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Geothermal Energy Use in Norway, Country Update for 2015-2019

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ABSTRACT

Geothermal energy use has increased in popularity in Norway. The total estimate of direct use of geothermal energy in Norway is 3.0 TWh. This represents 30 % growth since the 2015 WGC report. The majority of geothermal energy systems are geothermal heat pump (GHP) installations extracting or storing heat by BHEs in crystalline rocks. Single U –pipe is still the preferred technology regarding collectors.

1. INTRODUCTION

1.1 Government setting, policies and interests

Hydropower has historically been the backbone of the Norwegian power system. The hydropower accounts for around 95% of the total installed power capacity and has a large reservoir capacity of 85 TWh. The predominance of clean and low-cost hydropower makes Norway's power production nearly emission free. In Norway about 80 % of the heating demands are covered by direct electricity or heat

pumps (Bøeng, 2005) and thus, the energy use in buildings has already been almost decarbonized. The transport sector is decarbonizing. Today are 45 % of the new cars electrical(Elbil.no). Ferries and boats are also converting to electricity. By 2021, Norway will have 60 ferries in batteries (Stensvold 2017).

Norway has a long tradition of requirements for airtight and well insulated building envelop and constrains in energy use in buildings. The current structure of the energy performance requirements was introduced in 2007 (Statens Bygningstekniske Etat 2007). The requirements have been progressively tightened and the latest tightening, in 2016, placed energy performance requirements at passive house levels (Norge 2017; TEK 2016). The government aims to introduce a near-zero energy use standard by 2020 (Comission 2002). In 2016, the parliament also tasked the government to reach an absolute savings target of 10 TWh in existing buildings by 2030 (IEA 2017). The government also banned fossil fuel heating systems from new buildings in 2016 and is considering ways to ban fossil fuel use for all space heating from 2020 (IEA, 2017)

Norway is not a member of EU, but as a member of the European Economic Area (EEA), Norway shares internal market legislation with the European Union and has therefore implemented several European Union directives and regulations related to energy.

1.2 Lead agencies involved in geothermal development and funding

The Norwegian Water Resources and Energy Directorate (NVE) manage Norway's water and energy resources. NVE is a directorate under the Ministry of Petroleum and Energy. The directorate aims to promote efficient energy markets and cost-effective energy systems, and to contribute to efficient energy use. NVE bears the overall responsibility for maintaining national power supply.

Enova is a state-owned enterprise established in 2001. Its goal is to help reducing greenhouse gas emissions and increase the security of energy supply. Enova contributes to stable market changes for energy and climate solutions and supports the development and deployment of more energy- and climate-efficient technologies. Enova's main instruments are investment aid, conditional loans, and advisory services. Enova has an annual budget of more than 300 million Euro (IEA, 2017).

The Energi21 strategy is the Norwegian national strategy for research, development, demonstration and commercialization of new, climate-friendly energy technology. The fourth Energi21 strategy was launched in 2018. Development of integrated digitalized energy systems is overall priority area in the new strategy.

2. GEOGRAPHY AND GEOLOGY BACKGROUND

Norway is a country in Northern Europe comprising the western and northern part of the Scandinavian Peninsula. Norway mainland has an area of 324 000 km^2 and a population of 5.3 Million.

The climate is warmer than expected for this high latitude, varying between warm coastal dominated climate in the western regions, to colder weather in mountainous regions and inland or polar dominated climate in the eastern and northern regions.

Norway is located on the Fennoscandian Shield. The bedrock consists of Precambrian rocks with a belt of Caledonian rocks extending from SW to N Norway. Permian volcanic and intrusive rocks are found in the Oslo region. The porosity of the crystalline bedrock is low (Midttømme et al. 2010). The lithosphere is cool and thick and characterized by a low heat flow density varying between 50 and 60 mW/m^2 (Slagstad et al, 2009, Pascal, 2015).

3. GEOTHERMAL RESOURCES AND POTENTIAL

3.1 Geothermal Heat Pumps

Nearly all geothermal energy utilization is by means of geothermal heat pumps (GHPs). The majority of the GHPs are vertical closed-loop systems extracting energy (heat and cold) from crystalline rocks by use of borehole heat exchangers (BHE). The first known GHP system was installed in 1978 (Midttømme et al. 2008). Today there are more than 60 000 GHP installations.

3.2 Direct Use of Geothermal Energy

In 2018 a geothermal de-icing system was started at Oslo airport Gardermoen. The heat is extracted from two 1500 m deep BHEs. The BHEs is equipped with special designed coaxial collectors.

There have been investigations for deploying a geothermal based district heating system, but so far, no geothermal district heating (DH) has been established. There is a majoritarian move towards low temperature DH nets. This development owes to the reduced losses and increase of district heating network efficiency. This will make it easier to integrate renewable energy sources and especially geothermal energy in DH systems.

3.3 Geothermal Power

There are no installations or plans for developing geothermal power onshore in Norway. Offshore electrification is discussed as a measure to reduce the greenhouse gas emissions. Reusing abandoned oil and gas wells for geothermal energy production is considered an alternative for electrifying the offshore industry. This alternative competes with platform electrification via off-shore wind power.

4. GEOTHERMAL UTILIZATION

4.1 GHP – closed loop systems

The Nordic Countries have been among the leading countries on utilizing GHP (Lund et al., 2015). Single U –pipe collectors in a water-filled-no-grouting-borehole (d=115 mm) is the dominating solutions for Borehole Heat Exchanger (BHE). Many of the large GHP installations are Borehole Thermal Energy Storage (BTES) installations for both heating and cooling purpose. In general, the GHP systems are designed with an imbalance between heating and cooling, due to heat demands in Norway exceed cooling demands. Still, the cooling peaks may be substantially higher than the heating peaks. In new buildings, such as the ZEB Powerhouse Kjørbo, the dimensioning of the borehole park was done based on covering the cooling demands via free cooling.

All new boreholes shall be reported in the national database operated by the Geological Survey of Norway (NGU). The Norwegian Heat Pump Association (NOVAP) is also reporting yearly the sale of brine – to water heat pumps for the NOVAP members. There are uncertainties in both data registrations and there is a significant amount of installations that have not been reported, especially for early years.

The data of new GHP installations reported to NGU (Figure 1) show a growing trend with the maximum number of installations reported in 2013, when 3450 new installations were drilled.

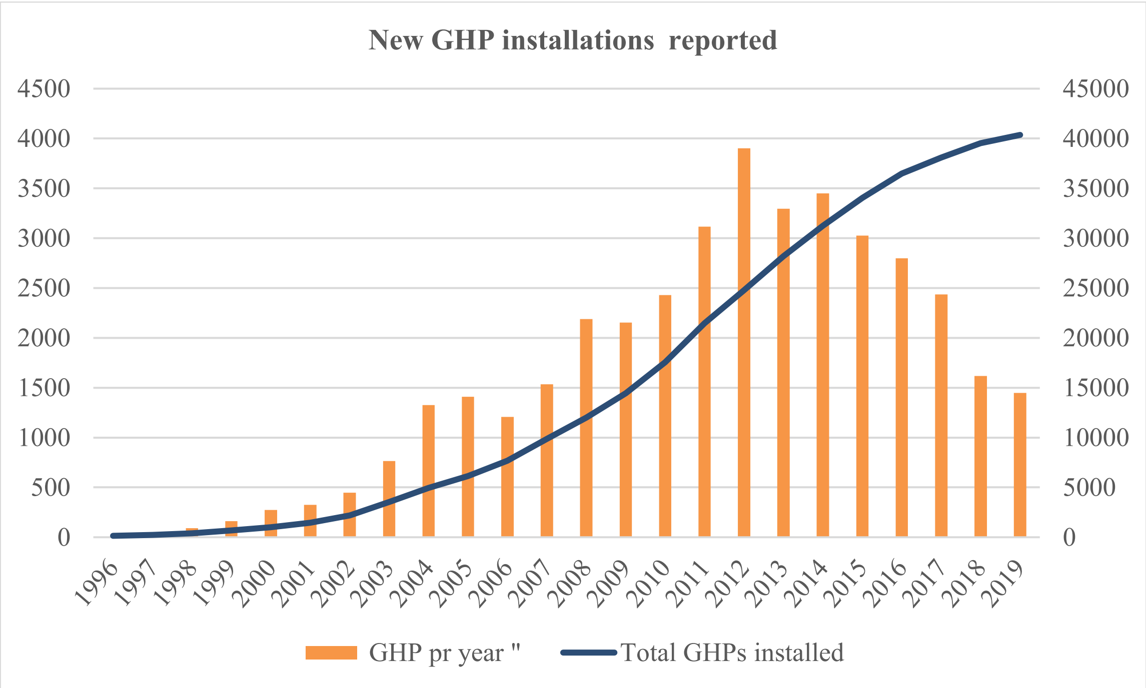

Figure 1: New GHP system reported to Geological Survey of Norway (NGU). The left y-axis shows the number of new installation pr. year shown by the orange columns. The right y-axis shows the accumulated number of installations reported. This is shown with the blue line.

Among the reported GHP installations, 1100 are large installations with more than four BHEs or open systems with direct use of groundwater (Figure 2). The trend for large installation is similar to that for all installations with increasing number of installation until 2015 but with a decreasing trend for the latter years. The maximum number of large systems installations was reached in 2014 and 2015 with 109 new large installations being reported.

It is not investigated if the decrease in reported installations during the last years is real or if it is due to underreporting. A fact that may be behind the sales decrease can be the reduction of the subsidies from Enova that was reduced from 100 000 NOK (10 000 Euro) to 10 000 NOK (1000Euro).

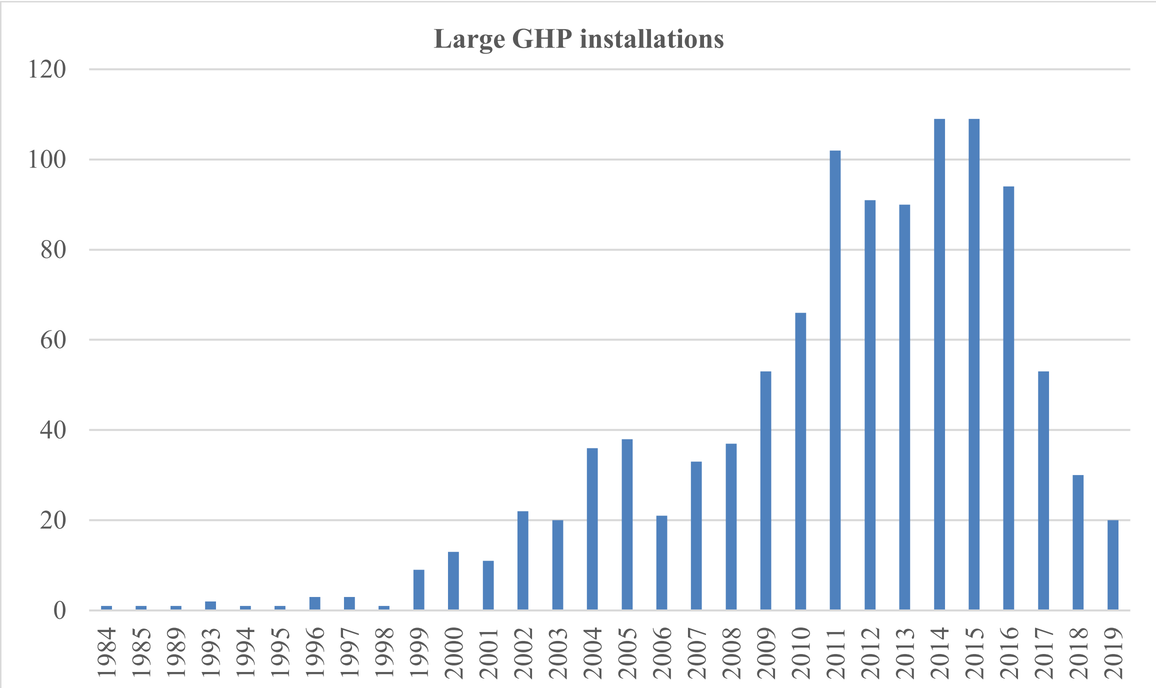

Figure 2: Reported new large GHP installations with four or more BHEs

Norway has been known for the large BHE installations. The largest GHP installations with an accumulated total borehole length above 10000 meters are listed in Table 1. The last three new large installations constructed after 2015 are marked with green color in Table 1.

Table 1: Reported GHP installations with total BHE length more than 10 000 m

Name	Boreholes	Average depth	Total borehole meters	Year
Ahus Hospital	228	200	45600	2007
Nydalen Business park	180	236	42500	2004
Sartor center	165	200	33000	2013
Arcus	91	300	27300	2012
Østfold Kalnes Hospital	100	244	24429	2013
Ullevål Stadion	120	200	24000	2009
Coop Åsane	114	209	23874	2013
Marikollen middle school	84	278	23327	2017
Stavanger Forum	85	250	21250	2011
Haukeland Hospital	77	243	18730	2012
Thon Sørland Center	90	200	18000	2011
Post Terminal, Lørenskog	90	200	18000	2010
Ørlandet Air Force Base	72	250	18000	2016
Western Norway University,	81	220	17820	2012
IKEA, Oslo	86	200	17200	2009
Univ. South East Norway	70	244	17110	2009
Torp Airport	60	250	15000	2012

Speilen Mandal	90	160	14400	2011
Bergen Kommune	48	294	14100	2015
Ericsson-office building	56	248	13872	2002
Ramstad school	45	250	12650	2012
Røyken Kommune	41	300	12300	2014
Kongsberg Kulturpark	38	300	11369	2014
Smedvig Eiendom	54	200	10800	2011
BTV	50	201	10050	2011

Borehole heat exchangers' length is continuously increasing (Kvalsvik et al. 2019; Midttømme et al. 2016). The average length of a single BHE for large GHP installations (with four or more BHEs) is shown in Figure 3. The average BHE length for the installations constructed in 2018 and 2019 is above 250 m. In 2016, two 800 meters deep BHE were completed in Asker and in 2018, two 1500 meters deep BHE were drilled at the Oslo Airport Gardermoen.

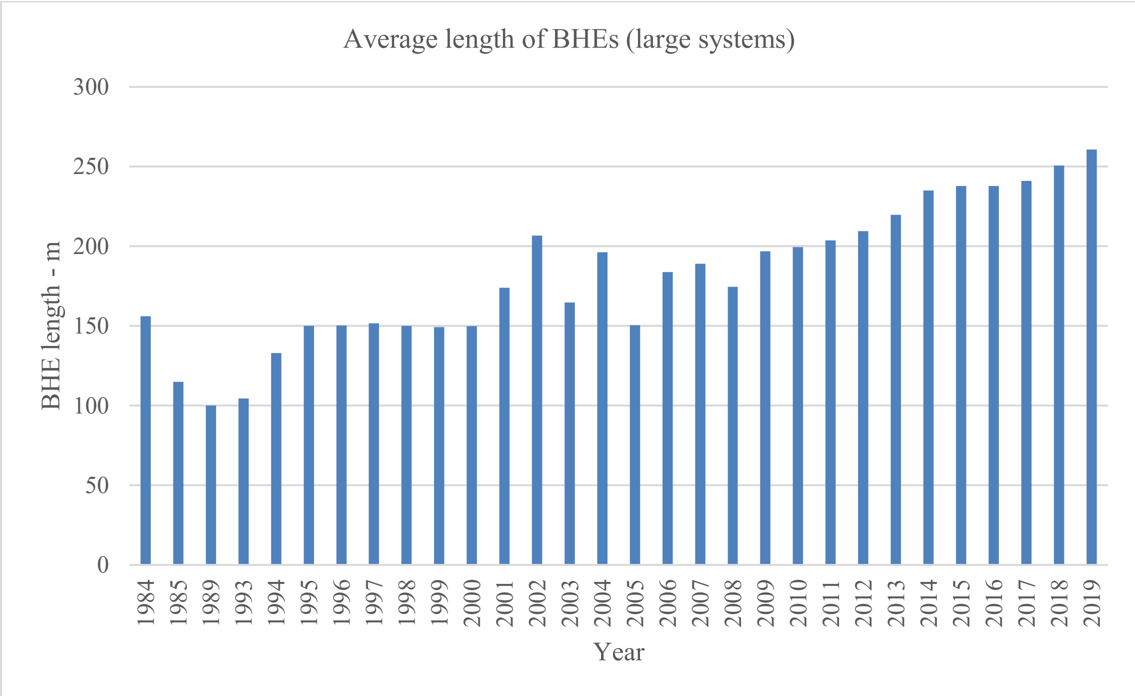

Figure 3: Development of the BHE length reported to NGU for large BHE installations (installations with four or more BHEs)

Another trend is to have a decrease on the number of BHEs in the large GHP installations (Figure 4). The average large BHE installations reported in 2018 and 2019 consist of 10 BHEs. The reduction is probably connected to the increased BHE length. The new GHP installations is also more integrated borhole thermal energy storage (BTES) systems e.g with solar collectors, PV, air heat pumps or PCM. This integration limited the need for heat or cold extraction from the BHEs.

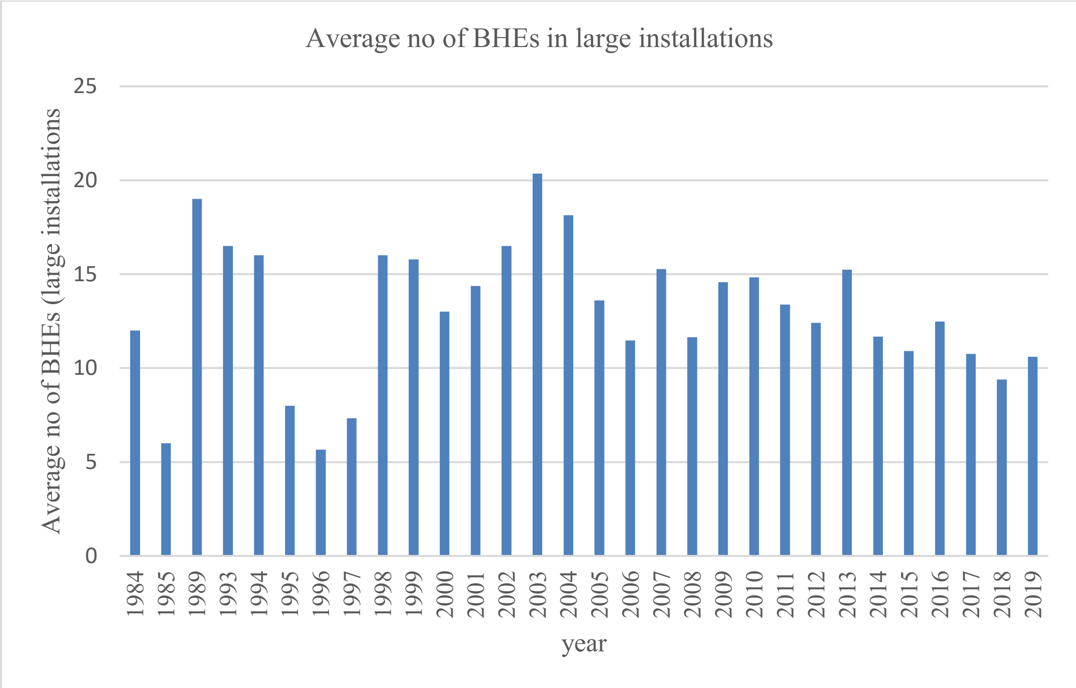

Figure 3: The average number of BHEs in the large installations registered at NGU.

4.2 Open GHP systems (Direct use of groundwater)

More than thirty open GHP installations using groundwater are reported. Several of Norwegian villages are located on coarse grained glacial-fluvial or river deposits and have a potential for direct utilization of groundwater for heating and cooling via GHP. Melhus, for example, is a village in middle of Norway, located on coarse grained glacial deposits. Ten large GHP installations are operating and providing heat and cold to several of the commercial and public buildings in Melhus centrum.

There are also approximately 10 GHP installations extracting groundwater from wells in crystalline rocks. The rhomb porphyry located at the west of Oslofjord has the highest known permeability among the Norwegian rocks. Many fracture zones connected to the Permian dikes in the region of Oslo have also potential for extraction of a large amount of ground water.

Additionally, there is the potential for direct utilizing of groundwater in other communities. Due to a ground water temperature below 7 °C, the open systems must be design carefully to prevent freezing. The water chemistry and in particular the contents of iron and manganese need to be monitored in the open GHP installations, as the case in Melhus proves.

5. FUTURE DEVELOPMENT AND INSTALLATIONS

Energy efficiency and integrated energy systems are in focus in this chapter. Norway has demonstrated several innovative energy-efficiency energy systems recently. The campus of Western Norway University in Bergen has an integrated thermal energy storage system that combines short term Phase Change Materials (PCM) storage and BTES (Henne et al 2018).

The efficient/zero emission neighborhood approach, sharing access to heat or cold to the neighboring buildings by use of BTES has been successfully demonstrated, for example the waste heat from computer cooling in Otto Nielsens vei 12 E in Trondheim, is stored in a BTES comprising 24 BHEs 220 meters deep and used as additional heat source for the four neighboring buildings.

High Temperature BTES is a trending focus area. The GeoTermos – Fjell2020 in Drammen outside Oslo is an innovative system and the first high temperature HT-BTES in Norway (Ramstad et al, 2017). Here the core temperature is planned to reach up to 50-60°C so that heating can be used directly even without the need for a heat pump. In this case most of the stored heat is harvested from solar energy. The BTES consists of 100 boreholes of 50-55 m depth, arranged in a circular pattern. The systems as a whole aims to effective energy integration with thermal sources (solar and air source heat pump) and electrical sources (grid and own PVs).An annual storage of about 700-800 MWh from these sources is assumed, and the storage is expected to deliver about 350 MWh/year of heat. The BTES is designed to produce a base load capacity of 80 kW, and peak loads up to 300 kW. Heat loss and performance will be monitored (Kvalsvik et al. 2019)

Another high temperature BTES is planned by a DH company at Furuset in Oslo. The project has received funding from Enova, and is in the planning phase (Teknisk Ukeblad, 2019).

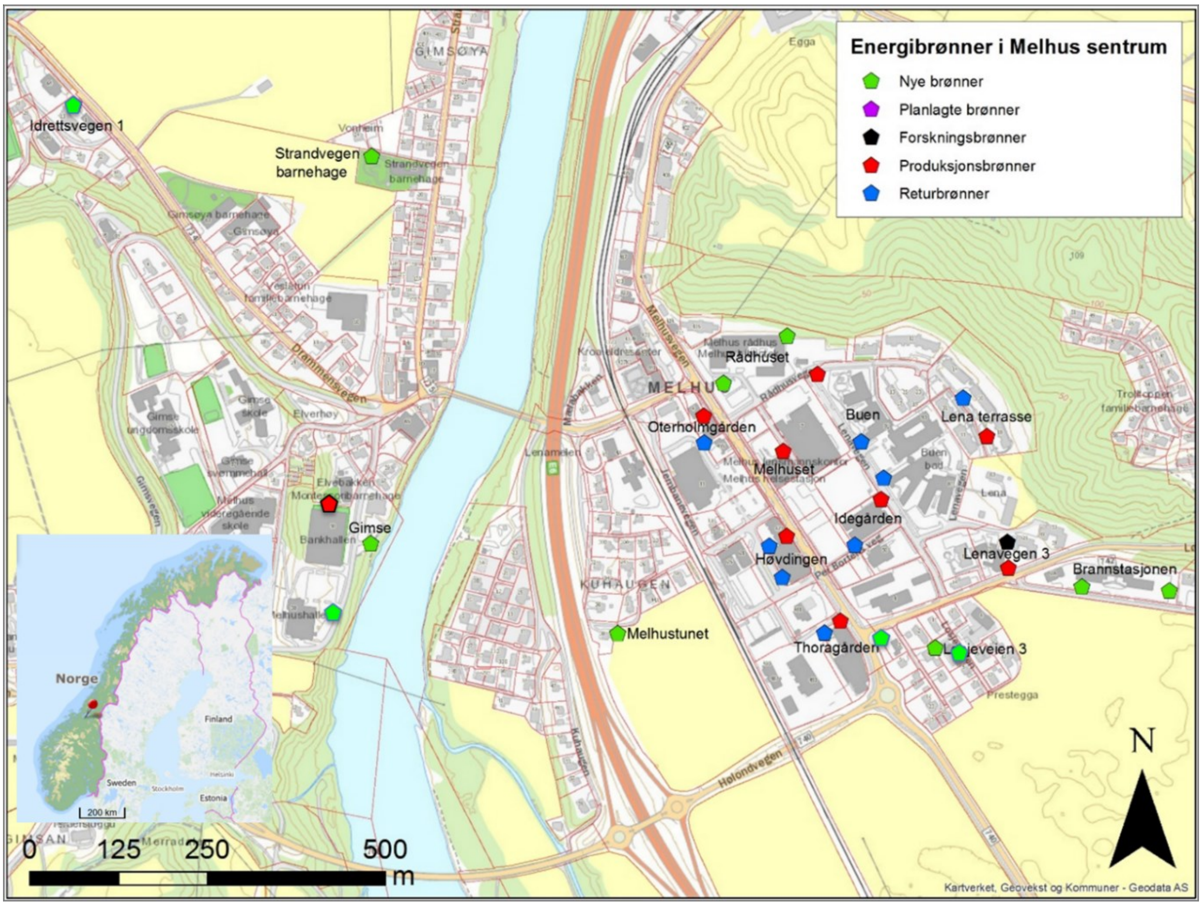

Figure 5: Melhus village, the red sympol shows the GHP production wells, the blue marks are the injections wells and the green are new wells no set in operation.

6. CONCLUSIONS

Geothermal energy is a stablished technology whose installation is not depending on supporting funds from public institutions as their reliability has been demonstrated in several existing cases both for large and small installed capacity.

There is a clear trend towards multi building integrated systems that often rely on geothermal boreholes for storage. The use as GHP as main provider for heating and cooling, is proven as a reliable technology but several cases proven the need for thinking about recharging of the ground due to large unbalance between heating and cooling demands.

ACKNOWLEDGEMENTS

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Wind		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	0			3	33 800	143			1 700	4		149
Under construction in December 2019					33				1 000			
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020												

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe[3)]	Total Running Capacity MWe[4)]	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe
Total									

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Oslo airport	S			10			0.18			
TOTAL							0.18			

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

Locality	Ground or Water Temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used[5)] (TJ/yr)	Cooling Energy[6)] (TJ/yr)
TOTAL	3-8 C	7kW - 8 MW	60 000	V	3	4000	12600	~1400

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting	0.18		
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	1150	12600	0.3
TOTAL	1150	12600	0.3

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)					
Production	>150° C					
	150-100° C					
	<100° C		9100			1880
Injection	(all)					
Total			9100			1880

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	5	5	10	0		130
2016	5	5	10			130
2017	5	5	10			130
2018	5	5	10			130
2019	5	5	10			130
Total	25	25	50			650

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0,5	1,5	20		90	10
2000-2004	1	0	70		90	10
2005-2009	2,5		100		85	15
2010-2014	3					
2015-2019	20	0,5	150		85	15