings (also sanitary hot water is produced by conveniently extracting heat from underground). In the summer, the excessive heat inside the building is eliminated by transporting it underground through the heat exchanger (summer air-conditioning is particularly convenient if compared to the electric consumption of air-conditioners).

Subsoil heat for our homes

A practically inexhaustible source of energy to heat our homes at a very low cost and in a clean and environment respectful manner: this is the dream of millions of families all over the world… certainly also ours! Geothermic energy seams to answer all these requests and, since the dawn of civilization, man has learnt to use the heat inside the Earth. Initially man enjoyed the pleasure of thermal baths with naturally heated water and later on, at the beginning of the 20th century, learning to use water to produce electric energy. Moreover, water was also used to warm houses of entire cities (the first district heating plant was started in Iceland in 1925). However, until a few years ago, the use of geothermal energy for domestic heating had two important limits which strongly held back its diffusion: geothermal power could be obtained in the presence of relatively high temperatures (60 – 80 °C) and only in the area of the geothermal fields; the heat used was therefore endogenous: it was not possible to transport the heat too far from its source nor was it possible to use it at a low temperature (that is to say at a “low enthalpy”). With the recent technological developments, it is now possible, through particular instruments known as heat pumps, to use the heat of the Earth even when temperatures are not particularly high (12 – 14 °C). This has brought about a new and important step forward in geothermic: with these new systems, it is in fact possible to obtain sufficient energy for a family's everyday heating and warm water consumption, in any place of the Earth, with any geological or climatic condition. The energetic possibilities of this new technology are huge and potentially unlimited.

The Sun's contribution

The subsoil does not only receive energy from the depths of the planet. The Sun's energy warms the Earth's surface and about 47% is directly absorbed by the soil: the temperature in the first metres of the subsoil is subjected to daily and seasonal variations according to the radiation received. These variations are more sensitive in the first decimetres or meters and weaken, until beneath about 20 m where the temperature is not affected by the external temperatures, but only by the geothermal gradient.

If there is the possibility of using even minor quantities of thermal energy, then the heat can also be obtained from this superficial layer: in this case, it is not the internal heat of the planet which is exploited but the energy provided indirectly by the Sun (so, in this case, the word "geothermic" is used incorrectly, but, as the same technology is used, usually this sector is included in the geothermal sources).

Two different sources. Low enthalpy geothermic therefore uses two distinct layers of the subsoil:

- the first layer is from 50 – 150 m to about 350 m deep, where deep geothermal heat from inside the Earth is exploited: here temperatures are constant all year round, and similar all around the planet, due to the effect of the regional geothermal gradient (on average about 12°C at a depth of 100 m, between 14 and 20°C at a depth of 150 – 300 m, with the exception of the geothermal fields, where the values are much higher);
- the second layer, instead, is superficial, from few metres to 50 – 60 cm deep (just below the layer of the Earth which can freeze during winter) and exploits the heat stored by the Earth by effect of solar radiation in the warmer months, and thermal inertia of the ground in returning the energy received: in winter the soil slowly releases the heat stored in the summer months, and will therefore be warmer on the surface, instead it will be fresher in the summer.

How it works

Even though it is characterised by very high technology and very high performance, a domestic geothermal system is very simple. It consists of three principal elements:

- geothermal sensors or probes: these are simple pipes dug in the ground which have the task of absorbing the heat of the subsoil. So that the heat exchange with the ground is more efficient, the probes are filled with a so-called "thermovector" fluid, characterized by high thermal conductivity;

- heat pump, or thermopump: it is the “heart” of the system, in practice a generator that uses the heat extracted from the probes so that it can be exploited by the distribution system;
- an internal heat distribution system: this is the normal heating distribution system that is present in all the homes; however, so that the system can exploit geothermal energy in the best manner, using only a very small amount of external electricity, it is advisable that this should be a low temperature type of system (35°C), for example, radiation panels instead of normal radiators, that use water at a high temperature(60-70°C). The same system can be used for cooling in summer by simply inverting the heat pump operation. Additionally there is a reservoir to accumulate the hot water (very similar to a normal “boiler”).

A “domestic” energy: geothermic for homes

“Classic” geothermic uses heat directly from the Earth, using warm water extracted from the subsoil and then distributed to households or industrial installations. Now the use of special instruments, heat pumps, allows a much larger use of geothermic, independent from the particular conditions of a geothermal field. These installations are small, and can satisfy small household needs - such as household air-conditioning; and for this reason, it is called “domestic geothermic”. Domestic geothermic uses natural subsoil heat through special probes positioned at various depths, using heat pumps to “multiply” the thermal energy (with a small addition of electricity), and then distribute it in the homes for the heating system in winter and air-conditioning in summer, and for the production of hot water for the bathroom.

What is a heat pump?

A heat pump is an instrument which allows heat exchange between a source of energy (for example the ground but also the air of the atmosphere or the water of the ground water table) and an environment with a different temperature. It works like refrigerator and can work both ways (for heating in winter or for cooling in summer).
A heat pump absorbs heat from the “vector” fluid in the probes, through evaporation in an evaporator, after which the temperature is increased using a compressor that releases heat into the surrounding environment through a condenser and is connected to a distribution system that distributes heat all around the home. In a domestic geothermal installation, the heat pump can increase the water temperature from 8 - 12° C of the vector fluid to about 35 – 40°C of the water that circulates in the radiant panels of the distribution system; however water temperature can be increased to much higher temperatures (approximately 70°C) if the system uses radiators. In summer, instead, water temperature for the air conditioning can be 8 – 10 °C lower than the temperature of the environment.
During this process the heat pump uses electricity, however modern heat pumps are extremely efficient systems with a very high performance, that can produce much more (thermal) energy than the (electric) energy that is consumed. The heat pump’s performance is indicated by “COP”,

coefficient of performance, that is to say the ratio between energy produced and energy consumed. In modern pumps, COP is about 4 or 5: this means that with1 kW of electricity it is possible to obtain 4 to 5 kW of thermal energy.
The heat pump's performance is inversely proportional to the difference in temperature between the source of energy (in this case the subsoil) and the environment to be heated (or to be cooled): the greater the difference in temperature, the lesser the performance of the heat pump will be, and therefore the greater the electricity consumption will be. For this reason low temperature radiant panels are preferable (in the floor or in the wall) to the radiators, and for the same reason geothermal heat pumps are more efficient than those using heat of the air outside as a source of heat (which is much colder than the subsoil: if the air temperature is less than -5°C, air heat pumps do not work). A heat pump for a home of approximately 100 m^2 is more or less as big as a fridge, and just as noisy, no exhaust gas or fumes are produced, no oxygen from the air is burnt (as in the case of common heating system burners) and therefore can be installed safely also inside homes. Heat pumps last about 15 years, just like heating system burners.

Different types of probes

To "capture" the heat of the subsoil, two types of probes are used, depending on how deep they are positioned. In order to use geothermal energy, "vertical probes" are set up. These are simply a couple of U shaped pipes with a 10 - 18 cm diameter, that are positioned in wells at variable depths, between 50 and 350 m. The optimum depth for a home of approximately 100 m^2 is about 70-100 m; if the volume to be heated is greater, the probe can be positioned at depths up to 300 – 350 m, but not deeper, because drilling deeper has decidedly noncompetitive costs.
The pipes are made of polyethylene, a material that is inert respect to the chemical composition of the soil, it does not corrode and can guarantee good thermal conductivity. The empty space between the pipes and the walls of the well is filled in with bentonite, a special clay which guarantees good thermal contact between the probe and the ground. The pipes are then filled with a mixture of water with 15-20% "thermovector" fluid, which is similar to the antifreeze liquid used for cars, which can absorb the heat of the ground to a higher degree than water alone. The pipes connect directly into the heat pump, and the circuit is sealed to guarantee there are no leaks: therefore there is no pollution and there is water saving, as the water is made to circulate constantly without adding more water. For the vector fluid, non-toxic substances are used, that do not damage the ozone in the atmosphere (so called "*ozone friendly*" compounds, without CFC), so also disposal, once the system closes, does not cause environmental problems.
A geothermal domestic system is installed in 3 – 4 days, the time required to dig the wells for the probes and to connect the system to the home distribution network. The probes last approximately 50 – 100 years and the system practically does not need maintenance. Instead, in order to use energy absorbed by the ground from Sun radiation, so called "horizontal sensors" are used. The principle is the same as for the vertical probes, but instead of digging a well into the ground, a coil of pipes (made of copper or polyethylene) is laid about 60 cm underground (just under the superficial layer of the soil, which could freeze during the winter), or a series of small probes ("heat energy piles") is

positioned a couple of metres deep. For a home of approximately 100 m^2, 120 - 150 m^2 of capture surface, in contact with the soil is necessary: it is therefore an economic solution, that is easy to install if there is a small garden where it is possible to lay the sensors underground. The only limitations linked to the use of the garden for a system with horizontal sensors are that the area above the probes must not be covered by paving or tar and tall trees cannot be planted because the roots may damage the sensors: apart from this, the garden or the orchard can be cultivated and used as usual. Also in this case, the circuit that conveys the fluid (usually water with glycol) to the pump is closed, so there are no problems regarding emissions of gas or fumes: also, this is a clean and environment respectful method.

In the presence of a water table, the so called “capture wells” can be used. These use the water directly from the water-table, which is extracted and then sent back into the ground: in this case the water is used both as a source of energy and as the vector fluid. It is a very efficient system but it is more expensive and cannot always be used, in particular in the presence of a water table used a source of drinking water. An analogous system can be realized, by exchanging heat and the water of a lake or of a pond close to the home: this type of system has been set up to supply air conditioning in the Palace of Nations in Geneva, using the water of Lake Geneva (Lac Léman).

Increasingly widespread

Domestic geothermic installations can entirely replace a traditional combustion plant with an autonomous and not just integrative solution (as in the case of solar panels, which do not allow a complete autonomy due to the variability of the energy supplied). They are systems which are particularly suitable to satisfy the needs of small homes, isolated villas and small groups of houses; and also schools, municipality buildings, gyms and swimming-pools. For this reason, in many countries, families decide more and more often to use this type of alternative energy for heating. But this system is not used only for homes: in the last years, a true boom of geothermal heat pumps has been noted, also for greenhouse farming, fish farming and balneology (heating in spas and swimming pools) and in many Northern countries also to heat the footpaths and streets, keeping them free from ice in winter.

The same system which guarantees heating in winter can be used for cooling during the summer, and a constant production of warm water, with a thermal energy production which does not vary during the course of the year. In our country (Italy), domestic geothermic is just beginning to take off, but in many countries, it is already a well-established tradition. It is estimated that a growing number of homes will plan on using domestic geothermic for the conditioning systems in the buildings: this system in fact allows the owners to save a large amount of money in terms of heating bill during the winter, it guarantees warm water and a cool house during the summer, nearly free of cost, and represents a great “global” saving for the environment, in terms of a minor consumption of fossil fuels and the consequent reduction of greenhouse gas emissions.

An inexhaustible energy

The geothermal air-conditioning system is indicated in the White Paper for the Future "renewable sources of energy" COM97 of the EU as a possibility to heat and air-condition our homes in a manner that is clean and sustainable for the environment. In fact, this system produces very low levels of CO_2 and gases which are noxious for the environment: the emissions depend on the amount of electricity required to make the heat pumps operate, however, observing the performance of the heat pumps, the thermal energy obtained from the subsoil and "increased" by the pumps, is 4 times greater than the energy consumed.
The energy obtained from the subsoil is a renewable energy, rather, it is practically inexhaustible, and very clean: the use of endogenous heat in fact does not produce emissions of any kind, neither CO_2 nor other gases (like sulphur compounds or nitrogen oxide), nor fine particles. Thermovector fluids, which circulate in the closed-circuit probes, never come into contact with the ground or the water of the water-table and, in any case, it is guaranteed that materials that are not toxic for the environment are used. Closed circuits allow a great water saving. The water, once put in the system, is continuously reused. The installations are quite small and their visual impact is practically inexistent: once built, all that can be seen is the heat pump, the size of a fridge, and the warm water reservoir similar to a normal "boiler". The noise of the pumps is similar to that of a fridge, they can therefore be installed inside the homes. The only "limit" to the diffusion of this new domestic air-conditioning is its use in big buildings (as for example a large building with numerous floors), which requires the installation of various probes (or deeper wells, with consequent higher expenses) and the installation a greater number of heat pumps.

A healthier home

The environmental benefits of this new form of geothermal energy exploitation are evident, not only on a "global" scale, but also inside homes, this system helps creating a healthier atmosphere. In fact, as there are no open flames, no exhaust gases, no fumes, no fine particles are produced and no oxygen is burnt, therefore the air inside the home will be cleaner: in the houses where this type of heating is used, there will not be any problems of black deposits on the walls and on furnishings (which instead usually force us to paint our homes periodically).
Also heating with radiation panels at a low temperature is healthier: in fact it allows a better regulation of the temperature in the rooms which will have more uniform temperature, and not concentrated near the radiator, the air will be less dry and the low temperature of the panels will not create the problem of a feeling hot legs caused by the high temperature radiation panels: our floors will be pleasantly warm in winter and nice and fresh during summer. Domestic geothermal installations are also extremely safe: there is no combustion, so no open flames, nor pipes containing gas, nor cylinders or tanks containing inflammable materials (like oil or LPG) and the possibility of an accident is practically inexistent.
Therefore, domestic geothermic seems destined to represent the future of thermal energy in our homes, and it is nice to think that while our garden fills with flowers, just a few metres below the

surface, energy which will keep us warm in the winter and cool in the summer is generated, with no wastes nor pollution.

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