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Geothermal Energy - Country Update for Norway

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ABSTRACT

The increasing emphases on energy efficiency and new building codes that restrict the use of energy for heating of new buildings have increased the interest for Geothermal Heat Pump (GHP) systems. New building codes will also increasingly demand environmentally friendly cooling which favors GHP and Underground Thermal Energy Storage (UTES) applications.

More than 90 % of the GHP systems utilize energy from boreholes in crystalline rocks. There is a trend towards deeper boreholes, Borehole Heat Exchangers (BHE) at 500 m depths have successfully delivered heat since 2011.

There are no deep geothermal installations in operation, but assessments and preliminary plans exist for utilizing deep geothermal in a district heating system in mainland Norway and to replace fossil fuel with geothermal energy for settlements on Svalbard, an archipelago in the Arctic Ocean, north of Norway.

To promote, cooperate and develop deep geothermal energy the “Norwegian Centre for Geothermal Energy Research” (CGER) was established in 2009. Today CGER have 17 partners from universities, research institutes, and industry. The government recently announced the ambition to establish a national long-term research center for geothermal energy to develop national expertise and promote innovative geothermal solutions.

1. INTRODUCTION

As the third-largest exporter of energy in the world and an electricity supply almost totally dominated by hydropower, Norway is unique with respect to energy resources. Norway has one of the largest shares of renewable energy both in its total primary energy supply (TPES) and in electricity supply. Norway has set itself an ambitious target to reduce global greenhouse gas emissions by 30% relative to 1990 levels by 2020, and to become carbon-neutral by 2050 meeting the 2020 target will be challenging because both the country’s electricity supply and energy use in buildings are already essentially carbon-free (IEA, 2011).

In 2002, Enova SF was established as a public enterprise to promote energy saving and new renewable sources of energy. Enova is funded through an Energy Fund made up partly from an earmarked grid levy and partly from the state budget. Today the Energy Fund is about 40 billion NOK (4.8 billion Euro) and will increase by 23 billion NOK (2.7 billion Euro) by 2016. The energy result from management of the Energy Fund for the period 2012 to the end of 2015 must constitute at least 6.25 TWh.

Over the last decade, Norway has strengthened its energy R&D efforts and the government funding is almost tripled in this period (IEA, 2011). A new national collective R&D strategy for the energy sector, Energi 21, was launched in 2008 and revised in 2011 and 2014. The vision of the strategy is for Norway to be the leading energy and environment conscious nation in Europe.

In 2008, the Norwegian Parliament adopted a Climate Agreement with the aim to increase energy research, development and deployment (RD&D) for CCS and non-fossil based energy systems. Public funding for energy RD&D is among the highest in the world (IEA, 2011). In 2013, 702 million NOK (84 million Euro) was allocated for research within environmentally friendly energy technologies including CCS (Forskningsrådet, 2014). In order to develop expertise and promote innovation in targeted energy R&D areas, eight centers for environment –friendly energy research (FME) were established in 2009. Each of the centers receives annual funding of 10-20 million NOK (1.2 - 2.4 million Euro) for eight years. Geothermal energy was not a prioritized area in 2009 but a new Climate Agreement was approved by Parliament in 2012 with a specific decision to establish a research center in geothermal energy.

Geothermal energy is considered as a highly significant alternative for the future and a subject of growing interest in our industry, universities and research institutes. In order to plan, coordinate and promote research and development within geothermal energy in Norway, the “Norwegian Centre for Geothermal Energy Research” (CGER) was established in 2009 and has today 17 partners from industry, universities and research institutes. This centre aims to facilitate the exploitation of geothermal energy as a national energy resource and an international business opportunity. Building on strong national competence, amongst others related to the petroleum industry, this centre will contribute to the development of knowledge and technology. One example of a strong national competence is advanced drilling and reservoir technologies. Such technologies and methods are transferable to geothermal applications, but for successful application, e.g.to crystalline rocks, the technologies needs to be adapted.

2. GEOLOGY BACKGROUND

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 that is below the continental average (Kukkonen, 2002).

The quality of the Norwegian heat flow data are improving. The Geological Survey of Norway has collocated a new heat flow data set from new and existing deep onshore boreholes. The new palaeoclimatical and topographical corrected values shows higher heat flow values than previous expected, with surface heat flow varies between 50 and 60 mW/m^2 in south and central Norway (Slagstad et al, 2009).

3. GEOLOGY UTILIZATION

The major geothermal activity in Norway is geothermal heat pumps (GHP). In Norway, the main uses of energy in household production is for space heating. Depending on winter temperatures, the proportion of energy used for heating varies from 40 to 50 percent of household stationary energy consumption. One of the major sources of increased energy efficiency in household space heating in recent times is the increased use of heat pumps in Norwegian homes during the last decade. In 2000, less than one percent of households owned a heat pump. In 2012, a quarter of Norwegian households owned a heat pump, approximately 90% of which are air-to-air heat pumps (Halvorsen & Larsen 2013).

More than 90% of the GHP systems utilize energy from boreholes in crystalline rocks by use of borehole heat exchangers (BHE). The Norwegian standard system is a 50-350 m deep borehole of 115 mm (casing 139 mm) diameter with a single 40 mm U tube installed. Most of the BHE is kept open without grouting. There is a trend towards deeper BHEs, an installation with a 500 m deep single U-tube has been successfully delivering heat since 2011. Some of the BHE fields established recently have boreholes of 300 m depth.

There has been an increase in GHP particular for larger buildings after a new building code with strict requirements for energy efficiency was introduced in 2007, and revised in 2010. These new energy performance requirements are expected to cut the need for energy for heating purposes by around 25% (IEA 2012). The new regulations also specify that, as a rule, a minimum of 60% of the energy required for heating and hot water in new and refurbished buildings above 500 m^2 must be supplied by energy carriers other than electricity and /or fossil fuels. This opens up the possibility that a lot of medium sized GHP installations will be needed for ubiquitous locations such as school buildings. The building code will be revised in 2015. The target level is the passive house standard or active houses producing energy.

Another new legislation which has contributed to increased interest for GHPs is the energy labelling scheme. From 2010 this scheme requires buildings to have an energy certificate and an energy consumption label when built, leased or sold These schemes are assumed to promote increased knowledge and awareness of the energy consumption in buildings.

A potential study of "Ground Source Heat in Norway – Mapping of Economic Potential" initiated by the Norwegian Water Authorities (NVE) (Ramstad, 2011) concluded with that (nearly) the entire heat and cooling demands of Norwegian buildings can be covered by the use of ground source heat pumps. The unit price of heating and cooling based on the ground source heat pump technology for middle sized to large installations is competitive with other energy alternatives. For the household segment, profitability is lower, but still interesting. The study does not include the indoor heat and cooling distribution system, but the heat pump, energy well and installations costs. The relatively good thermal conductivity of the crystalline bedrock makes Norway well suited for energy wells with closed loop collector systems. Due to the abrasive work from the ice age the Norwegian bedrock is quite fresh and borehole instability does not appear too often.

In 2013, two office buildings in Kjørboparken, a suburb in Oslo have gone from being typically a building of the 80s to providing the answer to the buildings of the future. By combining solar and GHP technology the Powerhouse cooperation has succeeded in rehabilitating a commercial building in Norway that, over the building's entire lifetime, will produce more energy than it consumes. As the first rehabilitation project in Norway, Powerhouse Kjørbo has achieved the BREEAM-NOR certification, 'Outstanding' (BREEAM-NOR is the Norwegian branch of the BREEAM, the world's foremost environmental assessment method and rating system for buildings). With this certification, it is the world's first rehabilitated plus building. Currently, the buildings are responsible for 40 per cent of all energy use, and nearly 80 per cent of the current building mass is expected to still be there in 2050 (Enova 2014).

As a result of a competition for an innovative heating system solution organized by Undervisningsbygg, the school building owner in Oslo municipality built a BTES system at Ljan School in Oslo (Figure 1). Here the ground is used in interplay with solar heat collected in the asphalt of the schoolyard. The solar collector is integrated into the asphalt and used to heat the brine for the heat pump during spring, summer and autumn, and maybe during some sunny and warm days throughout (late) winter. Excess heat from the solar collector in the summer is used for charging the energy wells (Midttømme et al. 2013).

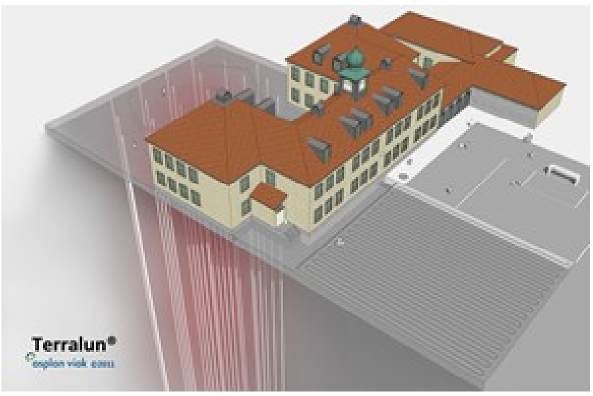

Figure 1: GHP system at Ljan school, Oslo (Ref Asplan Viak)

Two large GHP systems that have recently been established (Stavanger Forum and Høgskolen i Bergen) combines BHEs from than 80 boreholes with ice storage tanks. Most of the large BHE systems have additional heating systems for use in the coldest days in the winter. The size of the BHE field is therefore designed for the buildings cooling demand.

Some locations in Norway can also utilize groundwater resources in superficial deposits. The largest UTES system in Norway is at Oslo's Gardermoen international airport. This ATES system has been in operation since the airport opened in 1998 and comprises an 8 MW heat pump, coupled to 18 wells of 45 m depth, 9 for extraction of groundwater and 9 for re-injection. Like many other unpressurized open systems there are problems with clogging of the groundwater loop, the filter screens and heat exchangers. The airport will expand, but due to the operational problems, they will not expand the ATES system but rather utilize a nearby sewage plant to supply the existing ATES system. For effect purposes, it installed a snow storage system to provide cooling on the hottest days.

There are no geothermal installations deeper than 500 m in operation. An EGS demonstration project was planned in Oslo but was not realised due to lack of funding. The plan was to drill a closed loop system of 3.5 – 5.5 km depth. There has been preliminary investigations including drilling of a 800 m deep test well for utilizing deep geothermal energy in a district heating system in the Oslo region. The energy company has not yet decided if they will continue this geothermal project.

Svalbard is an archipelago in the Arctic Ocean, located north of mainland Europe (Figure 2). The Svalbard Treaty of 1920 established full Norwegian sovereignty over Svalbard. Store Norske, a mining company has received Norwegian research council funding for investigating the geothermal potential for Svalbard.

Figure 2: Ny Ålesund, Svalbard located on 79 ˚ N.

There are emerging small and large companies who are interested in penetrating the geothermal market, especially within drilling. Some examples are:

-Norwegian Hard Rock Drilling AS, NORHARD is a company that develops technology and production/operation equipment for deep drilling. Further development for drilling of geothermal wells and for oil and gas applications are ongoing.

The company 'Resonator' is developing a powerful electric hammer for improved percussion drilling, based upon a new proprietary technology. This work is taking place at the University for Life Sciences (UMB) south of Oslo. Demonstration of the technology is planned to take place in about 2 years

Norwegian companies are also working on development of thermal machines. Viking Heat Engines has developed and are testing a heat engine for electricity production from low temperature geothermal sources.

4. INTERNATIONAL ACTIVITY

Green Energy Group AS (GEG) is a Norwegian Company established in 2008, manufacturing and commissioning prefabricated modular geothermal power plants. Their concept reduces the time between when the geothermal well is successfully drilled to the first power online. In 2009, GEG signed a R&D contract with KenGen, the national power company of Kenya, to deliver the first 5 MW wellhead power plant. In 2011, GEG raised a combined MNOK 87 million (11.7 million Euro) in equity. The first modular power plant was put in operation in Kenya in January 2012.

The state owned oil company Statoil has an ambition to gradually build an international position in renewable energy production. In addition to the established interest within offshore wind, geothermal has been identified as a potential business area for further growth. The aim of Statoil is to build upon its core expertise from oil and gas, such as geology, drilling and reservoir management, in order to realize the full potential of geothermal power in markets where the company already has a presence.

The Research Council of Norway is funding a geothermal project in north western Indian Himalayas. The project is a joint effort between India, Norway and Iceland and the vision is to develop and demonstrate innovative and sustainable technologies for utilization of geothermal sources to supply the high mountain region.

5. DISCUSSION

There is no national overview of installed GHP systems. According to the National Drilling Associations (Norwegian Association of Heavy Equipment Contractors; MEF and Norwegian drilling association; NBF) there are about 5,000 installations per years. The Norwegian heat pump organization (NOVAP) have registered the number of sold heat pumps for their member companies since 1996, but not all heat pump suppliers are members of NOVAP. As example in 2011, 3,677 brine-water heat pumps were sold. Most of these were GHPs.

According to the National Water Directive all boreholes and wells drilled shall be reported by drillers to the Geological Survey of Norway (NGU). This boreholes/wells archive, which is available at NGUs website (http://geo.ngu.no/kart/granada/), contains information on the technical design, depth, yield, groundwater level, geographical location, soil depth etc. of around 60,000 wells and boreholes. A large proportion of the wells have not been reported particularly those drilled in large BHE systems, but the share of reported wells/boreholes is increasing. In 2011, a total of 3,600 BHEs were reported to the borehole archive where 2,930 boreholes were single BHE systems and 661 boreholes/wells were drilled in large GHP systems with two or more boreholes/wells.

In the estimation of the total installed capacity of the GHPs both the information from the boreholes archive and the NOVAP sales statistics are used. Depending of the size, the heat pumps are divided in 6 groups from 7 kW to 3 MW. The share of heat pumps in different sizes is estimated from previous sales statistics from NOVAP. These statistics are also the basis for calculating the number of installations, but there is added 10% more installations due to that there are heat pump suppliers who are not members of NOVAP.

European Union guidelines on calculating renewable energy from heat pumps from different heat pump technologies (2013/114/EU) pursuant to Article 5 of Directive 2009/28/EC of the European Parliament and of the Council is used in calculations of the total annual energy use from the GHP installations. Europe is divided in three climate condition areas. Norway is situated in the cold climate zone. The default values, $H_{HP,}$ for equivalent full load hours of operation for GHPs are 2,470 h. Previous in national calculations of the energy savings from GHP an annual operation time for the GHPs in heating modus has set to 4,000 h (Ramstad, 2011). New buildings have lower heating demand than the existing, but most of the heating demand is still required for existing buildings. Norway spans over 13 degrees of latitude, some of them north of the Polar circle with no sunshine in the coldest season. In addition, there is a large diversity of climate zones from coastal, high mountains to typical inland climate. There will be large differences in building heating and cooling demands depending on location, building type and age.

5. CONCLUSIONS

Ground Heat Pumps (GHP) are regarded both economically and technically as one of the best alternatives for energy efficient heating and cooling of new large and medium sized buildings, and these applications will be important in reaching national energy targets.

Deep geothermal energy is on the agenda, research projects are emerging, and a goal is to establish a Norwegian demonstration plant within some years.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables 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 2014	0	0	1646	3 358	30 960	142 810	0	0	770	1 548	33 376	147 716
Under construction in December 2014	0	0	0	0	646	1 476	0	0	45	122	691	1 598
Funds committed, but not yet under construction in December 2014	0	0	0	0	1210	3 552	0	0	3 280	9 054	4 490	12 606
Estimated total projected use by 2020	0	0	1646	3358	32 816	147 838	0	0	4 095	10 724	38 557	161 920

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat

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 (TJ/yr)	Cooling Energy (TJ/yr)
Oslo Airport	6	8000	18x45m	W				
Ahus Hospital	7	8000	228x200m	V				
Nydalen N.park	7	6000	180x 200m	V				
Sartor Center	8		165x200m	V				
Østfold Hospital	7		100x250m	V				
s Energy Central100 x	7		100x250m	V				
Ullevål Stadion	7	4000	120x200m	V				
COOP Åsane	8		112x212m	V				
Arcus	7		91x300m	V				
Stavanger Forum	8		85x250m	V				
Postterminalen	7		90x200m	V				
Haukeland Hospital	8		75x250m	V				
Høgskolen Bergen	8		81x220m	V				
Sørlandssenteret	8		90x200m	V				
IKEA, Oslo	7		86x200m	V				
Torp Airport	7		60x250m	V				
Speilen Mandal	8		90x160m	V				
TOTAL								

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

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184

or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W

since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

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			
Bathing and Swimming 7)			
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	1300	8260	0.2
TOTAL	1300	8260	0.2

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled: Electric Power	Direct Use	Combined	Other (specify)	Total Depth (km)
Exploration 1)	(all)			6	6	9
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total				6	6	9

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Progr
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	5	5	10	0	0	125
2011	5	5	10	0	0	140
2012	5	5	10	0	0	125
2013	5	5	10	0	0	125
2014	5	5	10	0	0	135
Total	25	25	50	0	0	650

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) 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	124		90	10
2000-2004	1	0	307		90	10
2005-2009	2,5		465		85	15
2010-2014	3		426		85	15