Geothermal Energy Use, Country Update for Finland

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ABSTRACT

In Finland a strong growth in the amount of all types of HPs started from the year 2005 with less than 100 000 HPs up to today`s 900 000 HPs of which about 140 000 GSHPs (Sulpu 2019). HPs replace the earlier popular oil and electric heating systems in small houses and sometimes also replaced district heating. The strongest growth has taken place in air-coupled HPs but also the increase of GSHPs was last year over 8000 units which means again a slight upward trend since 5-6 years` decline before, but not reaching anymore the historical top of 14 000 in 2011 (Fig. 1 and 2). After that the growth of GSHPs has been slower due to the stronger growth of air-to-water HPs (25 % 2018), and in common decline of building activity. But still today over half of new small houses utilizes GSHP technology for heating and cooling, and an increasing number of large buildings like office buildings, school houses, apartment buildings, shopping centres, markets, hospitals, churches prefer GSHPs for heating and especially cooling of spaces. Many of them preserve parallel coupling to district-heating and solar systems. So a clear increase and trend is seen toward large GSHP installations but still today domestic systems are growing fastest. As a growing sector are apartment houses in cities, which switch district heating to shallow geothermal energy, but still having district heating as a supporting/complementary energy source.

The largest installation still in Finland is in the logistics centre in southern part of Finland, 30 kilometers northward from Helsinki, with 150+150 closed-loop BHEs (two separate buildings) each 300 m deep (total 90 000 m). This energy field/installation has been provided by an advanced real-time fibre optic monitoring system designed by Geological Survey of Finland GTK and being in function since 2012.

A few mega class projects are on the way or in design phase. They are mainly shopping centres with hybrid energysystems combining geo+solar or geo+district heating. This size of projects is growing faster than earlier. An estimate for the total amount of mega class targets/projects so far (total BHE >10 km or more), is between 20 - 25.

New business models have been developed, and the first service models have appeared with all investments by sellers and the customer only pays for used energy.

EGS pilot

The first EGS - pilot project, run by a private company St1 Nordic Oy, and aiming to utilize geothermal energy from 6 – 7 kilometer`s depth for district heating with a thermal power of 40 MW , is situated in southern part of country, in the city of Espoo. The first borehole has reached the final depth of 6,4 kilometers, and the second hole has been drilled to 3,3 kms. The decision to continue the project and drill the second hole (production well) to final depth will come his year. The project started 2015 with a core sample boring up to 2 km`s depth into the crystalline granitoidic bedrock. This hole was made for research purpose only (petrology, seismics..). The decision to continue the project, and drilling of the second (production) hole to final depth, will be done during 2019 after finalized the analysis of the stimulation results.

Moreover an other licence to an other company is permitted, but no activities yet.

Energypiles

Energypiles for storing and extracting of geoenergy for heating and cooling, have aroused a growing interest, especially in urban areas and some projects are under construction.

Groundwater for cooling and heating

A couple of projects are on the way for extracting groundwater heat and cool.

Shallow geothermal potential map

The publication of the first Finnish shallow geothermal energy potential map by GTK (2016) (Fig.3) and its second more sophisticated, quantitative version GTK (2018) influenced an extra jump forward in utilizing GSHPs, and cities and districts are now interested to know about their geothermal energy potential.

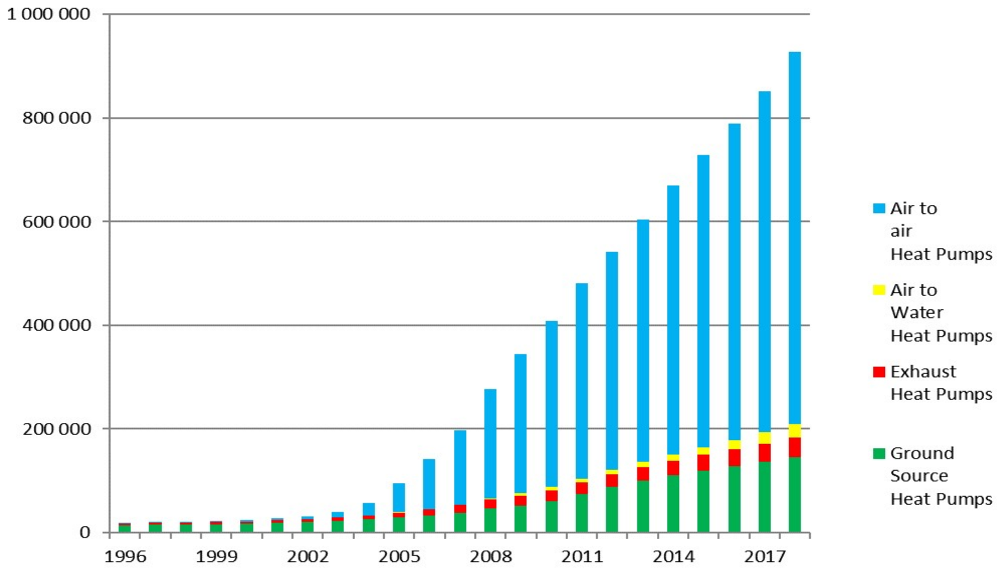

Fig. 1. Heat pump sales in years 1996 – 2018 (Sulpu 2019).

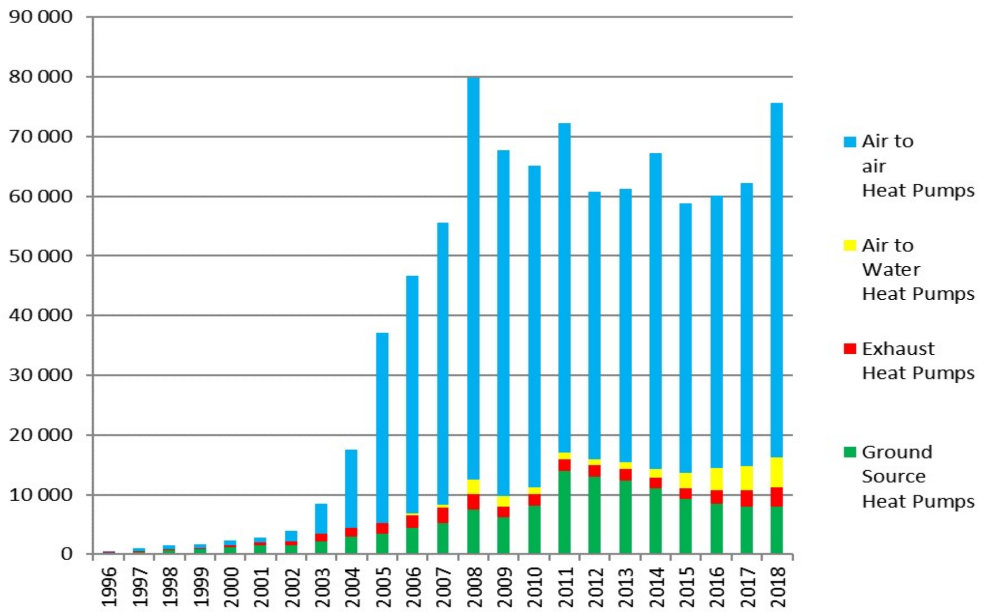

Figure 2: Annual heat Pump installations in Finland in years 1996-2018. (Sulpu 2019)

1. GEOLOGICAL CONDITIONS IN FINLAND

The Finnish bedrock/crust consists of Pre-Cambrian, (Archean) crystalline, metamorphosed ”thick” , cool craton, consisting of granitoids, migmatites, gneisses and schists with smaller areas of younger sandstones. Only 3 % of land is exposed as outcrops. Brittle deformation by fractures and cross-zones, filled with moving ground-water (reservoirs), gives favourable conditions for geoenergy exploitation. Low average temperatures of ground, around the year (2 – 8 Celsius) give good chances for increasing need of free cooling during summertime. Bedrock preserves summer heat until winter/spring and enough cold from winter over summertime. The bedrock is covered by Quarternary (< 10 000 yrs) sediments, clays, silts, fluvial sands, moraines, mires. Thickness of these are typically a few meters (2-6 m), sometimes > 30 m(– 50 - 60m and more). Over 9% covered by water (lakes, rivers).

All Fennoscandian Shield is low enthalpy area. The geothermal gradient is usually 8-15 K/km. The low gradient is due to the Precambrian geology, with a very thick lithosphere (150-200 km). The average thermal conductivity of Finnish rocks is 3.24 W/(m K) (Kallio & al 2011). Thermal conductivity is controlled by the mineral composition, texture and porosity, and jointing of the rock and moreover movements of groundwater. Typically maximum ground temperatures at the depth of 300 m are around 10 – 12 Celsius in southern Finland. For example in the Pyhäsalmi ore mine (central Finland) , in the depth of 1450 m, the temperature is about 22 °C. At Outokumpu area (eastern Finland) in the depth of 2500 m, the temperature is 40 °C. To reach 100 Celsius, depths from 6 to 8 km are required (Kukkonen 2000). It is expected that the bottom temperature of the Otaniemi 6,4 kms is around 100 – 120 C (no official information is available).

This means that no EGS systems have not been so far economically attractive but the present on-going pilot in Espoo Otaniemi hopefully will show the real economic and technical possibilities to utilize geothermal deep heat in Finland. There are some plans and trials to utilize medium deep 1000 - 2000 m geothermal heat especially for district heating of groups of houses and smaller communities, city areas, but without success so far.

The cool bedrock in Finland is very suitable for (free) cooling which makes the geoenergy system more profitable. The heat from cooling is transferred back to bedrock increasing the heat capacity. So far in Finland all geothermal energy comes from shallow geothermal energy sources, from the uppermost layer, 150-300 m (400m), of the crust. GSHPs are commonly used for heating. Free circulation through wells without GSHPs works in most cases for cooling.

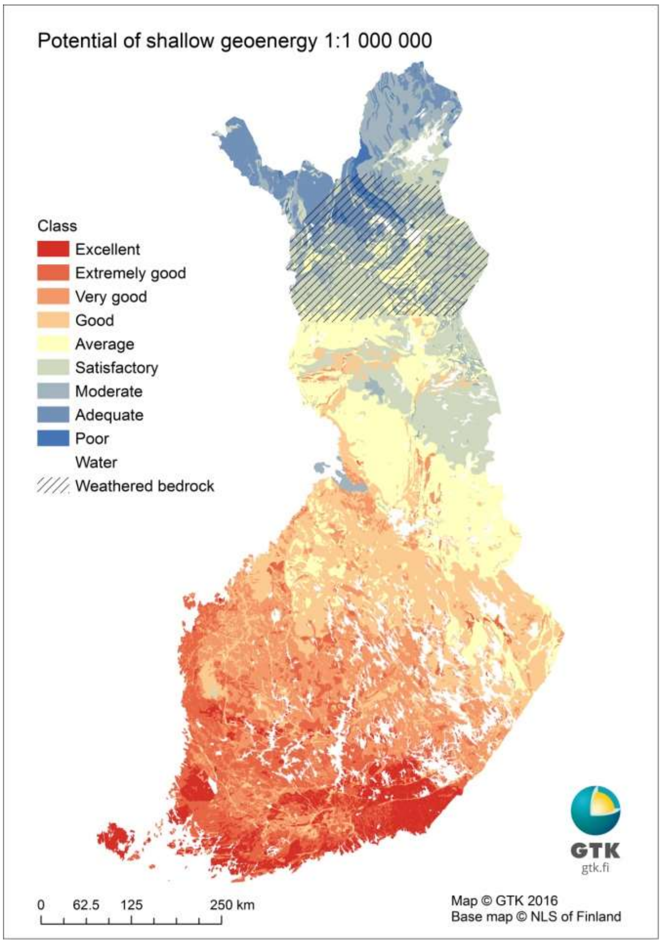

Figure 3: A qualitative shallow geothermal energy potential map from Finland (GTK 2016). A quantitative version was published 2018 (GTK).

2. TECHNOLOGIES IN USE

Only closed loop BHE-systems are in use with alcohol (ethanol) based fluid circulating in exchangers (pipes/co-axial/wells). The exchanger is typically a single or double U pipe with typical diameter between 32-40 mm. Some new innovative co-axial exchangers have emerged and under trial. Well depths are typically 150-300 m, with a tendency to go deeper down to 400 - 600 m. Spacing between single wells is 20m +/- and geometry mostly rectangular.

Today many of the large systems are hybrid renewable energy systems consisting of two or more energy sources (geo-/bio-/solar/district heat). In summertime surplus heat from air conditioning (cooling) is transported into e-wells " loading" the field for winter uptake, making the rock act as an Underground Thermal Energy Storage (UTES), in this case as a BTES. Often hybrid systems for peak loads are used and welcome. Some hybrids especially in the city areas utilize shallow geothermal energy together with district heating as for the Meilahti hospital in Helsinki, which is a geo-/district heat hybrid system (Fig. 3). The building is coupled also to district heating grid.

Fig. 3: Meilahti Tower Hospital (Helsinki University Hospital), a hybrid of geoenergy+district heating. Picture by Harri Kutvonen .

There are also some apartment houses in cities, which have changed to geoenergy with no coupling to district heating grid.

The used drilling technique is Down Hole Hammer (DHT) and no grouting is needed/used so far but has been tested and can be used especially in groundwater areas.

Planning, calculating and modelling of large geothermal installations are typically based on TRT – measurements and other local on –site research, and it is also recommended for all planners to use experts for this work. The value of this research has been understood more and more as a necessary and basic back-ground work for a successful final result. It gives the needed empirical planning parameters. Geological

Survey of Finland GTK utilizes also DTS- method as a routine method in its services for planners, (Fig. 4)

Figure 4: Distributed temperature system (DTS) measurements with fibre optic cable. Photo by I. Martinkauppi.

3. R&D CHALLENGES

The theoretical and basic research (theory for applications) in Finland is mostly run by GTK. It has very comprehensive geological and geophysical data bank collected during tens of years. All Finland has been covered by air borne geophysics. GTK has also two mobile TRT- vans/units for in-situ surveys (Fig. 5). Also resources are focused on research, especially to theoretical behaviour and modelling of an single energy well as well as multi hole storage systems, and for determining the thermal properties of bedrock from layer to layer using fiber optic thermometers combining TRT- method and called DTRT- test. Moreover large installations/hybrid systems including real-time monitoring and steering of energy uptake from a field are under active research. Some trials with bentonite grouting have been run. A new challenge for research and applications will come from the need to go deeper, to depths of 1000-2000 m.

4. CONCLUSIONS

Geothermal energy or geoenergy (as the shallow geothermal energy is called in Finland) has taken remarkable jumps forward during the last five years. The HP boom started with air-coupled HPs, still prevailing and most sold, but the trend is shifting today more and more to GSHPs both in small house as well as in large projects. The future seems positive and geoenergy takes even greater share from the renewable energy palette. The governmental target to be set for the year 2020 is now 8 TWh representing about 10% of the energy needed for heating of houses. With the present trend this figure will be surpassed.

Figure 5: The thermal response test unit (TRT) of GTK in operation. Photo I. Martinkauppi

The yearly total energy consumption for space heating (houses) in Finland is 70-80 TWh of which HPs deal is about 15 %, and of which GSHPs produce about 8-9 %. The yearly increase of HP`s is estimated to be around 1 TWh (Sulpu 2019).

Today about 40 % of the consumed energy in Finland is produced by renewables. Geothermal energy has taken an important and visible role in the renewable energy production of the country.

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SULPU (Finnish heat pump association), 2019 (www.sulpu.fi)

GTK (www.gtk.fi)

Tables A-G

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

There are no geothermal power plants in Finland

Table B: Existing geothermal power plants, individual sites

There are no geothermal power plants in Finland

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

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for buildings		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)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2018	none							
Under constru-ction end 2018	40		none		*		none	
Total projected by 2020	80							
Total expected by 2025	80							

* 10 % of the city Espoo`s district heating

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

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2018		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2018	140 000		6000	8000	100-150	>50%
Projected total by 2020						

Table F: Investment and Employment in geothermal energy

	in 2018		Expected in 2020	
	Expenditures (million €)	Personnel (number)	Expenditures (million €)	Personnel (number)
Geothermal electric power				
Geothermal direct uses				
Shallow geothermal	400	3000-5000	700	7000-9000
total	**400**	**3000-5000**	**700**	**7000-8000**

Table G: Incentives, Information, Education

	Geothermal electricity	Deep Geothermal for heating and cooling	Shallow geothermal
Financial Incentives – R&D			DIS
Financial Incentives – Investment		DIS	DIS, LIL
Financial Incentives – Operation/Production			none
Information activities – promotion for the public		yes	yes, by Sulpu, companies, GTK, municipalities
Information activities – geological information		yes	From GTK, companies
Education/Training – Academic		yes	some courses in basics at universities
Education/Training – Vocational			by organizations in heat pump business and by vocational high schools

Key for financial incentives:					
DIS	Direct investment support	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)