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GROUND SOURCE HEAT PUMPS APPLICATIONS IN ITALY

Davide Maritan and Roberto Panizzolo

Geotherm srl IVT Italia, Via S. Lorenzo 60a 37038 Soave (VR) Italy;
University of Padova, DIMEG, Via Venezia, 1 – 35131 Padova Italy
maritand@geotherm.it; roberto.panizzolo@unipd.it

ABSTRACT

Like other Mediterranean countries, Italy is an emerging market for ground source heat pumps (geothermal heat pumps). In this article some case studies are presented - residential for detached or semidetached houses and two systems for blocks of flats - over the last ten years, with the intent to describe the different technical approaches adopted during this time, errors done and financial/local regulations bottlenecks.

INTRODUCTION

Geothermal (ground-source) heat pumps (GHP) are one of the fastest growing applications of renewable energy in the world, with annual increases of 10% in about 30 countries over the past 10 years (J. Lund, B. Sanner, L. Rybach, R. Curtis, G. Hellström, 2004). In Europe, like some other southern countries, Italy has been one of the last to find interest in ground source heat pumps; the reasons should probably be found in some aspects:

- mild climate, because of the Mediterranean closed sea, with minimum temperatures normally not less than 26°F and maximum temperature not more than 86-95°F;
- different approaches to the heating solutions; in Italy there is a habit to natural gas furnaces, because there is a huge pipe network, that supply the gas at low cost, nearly to everyone; only isolated villages or houses in the countryside, isles, hills or mountains, are not reached by the gas net and they usually adopt propane gas or oil, as fuels for furnaces;
- a general culture that erroneously identifies electricity for heating with electric resistance, with an immediate callback to high running costs
- low interest in renewable energies.

Geotherm srl Earth Energy Systems was founded in the year 2000 after some years of groundwork and planning. The inspiration for the firm arrived by chance from a short article with the description of heating and cooling systems in the USA, that were "plugged to earth" (Maritan and Panizzolo, 2005). From 2004 Geotherm srl is the Italian partner of the Swedish heat pump manufacturer IVT Industrier ab; today Geotherm is a small commercial company that sells heat pumps and ground source related equipment.

In the first years it was very difficult to find customers, that could accept a) to abandon the furnace concept and b) the higher costs of a ground source heat pump system; only in the last three years the number of running heat pumps and competitors in the market have been growing at a significant rate.

Today, the Italian geothermal heat pumps market is still a niche one, where people show good interest but where different technical approaches, competitors and designers introduce a quite wide number of solutions, plugged to the ground: these solutions are sometimes standard and well tested, sometimes not tested or well designed; the effect is that the number of not working systems or saturated ground loops are growing too, with bad influence to the entire market. The second effect is that the final ground source customer is now often confused because he/she is pushed by companies or thermal engineers to follow a way and the opposite of it.

In the following sections we will be focused in some different case studies.

VERTICAL SYSTEMS

Vertical systems can be divided in closed loop and open loop systems: in a closed loop, polyethylene pipes are installed in small diameter boreholes and a closed circuit exchanges energy with the ground; in an open loop, water from an aquifer is pumped to the heat pump or to a heat exchanger and then to the same or another aquifer, with a second borehole, or to the waste water line.

Today, in Italy, open loops are historically definitely better known by thermal engineers than closed loops; in some areas of the North the aquifer is very close to the surface and for non domestic cooling it can be used with common chillers or heat pumps. Some big problems in open loops today could be ignored by the designers:

- pollution of the aquifer and legislation limits: normally the first aquifer (generally in the countryside the static level is from -20 to -60m) is most of the times polluted; this fact creates several law bottlenecks (aquifer is a public property and its control is sometimes managed by the local town council, sometimes by the countries, which Italy is divided in);
- submerged pump energy consumption: for a correct analysis of the performance of the system, designer and final customer must consider not only heat pump performance but electric load of this pump too;
- lower reliability than a closed loop system.

Closed loops are very common in Europe for domestic ground source heat pumps. Some points can be discussed here:

- Ground loop heat exchangers (GLHE): in the last ten years our firm moved from custom made ground heat exchangers to pre-assembled ones, with 4 pipes and double U-bend. Today we can identify two big producers of ground loop plastic heat exchangers (one from Switzerland and one from Germany) that sell in Italy; in the opposite hand we estimate that about 30-40% of the vertical installations are still done with "home made" polyethylene U-bends (the return U at the bottom of the boreholes), fused to normal water high density polyethylene pipes;
- Grouting: in the Italian market most used grouts are cementitious bentonite grouts but the grouting procedures are not standard; high thermal grouts are not commonly injected in the boreholes. We still have lack of legislation and the actual laws create conflicts each other, so, for example, there is still the open question to consider these boreholes as water wells or not;
- Drilling costs: from the first application we did in 1998 (Earth Comfort Update, 2000) the cost per meter that usually drillers asks to the customers (drilling and installation, without heat exchanger) has moved from 12€/m up to 45-60€/m, depending of the kind of soil. The main reason, for these high costs, should be that drillers have a very positive business in water wells and the cost is related to this kind of activity, not to the installation of the geothermal probes (heat exchangers).

<u>Case study 1 (2003) – a residential vertical system with radiant floor and an American water to water heat pump</u>

This is a retrofit application; the house is located in Padova, about 30 miles from Venice, North of Italy. This 120 sq meters, semidetached, two floors house has radiant floor for the heating; during hot season cooling is made with the radiant floor and a dehumidifier, both connected in parallel to a 300liters buffer tank and this last to the heat pump. Thermal loads at design conditions (66°F inside and 23°F outside) were calculated to be 7Kw (1Kw=3412Btu/h). The installed geothermal heat pump was an American water to water model. Ground loop consists in two 262 ft vertical double U-bend GLHE. Grouting was made with thermally enhanced grout and the stratigraphy of the soil is water saturated clay/sand. Natural gas is locally available, existing furnace was completely removed. The investment was:

- 14,000 EUR + taxes for the heat pump, ground loop, circulating pumps, grout, design, project management; actual investment for a similar system can vary from 15 to 18,000 EUR + taxes;
- 3,500 EUR + taxes for drilling and installation of the GLHEs. Actual investment for drilling can vary from 7,200 to 9,000 EUR + taxes;

Now we can consider positive results from this project and bottlenecks/difficulties met.

Positive results:

- Running costs reduction: we can see in figure 1 that average energy heating cost reduction, after the start up, was approximately 20%. Here we do not consider the cooling season savings, that are of about 35% in comparison to a air to air split unit. We see that when we try to compete with natural gas, the savings are not so high as we find in propane or oil projects. In the opposite side, for the next years we expect a progressive increase of the cost of natural gas, mainly because of supply limits from Eastern Europe and Russia.

COST COMPARISON		
NATURAL GAS COST	0.59 EUR / m3	
ELECTRICITY COST	0.12 EUR / Kwh	
FIX COSTS	0.06 EUR / DAY	
FURNACE		
AVERAGE COSTS FROM 12/16/03 TO 01/15/04		
Electricity average	7.7 Kwh/gg	1.01 EUR
Natural gas average	8.46 m3/gg	5.01 EUR
total/day		**6.01 EUR**
HEAT PUMP		
AVERAGE COSTS FROM 12/15/04 TO 01/14/05		
Electricity average	39 Kwh/gg	4.86 EUR
Natural gas average	0.11 m3/gg	0.07 EUR
total/day		**4.93 EUR**
DAILY SAVINGS		**1.09 EUR**
DAILY SAVINGS %		**18%**

Figure. 1. Running costs comparison and savings case study 1

- Greenhouse gases reduction: following the NRCan/CEDRL RETScreen standards (www.retscreen.net) the reduction estimated is 1.39 t_{CO2}/yr.

- Safety, comfort and satisfaction: the customer satisfaction level today after 5 years is still very high; in 2005, relatives of this family, in the nearly semidetached house, became our customers, with a new horizontal ground loop system and a heating only, high temperature, heat pump.

Bottlenecks/difficulties:

- Space needed for technical equipment: one of the big issues in our design is space reduction; "American style" water to water heat pumps tend to be "naked", with few equipment and controls inside, this is a good reliability approach but the negative result is the space needed, to position circulating pumps, controls, buffer tank and hot water tank. In this case we had to utilize a room 3x3m wide. If we compare this system to the present, today, for a house up to 200 sqm, we only need a space of about 0.65 cubic meters: in a box 0.6x0.6x1.8(h)m we have a heat pump with both the circulation pumps (geothermal and heat carrier), a 165l hot water tank, the digital control with heating curves for radiant floor or radiators; in addiction, in the last two years we eliminated completely the buffer tank, with a direct connection to the heating system collectors. Several customers, today, can position the heat pump under the first floor stairs or close to the bathroom.

<u>Case study 2 (2007) – two multi flat systems in Milano area</u>

In 2006-2007 two, multi flat, closed loop ground source heat pump projects started:

- the first is a 150Kw project, 9 heat pumps, 40 flats, divided in three blocks; each block will have three floor dedicated heating only heat pumps (capacity from 14 to 17 Kw); the borehole array consists of 47 boreholes 50m (164ft) deep with double U-bend pre-assembled HDPE100 32mm diam. GLHEs; the heat pumps start up is scheduled for mid 2008;
- the second is applied to a IXX century old Villa restoration (figure 2). The 9 apartments are heated with radiant floor and 3 high temperature heat pumps provide the 40Kw of capacity needed. The boreholes array consists of 7 boreholes 100m (328ft) deep with double U-bend pre-assembled HDPE100 32mm diam. GLHEs; geothermal natural passive cooling provides about half of the cooling needed and an air to water chiller covers the peak loads.

Positive results:

- Investment: for the first project the total investment is estimated in 250,000 EUR + taxes for equipment (heat pumps, buffer tanks, hot water tanks), thermally enhanced grout, main collectors, GHLEs and horizontal connection lines; about 150,000 EUR + taxes are needed for drilling and GLHEs installation.

Figure. 2. Boreholes field for a IXX cent. Villa restoration

The additional cost for each apartment is 9,000 EUR. The second project needs an investment respectively of 80,000 EUR + taxes and 45,000 EUR + taxes for drilling. In this case the additional cost for each apartment is 13,800 EUR (bigger flats than the first one). The cost for single flat can be managed with an increasing of the comfort for the future owners and the running cost reductions.

- Low after sales maintenance costs; the annual control, that must be done for furnaces, is not requested.
- Sales improved, because of this "excitement attribute"; we can see Kano model about customers expectations and demanded qualities (Kano, 1984)

Bottlenecks/difficulties:

- Limitations in the depth of the boreholes: in the first project, we had to re-design the system four times, because of the conservative and cautious evaluation, coming from the technical office of the local council: the first aquifer was polluted and the public technicians thought that the GLHEs had not to be positioned at a depth more than -164ft (the base of the aquifer): the result was from the initial design of 21 boreholes moved to 47, with big design problems, to manage the position of the boreholes in the space allowed and the horizontal line layout.
- More the managers are, more the time is wasted: we discovered that project management in these big projects is essential and an unique referee is needed; the first project had some months of delay, because the main contractor was not so firm in the decisions, as the second one, and

some architects and engineers play a role against the adoption of the technology. We discover that personal characters and relationships are crucial, sometimes, for a successful installation.

HORIZONTAL SYSTEMS

Horizontal GLHEs are installed in trenches or in an unique excavation at a depth that can vary from 1.0 to 1.5m. In the Italian market horizontal systems are not so common as the vertical ones but the situation seems to be changing. If we consider our customers, more than half have horizontal GLHEs. There are two bottlenecks for this kind of layouts:

– final customers often think that the performance of the vertical system is better, because of the depth: we have been spending a lot of time to explain that this is a mistake, because the performance of a system is related only to the design for the specific project.
– land availability: in countries like France or United Kingdom, horizontal loops are very common but the case of Italy is different and the extension of the garden can vary a lot from place to place.

In the last years, some European firms introduced different compact GLHEs (or collectors) of different shapes, as a solution for small gardens; in this case the heat extracted from a small portion of the soil determines a progressive reduction of the minimum temperature of the inlet geothermal cold medium: some kind of recharging is needed.

Case study 3 (2006-2007) – single detached country house in Marche region, with a horizontal ground loop

This case is quite common for us. It is a system for a restoration of a typical local villa, with walls, made of clay bricks and stones; the house is located in the hills in Marche country, about 20 miles from the sea, Centre of Italy. This 250 sq meters detached two floors house has radiant floor for the heating. Thermal loads at design conditions (66°F inside and 23°F outside) were calculated to be 14Kw. The heat pump (figure 3) is connected directly to the radiant floor main collectors, without buffer tank and a 300l hot water tank gives the hot water, needed to the English owners. A heat exchanger allows the heat pump to produce warm water for the nearly pool, during middle seasons. We designed a horizontal layout that consists in two 367 ft parallel trenches, 3.9 ft wide and 4.3 ft deep, where the excavator deployed the GLHEs, made with double U-bend HDPE100 32mm pipes. The investment in the system (heat pump, hot water tank, ground loop, etc) was about 20,000 EUR+taxes and the excavation and installation costs were about 2,500 EUR + taxes.
Positive results:

– Running costs: in this area only propane is available; in average, the reduction of the costs for similar projects is located from 50 to 70%;
– Increased value of the house
– High reliability for isolated houses

Figure. 3. Technical room, in the left side the pool heat exchanger

Bottlenecks/difficulties:

– Very low local technical support: in areas, where plumbers and installers have low technical knowledge, there is the risk to have high costs, for after sales maintenance: our technicians had to drive some times more than 600miles a day for a one hour work.

Case study 4 (2006-2007) – single detached wood house Piemonte, North West of Italy, with a horizontal compact collector and solar recharging

In the near future compact ground heat exchangers will probably be an answer for small gardens, without expensive drilling of boreholes. Solar recharging of ground loops is today a field of research in the geothermal heat pumps industry. This is a case of a 10Kw system installed in 2004 in the north west of Italy, with a reversible geothermal heat pump and patented compact collectors. In autumn 2006 the system was connected to solar panels for hot water production and ground loop recharging. Main parameters was recorded and they allow now an analysis of the possible performances, obtained from solar ground loop recharging. Each compact collector is like a big radiator: hose length per collector module is 131ft and the pipes are made of polyethylene 40mm diam. Twenty ground compact collectors were assembled in two separated lines and installed in a 118ft trench at a depth of 9 ft (figure 4). The investment (heat pump, hot water tank, ground loop, etc) was about 17,000 EUR+taxes and the excavation and installation costs were about 1,500 EUR + taxes. We discovered that rain conditions, during winter, make a big influence to the performances of these GLHEs; in this application, unlikely, the customer (that became, after, one of our local partners) lives in one of the driest areas in North of Italy: without recharging, during the first winter, temperature of the ground loop cold medium (water and antifreeze) fell below 17°F!

Figure. 4. Compact collectors ready to be fitted

The 2006 installed solar panel consists in a small array of 30 vacuum solar pipes, positioned in the roof of the house: this system gives hot water, when needed, but most of the times it recharges the ground loop, with an impressive amount of working hours; in fact it is not needed to wait for high temperature, to start the solar circulating pump. December 2007 was very cold and the minimum entering temperature from the ground loop was 32°F.

CONCLUSIONS AND FUTURE RESEARCH

Some different case studies for the Italian geothermal heat pumps market were presented. We tried to present the difficulties we met, because we think that it it more important to learn from errors done and bottlenecks encountered, than to read only success stories. Future research will be focused on compact collectors performances and design: they should be the solution for small gardens, as an alternative approach in comparison to the expensive drilling.

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