Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Geothermal Energy - Country Update for Norway

Kirsti Midttømme, Inga Berre, Audun Hauge, Thor E. Musæus, Bjarni R. Kristjànsson

Norwegian Geotechnical Institute (NGI), PO Box 1230, Havnegata 9, N-7462 Trondheim, Norway

Kirsti.Midttomme@ngi.no

Keywords: Norway, Ground Source Heat Pumps (GSHP), Enhanced Geothermal Systems (EGS), Underground Thermal Energy Storage (UTES)

ABSTRACT

Norway is among the "top five" countries regarding increase in geothermal energy use with 26,000 Ground Source Heat Pump (GSHP) installations including some of the largest Borehole Thermal Energy Storage (BTES) in Europe. There are no deep geothermal energy installations, but there is renewed interest in the potential for EGS systems, and a demonstration project is planned in Oslo in 2010. A Norwegian Center for Geothermal Energy Research is recently established with 19 participants from industry, universities and research institutes.

1. INTRODUCTION

Energy is an important issue in Norway. Abundant offshore oil and gas resources and extensive access to cheap and clean hydropower have enabled Norway to enjoy a high level of security of supply of energy and one of the highest standards of living in the world. Despite its successes, Norway is facing important energy policy challenges. Since 1990, the growth in onshore energy consumption has not been matched by an increase of onshore energy production. Today the construction of gas-fired power stations is delayed owning to concerns about CO_2 emissions, and the construction of additional hydropower stations and onshore wind farms has also been delayed by environmental concerns.

Norway's energy use per capita is similar to that of other countries with a similar climate. However, it differs completely in its structure because of the high share of cheap hydro-generated electricity which contributes with 99% of the domestic electricity production. The result is that Norway together with Iceland consume the highest amount of electricity per capita in the world, approx. 24 MWh in 2008 (IEA, 2005, 2009). This has created a high demand for electricity for heating purposes in private, public and commercial buildings, a demand normally met by oil, gas or district heating systems in other countries.

The main goal of the government energy policy is to reduce the dependence on hydropower by restricting demand and increasing diversity. In 2001 the state-owned enterprise Enova SF was established to achieve the energy targets. Enova manages an Energy Fund of 230 million Euro per annum. The funding comes from a levy on the electricity distribution tariffs.

A new national collective R&D strategy for the energy sector, Energi 21, was launched in 2008. The vision of the strategy is to be Europe's leading energy and environment-consious nation. Geothermal energy is considered as a highly significant alternative for the future but not yet a subject of great interest for the industry.

To promote, cooperate and develop deep geothermal energy the "Norwegian Centre for Geothermal Energy Research" (NCGER) was established in 2009 with 19 partners from universities, colleges, research institutes, and industry. The Norwegian industry is world leading in drilling technology developed for the oil and gas industry. This technology and methods are transferable to drilling of geothermal wells, however for successful application the technology needs to be adapted for crystalline rock found on the Norwegian mainland.

Norway is part of 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. The lithosphere is cool and thick and characterized by low heat flow density below continental average (Kukkonen, 2002).

There is lack of heat flow data from Norway and the country is still marked as a white spot without available temperature data below 1000 m in the Atlas of Geothermal Resources in Europe. A recently heat flow study with new data from deep onshore boreholes shows higher heat flow values and a higher geothermal potential than previous expected (Slagstad et al., 2009). The palaeoclimatically and topographically corrected surface heat flow varies between 50 and 60 mW/m^2 in south and central Norway.

2. ENHANCED GEOTHERMAL SYSTEMS

At present, no electrical power or direct heat is produced from deep geothermal resources in Norway.

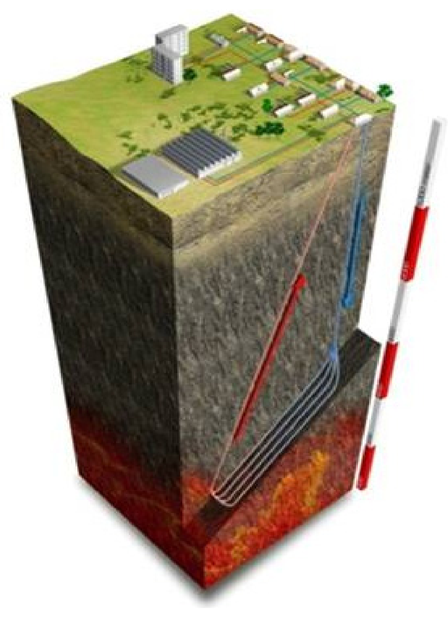

Figure 1: The planned EGS in Oslo.

Rock Energy AS, a Norwegian based company, has a patented EGS technology for exploitation of deep geothermal energy (Figure 1). The company has developed a secure inter-well connectivity without fracturing the rock between the wells. The inter-well connectivity is made by drilling a patented sub-surface heat exchanger of tubes in the EGS. Water is flowing freely within the drilled tubes preventing water loss. The drilling pattern gives predictable water flow and hence predictable energy output. A demonstration project of 5 MW is planned in Oslo in 2010. The ambition is to establish a closed loop system at 3.5 - 5.5 km depth. The installation will be in cooperated in a district heating system delivering about 20 GWh of heat each year.

3. GROUND SOURCE HEAT PUMPS (GSHP)

The total number of GSHP installations is estimated to 26,000 with an installed capacity of 1000 GWh. Above 90% of these installations are vertical boreholes with single U-shaped pipes in open groundwater-filled boreholes.

Installed brine/water heat pumps are shown in Figure 2. The yearly variation reflects the prices of electricity where 2003 was a dry year with low hydro power production and 2005 a wet year. There is a clear trend with increasing interest in GSHP, but the Norwegian heat pump market is still dominated by air/air heat pumps. In 2008 more than 90% of the total heat pump installed was air/air heat pumps and only 4% GSHP.

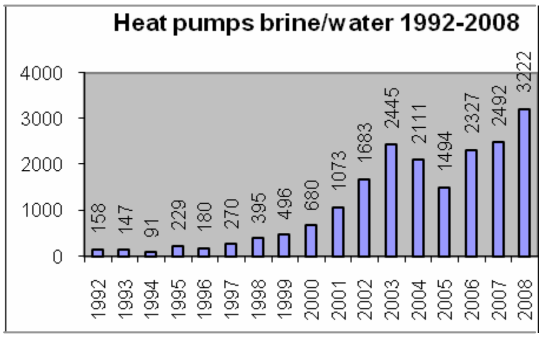

Figure 2: Installed brine/water heat pumps in Norway. Data from NOVAP, Norwegian heat pump association.

Today, about 350 larger GSHP systems for public, commercial buildings or multi-family dwellings is installed including some of European largest GSHP with Borehole Heat Exchangers (BHE) (Eugster and Sanner, 2007) (Table 4). These installations are Borehole Thermal Energy Storage (BTES) systems providing a balanced combination of both heating and cooling

A BTES system comprising 228 boreholes of 200 m depth was drilled during winter 2007 (Figure 3 and 4), and provides heat and cold to the new Akershus University Hospital (Ahus). The building has a total floor area of 137,000 m^2, and an annual heating and cooling demand of 26 GWh and 8 GWh, respectively. One of the goals for the energy systems was that renewable energy sources should provide a minimum of 40% of the supplied energy for heating and cooling. The BTES became operational in May 2007, but a second phase of drilling is planned in 2009/2010 to provide an extension of the BTES scheme making a total of 350 boreholes. The boreholes are drilled in dioritic rocks with 5-40 m clay cover. The thick clay cover increases the drilling cost. A combined ammonia chiller and heat pump system is installed (Stene et al., 2008). The total cost of the BTES and the GSHP system is 19.5 million USD.

It was originally planned to drill the boreholes close to the hospital, but seismic geophysical surveys and test drilling showed a high density of the clay filled fracture zones. This observation suggested that full-scale drilling would be difficult and expensive. The proposed BTES borehole array was therefore relocated to a field about 300 m from the hospital. Today the borehole heads are completely underground, and the farmer is using the field to grow crops (Midttømme et al., 2008).

Figure 3: The BTES at Ahus under construction in summer 2007 (Photo:Forum Fjernvarme).

Figure 4: Pipelines at Ahus from the boreholes to the manifolds (Photo: Fortum Fjernvarme).

4. SUMMARY AND FUTURE PERSPECTIVE

There is a growing interest for Ground-Source Heat Pumps (GSHP) for energy efficient heating and cooling of buildings, and these applications will be important in reaching their national energy targets. Norwegian heat pumps have at present a total annual heat supply of about 7 TWh/a. The estimated heat pump potential by 2020 is estimated at 10 to 14 TWh (Grorud et al., 2007).

Deep geothermal energy is set on the agenda, and an EGS demonstration plant is planned in Oslo.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables wind		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2009				1000	29030	121 800				900		123700
Under construction in December 2009												
Funds committed, but not yet under construction in December 2009				8000		1800				3900		13700
Total projected use by 2015												

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

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	8100	18	W	5,8		16,4	14
Akershus Hospital	6,5	8000,0	228,0	V				
Nydalen Business Pa	8,0	6000,0	180,0	V				
Ullevål Stadion	7,0	4000,0	120,0	V				
Post Terminal Build	6,5	4000,0	90,0	V				
IKEA Asker	7,0	1200,0	86,0	V				
Vestfold Univ College	8,0	800,0	70,0	V				
Ericsson Asker	7,0	800,0	56,0	V				
Alnafossen Office	7,0	1500,0	52,0	V				
TOTAL								

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] 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. (^oC) - outlet temp. (^oC)] 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)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, 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	3300	1000	
TOTAL	3300	1000	

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

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

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2005	2					
2006	2					
2007	2					
2008	1	5	2			11
2009		6	4			30 by yearend
Total	7	11	6			41

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999						
2000-2004						
2005-2009		18			74 %	26 %