Proceedings European Geothermal Congress 2007
Unterhaching, Germany, 30 May-1 June 2007

Shallow geothermal applications in Belgium

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Keywords: geothermal heat pumps, ATES, BTES, country update

ABSTRACT

The use of geothermal energy in Belgium is focused on shallow applications. There is little activity according to deep geothermal energy. The market for geothermal heat pumps has grown significant over the past years. In the past, most installations extracted heat from groundwater. Yet, there is a tendency for using vertical borehole heat exchangers as groundwater systems are considered as more expensive and more difficult to operate. At this time, more then ten large cold/heat-storage systems are installed and monitored which all operate with high efficiency.

Furthermore, borehole thermal energy storage systems (BTES) has good potential in Flanders. Main advantages compared to aquifer storage concerns less restrictions regarding the local underground, easier permission application, less technical problems and better possibilities of storing high temperature energy. One high temperature storage system was installed in 2002, used for storing heat from a coal-fired power plant (Hoes 2004 and Gysen 2003). Another system collects solar and road energy for heating a social housing area. At this time, some large BTES systems are at an installation phase and several feasibility studies are performed in order to evaluate economical parameters and ecological advantages.

1. INTRODUCTION

The energy crisis in the 70's lead to an increased number of installed heat pumps (mainly air/water heat pumps). The overall quality of these installations can be considered as very poor. When energy prices dropped again, heat pumps disappeared as well. Interest was regained in the 90's, but bad installations from the past made it hard to introduce heat pump systems due to a lot of prejudices on bad functioning and poor reliability. High energy prices and workmanship lead to a general take-off from year 2000 on. The number of installations increases at a small but steady pace. Most of the systems are installed in family buildings and are with horizontal heat exchangers in the garden (most people have a rather big garden). Systems with vertical heat exchangers gain interest over the past few years mainly for office buildings and hospitals.

Nowadays the acceptance of using underground thermal energy storage (UTES) for applications where heating and cooling is needed, is slowly forcing a way in Belgium without being a "booming" market. Two UTES concepts are now commercially available on the Belgian market: the ATES (aquifer storage) and the BTES (borehole storage). Only these two concepts are discussed in this paper. Due to the hydro geological limitations, the most interesting regions and cities of Belgium are not suitable for ATES technology. It became necessary to find alternative solutions for these regions, this is provided by BTES systems.

In recent years VITO carried out several feasibility studies in health and commercial building sector on ground source heat pumps (GSHP) in combination with vertical borehole heat exchangers (BHEs). In the present situation (2007), 5 large BTES systems are planned in Belgium resulting out of these case studies.

Nowadays there is also a growing interest in cooling and heating of greenhouses with thermal energy storage supported by a heat pump. One such an example is in operation in a greenhouse where strawberries are cultivated. An other research project is situated in the greenhouse sector where the aim is to look for an optimum technical installation for a closed greenhouse and to determine the effect on the productivity and quality of the produced tomatoes. This research program will end in August 2007.

Applications in the industry are rarely found in Belgium because they must compete with classical technologies such as compression chiller, cooling towers, etc. which are commercially successful on the market and this reduces the opportunities to implement ATES applications.

This paper gives an overview of the status of UTES applications in Belgium, where the focus changes from ATES to BTES applications, mostly in the commercial sector. The general applicability on Belgian territory of BTES makes it a very interesting renewable option for future buildings especially in the framework of the European Building directive. Furthermore the interest of several market actors (drilling companies, engineering, consulting companies, etc) towards UTES is increasing slowly. Development work has been performed on the design of a thermal response test trailer at VITO for measuring thermal characteristics of the underground. Also some research projects have been performed on the effect of different filling material in combination with single, double U-tubes and coaxial tubes.

2. STATUS ATES APPLICATIONS

The geological structure in Belgium is characterized by a very tabular area with a large number of accumulate sand layers separated by clay layers. This accumulation of sand and clay layers leads to a large number of different aquifers with their own characteristics (capacity aquifer varying from 25 to 100 m^3/h). The application of the ATES technology is specifically interesting for the northern part of Belgium (Flanders; 13,500 km^2). The hydro geological conditions are ideal in the northwest and the applicability (due to the presence or absence of aquifers) decreases heading to the northeast in order to become nil at the coast region. A list of geological layers (aquifers) in which the ATES technology in Flanders can be applied has been combined in a map on scale 1/250,000. This map is not intended to stop further investigations and fieldwork in the area where energy storage could be applied but should indicate if, taking into account the requested cold/heat installation, further investigations are useful, necessary and justified (Dirven et al. 1999).

The first ATES system of Belgium went in operation in 1998. Until today, more then ten large (> 500 $kW_{cooling}$) ATES systems are installed for different applications in Belgium which is very low in comparison with surrounding countries such as The Netherlands (Sanner et al. 2003). Most of the ATES applications in Belgium are used in the commercial sector such as hospitals and office buildings were a large amount of cooling and heating is needed. The fact that cooling in patient and consultation rooms becomes more and more a standard in new build hospitals gives ATES a much larger market. However the opposite is true.

Several of these ATES installations are/were monitored for 3 years as energy demonstration projects. These energy demonstration projects got an incentive of 35% on the total investments costs of the installation with a maximum of € 250,000. This was an initiative of the Flemish government in order to disseminate information on practical results of innovative energy technology systems. In Belgium financial incentives for thermal energy storage systems such as ATES, BTES, etc. are rather low and often not existing or not available in the sector. On the principle that "To measure it… is to know it !", an objective result overview of each project can be achieved by setting up measuring campaigns. These campaigns provide good information on the performance results and are absolutely necessary to inform future interested parties in the ATES technology on the reliability, effective economical impact and benefits for the environment. This action is needed to enlarge the market.

It assists still the persuasion of potential installation owners that the teething troubles and possible installation failures came to an end. It's very well known that one bad working installation overrules a dozen of excellent operating systems. By comparing operational results with initial design values and by evaluation of installation specifications, lessons can be learnt for the future by designers, performers and researchers. The implementation of the ATES technology in Belgium went unarguable together with some unavoidable growing pains. Some of these problems were caused by the unusual combination of technologies and working parties. Especially the knowledge of geohydrological and technical issues of ATES applications are not well understood or not existing with engineering companies. Drilling companies get involved in the process of HVAC installation. Most critical are the connection points between the traditional and innovative installation part, defined as the boundary zone between the underground and aboveground installation. As typical example, the communication between the control systems of HVAC and ATES system can be mentioned. Other common problems are the treating of the wells from time to time by the owner of the installation, the energy balance in the ground (cold storage), control problems, etc.

The clinics of Northern Antwerp (KLINA) decided to cooperate and to extend with 400 beds with full climatisation. The KLINA hospital was one of the first in Belgium to incorporate comfort cooling in the patient rooms with long term storage of cold and heat (Hoes and Robeyn 2006).

An ATES system was installed in combination with two reversible heat pumps (see figure 1). The maximum groundwater flow amounts to 100 m^3/h for both charging and discharging of cold. The project is monitored over the period 01/12/2002 - 30/11/2005. During this period more than 534,000 m^3 groundwater was moved from cold to the warm well and 515,000 m^3 groundwater in the opposite direction. This represents in total 4,8 GWh of heat and 3,7 GWh of cold.

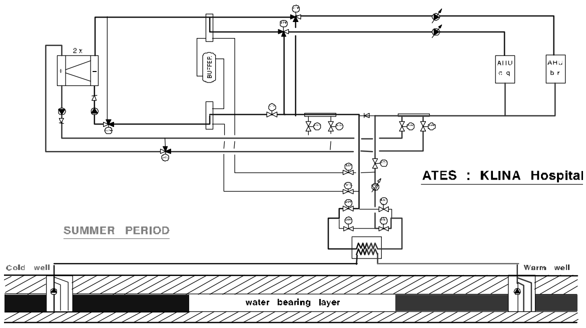

Figure 1 : KLINA ATES system during summer period

The energy supply by the ATES system (discharging of the cold source) for 2005 is presented in figure 2. The system provides a capacity between 100 kW and 1,2 MW. In the winter period there is a more constant but lower capacity supply with an average of 350 kW (provide heat to building or cold charge of cold source).

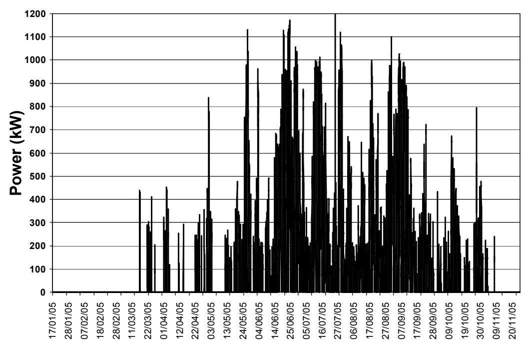

Figure 2 : KLINA - ATES power supply during cooling

The largest part (74%) of the ATES cooling is applied directly for comfort cooling of the building (incl. surgery, pharmacy,…). The remaining 26% is used for refrigeration of the condenser of the heat pump during summer situation (operating as a cooling machine). This operation is necessary for supplying cold on low temperature (for dehumidification purposes). Analogously the groundwater system provides heat, the proportion of direct heat supply to the building is rather limited (17%). Generally, the warm well will provide heat to the evaporator of the heat pump at heat demand. In this way, efficient heat supply is provided to the building and the cold well is charged. The seasonal performance factor (SPF_{cold}) for cooling amounts to 29.

The application of ATES reduced CO_2-production with more than 1909 ton over the past three years. The gas consumption for conditioning of the ventilation air is omitted entirely and is replaced by electricity consumption of the source and heat pumps. Because the heat pumps operate very efficiently, the total electricity consumption remains under this of the reference installation. There is a total primary energy saving of 69% on the climatisation of the ventilation air with a CO_2-reduction of 67 %. On an annual basis, this installation stands for a reduction of primary energy with approximately 9,000 GJ and a reduction of CO_2 with approximately 650 ton.

It's important to point out that the total heating demand of the building also involves a static heating system with classic radiators and a boiler as heat supplier. Recalculated to the total energy demand for heating and cooling the primary energy saving amounts 41 % for this renewable energy technology.

3. STATUS BTES APPLICATIONS

BTES applications are an alternative solution for regions where ATES applications can't be applied due to the absence of an aquifer and are normally used in small-scale applications in the commercial sector such as hospitals, office buildings, etc. for cooling and heating. In recent years there is large interest in BTES applications. The easy way of installing and operating the BTES compared with ATES applications has an important impact on this evolution. BTES applications are a proven technology to work without any leaks or collapses. One other advantage of these applications is that the system can be used for direct or natural cooling during summer period (without the need for a classical mechanical chiller consuming a lot of electricity), on one condition that the air handing units (AHUs) are suitable and designed for the higher temperature levels (eg. 14/18°C instead of 6/12°C for cooling purposes). This natural cooling can be delivered at a very high COP (coefficient of performance) and by regenerating the ground this delivers an improved heat pump operation in winter period.

Most of the BTES applications are situated in hospitals and office buildings where of course ATES wasn't possible for geohydrological reasons. The typical heating and cooling capacity is 25 – 650 kW using 10 - 250 boreholes 30 - 150 m in depth. Typical layers consists mainly of sand or sand and clay.

When designing BHEs with GSHPs the knowledge of ground thermal properties (thermal conductivity, borehole thermal resistance, undisturbed soil temperature, specific heat capacity, etc.) are important for correct functioning of the system. Due to the higher investments costs, over-sizing of BHEs and GSHPs pays a higher penalty than in conventional applications. Obtaining accurate values for thermal ground properties requires detailed survey on site by a thermal response test. Parameters that can have an influence on the result are the building load, borehole spacing, borehole fill material and the on-site characteristics. In the last year there is a growing interest in thermal response tests. In-situ testing has recently become a standard measurement for larger BTES applications.

The reason why BTES application are nowadays not common practice is the lack of technical knowledge from engineering companies, no financial incentives for the technology, extra investments costs, no believe in the proven BTES technology, etc. Most of the engineering companies and building owners find that the integration of BHEs and GSHPs can be simplified by some rules of thumb as they are used for calculating the heating and cooling demand of buildings. The opposite is true. When designing new buildings the owner appoints an engineering company that must know every innovative technique that is available in the sector. This is impossible for small engineering companies due to lack of specific knowledge. The building sector in Belgium has to search for advice by energy consulting companies when designing new buildings. This needs a change in mentality which can't be solved in a few years and needs the cooperation of several actors in the building sector.

3.1 EANDIS office building with large BTES field

In the new office building (15.000 m² surface) of EANDIS at Ghent (Belgium) a borehole thermal energy storage system (BTES) with 90 heat exchangers is combined with a water/water heat pump for heating and cooling. More then 75% of the total heat demand of the office building is covered by the heat pump and more then 50% of free cooling potential is available. Research on the feasibility was conducted by VITO in 2005 (Desmedt et al. 2005). A thermal response test was made with a measuring trailer by VITO in February 2006 leading to the appropriate design specifications and conditions (Desmedt et al. 2006). The drillings has started in December 2006 and are conducted by GMC and drilling company Johan Verheyden and the whole geothermal project is overseen by VITO in its design team.

3.2 New rest home project De Notelaer

For a new energy-efficient rest home with 150 beds a feasibility study (Desmedt et al. 2006) was made for the realization of a BTES system in combination with a water/water heat pump for heating and cooling. A thermal response test (see figure 3) was conducted by VITO (Desmedt et al. 2007). Around 40 heat exchangers are necessary in this project. Positive signs on the effective realization are received but are still to be approved by the council.

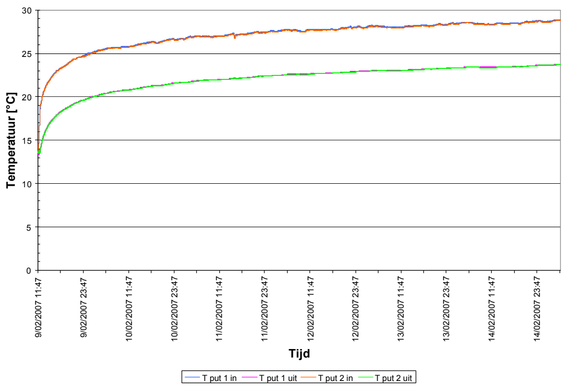

Figure 3 : Results thermal response test

4. FUTURE AND RESEARCH PROJECTS OF UTES

Research activities on ATES applications in Belgium are not existing. Research on a high temperature BTES application at VITO is finished and reported (Hoes 2004). On BTES applications the research activities at VITO are mainly based on feasibility studies, design and optimization studies of ATES and BTES systems. A second research activity at the high school DeNayer is based on thermally activated ceilings in combination with underground thermal energy storage. Simulations and practical guidelines will be developed.

In the feasibility studies the importance of building energy simulation becomes more and more important. The knowledge of these models is especially available in research institutes and less with engineering companies. With BHEs and GSHPs the estimation of the building energy demand is very important, oversizing these installations leads to improper working installations. The use of simulation models is also important as a tool for convincing building owners of the possibilities of new technologies.

For the environmental department of the Region of Brussels a study is on-going evaluating the technical and economical feasibility of different geothermal applications. The study will give a view of the potential of different geothermal techniques which are applicable in the capital of Belgium, Brussels. A large number of office buildings are located in this district. The study will result in geothermal maps for the area of Brussels.

5. CONCLUSIONS

In Belgium two UTES concepts have now reached a commercial status on the market: ATES and BTES applications. The number of ATES applications in Belgium is still very low in comparison with other countries. The interest in BTES applications is slightly growing in Belgium with several feasibility studies and some concrete projects in 2007. Recently the interest in thermal response test and GSHPs is also growing. However the knowledge on designing and thermal characteristics of the underground becomes available by a number of limited companies. In situ thermal response test are recently becoming a standard measurement for large-scale BTES projects.

Further development in UTES applications will be the dissemination of the results of ATES and BTES demonstration projects, the development of guidelines and best practices, the dissemination of simulation models for building energy consumption, etc. The potential for further market growth is expected to be high in both applications but it still needs an extra effort to finally launch them.

ACKNOWLEDGEMENT

The authors would like to thank the Flemish government (VEA) for financing ATES applications and several building owners for the feasibility studies and their interest in BTES applications.

REFERENCES

Hoes H., TESSAS High temperature thermal energy storage in saturated sand layers with vertical heat exchangers, VITO report, Belgium (2004).

Gysen B. High temperature storage in Flanders by use of vertical heat exchangers: TESSAS-project, 9th International conference on Thermal energy storage, Proceedings Futurestock 2003, Poland, 217-222. (2003).

Dirven, P., Patyn, J., Gysen B., Vandekerckhove P.: Promotie en marktintroductie in Vlaanderen van seizoensgebonden KWO in de ondergrond, VITO report in Dutch, Belgium (1999).

Sanner B., Karytsas C., Mendrinos D., Rybach L. Current status of ground source heat pumps and underground thermal energy storage in Europe. Geothermics 32 (2003) 579-588.

Hoes, H. and Robeyn, N.: Eindrapport KWO bij KLINA te Brasschaat. ANRE Demonstratieprojecten, VITO report in Dutch, Belgium (2006).

Desmedt, J., and Hoes, H.: Haalbaarheidsstudie naar het gebruik van een warmtepomp met ondergrondse energieopslag voor het kantoorgebouw EANDIS te Melle, VITO report in Dutch, Belgium (2005).

Desmedt, J., Hoes, H., Lemmens, B., Robeyn, N.: Voorontwerp BEO installatie kantoorgebouw EANDIS te Melle, VITO report in Dutch, Belgium (2006).

Desmedt, J., and Hoes, H.: Haalbaarheidsstudie naar het gebruik van een warmtepomp met ondergrondse energieopslag voor het rusthuis De Notelaer te Beveren, VITO report in Dutch, Belgium (2006).

Desmedt, J., Hoes, H., Robeyn, N. : In-situ geothermische respons test voor rusthuis De Notelaar te Beveren, VITO report in Dutch, Belgium (2007).