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Geothermal Energy Use, Country Update for Sweden

Olof Andersson[1] and Leif Bjelm[1]

[1]Engineering Geology, Lund University, PO Box 118, S-221 00 Lund, Sweden

olle.geothermal@hotmail.com

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ABSTRACT

Over the last two decades the market for ground source heat pumps (GSHP) has been continuously growing in Sweden. These systems are recognized as cost effective and environmental sound ways for space heating. Up to the mid 2000 the growth was connected to small size GSHP system for single houses. In later years larger systems have become more and more popular. Furthermore, seasonal storage of natural heat and cold in the underground (UTES) have become increasingly common for combined heating and cooling of commercial and institutional buildings. After some 20 years of operational experiences UTES systems are proved to be energy efficient, technically safe and profitable.

Most part of Sweden lack the geological conditions for deep geothermal exploitation. However, there is one plant in Lund from the mid-1980: tie that is still going strong with a production of some 250 GWh of geothermal heat to the DH of Lund annually.

In this paper the current statistics of GSHP and UTES applications are given as well as market trends and recent technical improvements.

1. INTRODUCTION

Utilization of ground source heat pumps (GSHP) is by far the most common way of using shallow geothermal energy in Sweden, especially for single residents. It is estimated that approx. 400 000 GSHP systems have been installed by the end of 2011. These systems extract approx. 12 TWh of heat with some 500 GWh of natural stored cold in addition (Geotec 2012). This makes Sweden an outstanding country using this form of energy supply (Lund 2010).

The market for small scale GSHP systems have levelled out the last few years. Instead there is a steady growth of larger systems, often in urban areas. These applications often replace or compete with district heating (DH). As a matter in fact this competition has recently led to a number of legal court decisions. The argument from the DH side is that GSHP systems use marginal “dirty” electricity for running the heat pumps. The court verdicts clearly point out that this is not the case and that geothermal installations are equal to district heating from an environmental point of view. They shall therefore be allowed in areas with both existing district heating/cooling systems but also areas being planned for such facilities (Geotec 2012).

A second shallow geothermal sector with continues steady growth is the underground thermal energy storage systems (UTES). In UTES systems thermal energy is actively stored in the underground. In most cases the storage of thermal energy is seasonal. The two systems that, since the late 1980: ties have penetrated the Swedish energy market are Aquifer Thermal Energy Storage (ATES) and Borehole Thermal Energy Storage (BTES). These systems are now totally commercial alternatives on the Swedish heating and cooling market.

Currently UTES applications are steadily growing in number, and have become strong competitive systems especially for commercial and institutional buildings, occasionally also district heating and district cooling. UTES systems are particularly competitive for cooling since there are few other alternatives at hand except for normal chillers or connection to district cooling.

Regarding the deep geothermal sector there are currently no plans for any further applications. The plant in Lund that was taken into operation 1985 is still in successful operation. From the early start it generated approx. 700 GWh of geothermal heat annually to the DH of Lund (Bjelm et al 2010). In later years the production has slightly dropped due to an increased injection pressure and a thermal breakthrough between the injection and the production side. However, recently the injection wells have been redeveloped and have now practically the same capacity as the original ones.

Up till a few years ago the marketing of geothermal in Sweden was unorganized. However, in later years the drilling association Geotec has voluntarily been taken the responsibility for spreading news and marketing through their homepage and a couple of magazines. However, a national Geothermal Association has been launched in March 2013.

This paper presents an overview of the geothermal applications in Sweden together with statistics on efficiency and market development. Some examples of applications in different market sectors are given as well as examples of technical improvements on design and construction over the last years. Finally, the current situation concerning environmental, legal issues and is overviewed as well as economic aspects.

2. TRADITIONAL GSHP SYSTEMS

The year 2011 Sweden passed 1 million heat pump installations (SVEP 2013). Of these approx. 400 000 are of the type “water to water”, in practice representing small scale closed loop, ground source, heat pump systems, also named GSHP. It is estimated that at least 300 000 of these are vertical borehole systems. The remaining installations are preferably horizontal loops. Open loop systems based on ground water is a minor fraction, estimated to be approx. 10 000 units.

The statistics are based on member reports to SVEP. These reports encounter type and size of installed heat pumps and states if it’s a new heat pump or a replacement of an old one. The types are divided into” air-air”, “exhaust air-water”, “air-water” and “water-water”. It is only the latter type that is referred to as GSHP. The market development of each type is shown in Fig. 1.

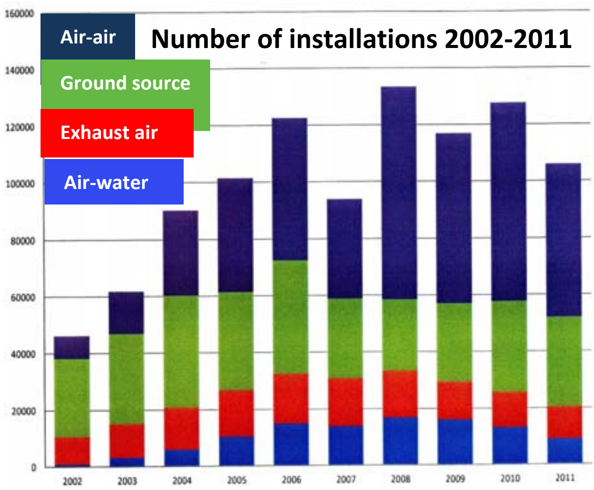

Figure 1: Heat pump installations in Sweden (SVEP 2013)

The size of the heat pump would in practice tell if the application is for a single family or a larger multifamily building. In this respect the statistics can be used to see the trends in applications. The statistics from the last years clearly indicates a growth of larger system for multifamily residential buildings and a levelling out of smaller units for single family houses. Currently (2012) the larger heat pumps, up to 100 kW, represent 21 % of all units. Larger heat pumps, preferably used for residential block centrals and for UTES systems are not reported to SVEP and therefore missing in this statistics.

The statistics from SVEP has also been backed up with statistics from drilled wells, a data base handled by the Swedish Geological Survey (SGU). Except for geological data, the boreholes that by law are reported to SGU states the application, and the depth. The numbers of reported energy boreholes the last 10 years are given in Table 1. The figures clearly correspond to the SVEP statistics when it comes to the number of boreholes and the peak in the year 2006. It also shows an increase of drilling depth those points on an on-going technical development of drilling knowledge and equipment. By the way, the number of employed people in the drilling sector has grown from 1 200 to 1 350 during the last ten years and the turnover from 500 to 2 500 million SEK during the same period. Currently, there are 220 active drilling companies in the energy drilling sector. (Geotec 2013).

Table 1: Borehole statistics based on reported GSHP boreholes to SGU (Geotec 2012)

Years	Number of boreholes	Average length (m)	Total length (km)
2002	15 734	130,1	2 108
2003	18 521	137,8	2 624
2004	22 805	141,0	3 295
2005	25 087	146,4	3 736
2006	27 755	150,8	4 247
2007	21 169	158,3	3 409
2008	17 125	162,0	2 827
2009	18 158	160,3	2 960
2010	19 962	162,3	3 283
2011	16 263	169,4	2 755

Furthermore the borehole statistics indicates a certain growth of larger systems looked upon as a fraction of totally drilled energy wells, see Table 2. However, it also shows that all sizes of applications drop when the market is declining.

Table 2: Size of GSHP systems derived from borehole statistics (Geotec 2012)

Years	Units with 1-2 wells	Units with 3-5 wells	Units with > 6 wells
2002	12 838	245	74
2003	14 630	311	103
2004	17 941	397	133
2005	18 457	590	226
2006	19 308	614	295
2007	12 727	560	318
2008	10 170	500	274
2009	13 151	399	174
2010	14 685	399	189
2011	11 804	328	164

The market decline has continued also during the year 2012, but less for GSHP than for the other types of heat pumps. The market for both single family houses and larger residential buildings peaked a few years ago and will probably not recover. The reasons for this statement are that most of the conversions for residential buildings have already been made, and that building sector is currently in a deep recession. On top of that the financial system has been changed in way that it is less favourable to have loans for heat pump installations.

3. UNDERGROUND STORAGE SYSTEMS

Underground thermal energy storage (UTES) has shown a steady market growth the last 10-15 years. These systems are preferably used for combined heating and cooling of commercial and institutional buildings. There are different systems commercially available on the market. In ATES systems (Aquifer Thermal Energy Storage) groundwater is used for transportation of heat and cold to be stores into and out of an aquifer. In BTES systems (Borehole Thermal Energy Storage) a number of boreholes will serve as a huge heat exchanger to the underground making the temperature of the rock mass seasonally swing as energy is stored and recovered.

3.1 ATES applications

The principal for ATES is shown in Fig. 2. Typically, these systems are heat pump supported. The temperature is often 12-16 °C on the warm side of the aquifer and 4-8 °C on the cold side. Normally the systems can cover the total cooling load, but in some applications the heat pumps are used for peak shaving. It should be noted that modern heat pumps can be applied for cooling as well by switching the mode of operation.

Figure 2: The principal of ATES, an open loop concept, where heat and cold are seasonally stored in an aquifer

In the design phase of such a system the thermal balance between the warm and the cold side has to be considered in order to avoid a long term thermal break trough. This can be studied by modeling the thermal behavior of the storage. These simulations are based on comprehensive site investigations and are used to establish the number of wells, the distance between wells in the same group, and the distance between the warm and the cold side of the aquifer. Furthermore, the simulations give input to environmental impact studies that is a part of the legal handling of any planed ATES plant. An example of such a hydrothermal simulation is given in Fig. 3.

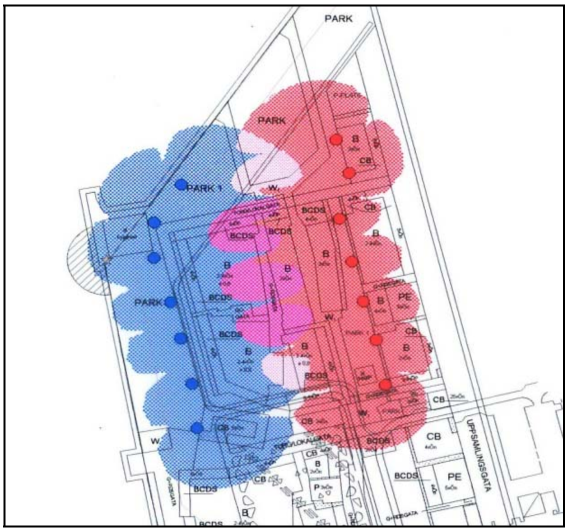

Figure 3: A 2D CONFLOW simulation for placing the wells at the ATES plant Bo01 in Malmö (Sweco 2013)

For detailed studies on how the static head in the aquifer reacts with respect to different flow rates a 3D simulation model (VISUAL MODFLOW) is commonly used by the designer. These simulations are necessary for establish the area of influence and are the basis for the legal assessment procedure that will always be an important permit item for the development of any ATES application. In recent years the MOD FLOW is used for hydrothermal simulations as shown in Fig. 4.

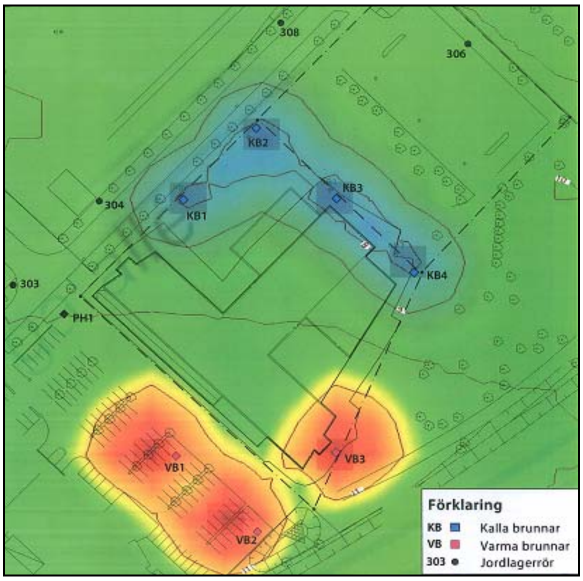

Figure 4: Hydrothermal simulation with MOD FLOW and SEAWAT for an ATES plant to a new prison in Helsingborg (Sweco 2013)

The groundwater is practically always handled with a double flow direction in a separate airtight and pressurized loop. Heat and cold is transferred to the HVAC system by means of plate heat exchangers. During the winter season the warm side is pumped, heat is extracted from the loop and chilled groundwater is injected through the cold wells. During the summer season the flow is reversed. The stored cold water is used for free cooling and the waste heat from that process is stored on the warm side of the aquifer. This type of system represents some 83 % of the known Swedish applications. As seen in Table 3, the remaining 17 % are designed for storage of heat or cold only (Andersson et al 2012 and Sweco 2013).

Table 3: Number of "known" ATES plants split into different applications and sectors

Application sector	Heating Cooling	Heating only	Cooling only
Com./Ist. buildings	39	2	0
DC/DC	6	2	4
Industries	3	0	2
Telecom	7	0	1
Agriculture	3	1	0
Total	**58**	**5**	**7**

There is no official statistics and the plants addressed in table come from the Sweco internal record of designed and realized plants, starting in the year 1983. However, a few of the older plants are known from publications originating from scientific reports (experimental and demonstration plants sponsored by the former Swedish Board for Building Research). Some of these are addressed in (Andersson 2007).

The largest plant is an ATES cold storage system taken into operation 1989. It is connected to the City District Cooling system in Stockholm and is operated at a capacity of 14 MW. This plant is the only short term storage (day to day) and is used for peak shaving only.

Another large and somewhat different ATES system is applied for Stockholm Arlanda Airport. It operates without heat pumps. The waste heat from cooling the airport is seasonally stored and used for preheating of ventilation air and snow melting of gates during the winter. Hence, the cold that is stored during the winter is generated from cold air and snow. It was taken into operation 2009 and the thermal capacity is the range of 6-7 MW (Andersson 2009). The year 2011 some 11 GWh of heat and cold respectively was produced from the system.

A rough estimate based on information from several sources such as drilling contractors and suppliers of large heat pumps indicates that there are at least 50 more plants in operation. However, the average size of these is less than for the ones presented in Table 3. These additional ATES plants seem to be applied mainly for commercial buildings such as hotels and offices that strengthen the majority within this sector.

The number of ATES systems grew steadily with a couple of new plants per year up till the turn of the century. Over the last ten years the growth rate has been doubled. This is far from the growth compared to the Netherlands with more than 1 000 ATES plants (Godschalk and Bakema 2009). However, the exceptional market growth of ATES in the Netherlands is supported by a much higher geological potential. In Sweden, the presence of suitable aquifers is limited to some 15 % of land surface. Other important growth limiting factors are restrictions due to water supply and an extensive permit procedure that normally takes years. Furthermore, comprehensive and costly site investigations would be another limiting factor. For this reasons, a potential ATES user may drop the thoughts of ATES and turn over to the BTES option instead, which is much simpler and faster to develop and realize.

3.2 BTES applications

The principal for BTES is illustrated in Fig 5. These systems can be regarded as huge tube heat exchangers where a large number of densely spaced boreholes are representing the tubes. By circulating a heat carrier fluid (brine) through the boreholes thermal energy is exchanged with the penetrated mass of soils and rocks.

Figure 5: The principle of BTES, a closed lope concept, where heat and cold are seasonally stored in a solid rock mass through a large number of densely spaced boreholes.

The Swedish BTES boreholes have a dimension of 115-140 mm and are commonly 150- 200 m deep. The Borehole Heat Exchanger (BHE) is typically a single or double U-pipe and the tubes are filled with a fluid consisting of water and bio-ethanol. The content of ethanol varies between 15-27 % that gives a freezing protection -8 to -17^{o}C. No solid backfill (grout) is required unless the systems are located to water protected areas, or at sites with specific geological conditions. Instead the boreholes are filled with groundwater. The main reason for not using grout is that water filled boreholes are normally more thermal efficient than grouted ones. It is also more cost effective. Protection from potential groundwater contamination from the surface is obtained by sealing a permanent steel casing with grout at the bottom part according to a norm (SGU 2007).

The boreholes are normally spaced in the range of 5-10 m and coupled in parallel and connected to field manifolds, from which major pipes are entering the building. The fluid is circulated to store or discharge thermal energy into or out of the underground. The storing process is mainly conductive and the temperature change of the rock will be restricted to only a few meters around each one of the boreholes. The storage temperature will in most cases swing between +2 and +8°C.

In the design of BTES systems the load characteristics have to be fairly well established and one or several test drillings with Thermal Response Tests (TRT) will describe the thermal properties of the underground, but to some extent also the local hydrogeological conditions at site. The latter ones are of importance since flow of groundwater may have an influence on the storage efficiency.

Another important factor is the long term thermal balance. In some cases additional heat or cold must be supplied to the storage (air or surface water).

The most common tool for designing storage is the simulation program Earth Energy Design (EED). This program has shown to be user friendly and accurate enough for standard projects see Fig. 4. However, for larger and more complex designs the model Duct Storage (DST) or TRNSYS with DST-module is sometimes used (Andersson and Rydell 2012)

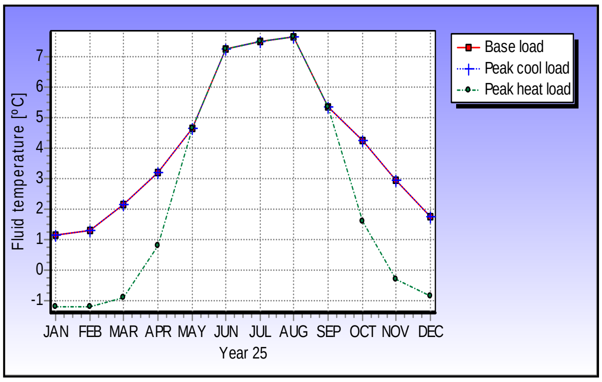

Figure 4: The simulation model EED is commonly used for design of BTES systems

There is no official statistics on the number of BTES plants. Still, by combining several sources such as sales statistics of large heat pumps, U-pipes, field manifolds, official borehole records at the Swedish Geological Survey, and verbal information from the main drilling contractors and consultants it can be estimated that there are approx. 400 BTES systems in operation at the end of 2011. To be qualified for the statistics of the BTES applications the installation should contain at least 1 000 m of borehole length. Commonly the applications have 20-80 boreholes 150-200 m deep. In average, the borehole length is in the order of 8 000 m. Put into applications with a heat pump, this length would generate some 350 kW of heat and 200 kW of cold. Based on these rough figures, the total thermal heat capacity of BTES installations, heat pumps included would be in the order of 140 MW, while the free cooling capacity would be in the order of 80 MW. This is in the same magnitude as the cooling capacity of the ATES systems; see Table E/2 (Geotec 2012).

The largest Swedish BTES plant so far consists of 163 boreholes with an average depth of 230 m. It was taken into operation in 2004 and serves a number of buildings connected to the University of Lund. The capacity is roughly 1 800 kW of heating and 1 100 kW of free cooling (Geotec 2012).

A minor fraction of BTES plants are for storage of heat only. As heat sources surface water, out-door air or exhaust ventilation air are used for storage at a temperature of 15-20°C. Compared to traditional GSHP solutions these applications are limiting the number of boreholes and the space between boreholes that will bring the investment cost down. For high temperature applications there is one plant connected to solar collectors and one for storage of industrial waste heat in operation (Andersson and Rydell 2011).

Except for a large number of the BTES systems used for cooling in the telecom sector, there is so far only one system applied for industrial process cooling. This is an 850 kW free cooling system for the chilling of an electric generator in Karlskrona. In this case cold from the air is seasonally stored in BTES system with 120 boreholes, representing 21 600 m (Geotec 2012).

In general, applications of BTES systems are to the major part found in the commercial and institutional building sector, where it has become a natural and competitive option for the supply of heat and cold. The systems are typically installed in new buildings that are used as offices, stores, hotels, hospitals, schools and libraries. There is also an increasing utilization when older buildings in the same sector are being refurbished.

A recent frequent user of UTES for new store establishments is IKEA. Up till now there are six UTES applications in operation and two under construction. As can be seen in Table 4 the dominating system is BTES. During the upcoming four years there are far reaching plans for another 6-7 UTES installations (Sweco 2013)

Table 4: UTES installations for IKEA stores and other buildings in Sweden

Name/ Starting year of operation	UTES type	Cap. (kW)	Borehole length (m)
Torsvik DC/1999	BTES	130	1 800
IKEA MP /2003	BTES	370	5 200
Karlstad /2007	BTES	1 000	14 000
Uppsala /2008	BTES	1 300	18 000
Malmö /2009	ATES	1 300	11 wells
Helsingborg /2010	BTES	1 300	14 400
Uddevalla /2012	BTES	1 000	11 000
Borlänge /2013	BTES	1 000	11 000

DC: Distribution Centre
MP: Meeting Point in Helsingborg

The cooling demand for IKEA stores is in the same order as the demand for heating. For BTES concepts the free cooling is limited to some 75-80 % of the need, while the peak load is covered by running the heat pump as a chiller. The heat pump is designed to cover some 50-70 % of the heat load, and supply the building with 85-95 % of heat demand, while the peak load is covered by electric boilers.

4. DEEP GEOTHERMAL

4.1 Experiences from the Lund geothermal plant

There is only one geothermal installation in operation that can be classified as “deep”, the Lund Geothermal Heat Pump plant. Compared to all other geothermal heat pump operations in Sweden the Lund facility is by far the largest with a double set up of heat pumps. The first unit came into operation late 1984 and the other about one year later (Bjelm and Alm 2010).

The two heat pumps can deliver 21 and 27 MW of heat energy respectively. There are four production and five injection wells. The wells are approx. 600 m deep and have all gravel packed screens opposite the sandstone aquifer.

The production rate has ever since the start been kept around 450 l/s (1 620 m^3/h), see Fig. 5. The smooth declines visible in the production rate graph are due to a slow growing clogging of injection wells. The drop spikes are caused by periods of heat pump revisions and maintenance.

The production temperature was initially around 22 °C but has lately for some wells dropped to 16-17 °C. This cause a minor decrease of thermal capacity as can be seen in Fig. 5.

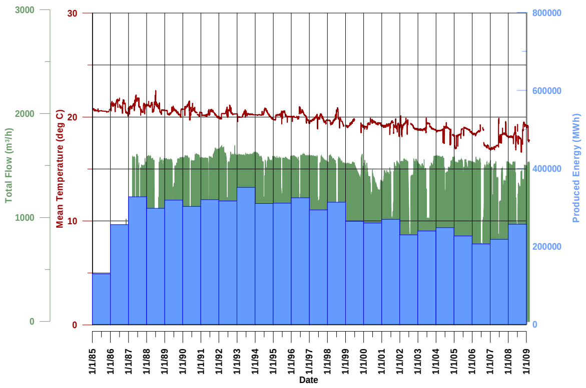

Figure 5: Flow rate, mean temperature and annual energy production for the Lund geothermal plant

Since the gravel pack in the injection wells tend to settle they have been a subject for air-lift treatment several time a year in the past. This procedure is time consuming, ineffective and costly. For this reason a more effective cleaning procedure has recently been introduced. The method is based on hydro jetting using a jetting tool with nozzles. Four of the five injection wells have now been treated and the specific injection capacity has been significantly improved. As much as 30 % has been verified. The jetting was carried out with slightly modified coiled tubing equipment.

4.2 Exploration projects

Traditional geothermal energy, extracting geothermal water from deep seated formations has been explored several times in southern Sweden but so far there is only the plant in Lund that is commercial operated. However, geothermal research and exploration efforts are an on-going subject, especially at Lund University, Engineering Geology, that are the main scientific organisation in Sweden for the exploration and utilisation of geothermal energy sources.

In 2003-2003 two geothermal exploration boreholes were drilled in Malmö by E.ON some 20 km west of Lund. The goal was heat extraction in combination with heat pumps. The wells were drilled to about 2 km depth into Triassic sandstones but only one of the wells could provide enough production capacity. The wells are now abandoned but may in the future.

The latest exploration wells were drilled 2002-2004 and one of the wells was drilled to 3700 m in crystalline basement, partly as a drilling technology project, (Bjelm et al 2006). The wells have so far not been put into production because of too limited water production from the second well.

In recent years complementary site investigations have been carried out for drilling new production wells for the Lund geothermal heat pump plant. This project is caused by the aquifer cooling by the production water shown in Fig 5. A seismic campaign was carried out for an enhanced geological and geophysical understanding of the production field and for final well site selections. The wells are currently designed, but are still waiting to be realized.

An on-going prospect for geothermal exploration is located to the Siljan impact crater area. Here a number of shallow exploration wells have been drilled with the objective to gain detailed knowledge of a shallow geothermal sandstone aquifer. This may also contain a high content of natural gas that is dissolved in the geothermal water. The company is currently looking for financial support to continue the exploration.

4.3 A new national infrastructure for deep core drilling and sampling.

A few years ago the Royal Institute of Technology in Stockholm started exploration for geothermal energy related to impact craters, one at Birka not far from Stockholm, and one in central Sweden, the so called Dellen prospect. At Birka, two wells were core drilled to about 1000 m, but the wells proved to be tight and were abandoned. The Dellen project is still in an early planning stage and exploration drilling might be executed in a couple of years as part of the Swedish Deep Drilling Program, SDDP, (Bjelm and Rosberg 2006).

Recently the National Science Foundation released 4 MUS to Lund University for purchasing and implementing a top of the line core drilling package capable of drilling to 2500 m in NQ size (76 mm). Lund has thereby the responsibility to serve all national Universities and research institutions in research related to deep drilling needs. The equipment can also be used abroad if such demands occur, Fig 6.

Figure 6: The National infrastructure for deep coring and sampling. Atlas Copco CT20.

5. RECENT IMPROVMENTS

5.1 The ATES sector

It is a common fact that ATES systems are sensitive for clogging and corrosion of wells and other system component. This problem was studied in the 1990: ties within the frame of International Energy Agency, the Implementing Agreement for Energy Conservation through Energy Storage (ECES). The processes that cause clogging and corrosion in ATES systems was defined and guidelines for minimizing such problems were developed (Andersson 1992). The main lesson learned is to design the wells carefully in order to avoid large draw down and hence pressure drops and to always keep the groundwater loop under pressure. This way stripping of gas and entrance of air to the loop is prevented and clogging by precipitation of dissolved iron minimized, as well as an enforced corrosion potential. These preventive measures have gradually been adopted by the ATES designers and installers by know-how transfer. In later time it has been used in the education of drillers/designers within the EU-project Geotrainet (Mc Corry and Jones 2011).

When it comes to well technology, nothing much has been developed the past decade. In most cases screened wells with formation filters are used in eskers and other glaciofluvial deposits. In consolidated sedimentary rocks simple “open hole” wells are applied. For treatment of wells the former method of using acid has totally been replaced by mechanical treatment methods. One such advanced method is using high speed rotation combined with high pressure jetting. This method, called Jet Master, and developed by Etschel Brunnenservice AS, has proven to be very efficient for development and cleaning of screened wells. An example of the treatment results of six wells at the Stockholm Arlanda Airport ATES plant is shown in Fig 7.

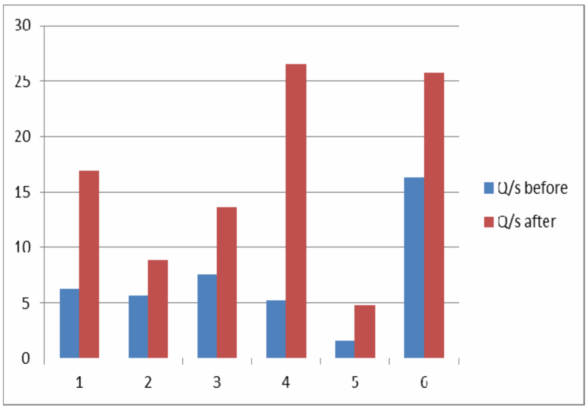

Figure 7: Specific capacity, Q/s, (l/s per m draw down) before and after Jet Master treatment of six screened wells at the Stockholm Arlanda Airport ATES plant

The treated wells were back to their original efficiencies and in five cases even slightly better. At construction these wells were developed by air lifting that is the most common method. It is obvious that the combination of vibration and high pressure of the water jets is more efficient than the air lift method. It should be noticed that the jetting treatment requires that the well is pumped during the process.

A substantial recent improvement of ATES is related to the highly developed control and monitoring systems. Potentially, the UTES systems can be equipped with sensors that make it possible to closely monitor the functions from a computer screen. It is also possible to have alarms on parameters that indicate malfunctions of almost any kind.

5.2 The BTES sector

A former technical problem for BTES has been to get rid of the air in the closed loop system, especially the large ones with several m^3 of fluid. The problem has shown to be micro bubbles that lower the efficiency of the system. To solve that problem, automatic vacuum gas removers are installed in recent larger BTES plants. This type of equipment works by continuously remove gas from a small portion of the flow. This method has proven to be an effective way to avoid problems with air in the BTES loops.

Water filled boreholes in which single or double U-pipes (BHE) are installed is fully accepted by the Swedish authorities. However, in special cases the authorities require tight boreholes, preferably by solid grout. Since grout limits the thermal efficiency, an alternative to grout has been developed. This BHE consists of a capsule inside which a centralized single pipe is installed (or a single or double U-pipe). By applying a hydrostatic overpressure in relation to the static level in the borehole, the capsule is pasted towards the borehole wall and effectively tightens it, see Fig 8. Field tests have shown that an overpressure of 0.3-0.5 bar is enough to keep the borehole tight (Pemtec 2010).

Figure 8: The capsule comes to the site, folded and easy to install with a bottom weight.

It has also been shown by experiments that the thermal borehole resistance will be favorable low (Acuna 2013). This new BHE has been successfully installed in approx. 200 boreholes. An advantage compared to grouted boreholes is that the function can be controlled and the capsule replaced if it should start to leak. Another is that the capsule is thin and does not reduce the thermal efficiency to a detectable degree.

The boreholes in BTES systems are expected to have a technical lifetime of 50-100 years. This is probably fulfilled, but one sensitive component in the system is the field manifold. The humid inside of traditional manifolds represent a corrosive environment that may cause damages to valves, monitoring equipment and perhaps other components. Moreover, they represent very narrow and inaccessible working places. For these reasons a couple more accessible and spacious manifolds have been developed and introduced on the market. One of these is shown in Fig.9. It consists of a large size plastic tube that is placed beneath the surface and in which manifold pipes are placed. Each individual borehole is connected to these pipes together with an adjustment valve and a flow deviser meter. The manifold system is placed below surface with an up sticking entrance, through which you can climb down on a ladder. Furthermore, it’s heated and ventilated and has light installed.

There are also pre-manufactured field manifolds to be placed directly on the surface. These are designed for plants with 30-60 boreholes and are well insulated in order to prevent freezing damages.

Figure 9: A new type of field manifold, that was first applied at IKEA Helsingborg 2010.

5.3 National geothermal platform

Even if Sweden has a lot of geothermal installations and is fairly well known by common people, the lack of awareness of the technology and what it represents is not very well known. This is especially the case among politicians and officials working in the authority sector.

The energy savings have proven to be substantial especially when UTES concepts are applied. The SPF value would in most cases be in the range of 4 -7. This will make those systems profitable. Hence, there is an on-going conflict between the established energy suppliers (owners of district heating and district cooling systems) and the representatives of the geothermal sector. This is one of several reasons for the forming a national geothermal platform named as requested by the Geotrainet program. The platform is named “Kunskapscenter Svensk Geoenergi” and is focused on the shallow geothermal sector. It was recently launched and will be a centre for collecting information and sharing that to all sectors of the society. It was initiated by and will be governed by the largest Swedish drilling association, Geotec.

One of the very first targets for Svensk Geoenergi will be to carry on with is to refine the existing statistics on shallow geothermal. This work will especially focus on UTES applications and large heat pumps that are missing in the statistics from SVEP. Already decided is to organize a geothermal conference combined with a workshop. The plan is to repeat this annually.

6. CONCLUSIONS

The battle of reaching single resident buildings has already been won. The future market for installation of small GSHP would preferably be limited to a mixture of new houses and “late users”. The prognosis for such installations would be in the order of 15-20 000 annually the next coming 2-3 years. The possibility to use the vertical systems for air conditioning may play an important role to choose boreholes prior to horizontal coils..

UTES concepts are steadily growing and have become commercially compatible alternatives for heating and cooling on the Swedish energy market. The main applications are so far connected to commercial and institutional building sector. By the end of 2012 some 300 MW has been installed. The current tendency indicates that BTES applications will continue growing with a rate of 10-20 % the next coming years. ATES applications expect to have a slower growth in number due to less geographical potential, but also to a time consuming legal procedure. Still, the plants being realized will be large sized.

Deep geothermal applications will continue to be a subject for exploration within the frame of the Swedish Deep Drilling Programme. However, it is not likely that new plant is to be realized in the nearby future. The only foreseen activity a year ahead is a planned new production well for the existing geothermal heat pump plant in Lund.

From a technical point of view the ATES systems have gone through a continuous development of well design and well installations. This development has resulted in increased well efficiency and measures have been developed to prevent the wells from clogging and corrosion. Development of advanced controlling and monitoring systems makes the systems easier to optimize and monitor. However, proper maintenance programs are still to be developed and standardized.

BTES applications have step by step seen a technical development as a natural part of the market growth. Failures that were common in the past are nowadays considered and the modern systems are running with a minimum of failures. However, the BTES technology is still under development, especially when it comes to drilling procedure and different components in the systems, such as borehole heat exchangers.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers*

*Geothermal power plants are not available in the country.

Table B: Existing geothermal power plants, individual sites*

*Geothermal power plants are not available in the country.

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH Plants		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2012	48	270				
Under construction end of 2012	none	none				
Total projected by 2015	48	270				

Table D: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commiss.	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geotherm. capacity (MW_{th})	Total installed capacity (MW_{th})	2012 geo-thermal heat prod. (GWh_{th}/y)	Geother. share in total prod. (%)
Lund	Lund Geotherm. HP plant	1985	no	no	33	48	270	69
total					**33**	**48**	**270**	**69**

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2012		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2012	425 000	4 600	15 200 *	24 500	270	4
Projected by 2015	500 000	6 500	21 500 *			

* HP electricity included

Table E/2: Shallow geothermal energy, Underground Thermal Energy Storage (UTES)

	In operation end of 2012			
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	of which free cooling (GWh_{th}/yr)
Aquifer Thermal Energy Storage (ATES)	150	150	800 *	350
Borehole Thermal Energy Storage (BTES)	400	140	800 *	150

* electricity excluded

Table F: Investment and Employment in geothermal energy *

	in 2012		Expected in 2015	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power	none	none	none	none
Geothermal direct uses	none	none	none	none
Shallow geothermal	2 500	3 000	3 000	3 500
total	**2 500**	**3 000**	**3 000**	**3 500**

* rough estimation

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	None	None	A few demonstration projects partly financed by the Swedish Board for Energy (STEM)
Financial Incentives – Investment	None	None	Part of investment (max 4 500 Euro of the labour cost) for a GSHP installation is deductible from tax the house owner (only for private residential houses). The same incentive is used for a number of other types of renovation work.
Financial Incentives – Operation/Production	None	None	None
Information activities – promotion for the public	None	None	Mainly through the platform “Svensk Geoenergi” arranging conferences/workshops and a Journal.
Information activities – geological information	None	None	Through a data base run by SGU
Education/Training – Academic	None	None	Only informative short courses or lectures at some Techn. Institutes
Education/Training – Vocational	None	None	-2 day courses for EED training, twice a year -2 weeks in education of new drillers, once a year

Key for financial incentives:					
DIS	Direct investment support	RC	Risc coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota