PROMOTING TES SYSTEMS IN SWEDEN

S. Gehlin

The Swedish Society of HVAC Engineers (SWEDVAC)
Vasagatan 52, SE-111 20 Stockholm, Sweden
Phone: +46-8-7916690
gehlin@siki.se

B. Nordell

Luleå University of Technology
Division of Architecture and Infrastructure
SE-971 87 Luleå, Sweden

1. BACKGROUND

Swedish nuclear plants are slowly being shut down as a result of a referendum in 1980. During the years after the referendum, four nuclear reactors were completed and taken into operation. The nuclear power then covered 50% of the Swedish production capacity resulting in large over capacity, which meant inexpensive electricity. For many years thereafter direct electrical space heating was the only feasible option. This development continued until direct electrical heating was used for about 30% of all space heating in Sweden. Swedish consumer prices were then about one third of that in most European countries. The much later deregulation of the electrical market and connection of the power grid to other European countries meant that Swedish consumer prices increased rapidly. Within a few years the prices are expected to be at the same level all over Europe and direct space heating is no longer a feasible alternative. This is why it is so attractive to Swedes to use heat pumps to reduce their electricity consumption. The present Swedish energy policy aims to a changeover from the use of prime energy sources to renewables. This is partly because of international agreements on the reduction of greenhouse emissions and partly to obtain a more independent energy system. Since the use of heat pumps mean that the electrical consumption is reduced by 70% and also means less emission to the atmosphere, heat pump systems have been encouraged by subsidies. This present subsidy, which covers about 15% of the investment, has been on and off during the last decades.
Now, the new EU directive on energy efficient buildings offers a platform for the promotion of thermal energy storage (TES) technology in Europe. Therefore HVAC engineers and civil engineers look for new methods to reduce electricity consumption and improve energy performance in new and existing buildings.

2. TES IN SWEDEN

Sweden is among the top 5 countries in the ranking of geothermal direct utilization worldwide, regarding annual use and capacity. Roughly 25% of all geothermal boreholes in the world are drilled in Sweden. Table 1 shows different ways of ranking the worldwide direct utilization of geothermal energy. In some of the cases e.g. for Iceland, Hungary etc. the utilized heat is from hot springs. In the case of Sweden, it is either storage or extraction of passively stored solar heat.

Table 1. Ranking of geothermal direct utilization worldwide by May 2005.

Use (TJ/year)	Capacity (MWt)	TJ/population	MWt/population
China	USA	Iceland	Iceland
Sweden	Sweden	Sweden	Sweden
USA	China	New Zealand	Norway
Iceland	Iceland	Georgia	Switzerland
Turkey	Turkey	Denmark	Hungary

After Lund et al., 2005.

The first ground-coupled heat pumps were installed in the 1970's and in the early 1980's geothermal heat, using smaller geothermal heat pumps, gained popularity in Sweden. By 1985 about 50,000 units had been installed and by 2005, about 275,000 residential units were in operation, annually producing 7.9 TWh of thermal energy (Lund et al., 2005). In addition to the residential sector, there are also numerous large district-heating networks to which 600 units, with an average heat power of 900 kWt, deliver 6 TWh/year [STEM, 2005].

At the end of the 1970's and during the next 20 years lots of theoretical research and field tests were carried out. Numerous research projects on ATES, BTES and CTES were initiated, mostly at Lund University of Technology, Luleå University of Technology, and Chalmers University of Technology. The Swedish Council of Building Research (BFR) was the main sponsor for these projects, and an extensive series of research reports were written and collected on BFR's account.

Several demonstration plants, of different types, were tested and evaluated. In 1982 the very first large-scale borehole heat store (120,000 m^3 rock volume) was constructed at Luleå University of Technology (Nordell, 1994). The following year the very first large-scale rock cavern heat store (115,000 m^3 water volume) was constructed in Uppsala (Kjellsson, 1983). There were also studies and tests on storage systems built in clay, soils, pits, and tanks for many different applications. All storage methods had their advantages, but the most generally feasible technique proved to be the borehole system.

Available national funding for TES research was partly directed to international collaboration. Most of this collaboration was carried out within the framework of the International Energy Agency (IEA). Sweden has been strongly engaged in the Energy Conservation through Energy Storage Implementing Agreement (ECES IA). One of the projects within ECES was Annex 8, Implementing Underground Thermal Energy Storage[1]. The overall objective was the promotion of TES in the eight participating countries. These countries are still among those who have had the strongest TES development. Annex 8 was finished in 2000 and by then the major obstacles for the widespread use of TES were defined. Several measures to speed up TES introduction were suggested: Education of engineers and students; Model development; Important UTES plants on the Internet; Marketing and industrial collaboration; Technical development; Legal and environmental aspects.

Among the Swedish population there is today a general awareness of TES technology that gives a unique position in the implementation and development of the technique. In small residential buildings, heating with geothermal heat pump is one of the most common heating systems, with an annual increase of about 30,000 systems. These systems deliver almost 15% of all space heating in Sweden of which one third is distributed by district heating. The market for larger TES systems is also increasing; though it is still considered a non-conventional technique. Most HVAC engineers and estate owners lack experience and education in these systems. Figure 1 show the accumulated development of heat pump installations operating in Sweden. Figure 2 shows the corresponding development for ground coupled heat pumps.

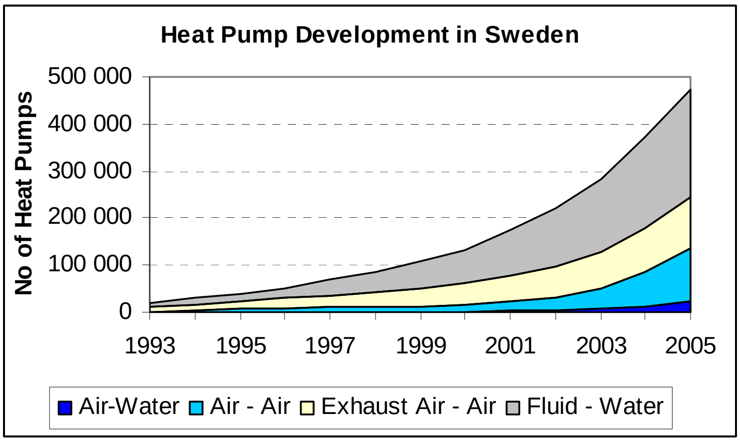

Table 2. Accumulated Number of Heat Pumps in Operation.

Air-Water	22 257
Air-Air	112 543
Exhaust Air- Air	108 999
Fluid - Water	230 094

Figure 1. Swedish heat pump development, 1993-2005. It was estimated that 10,000 Exhaust Air-to-Air and 10,000 Fluid-to-Air Heat Pumps, installed before 1993, are still in operation in 2005. [SVEP, 2005]

[1] http://www.ltu.se/web/shb/~bon (Thermal energy storage, Annex 8 Final Report)

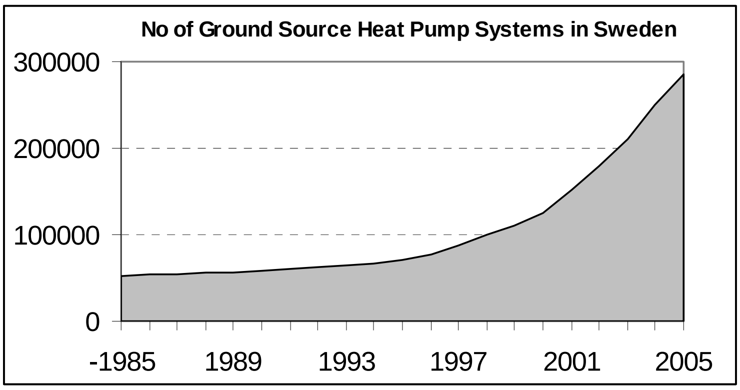

Figure 2. Number of TES projects in Sweden 1985 -2005. A few systems extracting heat from lakes and rivers are included. (SVEP, 2005)

3. PROMOTING FORCES AND BARRIERS

Various factors have coincided to create the favourable conditions that have brought TES technology forward in Sweden. During the 1980's, as a result of the recent oil crisis, the Swedish government encouraged research on alternative energy systems. This led to a great number of different heat pump applications.

Nice green technology: After three decades, the number of ground source heat pumps continues to grow. One important factor for this success is that people in general like the idea of extracting heat from the cold underground. It is like a "miracle" and this has been an important driving force for the rapid growth in single-family houses. In larger commercial buildings (hotels, schools, offices etc) the system was used to market the owners' green image.

Economy: TES has been a relatively good investment. The value of the heated house increased with the investment, which also gave an annual payback considerably higher than the interest rate. The subsidies always work but it was rarely an argument for why the system was built.

Independence: During the recent decade hundreds of larger borehole systems for residential areas with tenant-ownerships, usually with a heat demand 250-1000 MWh, have been built for still another reason. The tenant-owners wanted to free themselves from the district heating companies who could dictate the conditions as long as there were no alternatives available.

Technical development: The mobile thermal response test equipment (Gehlin, 2002) was important for the implementation of large-scale borehole systems. This test method, which was developed in the 1990's in the US and Sweden, gives site specific thermal properties of the ground. This simple measurement method demonstrates to consulting engineers and property developers, in a very convincing way, how and why the system will work.

Geology: The Swedish geology means generally good conditions for BTES systems. This means a commonly shallow soil layer on top of crystalline bedrock, and a groundwater table merely 5-10 m below ground surface. The climate has a large temperature difference between summer and winter and offers a good potential for seasonal storage.

Legislation: Present legislation and regulations have simplified the construction of TES systems, though it varies in different parts of the country. Many other countries have requirements on backfilling boreholes with grouting of some kind, but such regulations do not exist in Sweden. Neither do restrictions in drilling depth exist.

Market: Swedish drilling companies are organised in two national associations, both of them marketing the systems. The Swedish heat pump branch has been well organised on a national level and Swedish experts have been active within IEA activities regarding TES in general and heat pump technology. The IEA Heat Pump Centre is located in Borås, Sweden.

Politics: The new EU directive on building energy performance with a demand on energy efficiency has led to a revived interest in alternative techniques for heating and cooling of buildings and a greater awareness of primary energy and exergy-thinking. This, in conjunction with the implementation of lifecycle analyses for buildings and building services, also speaks in favour of TES. There are today also several severe obstructing factors for the further development of the TES market in Sweden.

Research One obstructing factor is diminishing research funding and the recent confusion in research support for TES, caused by the closing of BFR in 2000, and the re-organisation of governmental research funding to the two new authorities FORMAS (The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning) and STEM (the Swedish Energy Agency). In this re-organisation, TES technology has sadly become a marginalised research area. One reason was probably that for many years the contribution of TES to renewable energy was not clearly understood. In national energy statistics heat extracted from the ground was referred to as energy saving. The role of storage was not properly recorded and thus not well understood.

Publication: There is a rather weak interest in TES from media. A few technical magazines with connection to energy have been reporting on TES activities, but the discussion on TES is still largely going on through international scientific journals. This means that there is little educational material available for practitioners, such as design engineers, contractors and estate owners. A small number of experts have deep knowledge in TES, and these experts are involved in more or less all TES projects. Efficient communication of TES technology and examples to practitioners and the building sector are essential for the further development.

Education and training: Today no extensive TES education is available in Sweden. The only courses for practitioners are within heat pump technique, e.g., maintenance for technicians. One single university course on TES is available in Sweden, at Luleå University of Technology. Approximately 20 engineering students follow this unique course every year.

4. HVAC AS AN ADVOCATE FOR TES

One barrier for TES technology is the lack of a natural affiliation. Since TES is a technology right on the boundary between heat/cold production and building services, the connection is not obvious.

Since 2002, the Swedish Association for HVAC Engineers (SWEDVAC) has taken an active part in promoting TES technology in Sweden. The connection is natural between HVAC and TES. Energy efficient heating and cooling of buildings are strong parts of the HVAC field. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is another HVAC association that has adopted TES technology to some extent. ASHRAE runs an active technical committee (TC 6.8) working on geothermal energy utilization (www.ashrae.org). The committee has initiated a number of research projects, and is responsible for the chapter on geothermal energy technology in the ASHRAE Handbook. In Europe the connection between HVAC associations and TES is not yet established. Within the Federation of European Heating and Air-Conditioning Associations, REHVA, TES technology is rarely mentioned. Only a small number of REHVA's 30 national associations have adopted TES as part of their field.

SWEDVAC takes part in promoting TES in several ways. Through the association's local chapters, numerous lectures and seminars on TES have been held all over Sweden, reaching out to HVAC contractors as well as consulting engineers. Several of these seminars have been arranged in cooperation with other organisations, such as drillers and contractors etc., and in conjunction with the biggest Swedish HVAC and Building expo, Nordbygg. During the last three years SWEDVAC has offered a unique two-day course on basic UTES. The course has been very popular and many engineers, estate owners, drillers and contractors have passed the course. The efficiency in promoting TES through these courses is evident and immediate. They have generated several TES projects and pre-investigations all over Sweden.

Another important tool for the promotion of TES by SWEDVAC is the monthly technical journal Energi & Miljö (Energy & Environment) that SWEDVAC is editing. Technical articles on BTES technology are frequently published, as well as general articles on various UTES projects, which help to establish TES as a known technology and a part of the HVAC field. Further initiatives are a BTES handbook for engineers, and a newly formed technical committee on TES.

The connection to HVAC is positive for TES technology, as the HVAC engineers are those who recommend and design energy systems for commercial and residential buildings. Considering the aim of the new EU directive on energy efficiency in buildings, the extended use of TES is a key to success.

5. MARKET NEEDS

The immediate need for the TES market is communication and education. In Sweden several projects have been shown to be economically beneficial and competitive. Increasingly more applications will be profitable with the expected rise in price of electricity. As for the technology, there are still gains to be made by developing more efficient manufacturing processes (especially for PCM elements) and larger series. There is a need for more user-friendly design software, especially in terms of visualisation and combinations with other building services systems such as solar collectors etc.

Communication is the key market need. It is essential to establish a natural affiliation for TES technology, and HVAC may in many ways be the right way to go. With an established affiliation, further communication of TES technology may be done in an organised and efficient way, via education efforts, books, media contacts and efficient lobbying.

Few books on TES are available today, in Swedish or in other languages. Some books, mainly on a scientific level, written in 1980’s and 1990’s, are available at libraries, and a small number of academic theses from recent years may be found. ASHRAE provides a few books on geothermal heat pump technology, mainly based on American standards and regulations. Also some German literature of recent dates exists. Little is written in Swedish, which is unfavourable when communicating TES to practitioners and estate owners. There is a need for modern TES literature for engineers, practitioners, and consumers.

Popular science articles and project descriptions in magazines are an efficient way to enhance the public awareness of TES. SWEDVAC has experienced a demand for practical courses and workshops on TES technology, directing installation, operation and maintenance of TES systems. Good examples and follow-ups need to be communicated, as well as failures.

It is essential to the future of TES technology in Sweden that more experts are educated on BTES design and on performing thermal response tests. These new experts must also establish contacts with TES experts worldwide and continue to represent Sweden in IEA and EU projects on TES.

6. CONCLUSION

Various factors have coincided to bring TES technology forward in Sweden, making Sweden one of top 5 countries in the ranking of geothermal direct utilization worldwide. Generous research funding during the 1980’s, favourable climatic and geological conditions as well as favourable legislation and a traditional environmental engagement are some of these factors. Severe barriers for the further development of TES market in Sweden have been recently diminishing research funding, weak media communication, lack of education opportunities on TES, scarce modern TES literature, and the lack of a natural affiliation for TES technology. Since TES is a technology on the boundary between heat/cold production and building services, the connection is not obvious.

Since 2002, the Swedish Association for HVAC Engineers (SWEDVAC) has taken an active part in promoting TES technology in Sweden. Heating and cooling of buildings as well as energy efficiency are strong parts of the HVAC field, thus making the natural connection between HVAC and TES.

The current bottle-neck for the TES market is communication and education. With an established affiliation within the HVAC field, further communication of TES technology may be done in an organised and efficient way, via education efforts, books, media contacts and efficient lobbying.

REFERENCES

Gehlin, S (2002). Thermal Response Test. Method Development and Evaluation. Doctoral Thesis. 2002:39, Luleå University of Technology, Sweden. http://epubl.luth.se/1402-1544/2002/39/LTU-DT-0239-SE.pdf

Kjellsson, E (1983). The Lyckebo Project – Solar district heating with seasonal storage in a rock cavern. Int. Conf. Subsurface Heat Storage in Theory and Practice. Stockholm June 6-8, 1983

Lund, J.W., Freeston, D.H.& Boyd, T.L. (2005). Direct application of geothermal energy: 2005 Worldwide review. Journal of Geothermics 34, Elsevier, 691-727.

Nordell B (1994). Borehole Heat Store Design Optimization, PhD-thesis 1994:137D. Div Water Resources Eng., Luleå University Technology. pp.250.

STEM, 2005. Energy supply in Sweden. (Energiförsörjningen i Sverige). Report No: ER2005:20. Swedish Energy Administration. 2005-08-15.

SVEP, 2005. Swedish Heat Pump Organization, Stockholm.