Heating and cooling with geothermal energy for residential buildings in Latvia

I. Skapare, A. Kreslins
Riga Technical University, Institute of Heat, Gas and Water Technology

ABSTRACT

In the recent years in Latvia is rapidly developing construction sector of residential buildings. Engineers have to give more attention to heating and cooling system's technology in the buildings to stay competitive in the realty's market. Every year is increasing part of geothermal heat pump's use. An increasingly important economic factor and parameter in calculating the economic feasibility of geothermal heat pumps, is the extent to which a market exists for CO_2 emissions in the country of operation. Just few years ago because of economical situation and climate in Latvia cooling systems in the residential buildings weren't common, but now it is getting more popular. The latest version of geothermal heat pump's use is implementation combined heating/cooling systems for residential buildings that can provide heating during the winter and cooling during the summer, which is very suitable for Latvian climate.

In 100m depth where the temperature of the earth is constantly around 12°C, is possible to put pipes filled with a cooling agent and bring it up to the heat pump.

In heating mode the heat pump compresses cooling agent pushes its temperature up to 55°C or even 70°C for the heating system. In cooling mode during the summer the heat pump only "heats up" the liquid up-to around 20°C and circulates it through the heating system and absorbs the heat from the rooms and brings it down to the earth again. The effect is that residential building will always have a delta of 10°C to the outside temperature. Special attention has to be given to the construction of heating/cooling system inside the building and its automatic regulation. Also ground heat exchanger type, its geometry and its efficiency has to be considered for each special case.

1. INTRODUCTION

There are two kind of geothermal energy that can be used for space conditioning of residential buildings: deep and shallow geothermal energy. Deep geothermal energy sources in Latvia are presented by two zones of geothermal anomalies in central and South-western Latvia with temperatures of geothermal water – 20-55 ^{o}C. Such range of temperatures is difficult to make geothermal project feasible for heating and cooling even considering that energy prices are getting higher every year. However such low-temperature geothermal energy has been used in a number of countries where appropriate geological, hydrological and geophysical conditions are present such as in sedimentary strata. Examples of this are found in European countries like France, Poland, Hungary, Romania, Slovakia and Serbia. Often in spite of favorable geological conditions, drilling costs stop deep geothermal developments. That is also one of the reasons, why shallow geothermal energy (0-200m) is more perspective in Latvia at the moment.

In many countries, all energy stored in form of heat beneath the earth surface is per definition perceived as geothermal energy (VDI 1998; BFE, 1998). The ubiquitous heat content of shallow resources can be made accessible either by extraction of groundwater or, more frequent, by artificial circulation like the borehole heat exchanger (BHE) system. This means, the heat extraction occurs in most cases by pure conduction, there are no formation fluids required.

2. TECHNICAL PERFORMANCE

There are several ways for heating energy transportation from the ground to the heat pump: using borehole heat exchangers (BHE), groundwater wells, horizontal heat exchanger pipes, deep boreholes, heat exchanges geostructures, tunnel waters and deep borehole heat exchangers.

The ground system links the heat pump to the underground and allows for extraction of heat from the ground or injection of heat into the ground. To choose the right system for a specific installation, several factors have to be considered: Geology and hydrogeology of the underground, area and utilization on the surface, existence of potential heat sources like mines, and the heating and cooling characteristics of the building(s). In the design phase, more accurate data for the key parameters for the chosen technology are necessary, to size the ground system in such a way that optimum performance is achieved with minimum cost.

Horizontals loops - the closed system easiest to install is the horizontal ground heat exchanger (synonym: ground heat collector, horizontal loop). Due to restrictions in the area available, in Latvia the individual pipes are laid in a relatively dense pattern, connected either in series or in parallel.

To save surface area with ground heat collectors, some special ground heat exchangers have been developed: Spiral forms, mainly in the form of the so-called "slinky" collectors, and trench collectors. Exploiting a smaller area at the same volume, these collectors are best suited for heat pump systems for heating and cooling, where natural temperature recharge of the ground is not vital.

If we look at the vertical loops - because the temperature below the "neutral zone" (10-20 m) remains constant over the year, and because of the need to install sufficient heat exchange capacity under a confined surface area, vertical ground heat exchangers (borehole heat exchangers) are widely favored. In a standard borehole heat exchanger, plastic pipes (poly-ethylene or polypropylene) are installed in boreholes, and the remaining room in the hole is filled with a pumpable material (Sanner, 2005).

In Latvia mainly horizontal heat exchanger pipes are used due to the lower price of installation, but when earth surface is not big enough, BHE become more suitable.

Heat pumps are widely used in Latvia for residential buildings, especially in areas, where natural gas lines are not available. Nevertheless cooling is provided mainly by traditional air conditioners. There are two ways how to provide cooling for the building, where is envisaged to use heat pump.

First, the heat pumps may be reversed and can be used for cooling with the addition of a reversing valve (Fig. 1) that reverses the direction of the working fluid and so the direction of the heat transfer . Second, it may be possible to provide cooling by circulating water directly between the ground loop heat exchanger (GLHE) and chilled ceilings or beams.

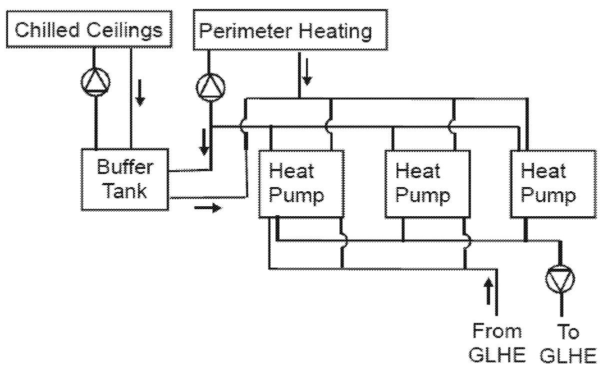

Figure 2: Conventional heating/cooling ground source heat pump systems (Spitler, 2003).

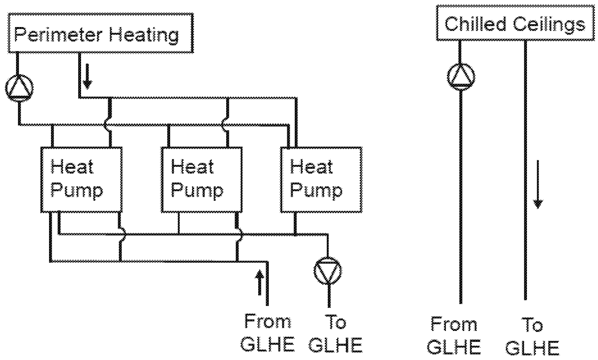

Figure 3: Direct heating/cooling ground source heat pump systems (Spitler, 2003).

Comparing the two alternatives (Fig. 2.3), the first should allow the use of a smaller GLHE, because higher summer loop temperatures will be acceptable. However, the first alternative will consume more electrical energy to power the heat pumps in cooling mode. Thus, there will be a trade-off between first cost and operating cost.
If we look at the heating/cooling system inside of the building – the best would be floor heating and ceiling cooling. However all surfaces (Fig. 4) inside of the building as well as fan coils can be used for either for heating or cooling, but less efficiently.

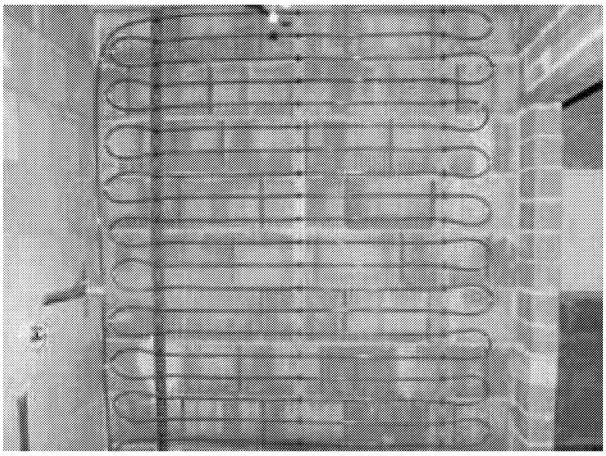
Figure 4: Installation of wall heating/cooling.

During the design process it is important to remember that for comfort feeling floor temperature for heating should not exceed 29^{0}C, but for cooling – should not be lower than 19 ^{0}C.

3. EFFICIENCY AND ECONOMIC CONSIDERATION

It must be borne in mind that many factors affect the efficiency and economics of heat pumps, and decisions must be carefully assessed. Heat pump systems are getting more efficient, whereas fossil fuelled heating is approaching its efficiency limits. The environmental argument will therefore increasingly swing towards sensible application of heat pumps in the future.
The heating efficiency of ground-source and water-source heat pumps is indicated by their coefficient of performance (COP). Their cooling efficiency is indicated by the Energy Efficiency Ratio (EER), which is the ratio of the heat removed to the electricity required to run the unit. For the heat pump COP should be 2.8 or greater and an EER 13 or greater.
Oil and gas resources are getting shorter and their prices will consequently rise. In some European countries the government has aid programmes, when in new project is envisaged geothermal or other renewable energy utilization. Hopefully in Latvia it will be similar in the future.
However geothermal heat pumps (GHP) save money in operating and maintenance costs (Fig. 5).

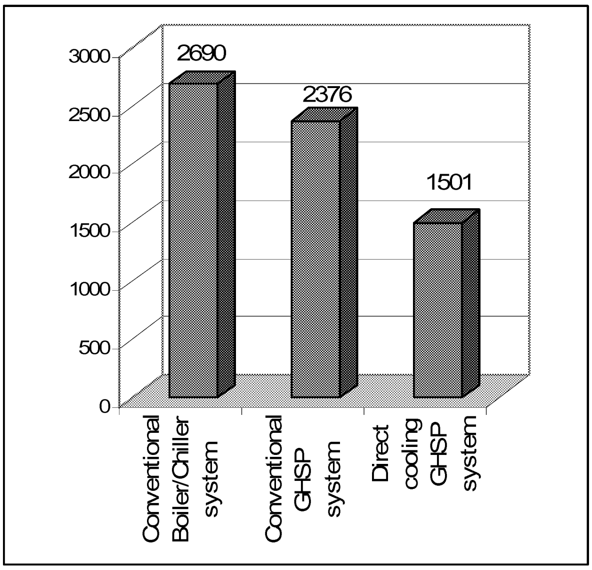

Figure 5: Estimated annual energy cost for heating and cooling for building with area 4600 m^2, EUR

While the initial purchase price of a residential GHP system is often higher than that of a comparable gas-fired furnace and central air-conditioning system, it is more efficient, thereby saving money every month. For further savings, GHPs equipped with a device called a "desuperheater" can heat the household water. In the summer cooling period, the heat that is taken from the house is used to heat the water for free. In the winter, water heating costs are reduced by about half.

4. ENVIRONMENTAL EFFECTS OF GEOTHERMAL HEAT PUMPS

Geothermal heat pumps can have positive and negative environmental effects.

A potential negative effect of all geothermal heat pumps is the release of antifreeze solutions to the environment. Vertical boreholes also may pose environmental threats. If these boreholes are not properly grouted or the grout fails, groundwater could be contaminated by surface water infiltration, interaquifer flow, or antifreeze leakage.

However, despite potential environmental problems, geothermal heat pumps pose little if any serious environmental risk when best management practices are applied during the installation, operation, and decommissioning of these systems (Mehnert, 2004).

Nevertheless heat pumps access renewable or waste energy and so displace consumption of conventional fossil fuels (gas, oil, coal). As electricity generation technologies improve, the emissions performance from the combustion of fossil fuels and renewable electricity generating capacity increases, so the greenhouse gas emissions associated with electricity consumption are reducing – making heat pumps even more environmentally beneficial.

Nearly 50% of electrical energy in Latvia is gained from renewable source (hydropower plants). So, nearly half of the energy needed for heat pump operation is also environmentally friendly.

5. CONCLUSIONS

Nowadays in Latvia is desirable to have a flexible system that can be used both for heating and cooling. However such systems are not widely used jet, because of high installation cost.

Using GHP for heating and cooling of residential buildings is environmentally friendly solution, because of renewable energy utilisation. It is also easy to control, using armatures, widely available (Fig. 6) that may help to save energy.

Because GHP systems have relatively few moving parts, and because those parts are sheltered inside a building, they are durable and highly reliable. Because GHP systems have no outside condensing units like air conditioners, there's no concern about noise outside the home. Also, there are no blasts of cold or hot air.

Such systems improve humidity control by maintaining about 50% relative indoor humidity, making GHPs very effective in humid Latvian climate.

Increased energy efficiency of heat pumps for a major use of energy will reduce the amount of fossil fuels burned, greenhouse gases such as carbon dioxide (CO_2) generated, and other air pollutants (NO_x and SO_2) emitted.

Briefly benefits of GHP surface heating and cooling in the building:

- energy-saving
- economical
- no air pollution
- environmentally friendly
- long service life
- comfortable.

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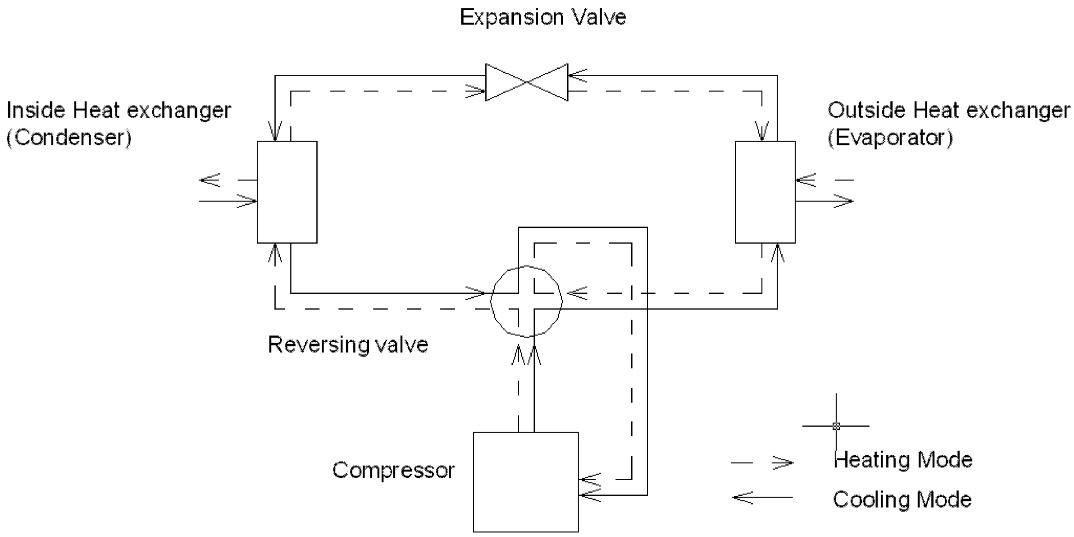

Figure 1: Reversible heat pump.

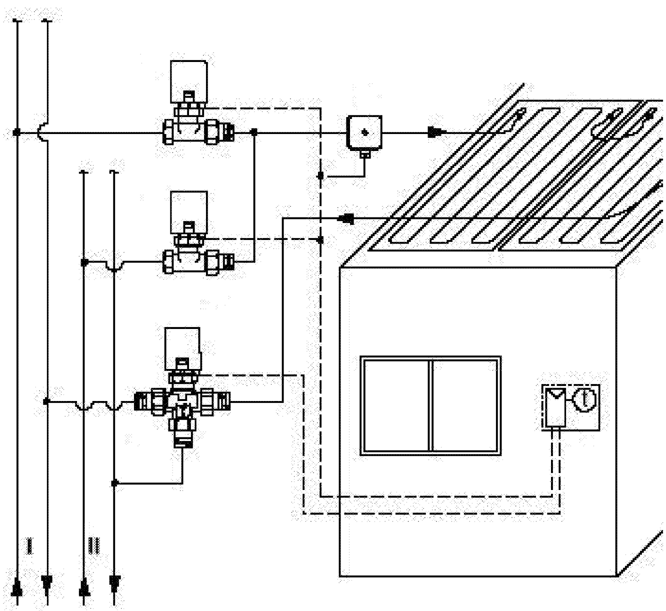

Figure 6: Example of heating/cooling system control (I – Cooling, II – Heating).