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Country Update for Sweden 2023

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ABSTRACT

This paper presents the current status of geothermal energy use and market development in Sweden. There is a wide-spread use of geothermal energy in Sweden, dominated by shallow geothermal energy systems. These are typically using a heat pump to extract heat from the ground, and the bulk of the installed systems are vertical or horizontal ground source heat pump systems for space heating and domestic hot water heating in single-family houses. The market for such small geothermal systems has been relatively stable over several years, while the market for larger residential and non-residential shallow geothermal energy systems for heating and cooling is growing. The Swedish geology mainly consists of hard crystalline rock with low geothermal gradients. Hence the conditions for shallow geothermal energy use are favourable, while the conditions for traditional deep geothermal energy use are less favourable. No deep geothermal energy systems for power production exists in Sweden. Since the mid 1980's there is one large-scale geothermal heat plant in operation in Lund in the southern part of Sweden, providing heat pump supported geothermal heat to the district-heating network. In recent years the interest in deep geothermal heating in Sweden has grown, which has resulted in several deep geothermal exploration projects. Shallow geothermal energy is the fourth largest renewable energy source in Sweden. In 2021, shallow geothermal energy systems provided approximately 18.8 TWh (67 680 TJoule) of heating from the ground (no heat pump electricity included). The installed heating capacity is 7 280 MW_{th}. In addition to this geothermal heat, 1-2 TWh cooling is provided as ground source direct-cooling.

1. INTRODUCTION

The geothermal energy utilization in Sweden was largely triggered by the oil crises in the 1970's and 1980's. At that time there were nationwide efforts to achieve an oil-independent energy system. This led to the promotion of heat pump technologies and was further favoured by the national power production strategy based on nuclear power and hydropower. During the 1990's the heat pump technology and ground source heat pump (GSHP) technology developed rapidly in Sweden, resulting in a world-leading role in the GSHP research and industry.

In Sweden the focus of the geothermal market and development is mostly on shallow geothermal systems. Deep geothermal exploration has so far resulted in one geothermal district heating plant, the Lund geothermal plant in the south of Sweden. It was established in the 1985 and is still in operation (Aldenius 2017). It has a moderate depth of 700-800 m and has an extraction temperature of around 20°C. In the early 2000`s several unsuccessful efforts were made to utilize deeper geothermal resources in Sweden. Instead, the shallow geothermal applications, in particular vertical boreholes as a heat source, and underground thermal energy storage (UTES), have grown rapidly. Lund and Toth (2020) lists Sweden as top three world leading country in geothermal energy utilisation, in terms of installed capacity and extracted thermal energy.

2. GEOLOGICAL AND CLIMATE CONDITIONS

The Swedish geology (Figure 1) is characterized by the massive Baltic shield and its diverse crystalline eruptive and metamorphic rocks. In the southern parts of the country, sedimentary rock formations of significant thickness are found, spot-wise containing porous sandstones at considerable depth and with very good hydraulic properties.

The geothermal gradient varies in the range of 15-25ºC/km. The higher value represents a geothermal well in the sedimentary basin in SW Sweden (Gustafson et al. 1979), while the lower values (15-19°C/km) were found in deep boreholes in the Baltic shield region (Odén 2013). Rosberg and Erlström (2019 and 2021) presented gradients between 22-24ºC/km for two wells drilled through the sedimentary basin and further into the basement (3700 and 3330 m deep) in southernmost Sweden. Lorenz et al. (2015) presented a gradient of 20ºC/km for a deep well in the Swedish Caledonites.

The basement consists mainly of solid granites, and gneisses. The rock is suitable for Down-The-Hole (DTH) hammer drilling and has a generally low groundwater yield. Shallow geothermal boreholes are drilled to a depth down to 450-500 m without any major problems, though drill depths are more commonly in the range 250-300 m.

Groundwater in the form of aquifers is mainly found in eskers. These are glaciofluvial deposits from the melting of the inland ice that covered Scandinavia some 10-20 000 years ago. The eskers with highly permeable gravel and sand deposits are located along the river valleys where also the population is dense. Apart from the use of eskers for drinking water supply, these eskers are also of interest as groundwater-based shallow geothermal systems for heat or cold extraction, as well as aquifer thermal energy storage (ATES). A limited number of large aquifers are also found in the sedimentary rock, mainly located in the southernmost part of Sweden. Mesozoic sandstones and limestones are successfully used for shallow geothermal systems in these areas.

Sweden has a climate that varies widely from north to south. The climate in the southern half of the country is temperate continental while it is continental climate in the northern half. The variation in average high summer temperatures is small, with 21ºC in the south and 20ºC in the north. However, the variation during the winter season is more pronounced, with average temperatures varying from -3ºC in the south to -14ºC in the north (climatedata.eu 2019). The seasonal swing between summer and winter is favourable for underground seasonal storage systems. Ground temperatures at a depth of 100 m vary between +9ºC in the south and +2ºC in the north. The ground temperature features the annual mean temperature in the air at the location, but is slightly higher in the north due to the insulating effect from snow cover in the winter.

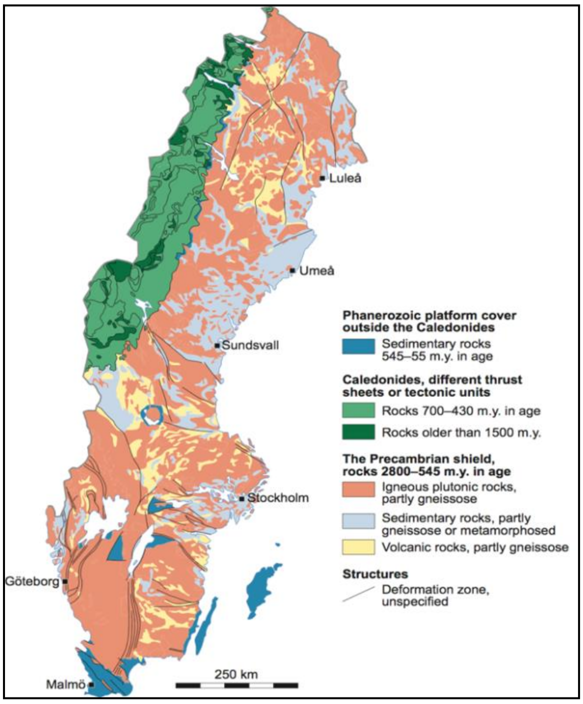

Figure 1: The bedrock geology of Sweden (© Swedish Geological Survey)

3. DEEP GEOTHERMAL EXPLORATION

The first geothermal well (Höllviksnäs-1) was drilled and tested in 1977-78. It indicated a large potential in the Bunter sandstone at 1800-2000 m (Gustafson and Andersson 1979). In the next step a full-scale geothermal district heating plant was designed for a nearby village (Andersson 1980) but was never built. These initial exploration projects resulted in the Lund Geothermal Heat Production plant in Värpinge, which has been in operation since 1985. Low-temperature, initially 22°C, saline water is extracted from and reinjected into a sandstone aquifer located between approximately 500 m and 800 m depth (Bjelm and Alm, 2010).

Initially, four production wells were pumped with a flowrate of 450 l/s (1620 m^3/h) at an average temperature of 21ºC. After heat extraction the water is reinjected into five injection wells, normally at a temperature of 3ºC. The medium distance between the two well groups is on the order of 2.1 km. The geothermal fluid is used as the heat source for two heat pumps with a combined nominal capacity of 47 MW. At its peak in 1993, the plant produced 350 GWh of heat, providing 40% of the energy in the Lund district heating network Aldenius (2017). Between 2015 and 2020 the heat production was between 100 and 140 GWh/year and in 2021 the production was 68 GWh. The decrease in production is mainly due to an increased amount of waste heat and co-generation heat production in other parts of the district heating system and is therefore not related to the geothermal well capacity. In December 2021 the geothermal heat pumps were shut down due to the unusually high electricity price. By 2021 the plant had produced approximately 8 TWh of heat, replacing some 800 000 m^3 of oil.

In 2002, Lund Energi AB (today Kraftringen AB) and the Department of Engineering Geology at the Lund University started a geothermal exploration project, with the aim of finding hot water in fractured crystalline bedrock associated to the Romeleåsen Fault Zone (e.g., Rosberg and Erlström, 2019). Two wells were drilled, the first borehole, DGE-1, was drilled to 3702 m depth, and penetrated the sedimentary succession before entering the crystalline basement at 1946 m depth. The drilling of the second well, DGE-2 was stopped at 1927 m depth after penetrating the sedimentary succession. Around that time Sydkraft (today E.ON) drilled two wells, FFC-1, 2110 m deep, and FFC-2, 2801 m MD or 2120 m TVD, for exploring the deep seated sandstone aquifers within the Mesozoic succession in Malmö (Tengborg and Erlström, 2007). An impact structure was investigated for geothermal purposes at Björkö in lake Mälaren, west of Stockholm at the same time (Henkel et al., 2005). None of the projects were commercialised.

In 2016, around 10 years after the projects in Lund and Malmö were terminated, the interest for EGS (Enhanced Geothermal System) applications in the crystalline basement increased. The increased interest was driven by the EGS exploration project in Espoo, Finland with the focus on the Fennoscandian bedrock (Kukkonen and Pentti, 2021, and Malin et al., 2021). E.ON (a large European electric utility company) initiated a geothermal exploration project to investigate the potential for applying EGS-plants in the city of Malmö, in the south of Sweden. In 2020, after several years of feasibility studies, a decision was made to re-enter FFC-1, the well drilled in 2002, as mentioned above. The objectives were to obtain information such as drilling performance using air-percussion drilling, evaluate seismic monitoring during the drilling operation, obtain information about rock types, fracture intensity and characteristic, as well as information about hydraulic, mechanical, and thermal properties. The initial plan was to deepen the well from about 2100 m depth to 4000 m depth using air-percussion drilling. The drilling method was only used for around 90 m of drilling and was found infeasible, due to too high inflow of formation fluid. The subsequent drilling was conducted with conventional rotary drilling using a solid-free salt polymer mud and it was used to the new target depth of 3133 m. Data from the crystalline basement section acquired during and after the drilling is compiled in Rosberg and Erlström (2021). The bottom hole temperature in FFC-1 is of 84.1 °C and the calculated mean temperature gradient is 23.5 °C/km in the upper part of the crystalline basement, down to 2610 m depth and below 2880 m the calculated mean temperature gradient is 17.4 °C/km. The zone in between seems to be thermally disturbed. The lower gradient is more like gradients measured in other deep wells located in the Fennoscandian basement, see comparison in Rosberg and Erlström (2021). The EGS exploratory project in Malmö is for now put on hold.

In recent years a feasibility study to use EGS-plants for district heating production has been conducted in Gothenburg. The project was a cooperation between the energy company Göteborg Energi and Gothenburg University, but the project has now been closed. In 2021, a borehole was drilled with continuous core drilling in crystalline bedrock to 1000 m depth. The temperature at the bottom of the first borehole is 23.4 °C with a calculated mean temperature gradient is 15.1°C/km. In 2022 a second core drilling was done to a depth of 987 meters and with a 20-30 degrees inclination. The temperature at the bottom of the second borehole is 22.2°C. Temperature and acoustic televiewer loggings were conducted in the boreholes.

Despite the moderate geothermal gradients in the Swedish geology, the interest in deep geothermal energy in Sweden has increased in the last few years. However, the possibility to produce geothermal power in Sweden is very limited, considering the low geothermal gradients. It is conceivable that geothermal resources at depths down to 5-7000 m, in the future may be utilized for heat pump supported district heating applications.

4. SHALLOW GEOTHERMAL RESOURCES AND POTENTIAL

While the predominant crystalline rock in the Baltic shield provides little potential for deep geothermal exploitation, it provides the more potential for shallow geothermal energy use. The granites and gneisses are normally solid with a generally low groundwater yield, which makes them favourable for drilling holes down to 200-300 m or more without technical problems.

The Cretaceous formations in Skåne are, at many locations, suitable for GSHP or ATES applications, often in large scale. In other areas with less or no groundwater it has become common to drill boreholes for closed systems and BTES applications. The limestone and chalk is easily drilled to depths of 300 m or more. In these deeper boreholes, commonly pipe sizes DN45 or DN50 are used in borehole heat exchangers. The sedimentary rock in the rest of Sweden mainly consists of Precambrian and Cambrian sandstones, Ordovician limestones and Silurian shales with a total thickness of 300 m or less. These are covering a minor part of the surface area. On the islands of Gotland and Öland the limestones are commonly used for closed GSHP applications.

Using groundwater from shallow aquifers as thermal source for heat pumps has a vast potential in those areas where either eskers or sandstone and limestone formations are present. About 10% of the Swedish land area contains aquifers suitable for shallow geothermal energy utilization, and approximately 25% of the population lives in these areas (Andersson and Sellberg 1992), However, using groundwater is strictly regulated making the real potential for shallow geothermal groundwater utilization considerably lower.

All in all, the potential for ground source heat pump (GSHP) systems throughout Sweden, using the ground (rock or soil) or groundwater as heat sources, is very high. The vast majority of the Swedish shallow geothermal energy systems are vertical boreholes in hard rock, serving as heat source for heat pumps to single-family houses. There are bout 2.1 million single-family houses in Sweden, and approximately 20-25% of these houses are heated with a GSHP. Market development for these small systems has been strong over many years, with a peak in 2006. Between 2016-2021 an average of around 15 000 new GSHP systems per year have been installed in Sweden. The market for larger GSHP systems for residential and commercial buildings as well as for underground thermal energy storage (UTES) for large facilities is steadily growing. The two main UTES categories are Aquifer Thermal Energy Storage (ATES) and Borehole Thermal Energy Storage (BTES). These are used for both heating and cooling purposes, preferably combined. Geothermal energy is considered an environmentally friendly technology by the general public and tends to increase the commercial value of a building. Geothermal energy has played a major part in replacing fossil fuels in heating the Swedish building stock, especially for small residential buildings.

5. SHALLOW GEOTHERMAL UTILIZATION

The typical shallow geothermal energy system in Sweden is a vertical groundwater-filled borehole drilled in crystalline rock, connected to a ground source heat pump (GSHP) used for extraction of heat for space heating and domestic hot water (DHW) in a single-family house. The heat pump compressor is run on electricity.

Horizontal ground loops are used for heat extraction for heating and DHW in some small buildings in Sweden, especially in the southern parts of the country. As they require larger surface areas these systems are mostly found on the countryside where sufficient space for the loops can be more easily found than in urban areas. In Sweden these systems are used only for heat extraction.

Shallow geothermal energy systems for larger buildings in Sweden occur both as GSHP systems and underground thermal energy storage (UTES). GSHP systems for larger residential buildings often require some kind of active recharge, such as waste heat from exhaust air or solar heat. Commercial buildings typically apply boreholes or aquifers for extraction and storage of both heating and cooling.

Vertical boreholes in rock and groundwater wells are also used for free cooling only. Such systems are mostly applied in the telecom and industrial sectors, but there are rare examples of low-temperature geothermal free heating and cooling applications also for residential and commercial buildings, developed and described by Skanska (2014). In these systems no heat pumps are used (Liu and Chang 2020). The housing company HSB has also developed a ventilation concept called Geo-FTX where boreholes are used for pre-heating of ventilation air in residential buildings (Kempe and Jonsson 2015, Kempe et al. 2021).

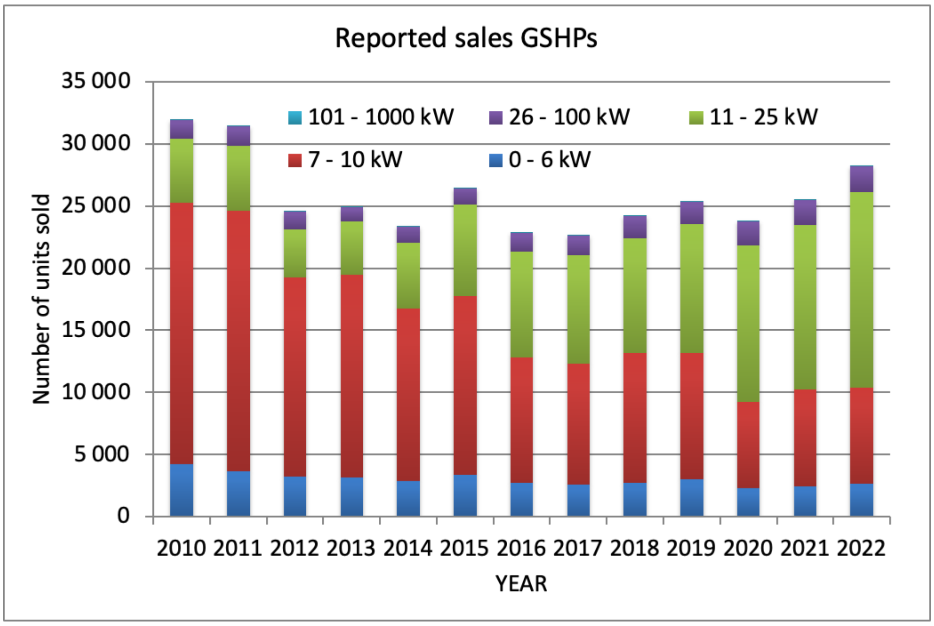

Figure 2: Reported GSHP sales in Sweden (SKVP 2023)

Figure 2 shows trends in sales for GSHP units in Sweden between 2010 and 2022. Sales volumes for smaller fluid-to-fluid heat pump units (<10 kW) have decreased with three fifths between 2010 and 2022. Improved energy efficiency in buildings, competition from air-source heat pumps and an ambition to minimize the need for supplementary heating while maximizing the heat pump use, are likely explanations to this development. Sales volumes for larger GSHP units with capacity >10 kW for single-family buildings, multi-family buildings and commercial buildings have tripled since 2013. The biggest increase is seen for heat pump sales of units with a capacity between 11-25 kW for the single-family house market, which compensates largely for the decreased sales volume of smaller heat pump units. Larger heat pump units (>100 kW) are not always reported to the Heat Pump Association. Hence, many of the largest systems are missing in the statistics.

Figure 3 shows the number of borehole meters drilled between 2010 and 2022 and registered in the Swedish Geological Survey (SGU) Database. The data for 2022 is incomplete due to a delay in registration to the well database and are expected to reach the same level as the previous years, once all entries have been registered. The number of drilled meters per year has been relatively stable over the last decade, with 3.3-3.4 million drilled meters per year.

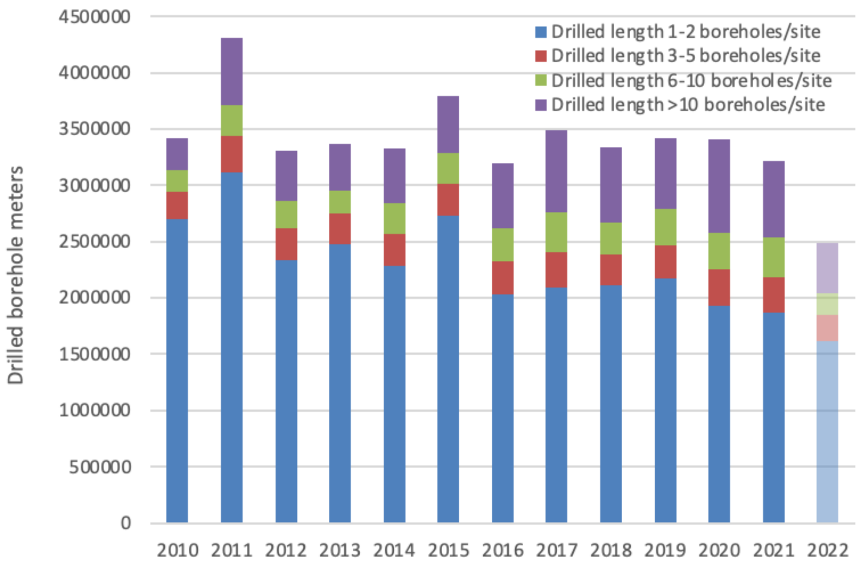

Figure 3: Reported annual number of drilled borehole meters for different system sizes. (SGU 2023).

The trend with increasing borehole depth for GSHPs and BTES systems that started in the late 1990's when drill rig compressor capacity increased, as mentioned by Gehlin and Andersson (2016) and Gehlin and Andersson (2019), has continued. The overall average borehole depth in Sweden in 2021 was 203 m, as compared to 162 m in 2010 and 193 m in 2018, an increase with ~1-2% per year (SGU 2023).

Based on the sales volumes for GSHP units reported to the Swedish Heat Pump Association (SKVP 2023) around 630 000 ground source heat pumps were installed in Sweden by the end of 2021. Roughly 475 000 of these are vertical closed loop borehole systems while some 145 000 systems are estimated to be horizontal loops in soil and lake sediments. An estimate of 10 000 systems are open loop systems using groundwater or surface water as the heat source. This figure has been near constant over time with only a handful new registered systems per year. Since 2016 around 22 000 new ground source heat pump units in sizes ranging from 3 kW to 25 kW have been installed per annum, with an increasing trend in 2021 and 2022. These numbers include heat pump units that replace units installed before 2000. Many of those older GSHPs have now reached the end of their technical life and need replacement. In 2020 GSHP sales were slightly affected by the general financial decline due to the pandemic, but bounced back in 2021, despite component shortage due to the temporary world-wide shortage of semi-conductors. New installations of larger GSHP units (>25 kW nominal capacity) increased by 27% between 2016-2021.

The calculated heating energy provided by GSHP systems in Sweden in 2021 reached 25.5 TWh (gros), of which 18.8 TWh (net) was provided by the ground source. The total installed GSHP nominal capacity was 7.3 GW in 2021. The calculations assume an average heat pump running time of 3500 hours/year. In addition to this, ATES and BTES systems provide approximately 1-2 TWh free cooling from the ground. The latter estimation is derived from an assumption that approximately 1000-2000 systems run with 1000-2000 full load hours of cooling on average. Commercial and institutional buildings often need cooling throughout the year and may reach 2 000 full-load hours. Within the residential sector the need for comfort cooling is approximately 500 full-load hours annually. A small number of ATES and BTES systems are used for cooling only and may reach 4 000 full-load hours per year.

6. LARGE SYSTEMS

The figures in chapter 4 and 5 above include a steadily growing number of large ATES (≥100 kW) and BTES (≥1000 borehole meters) systems, typically providing both heating and cooling.

6.1 ATES systems

ATES systems use groundwater for carrying the thermal energy into and out of an aquifer. The wells are normally designed with a double function – both as production and injection wells. Energy is stored in the groundwater and in the grains (or rock mass) that form the aquifer. An estimate of some 210 ATES plants with a capacity of 100 kW or more are installed in Sweden, as of 2022. This estimate is based on the number of boreholes that are classified as “energy wells” in the SGU well data base and are not deep enough to belong to the closed system category. The largest ATES systems (>1 MW) are fairly well known from engineering reports, articles etc.

Systems larger than 100 kW nominal capacity are estimated to account for a total of some 195 MW. These are mainly located in aquifers in eskers, sandstones, and limestones (Table 1). In addition to these ATES plants, there are approximately 320 installed groundwater-source heat pumps with an average capacity of 50 kW. Some of these may still be ATES applications, but the majority is probably used for heat extraction only within the residential sector.

Table 1: Estimated number and size distribution of ATES plants with a capacity ≥ 100 kW

Capacity size (MW)	Number of units	Total capacity (MW)
0,1-0,49	125	40
0,5-0,99	50	40
1,0-5,0	30	75
>5,0	5	40
Sum	**210**	**195**

Typical ATES system storage temperature levels are 12-16ºC on the warm side and 4-8ºC on the cold side (Andersson 2007). One of the largest ATES systems in Sweden is the Stockholm Arlanda Airport ATES plant. An esker is used for seasonal storage of heat and cold. The cold is used for air conditioning of the airport buildings, while the heat is used for pre-heating of ventilation air and for snow melting at some airport gates. Cold is stored at 2-3ºC and heat at 20-25ºC. The system has been designed for a capacity of 10 MW and uses no heat pumps. The system delivers 22 GWh of heat and cold annually (Arvidsson 2016).

The very largest ATES plant in Sweden was designed in 1998 for short-term storage for cooling. It is connected to the district cooling system for Stockholm City and was designed for a cooling capacity of 25 MW for peak shaving during hot summer days. Due to well problems it is working at approximately 15 MW capacity. The working temperature is +3/+14ºC and when fully charged it holds around 1 000 MWh of cold (Andersson 2007).

6.2 BTES systems

Swedish BTES systems typically consist of multiple closely spaced groundwater-filled boreholes of 150-300 m depth in crystalline rock. Single or double U-pipe borehole heat exchangers (BHE) are commonly used, and the storage temperature typically ranges between +2ºC in the winter and +8ºC in the summer, though some systems with direct-cooling may reach +16°C in the summer. BTES systems have been in use in Sweden since the 1970’s and 1980’s (Gehlin 2016).

By the end of 2022 there were about 5500 GSHP and BTES systems with more than 1 000 borehole meters and near 2500 systems with 10 boreholes or more registered in the Swedish Geological Survey Well database (SGU 2023).

The number of new large GSHP and BTES systems per year has been relatively stable over the past decade (Table 2 and Figure 4). On average around 50 new systems with >20 boreholes have been registered in the well database annually since 2016. Figure 4 shows that systems with 20-50 boreholes account for a major part of these systems. The numbers for 2020 and 2021 are incomplete due to a lag in registration of borehole systems in the SGU well database of up to 3 years.

The largest BTES system in Sweden is still the BTES system at the Volvo Powertrain plant in Köping, constructed in 2015-2016. The system has a total of 215 boreholes with average borehole depth of 270 m, and a total borehole length of 58 200 m (Svensk Geoenergi 2017).

Two high-temperature BTES systems are currently in operation in Sweden: The Anneberg residential plant and the Xylem Emmaboda HT-BTES plant. The Anneberg HT-BTES has been in use for seasonal storage of solar heat for residential heating of 50 houses since 2002. It uses no heat pumps and has a measured solar fraction of 40% after 12 years in operation (Heier 2013). Many of the system components (solar collectors and control system) are now reaching the end of their technical life span and in 2021 a process started in which the future of the HT-BTES will be decided. An option is to decrease the storage temperature, replace the solar collectors with PV panels and install heat pumps.

The Emmaboda Xylem HT-BTES plant is used for seasonal storage of industrial waste heat, as well as for process cooling. To make the storage more efficient heat pumps were installed in 2018 and the storage temperature was decreased to work at 20/40°C (instead of designed 40/60°C). The installation of heat pumps improved the system efficiency greatly as is shown in the case study report from the IEA HPT Annex 52 project (Andersson et al. 2021).

Table 2: Number of new BTES systems of various sizes reported in SGU Database *(SGU 2023)*

Year	Units 1-2 holes	Units 3-5 holes	Units 6-10 holes	Units 11-19 holes	Units ≥20 holes
2000	5673	134	27	8	4
2001	7886	151	26	6	2
2002	12989	227	41	10	7
2003	14875	294	52	25	4
2004	18260	381	78	21	7
2005	18987	569	142	39	9
2006	20833	609	154	43	23
2007	14279	555	171	50	34
2008	10862	489	146	62	33
2009	13387	392	114	37	16
2010	15377	404	136	39	26
2011	17303	517	187	75	46
2012	12824	434	163	69	36
2013	13559	416	141	50	35
2014	12344	426	180	57	32
2015	14564	424	178	73	38
2016	10511	406	191	71	50
2017	10741	457	213	86	60
2018	10740	367	182	76	54
2019	10896	393	187	70	46
2020	9583	425	195	97	57
2021	9249	409	197	88	43

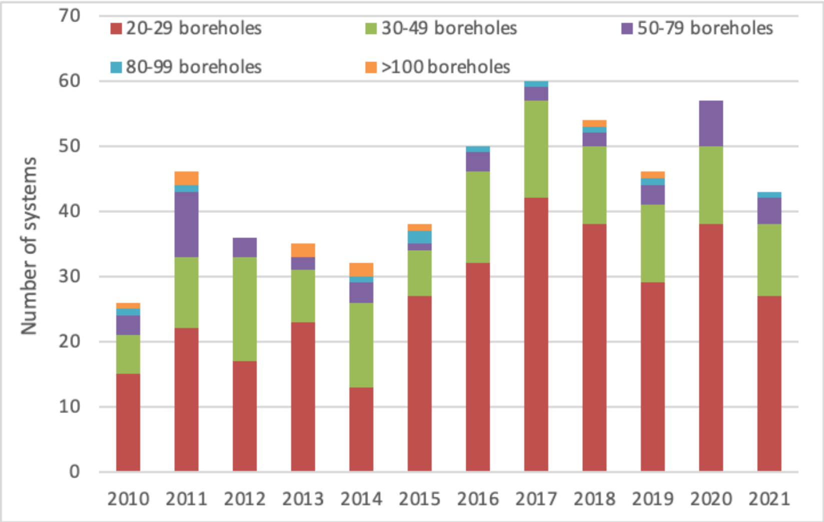

Figure 4: New large BTES systems 2010-2021 registered in the SGU Well Database. (SGU Well database 2023).

7. MARKET TRENDS

The market for small residential building GSHPs has been relatively stable since the previous World Geothermal Congress country update (Gehlin et al 2020) and the market for larger GSHPs and UTES applications is growing, despite uncertainties in material delivery, increased material cost and component shortage due to the pandemic in 2020-21 and the Ukraine war starting in 2022. Several recent EU initiatives encouraging an increased implementation of heat pumps in Europe, as well as rising energy prices in Sweden, have stimulated the Swedish geothermal energy market. The GSHP sales during the fourth quarter of 2022 was very strong. In parallel with this, the photovoltaic (PV) market sky-rocketed in Sweden in 2022, where many households and multi-family buildings combine GSHPs with PV for increased implementation of renewable energy resources.

The on-going research program TERMO (Swedish Energy Agency 2017) on heating and cooling technologies, run by the Swedish Energy Agency has funded and stimulated several R&D projects related to geothermal energy and thermal energy storage. The research program encourages development of geothermal and thermal storage applications combined with district heating and small to medium scale thermal networks. Several research and development projects related to geothermal energy have been initiated with funding from the TERMO program. These include studies of new high-temperature ground heat exchangers, and high-temperature underground thermal energy storage applications, as well as deep geothermal exploration projects. One of the funded TERMO projects is the Swedish participation in the international collaboration project IEA HPT Annex 52 on long-term performance measurements of large GSHP systems. The project closed in 2021 and Sweden contributed with 14 case studies (IEA HPT Annex 52, 2022). Sweden was part of the EU supported InterReg project CoolGeoHeat that focused on the fifth generation (5G) district heating and cooling with integrated thermal energy storage. The project was completed in September 2022 (CoolGeoHeat.eu, 2023). Sweden also currently participates in the international collaboration project IEA TCP ES Task 38 – Ground Source De-Icing and Snow Melting Systems for Infrastructure. The project is running until the end of 2024 and has its focus is set on geothermal systems for de-icing and snow-melting (IEA ES Task 38 2023).

Triggered by the deep drilling SP-project in Otaniemi (Espoo) in Finland there has been a growing interest in Sweden for Enhanced Geothermal Systems (EGS) in the crystalline basement. This has resulted in several workshops, seminars, funding applications and exploration projects since the last country update. However, after the Finnish deep geothermal project in Otaniemi was stopped, also Swedish deep geothermal activities have slowed down.

8. DISCUSSION

The statistics on number and size of shallow geothermal applications in Sweden suffer from lack of officially proven data. The numbers given in this paper are based on two main sources, (1) annual heat pump unit sales figures in the capacity range 0-1000 kW (i.e. units for single and multi-family buildings), collected by the Swedish Heat Pump Association from 1982-2022, and (2) registered boreholes for energy utilization in the open source well database at the Swedish Geological Survey (SGU) over the period 1980-2023. Other sources, especially for larger projects, are various engineering reports, reference lists from drilling contractors and HVAC installers, articles in newspapers and magazines, etc.

The heat pump sales numbers reported by the Swedish Heat Pump Association, include only sales from those manufacturers that are members of the heat pump association, which, however, accounts for approximately 90% of the total sales. The numbers presented in this paper are adjusted with regards to the market share of reporting manufacturers. The sales figures do not include every large heat pump, as the largest heat pumps tend to be built on site; hence many large heat pumps (>80 kW nominal capacity) are missing in the data. On the other hand, there may in several cases be multiple heat pump units installed at one site, in order to cover the full capacity need. This means that the number of GSHP systems may be either underestimated or overestimated by some percent. Replacement heat pump sales have been accounted for in the statistics by estimating the technical life span of the sold heat pumps to 20 years, and only adding the difference between total sold heat pump units and the estimated number of replacement heat pumps each year, as new systems.

Although it has been obligatory since 1978 to register all drilled wells in Sweden, it is a well-known and proven fact that far from all drilled boreholes and wells for shallow geothermal are in fact registered in the database. The Swedish Geological Survey has estimated the fraction of un-reported boreholes to be between 20-40%. The fraction of registered wells and boreholes is believed to increase over the latter years as a result of fruitful information campaigns and improved tools for reporting. There is still a lag in registration of boreholes to the database, especially regarding multi-borehole systems. This means that boreholes may not be registered until a year or two, sometimes even longer, after they were drilled.

Another uncertainty is the amount of geothermal energy (heat or cold) provided by the geothermal systems. The estimates are based on theoretical analyzes in which it is assumed that the major parts of installed GSHPs are designed to cover 60% of the building load the coldest day of the year. The result is an average full load running time for the system of 3500 hours in average during a normal year. This figure includes production of domestic hot water. Due to differences in climate zones over Sweden, the number of full load hours will be lower in the south and higher in the north. In addition to that, newer buildings tend to have considerably lower heating demand than older buildings, and the heat pumps installed in newer buildings are normally designed to cover the entire building heating demand without the need for supplementary heating sources.

9. CONCLUSIONS

The pandemic in 2020-21 and the war in Ukraine in 2022 temporarily slowed down the growth in geothermal energy in Sweden to some extent. However, the market for GSHP and UTES systems has continued to grow and even had a boost at the end of 2022. Geothermal energy systems are recognised as favourable commercial alternatives for new or retrofit, system for heating and cooling.

For many years, Sweden has been rated number three world leading country in geothermal energy utilisation (Lund and Toth, 2020) and is yet unthreatened as the leading geothermal energy market in Europe. The Swedish market is completely dominated by shallow geothermal energy. Deep geothermal resources are comparably limited, as geothermal gradients are low and the bedrock is hard and cold. The potential for geothermal power production in Sweden is even lower. However, stakeholders are taking steps to drill deeper in the Scandinavian crystalline bedrock to achieve higher temperatures. This effort seems to be partially linked with the increased interest in the fourth and fifth generations district heating and cooling with lower source temperatures and integrated renewable energy sources.

The current energy prices in Sweden are remarkably high due to the war in Ukraine. The long-term effect on the geothermal market is yet to be seen, and shallow geothermal systems are dependent on moderate electricity prices for running the heat pumps. The cost of fossil fuels also significantly affects the drilling cost, which in turn affects the willingness to invest in geothermal projects. On the other hand, the goal to use less fossil fuel in favor of renewable energy sources, and the environmental benefit from geothermal energy speaks in favor of the future use of shallow geothermal.

Although the geological conditions in Sweden are non-favourable for deep geothermal power and heat production, there is currently a definite budding interest in deep geothermal energy for district heating. Geothermal energy, shallow and moderately deep, significantly contributes to the Swedish energy goals for 2030, and has the potential of contributing to an even larger extent in the future.

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