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Norway's Geothermal Energy Situation

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ABSTRACT

Key features of Norway's energy policy today are: Improved energy efficiency, more flexibility in the energy supply, decreasing dependence on electricity for space heating, and an increased share of renewable energy sources other than large hydropower

At present, no electrical power or direct heat is produced from geothermal resources in Norway. In 1999, an attempt was made to develop a Hot Dry Rock pilot plant of 2MW in Oslo failed for technical reasons.

Today, about 100 larger GSHP systems for commercial buildings or multi-family dwellings exist in Norway. Traditionally, these systems are only for heating purposes, but some systems use the exhaust ventilation to recharge the boreholes, and the increasing interest in cooling in the commercial and industrial sector seems to favour GSHP and UTES (underground thermal energy storage) systems.

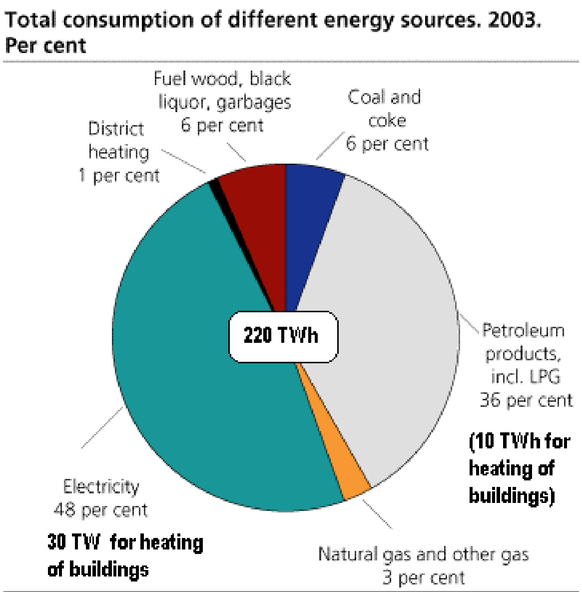

Figure 1:Total consumption of energy in 2003 both stationary use and transportation Figure from Statistics Norway (SSB).

1. INTRODUCTION

Norway is endowed with hydropower resources that supply almost all domestic electricity demand. The availability of inexpensive hydropower has led to the world's highest electricity consumption per capita. Electricity is the main source for space heating in 90 % of residental and 85 % of the commercial and service buildings, and the share has been increasing steadily the last decades primarily displacing oil. (Unander & Schipper, 2000). Total consumption of energy in 2003 is shown in Figure 1. In contrast to Sweden and Denmark, district heating systems are not an alternative to electrical heating.

Traditionally, electricity demand growth has been met by developing more hydropower, but today Norway has more or less reached the limit for how much hydropower that can be developed without unacceptable environmental consequences.

Key features of the energy policy today are: Improved energy efficience, more flexibility in the energy supply, decreasing dependence on electricity for heating, and an increased share of renewable energy sources other than large hydropower. A new public enterprise, Enova SF was established in 2001. Enova's mission is to implement the new energy policy mainly by stimulating market actors and mechanisms by financial incentives. Enova is also administrating an energy fund of 65 mill. Euro per annum.

2. CLIMATE AND GEOLOGY

Norway is situated in the cold climate region though the warm Gulf Stream in the Atlantic gives a milder climate than areas equally far north. A long coastline and high mountains result in a variation of regional climates from typical maritime in the western part to continental in the east, and more arctic dominated in the northern region. The annual average temperature vary from -3 to +8 ºC. The location near the Artic Circle gives short days in the winter with only a few hours of daylight which increase the heating demand in the winter. The global warming trend with higher temperatures has also affected Norway, and there is a growing interest for cooling systems in the summer.

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. A thin layer of glacial sediments generally covers the bedrock, and in some of the larger valleys, there are groundwater aquifers in alluvial or glacial sediments.

The lithosphere is cool and thick and characterized by heat flow density below continental average (<65mW/m^2) (Kukkonen, 2002). There is lack of heat flow data from Norway. New measurements in the Oslo area gave higher values than expected.

2. HDR PROJECT

At present, no electrical power or direct heat is produced from geothermal resources in Norway. In 1999, an attempt was made to develope a Hot Dry Rock pilot plant of 2MW at the new State Hospital in Oslo. A drilling technique including water driven percussion hammer and coiled tubing technique was tested. The plan was to drill a closed

Table 1. Wells drilled for electrical, direct and combined use of geothermal resources from January 1, 2000

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration	(all)				4	3.0
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total					4	3.0

loop system with two wells connected by horizontal drilling at 5000 m depth. The geology of the area consists of a basement of gneiss of Proterozoic age covered with sedimentary rocks of Cambrian to Silurian age. Unfortunately, the site was located in a strong contact metamorphic zone with 700 m of hard hornfels overlying the gneiss.

The project was abandoned because drilling tools were lost at 1600 m depth. However , the results obtained hold some promise as to the future development of Hot Dry Rock systems in Norway.

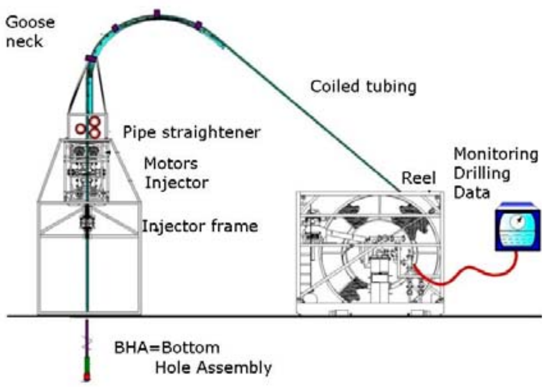

Figure 2:. Drilling tools used for the HDR project at the State Hospital in Oslo.

A heat flow study has recently started, and four exploration wells to 800m have been drilled in 2004. (Table 1)

4. GROUND SOURCE HEAT PUMPS (GSHP)

55 100 heat pumps were installed in Norway in 2003. The development of installed heat pumps since 1992 is shown in Figure 3. In contrast to other countries, 94 % of the installed heat pumps in 2003 were air-source heat pumps and only 5% were ground-source heat pumps (GSHP). Last year was extraordinary. Because of a dramatic increase in electricity cost, financial support to install heat pumps was provided by the government. The subsidies favour installation of air-source heat pumps.

The total number of GSHP installations is estimated to 13,000 with an installed capacity of 450 GWh. Above 90 % of these installations are vertical boreholes with single U-shaped pipes in open groundwater-filled boreholes.

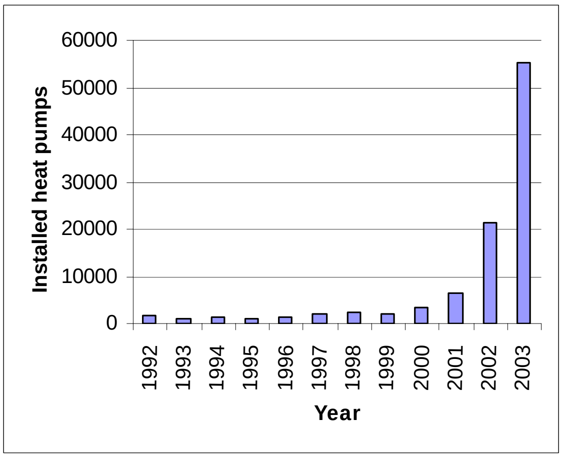

Figure 4: Installed heat pumps in Norway. Data from Norwegian heat pump association.

Today, about 100 larger GSHP systems for commercial buildings or multi-family dwellings exist in Norway. The largest GSHP installation in Norway is at Oslo Gardermoen Airport. An ATES (aquifer thermal energy storage) system, with an 8 MW ammonium heat pump and 18 wells to 45 m depth, is incorporated in the airport's heating and cooling system (Tokle, 1998). The total cooling capacity is 9.6 MW. The airport is situated of one of Norway's largest groundwater aquifers and there is a political decision that the airport should not have any negative impact of the ecological systems in and around the groundwater reservoir. The use of groundwater is therefore restricted and thoroughly monitored.

Table 2 Some of the large geothermal heat pumps in Norway.

Locality	Ground or water temp. (°C)[1)]	Heat Pump Capacity kW	Type[2)]	COP[3)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Oslo Gardermoen Airport	6	8100	W	5.8	16.4	14
Rana hospital	4.5		W		4	
Lena Terasse	5.4	150	W			
Tønsberg sykehus	8.2		W			
Kautokeino helsesenter	4	150	V		2.1	
Borgen skole	6.5					
Vetleflaten omsorgsentert	5	200	V	3.2	3.6	
Alnafossen kontorpark	6.5	1200	V			
Ericsson kontorbygg	6.5	750	V		7.1	
Kvernhuset skole	7	300	V		4	
Våler Helse og sosialsenter	5	250	V		2.9	
Sentermenigheten	6.5	100	V		0.8	
Fusdal skole	6.5	200	V		2.9	
Rosenvilde skole	6.5	200	V		2.4	
Langhus skole	6.5	150	V		2.4	
Deliskog Ind området	6.5	180	V		2.6	
Apaløkka skole	6.5	150	V		2.1	
Bjølsen studentby	6.5	700	V			
Bjøråsen skole	6.5	150	V		2.3	
Lillo sykehjem	6.5	188	V		4.1	
Maridalsveien 3	6.5	223	V	3.5	3.9	0.5
Nedre Bekkelaget skole	6.5	230	V		1.8	
Nøstehagen bo og omsorgsenter	6.5	120	V		1.8	
Rødtvet skole	6.5	250	V		2.7	
Ulsrud skole	6.5	300	V		3.3	
TOTAL		14241			73.2	14.5

At present 15 GSHP systems based on direct use of groundwater are in operation. Dominating groundwater aquifers are in alluvial and glacial sediments. Of these plants 30-40% have operational problems caused by iron and manganese precipitation and there are examples of plants that have been closed or never been in operation because of clogging problems.

Even with groundwater temperatures below 4ºC, it is possible to use the groundwater as heat source. During a period of 17 years from 1985 to 2002 the groundwater was successfully heating six semi-detached houses in Målselv situated at 69ºN. The GSHP system used 5 l/s from a well at 3.5ºC providing 52 kW of heat.

Bedrock is aquifer for three plants. Rhomb-phorphyry lava , a porous rock of Permian age, is successfully used as aquifer for two GSHP system in Tønsberg and an ATES system in Sande extracts groundwater from a fracture zone in impermeable sandstone. This plant has been in operation since 2003. It was originally designed as a BTES (borehole thermal energy storage) system, but because of drilling problems due to high groundwater flow, the plant was constructed as an ATES system with two productions wells to a depth of 300 m and two injections wells in a distance of 60 m. The capacity of the heat pump is 180 kW.

In Nydalen in Oslo, the largest BTES (borehole thermal energy storage) in Europe is under construction. The BTES system will supply heating and cooling to a building of 180000 m^2 including a school, shopping centre, hotel, offices and residential area.. The total storage volume of the bedrock is 1.8 million m^3 with 180 boreholes to 200 m depth. The output of the system is 9MW heating and 6 MW cooling (Lund & al. 2003).

The cost of the project is 7.5 million Euro (60 mill NKR) with a financial support of 1.5 million Euro. from Enova and the Muncipality of Oslo. The payback time compared to traditional heating is estimated to 4-5 year

In recent years, about seven larger BTES systems or GSHP with borehole heat exchanger have been installed annually. Since 1999, fifteen schools in the Oslo region have installed BTES systems. In addition thirteen new health service buildings have chosen borehole heat exchanger systems instead of electricity heating.

Compared to other countries standard borehole depth seem to be deeper in Norway. For larger BTES system borehole depth is 170-200m and there are installations with 300m deep boreholes.

Table 3 Allocation of professional personal to geothermal activities . (1. Government, 2. Public Utilities, 3.Universities, 4. Paid Foreign Consultants, 5. Contributed Through Foreign Aid Programs, 6. Private Industry.

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	3		1			1
2001	3		1			1
2002	3		1			
2003	3		1			
2004	2		1			
Total	14		5			2

Table 4. Total investment in Geothermal in (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1990-1994						
1995-1999		3			40	60
2000-2004	0.8	1.4			70	30

5. FUTURE FOR GEOTHERMAL ENERGY

Traditionally, GSHP installations have only been used for heating purposes, there some systems have used the exhaust ventilation to recharge the boreholes. The increasing interest in cooling in the commercial and industrial sector favours GSHP and UTES (underground thermal energy storage) systems. Today, UTES installations have taken over the marked. UTES systems are economically favourable with lower drilling cost and more efficient use and particular the BTES concept seems to have reached a commercial breakthrough. For ATES systems operational failures are still quite common.

For residential sector the potential for GSHP is high, and it is expected that the heat pump market will change from air-source dominated to GSHP dominated within some years.

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