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THE ROLE OF GEOTHERMAL ENERGY IN THE COOLING AND HEATING SYSTEMS

Introduction

As it is commonly recognized nowadays, energy patterns lead to an unsustainable future that not only concerns natural resources narrowness and scarcity but is also strictly linked to greenhouse gas emissions (GHGs), mainly CO_2 ones. The Commission publication of January 10th 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 technical profile.

Furthermore, the latest crisis has highlighted the need for an effective energy strategy towards the preservation of depleting resources and towards protection of the environment. Since March 2007 the EC has claimed to have increased 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 energy demand by means of energy conservation actions and low consumption decentralized techniques.

This awareness makes policy makers more and more engaged in finding the right way to effectively harmonize the growing energy demand and climate change mitigation. In order to achieve the goal of a low carbon economy, the innovations or the options explored for the energy sector investigated: energy saving, energy systems efficiency improvement, switching to less carbon-intensive fossil fuels, capture and storage of CO_2 emissions and a wider use of renewable energy sources.

According to *Eurostat* data (2011) the ultimate consumption of energy by the residential sector in 2008 was 23,5% with an increase of 4.3% from 2007. Heating and cooling are the most relevant elements of energy demand but they are characterized by the 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 was pointed out that the biggest energy savings must be made with buildings and the tools to boost the restoring proc-

ess 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 regarding 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 points of the directive is to boost the systems of alternative energy supply and, at the same time, to optimize and minimize the energy needed for cooling and 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 bio-economic 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 technology which exploits low enthalpy geothermal sources and plants designed according to the individual building which exploit, in reference to heat, the constant soil temperature and the difference of temperature in respect to the outdoor temperature. The European Directive 2009/28/CE considers geothermal heat pumps to be sources of renewable energy, provided that the output heat is more than the input electricity needed to make it work. Usually, for every 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 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:

$$E_{RES} = Q_{USABLE} \times (1 - 1/SPF),$$

where:

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 $SPF > 1.15 \times 1/\eta$,

SPF – medium seasonal yielding factor esteemed for such heat pumps,

η – 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 a 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 the real possibility of decreasing emissions in a short time, it is estimated that by introducing heat pumps in 20% of European buildings, that it could lead to reaching an 8% portion for the objective of 20% of the reduction planned by 2020. The spread of geothermal heat pumps could represent a real renewable alternative for sustainable development and will offer new market opportunities.

The geothermal system based on the Heat Pump

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's heat dissipates towards the surface through the rocks or through the fluid vectors such as water and gas. So rock temperature progressively increases about 3°C every 100m in depth.

With the D.L 11/02/2010 n.22 geothermal resources are defined: *high enthalpy*, when they are characterized by fluid temperatures 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, the knowledge of geological-geothermal environment is of fundamental importance as a starting point in building geothermal plants. At not very low depth, the underground maintains an almost constant temperature throughout the year; therefore it can be considered as a seasonal storing reservoir which can be used to produce heat or cold when needed. The constant temperature makes it possible that soil temperature is higher in respect to the external air in winter while it is lower in summer.

Heat at low enthalpy in the soil can be used for heating or cooling buildings exploiting the technology of heat pumps, a thermal machine is able to change otherwise unusable low enthalpy energy into useful energy. 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 by simply inverting the cycle path. When heating, the heat source comes from underground, below the building, when cooling, the source is the building itself. A 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 vapor arriving from the evaporator, pushing it through the system, and increasing the vapor's temperature; a *condenser*, where the refrigerant vapor condenses to a liquid, and the transfer of heat with the external environment occurs and an *expansion valve* which takes the fluid back to the starting point to restart the thermodynamic cycle. The ratio between

thermal energy delivered by the process of heating and the electricity consumed to make the transfer of heat possible is defined as "Coefficient of Performance" (COP) and it is an index of heat pump efficiency. On average we consider an efficient system one which has a COP value of 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 1m. A mixture of water and anti-cooling flows through them, exchanging energy with the soil, caused by conduction or convection. The advantage of using soil as a cooling source is that it undergoes lower changes in temperature change as opposed 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 it to perform the necessary thermal rise to obtain the desired 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. A radiant wall and floor system is the most efficient supply system. Radiant panels work with temperatures between 28 and 35C° versus the 60–70C° of existing heating systems. Since the temperature that can be obtained from the soil using a geothermal plant is about 14C°, the energy needed to reach the useful 35C°of radiant panels is less than that essential to reach 60/70C° of these heating systems, thus saving more than 55%.

Minable thermal energy can be achieved using open loops or closed loops. The open loop system utilizes water freely flowing underground or on the surface, as primary heat vector by means of a geothermal rig, while the closed loop is achieved by means of geothermal wells and horizontal manifolds. The return on investment time for a heat pump heating system with a geothermal rig for a new detached or semidetached building is about 20 years. In Figure 1 the two methods of extracting thermal 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)

The choice between the two techniques depends on the space surrounding the building. For smaller spaces drilling deep is more advantageous. In this case the exchange of heat with the soil is by means of drills installed by drilling of a few centimeters in diameter hole dug next to the building. The number of pipes and the depth of the plant changes according to the energy supply demanded. The geothermal wells reach a depth of 80 m to 150 m; The horizontal manifold method is set at a depth of 1–2 m and a 50–80 cm distance from each other which is then covered with sand. In comparison with traditional air conditioning, split systems (air- air heat pump), a geothermal plant has important potential for energy saving, and environmental as well as visual impact. The splits use outdoor air as a source, which has a high consumption of energy since the starting temperature is higher. Furthermore, there is risk in creating convective streams inside a location, because of the temperature differences due to the unequal 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 also becomes noticeable ; geothermal heat pumps can be placed in cellars without being seen in contrast to those of unaesthetic fans of traditional splits placed everywhere and that shouldn't be placed in archaeological or historical palaces. Radiant panels used with 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 23C° is felt when actually it is between 20/21C°; 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 a 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, minus tax allowances if allowed. Installation costs include those for the machine, extra equipments and well drilling costs. 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.

Geothermal Heat Pumps in Europe

In recent years a boost in using geothermal resources has been recorded. Forecasts predict that by 2015 the global geothermal energy 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 120.300 Mw in 2015. Moreover, according to forecasts about the future scene of IEA Energy Technology Perspectives (ETP) the exploitation capacity of geothermics will increase to above 1.000 Wh by 2050 and the use of heat pumps will increase by 20 more times during the same period. From a world perspective, the USA produces the highest 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 11th place as far as direct use of geothermal energy, 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 has undergone the effects of the economic crisis of the latest few years. Indeed, between 2009 and 2010 this market has undergone a 2.9% drop in sales. According to EurObserv'ER data (2011), within the main European markets, 103.846 GSHPs were sold in 2010. In this regard, 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 in other European Countries such as Italy where the use of geothermal plants has hardly begun. In 2005 there were plants for 120MW; in 2008 they reached 150MW with a minimum increase over three years. At the same time Germany grew from 681MW to 1.652MW and France from 702 to 1.366MW. They have tripled with respect to other nations and shows what must be done in Italy in order to conform with European standards, and above all from financial reasons. It is expected to drop costs by 10% by 2030 within economies that are linked to the system's development (IEA 2010). In 2010 there were 12.357 units with a capacity of 231MWh and 23 Ktoe of renewable energy captured. A boost in the spread of the system could arrive from its insertion into the National Action Plan for renewable energies achieved in 2010, as acknowledging in 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 estimated 131.2 Mtep consistent with the objective of a 20% reduction. In fixing such objectives, energy captured by heat pumps according to the E_{RES} formula has been 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 continues to affect the availability of credit and the potentiality of investment by consumers. Up to now, market growth has been linked to incentives and support schemes. Budgetary constraints, at European and national levels, have had as consequence cuts to incentives and support schemes. For example, the Swedish market has gone in the opposite direction with respect to the general situation in Europe. It has registered an increase compared to 2009 thanks to a new incentive system which enables investors to make a 50% tax deduction of up to 5000 Euros per house owner and also thanks to a slight increase in the building sector and a strategy towards renewable energy developed by a big company, for example IKEA. The opposite situation has appeared in Germany where the interruption of the Renewable Energies Incentive Program called MAP and the creation of more complex authorization procedures have created a contraction in the

market. A special mention should be given to Poland where, unlike other countries, we can promote the growth of GSHPs regardless of the presence of some form of economical incentives. The geothermal 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 geothermal heat pump technology in Italy. First of all cultural obstacles, which one side, is our tradition approach to energy and on the other side the lack of information about current technology, its application and the advantages in terms of thermo-efficiency. Indeed, for public opinion the exploitation of geothermal resources is considered achievable only when there is a high enthalpy geothermal resource for the production of electricity, as for example in Lardarello; even if it is not considered economically feasible because of location costs or deposits which have high temperatures and pressures. The capacity of use, linked to the exploitation of heat from the underground for the direct heating, foresees plants on every single building. Furthermore, the application of technology can be more difficult with renovations even if it is preferred 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 will not be any incentive towards the adoption of this technology unless tax relief is ratified such as that within *Finanziaria 2012*, for example the 55% of tax allowance from IRPEF (personal income tax) and from IRES (corporate income tax) of the expenditures.

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

A step in this direction has been made with revising the Act 896/1986 with Legislative Decree 11/02/2010 n°22. IT foresees a annual public report "on the state and perspectives of geothermics in Italy" which will have to be reviewed by the Ministry of Economy Development of sources of national interest, and by the regions and the communities for local interest and smaller use.

Moreover, regulations to obtain the necessary permissions for the realization of projects to exploit geothermal resources have been simplified. Within 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 its way towards incentives and promotions in order to foresee the integrated management of energy which combines geothermal heat with an electric supply from renewable sources, with an aim of

maximizing efficiency. A boost towards the sustainability of heating and cooling can arrive from the housing market. Indeed, notwithstanding buildings should follow energy certification regulations. This energy class has not yet obtained a leading role in the housing market since the advantages which can be reached using geothermal sources at low enthalpy have not been properly highlighted. When using energy at low enthalpy there greater energy efficiency and the heat pump permits an increase in energy class and a better way if combined to other hybrid systems. For this reason it is hoped that a class of energy efficiency will be included among the leading factors for the economic evaluation of real estate. In this way it is interesting that the initiative undertaken by the province of Bolzano about the "Casa Clima" system of energy certification. It is based on the drastic reduction of heating costs, on living comfort and on climate defense. The different certification classes, CasaClimaOro, CasaClima A, CasaClima B, are established according to the KWh/m^2 consumed per year for every building and the measured energy savings.

Conclusion

Climate changes and other negative environmental impacts, combined with the need for energy independence, the growing cost of fossil fuels and the steady rise of energy demand, have pointed out the need to look for new renewable sources locally available. That is the reason why there is much interest around geothermic. Subsoil heat represents a very interesting energy source for the heating/cooling sector towards sustainability and a positive step towards the ambitious European Community's objectives to increase the use of renewable sources and reduce CO_2 emissions. Not surprisingly this sector moves slowly and unevenly in the world, geothermal heating/cooling plants have real advantages when it comes to visual impact, efficiency, as well as a firm and lasting investment. The amortization time of the initial cost can be diluted to 50 years, anchored by low operation costs related to both the fuel used for production of electricity and by their heat pump efficiency. Furthermore, reversible heat pumps create both heating and cooling with the guarantee of energy savings due to high seasonal efficiency and savings on operating costs. In respect to traditional solutions, during summer these plants take advantage of subsoil heat, generating 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 design which makes it easier to realize. For this reason there will be a need for the development of a certification system of installations so as to not oversize or undersize these systems. There is, however, a high acknowledgement for the potentialities of use and lack of information which determine doubts about the systems future. Indeed, there is a lot of concern about social/environmental impacts as for example the possibility of seismic activity, or of soil failure or sinking due to drilling. Regarding environmental risks, the protection of underground well water is a major priority. Heat pumps represent a technology to strive for in the near future since they can offer a great contribution to a post-oil future as well as great savings through energy efficiency.

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Summary

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.

ROLA ENERGII GEOTERMALNEJ W SYSTEMACH CHŁODZENIA I OGRZEWANIA

Streszczenie

Nieprzerwany wzrost zużycia energii w krajach rozwiniętych i rozwijających się, stopniowe i szybkie wyczerpywanie się kopalnych zasobów paliw, powtarzające się kryzysy polityczne i gospodarcze, które w konsekwencji prowadzą do wzrostu cen ropy naftowej i gazu ziemnego, wskazują potrzebę dywersyfikacji dostaw źródeł energii, wykorzystania źródeł odnawialnych i zwiększenia środków krajowych i lokalnych.

Energia geotermalna może być trwałym rozwiązaniem dla szerokiej gamy zastosowań, począwszy od produkcji energii elektrycznej do bezpośredniego wykorzystania ciepła do zastosowań domowych i przemysłowych. Jego zastosowanie może zmniejszyć emisję i zwiększyć zgodność z ograniczeniami nałożonymi przez Protokół z Kioto i pomóc w spełnianiu dalszych zobowiązań w celu zmniejszenia emisji gazów cieplarnianych po roku 2012, na poziomie UE i międzynarodowym.

Niniejsze opracowanie analizuje znaczenie wykorzystania energii geotermalnej do chłodzenia/ogrzewania budynków publicznych i zastosowań prywatnych. Opiera się na zasadzie zdolności wymiany cieplnej gruntu, co stanowi atrakcyjne rozwiązanie w wymiarze technicznym, ekonomicznym i środowiskowym.