The Role of Geothermal Energy in the Cooling and Heating Systems

Grazia CALABRÒ
Università degli Studi di Messina
Dipartimento di Studi e Ricerche Economico
-Aziendali ed–Ambientali –Sez RIAM –
Piazza Pugliatti, 98124 Messina
E-mail: grazia.calabro@unime.it

Alessandro FAZIO
Università degli Studi di Messina
Dipartimento di Scienze geografiche e merceologiche
Piazza Pugliatti, 98124 Messina
E-mail: afazio@unime.it

ABSTRACT
The uninterrupted growth of energy consumption of developed and developing countries, the gradual and rapid depletion of fossil fuel reserves, the repeated political and financial crisis, consequently leading to a rise in prices of oil and natural gas, imply the need for a diversification of supply sources, the use of renewable energies and the enhancement of national and local resources. Geothermal energy can be a sustainable solution for a wide range of applications, from electricity production to the direct use of heat for civil and industrial applications. Its use can reduce emissions and comply with the limits imposed by the Kyoto Protocol and further commitments to EU and international levels to reduce greenhouse gases beyond 2012. The present study analyzes the importance of using the geothermal energy for cooling/heating of public buildings and private uses. It is based on the principle of the thermal exchange capacity of the soil, representing an attractive solution in technical, economic and environmental terms.

KEY WORDS
Renewable energy, efficiency, sustainability

JEL CODES
Q42, O13

1. Introduction
As it is commonly recognized nowadays energy patterns lead to an unsustainable future, that not only concerns natural resources narrowness and scarcity but it is strictly linked to greenhouse gas emissions (GHGs), mainly CO$_2$ ones. The Commission communication of January 10$^{th}$ 2007 entitled “Restricting overheating due to climate changes to 2° C – the roadmap to 2020 and further”, clearly shows that it is essential to have a reduction in the order of 30% before 2020 and up to 60- 80% before 2050 in the industrialized world. This reduction is achievable both from an economic and a technical profile.

Furthermore, the latest crisis highlights the need for an effective energy strategy towards the preservation of depleting resources and towards the environment protection. Since March 2007 the EC claimed the urge to increase energy effectiveness in the Union so to reach the goal of the reduction of 20% by 2020; for the period 2007-2012 the EC issued the “Action Plan for Energy Efficiency: Realizing the Potential” with the objective to limit the energy demand by means of energy conservation actions and low consumption decentralized techniques.
This awareness makes policy makers more and more engaged to find the right way to effectively harmonize the growing energy demand and climate change mitigation. In order to achieve the goal of low carbon economy, the innovations or the options explored for the energy sector looked upon: energy saving, energy systems efficiency improvement, switching to less carbon-intensive fossil fuels, capture and storage of CO₂ emissions and a wider use of renewable energy sources.

According to Eurostat data (2011) the ultimate consumption of energy by residential in 2008 was 23.5% with an increase of 4.3% respect to 2007. Heating and cooling are the most relevant elements of energy demand but they are characterized by a low use of renewable energies. According to these remarks, by adopting suitable measures and politics we should encourage a wider use of renewable sources.

In the EU Action Plan for Energy Efficiency 2011 it is pointed out that the biggest energy saving must be made with buildings and the tools to boost the restoring process of public and private buildings and the improvement of energy yield of appliances and other energy-using equipment are being outlined. This Plan combines with the EU directive 2010/2013 which must be acknowledged by member states starting from 2012 about energy performance in buildings. New directions about minimum requirements of energy performance have been established for new buildings, renovated buildings. According to local climate conditions and internal thermal conditions and cost efficacy. One of the most important point of the Directive is to boost the systems of alternative energy supply and, at the same time, to optimize and minimize the energy need for cooling or heating buildings. The European Commission considers that the biggest energy consumption is made by residential and commercial buildings: 40% of the total European energy consumption and 50% referring to methane.

Promoting the use of renewable sources for heating and cooling is a valid opportunity to satisfy bioeconomy objectives; turning to decentralized techniques, i.e. local energy sources will bring unquestionable advantages from the social-ethic point of view due to the improvement of local employment above all in rural areas. A sustainable solution for heating and cooling is represented by the technology which exploits low enthalpy geothermal sources and plants designed according to the single building which exploit, referring to heat, the constant soil temperature and the difference of temperature respect to the outdoor. The European Directive 2009/28/CE considers geothermal heat pumps sources of renewable energy, provided that the output heat is more than the input electricity needed to make it work. Usually, for a kWh of electric power needed to make a geothermal heat pump operative, 3 kWh of thermal power are extracted from the soil. Therefore such a system provides a greater thermal energy than the electrical energy consumed. In Italy the Legislative Decree 3/3/2011 n. 28 which acknowledges the EU Directive 2009/28 CE about promoting the use of renewable energy sources points out the quantity of renewable geothermal energy captured by heat pumps, E_RES must be calculated according to the following formula:

\[ E_{RES} = Q_{USABLE} \times (1 - \frac{1}{SPF}) \]

- \( Q_{USABLE} \) = refers to the total esteemed heat produced by the heat pumps on the condition that the final yield of energy exceeds in a significant way the energy needed to make the heat pumps work and only for those heat pumps for which SPF >1.15*1/\( \eta \);
- SPF=medium seasonal yielding factor esteemed for such heat pumps;
• $\eta$ is the ratio between the gross total production of electricity and the consumption of primary energy for the production of energy and it will be calculated on an European average based on Eurostat data.

By January 2013 the Commission will establish the guidelines about the value the Member States can give to the values of $Q_{usable}$ and of SPF for the different technologies and applications of heat pumps, taking into consideration the different climate conditions, above all in those areas with cold temperatures, where the system is more efficient. Low enthalpy geothermal heat pumps offer a real and possible perspective to decrease emissions in a short time, it is esteemed that by introducing heat pumps in 20% of European buildings could lead to reach the 8% of the objective of 20% of the reduction planned by 2020. The spread of geothermal heat pumps could represent a real renewable alternative for a sustainable development and it could offer new market opportunities.

2. The geothermal system based on the heat pump

The geothermal heat is a renewable source of energy available in large quantities but which can be found in scattered areas mostly. It is known that the internal Earth heat dissipates towards the surface through the rocks or through the fluid vectors such as water and gas. So the rock temperature progressively increases of about 3°C every 100m in depth.

With the Law n. 22 of 11 February 2010 geothermal resources are defined: high enthalpy, when they are characterized by the fluid temperature above 100°C; medium enthalpy when they are characterized by the fluid temperature between 90°C and 150°C; low enthalpy when they are characterized by a temperature lower than 90°C. The best known geothermal uses are connected to high enthalpy resources and they are meant to produce electric energy. In order to carry out an evaluation and a mapping of available resources, it is of fundamental importance the knowledge of the geological-geothermal context as starting point to create the plants. At not very high depth, the underground maintains an almost constant temperature in a year; therefore it can be considered as a seasonal storing reservoir which can be used to produce heat or cool when needed. The temperature constant makes it possible that the soil temperature is higher respect to the external air in winter while it is lower in summer.

This heat at low enthalpy of the soil can be used for heating or cooling buildings exploiting the technique of the heat pumps, a thermal machine able to change in useful energy a type of energy at low enthalpy otherwise unusable. The heat pump technology includes a heat source, a heat pump unit and a cold/hot distribution system inside the building. It is possible to use the same device to heat and cool the buildings just inverting the cycle path. When heating, the heat source is the underground outside the building, when cooling, the source is the building itself. The heat pump is made up of a loop with refrigerant liquid. It is composed of an evaporator; a compressor, which increases the pressure of the refrigerant vapour arriving from the evaporator, pushing it through the system, and increasing the vapour's temperature; a condenser, where the refrigerant vapour condenses a liquid, and the transfer of heat with the surrounding environment occurs and an expansion valve which takes back the fluid to the starting pressure so to start again the thermodynamic cycle.

The ratio between the thermal energy delivered by the body to heat and the electricity consumed to make the transfer of heat possible is defined as “Coefficient of Performance” (COP) and it is an index of the heat pump efficiency. On average, we consider an efficient system the one
which has a COP value equal to 3. Among the different kinds of heat pumps classified according to the cold source and the hot well, the ground-water heat pumps exploit the natural energy of the soil.

The exploitation of geothermal energy is performed by means of geothermal vertical drilling rigs set from 50 m to 300 m or through horizontal set at a depth of 1 m. A mixture of water and anti-cooling flows in them exchanging energy with the soil, thanks to conduction or convection. The advantage of the soil as a cold source is that it undergoes lower changes of temperature respect to air allowing steady performances all year long and a high COP.

The geothermal cooling and heating system is characterized by: a central device, or heat pump, which allows to perform the necessary thermal rise to obtain the wished temperatures inside the buildings; energy geo-structures to exchange heat with the soil; a heating supply system: the geothermal plants can fit to any output but the choice of unsuitable ones can negatively draw on energy costs essential for making the heat pump work.

The radiant wall and floor system is the most efficient supply system. Radiant panels work with temperatures between 28 and 35°C against 60-70°C of the existing heating systems. Since the temperature that can be obtained from the soil with a geothermal plant is about 14°C, the energy needed to reach the useful 35°C of radiant panels is less than that essential to reach 60/70°C of the heating systems, with a saving above 55%.

The minable thermal energy can be achieved by open loops or closed loops. The open loop is a system which utilizes water freely flowing underground or on a surface, as main heat vector by means of a geothermal rig, while the closed loop is achieved by means of geothermal wells and horizontal manifolds. The payback time for a heat pump heating system with a geothermal rig for a new detached or semidetached building is of about 20 years.

In Figure 1 the two methods of extracting earth heat are shown. The building on the left points out the geothermal rigs, while the building on the right shows the horizontal manifolds.

![Figure 1. Vertical and horizontal loop (Source: Rehau)](image)

The choice between the two techniques depends on the space surrounding the building. For smaller places the drill is more advantageous. Indeed, in this case the exchange of the heat with the soil is by means of drills installed with a drilling of few centimeters of diameter in a hole dug next to the building, invisible after the plant.

The number of pipes and depth of the plant changes according to the energy supply demanded. The geothermal wells reach a depth from 80 m to 150 m; the horizontal manifolds are set at a depth of 1-2 m and 50-80 cm distant one another and covered with sand. In comparison with the traditional air conditioning split systems (air-air heat pump) a geothermal plant has
important advantages as for energy savings, environmental impact and visual impact. The splits use outdoor air as source; they have a high consumption of energy since the starting temperature is higher than the environment to heat or cool. Furthermore, there is the risk to create convective streams inside the place, because of the temperature differences due to the not equal distribution of heat inside the building.

Another environmental problem connected to splits is “the thermal isle” phenomenon that is the extreme heating of the air around the building and the temperature increase in urban areas, where thousands of heat pumps exist. Eventually visual impact is not negligible; geothermal heat pumps can be placed in the cellars without being seen on the contrary of the anaesthetic fans of traditional splits placed everywhere and that couldn’t be placed in archaeological or historical palaces. Radiant panels used in geothermal plants guarantee a steady and even temperature in every room and the absence of convective movements in the air. So, a temperature between 22 or 23°C is felt when actually it is between 20/21°C; this leads to a lower loss and real energy savings.

A cooling/heating geothermal plant produces higher installation costs, therefore it is suitable to start a common implanting project for the entire place during the construction or an important renovation since the single plant is more expensive, difficult if not impossible. To quantify the total cost of a plant, installation and management costs must be taken into consideration, detracting tax allowances if expected. Installation costs include the charges for the machine, extra equipments and the well drilling costs. The management costs refer to the consumption of electricity. The system improves its efficiency if the electricity used comes from renewable sources and the heat pumps have an environmental certification such as Ecolabel or meet the European Quality Label for Heat Pumps (EHPA-Q) criteria.

3. Geothermal heat pumps in Europe

In recent years a boost in using geothermal resources is recorded. The forecasts say that by 2015 the geothermal energy global market (both for the production of electricity and heat use) will record an average annual growth rate of 14% from 61.200 Mw in 2010 to 120.300Mw in 2015. Moreover, according to the forecast about the future scenery of IEA Energy Technology Perspectives (ETP) the exploitation capacity of geothermal will increase above 1.000Wh by 2050 and the use of heat pumps will increase 20 more times for the same period. On a world perspective The USA produce the higher quantity of electricity from geothermal sources (16.603 GWh/per year), followed by The Philippines (10.311 GWh/per year), Indonesia (9.600 GWh/per year) and Mexico (7.047 GWh/per year). Italy gets the 5th place with 5.520 GWh/per year and the 11th place as for geothermal energy for direct use, including heat pumps (Geothermal Energy Association- IEA 2010).

In detail for the exploitation of geothermal energy in cooling and/or heating private buildings, the ground source heat pumps (GSHPs) market undergo the effects of the economic and immovable crisis of the latest years. Indeed, between 2009 and 2010 this market underwent a 2.9%drop in sales. According EurObserve’ER data (2011), in the main European markets, 103.846 GSHPs were sold in 2010. In this way, the European Union’s total number of GSHP is 1.014.436 with a capacity of 12.611,1 MWh and 2.056 ktoe of renewable energy captured. The countries where GSHPs are widely spread are Sweden (378.311 units), Germany (205.150 units) and France (151.938 units).
Notwithstanding the technologies of GSHP are reliable unlike the other European Countries in Italy the use of geothermal plants hardly takes off. In 2005 there were plants for 120 MW, in 2008 they reached 150MW with a minimum increase in three years. At the same time Germany passed from 681MW to 1.652MW and France from 702 to 1.366MW. It is a triple rise respect to the national one it shows what must be done in Italy in order to conform to European standards, above all from financial provisions. It is expected costs to drop of 10% by 2030 due to economies linked to the system development (IEA 2010). In 2010 the unit were 12.357 with a capacity of 231MWh and 23 ktoe of renewable energy captured. A boost to the spread of the system could arrive from its insertion into the National Action Plan for renewable energies achieved in 2010, acknowledging the Community Directive 2009/28/CE. According to the Plan, applying all the possible strategies of energy efficiency and assuming the objective, to be obtained by 2020, to cover with energy from renewable sources 17% of the final gross consumptions, by 2020 the final gross consumption of energy in Italy is esteemed 131.2Mtep consistent with the objective of 20% reduction. In fixing such objective energy captured by heat pumps according to the $E_{RES}$ formula is taken into consideration.

The contraction of the market in 2010 can be explained by the fact that the on-going global economic and financial crisis continue to affect the availability of credit and the potentiality of investment by consumers. Up to now, the market growth is linked to incentives and supports schemes. Budgetary constraints, at European and national level, had as consequence cuts of incentives and support schemes. For example, the Swedish market went in countertendency respect to the general situation in Europe. It registers an increase compared to 2009 thanks to a new incentive system which enables investor to deduct 50% of the installation costs against tax to the limit of 5000 euro per house owner and also thanks to a slight increase in building sector and the strategy towards renewable energy developed by big company, for example IKEA. The opposite situation appears in Germany where the interruption of the Renewable Energies Incentive Program called MAP and the creation of more complex authorization procedures determined the contraction of the market. A special mention needs to be done to Poland where, unlike other Countries, we assist to a growth of GSHPs not determined by the presence of some form of economical incentives. The units installed, in 2010, were 19.320 with a capacity of 257 MWt and a renewable energy captured of 33.5 ktoe.

There is a great number of obstacles to the spread of the geothermal heat pump technology in Italy. First of all cultural obstacles linked, on one side, to our tradition to energy approach and on the other side the lack of information about technology, its application and the advantages in terms of thermo-efficiency.

Indeed, for the public opinion the exploitation of the geothermal resource is considered achievable only when there is a high enthalpy geothermal resource for the production of electricity, as for example in Lardarello (Pisa); even if it is not considered economically convenient because of location costs of the deposits which have high temperatures and pressures. The capacity of use linked to the exploitation of heat from the underground for the direct heating that foresees plants sized on every single building with no longer payback are unknown. Furthermore, the application of the technology is more difficult with renovations even if it is wished that the new building standards for the energy efficiency of buildings can push this field forward.

An important role is played by economical and prescriptive aspects.
In Italy there is not going to be any incentive towards the adoption of this technology unless some tax relieves ratified with Finanziaria 2012, as for example the 55% of tax allowance from IRPEF (Tax on income of a person) and from IRES( Tax on the income of a firm) of the expenditures.

The provisions action to regulate the sector, unlike the other countries, i.e. Switzerland, has not yet been undertaken and it is inhomogeneous because it is assigned to the regions. Considering that in Italy the energy obtained from geothermal sources represents the 10% of the energy produced from renewable sources, the Ministry of Economy Development foresees it to double in a short time by suitable regulations.

A step in this direction was made with revising the Act 896/1986 with the Legislative Decree 11/02/2010 n°22. It foresees a public annual report “on the state and perspectives of geothermic in Italy” which is edited by the Ministry of Economy Development for the sources of national interest, and by the regions and the Communes for those of local interest and for small use.

Moreover, regulations to obtain necessary permissions for the realization of projects to exploit geothermal resources are simplified. Within the small local uses the decree refers specifically to heat pumps; article 10 says “the exploitations of geothermal heat made by means of geothermal pipes which exchange heat with the soil without taking or reintroducing hot water or geothermal fluids from the underground are considered small local uses of geothermal heat”. Simplified forms of permissions consistently with incentives provided with renewable energy sources and energy efficiency are foreseen for the application of minor geothermic usually used by private citizens to heat or to cool buildings, greenhouses and sport facilities. It is clear that the government policy should see towards ways for incentives and promotions in order to foresee integrated management of the energy which combine geothermal heat with electric supply from renewable sources, with the aim to maximize efficiency. A boost toward sustainability of heating / cooling arrives from the housing market. Indeed, notwithstanding buildings should follow the energy certification regulations, the energy class hasn’t a leading role in the housing market since the advantages which can be reached using geothermal sources at low enthalpy are not properly highlighted. When using energy at low enthalpy there is a great energy efficiency and the heat pump permits to increase the energy class in a better way respect to other system above all if combined to other hybrid systems.

For this reason it is hoped the class of energy efficiency to be included among the leading factors for the economic evaluation of a real estate. In this way it is interesting the initiative undertaken by the province of Bolzano, in the north of Italy, about the “Casa Clima” system of energy certification. It is based on a drastic reduction of heating costs, on the living comfort and on climate defense. The different certification classes, CasaClimaOro, CasaClima A, CasaClima B, are established according to the KWh/m² consume per year for every building and they measure the energy saving.

4. Conclusions

Climate changes and other negative environmental impacts, combined with the need of energy independence, the growing of fossil fuel costs and the steady rise of energy demand, pointed out the need to look for new renewable sources even locally available. That is the reason why there is a lot of interest around geothermic.
Subsoil heat represents a very interesting energy source in order to guide the heating/cooling sector towards sustainability and to answer to the ambitious European Community objectives to increase the use of renewable sources and reduce CO₂ emissions. Notwithstanding this sector moves slowly and unevenly in the world, geothermal heating/cooling plants have real advantages as for the visual impact and for efficiency, since they represent a firm and lasting investment.

The amortization time of the initial cost can be diluted in 50 years, counterbalanced by low operation costs that depend on both the fuel used for the production of electricity and on the heat pump efficiency. Furthermore the association with the reversible heat pump permits to create both heating and cooling with the guarantee of energy savings due to high seasonal efficiency and with saving on operating costs. Respect to the traditional solutions, indeed, during summer these plants clear the subsoil heat, generating a thermal storage for the following winter season. Another advantage is represented by the fact that it is easily adaptable to any building system and to higher sustainability due to the application of a suitable system of designing which makes it easy to realize. For this reason it is also expected the development of a certification system of the installers so not to oversize or undersize the system.

There is, however, a high acknowledgement on the potentialities of use and lack of information which determine doubts about the system future. Indeed, there is a lot of concern about social/environmental impacts as for example the possibility of seismic activity, of soil failure or sinking due to drilling besides environmental risks, underground waters in particular whose defense is of major priority.

Heat pumps represent the technology to work for in the near future since they can offer a great contribution in post-oil future and we can obtain profits as for consumption and energy efficiency.

References
13. Piva A. (2005), Geotermia, una fonte energetica rinnovabile per l’edilizia sostenibile, Ambiente, Risors e Salute, n. 106, pp. 36-37
19. Università degli Studi di Messina, Dipartimento di Studi e Ricerche Economico-Aziendali ed–Ambientali -Sez RIAM-, Piazza Pugliatti, grazia.calabro@unime.it
20. Università degli Studi di Bari, Dipartimento di Scienze geografiche e merceologiche, Via C. Rosalba, 53 – Bari, afazio@unime.it.