Utilization of geothermal energy in Iceland

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Abstract

Geothermal energy provides over half of the primary energy supply of Iceland. The principal use of geothermal energy is for space heating and about 87% of all energy used for house heating comes from geothermal resources. The paper gives an overview of the main utilization sectors for geothermal energy in Iceland. Space heating is by far the most important one, but other sectors of direct use briefly described are: swimming pools, snow melting, industrial uses, greenhouses and fish farming. Geothermal energy plays an important role in fulfilling an increasing electricity demand in the country and several new installations for geothermal power production are at the planning stage.

Keywords: *Iceland, geothermal energy, district heating, direct use, electricity generation.*

1 Introduction

The primary energy use per capita in Iceland is among the highest in the world. Geothermal energy plays an important role in the energy balance of the country as it provides over half of the primary energy supply. Other energy sources are hydropower and imported fossil fuel. The share of renewables is about 70% of the primary energy supply of the country.

The geothermal resources in Iceland are closely associated with the country's volcanism and its location on the Mid-Atlantic Ridge. The high-temperature resources are located within the active volcanic zone running through the country from southwest to northeast, while the low-temperature resources are mostly in the areas flanking the active zone. There are over 600 hot water springs in 250 low-temperature fields and 26 potential high-temperature areas have been identified.

An overview of the direct uses of geothermal energy in Iceland and how the uses are divided on the different utilization sectors is given in Table 1 and Figure 1.

Table 1: Direct use of geothermal energy in Iceland 2001.

Utilization sector	**Annual energy consumption**		
	TJ/year	GWh/year	%
Space heating	17,223	4,784	72.4
Swimming pools	1,200	333	5.0
Snow melting	1,150	320	4.8
Industrial uses	1,600	444	6.7
Greenhouses	940	261	4.0
Fish farming	1,680	467	7.1
Total	23,793	6,609	100.0

2 Space heating

The main use of geothermal energy in Iceland is for space heating. It had its beginning early in the 20th century and in 1970 about 43% of the population was served by geothermal district heating systems. After the oil crisis in the 1970s, high priority was given to replacing imported oil with the indigenous energy sources hydro and geothermal. Today about 87% of the space heating is by geothermal energy, the rest is by electricity (11.5%) and oil (1.5%).

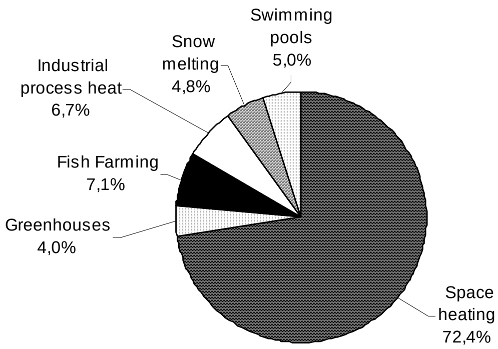

Figure 1: Direct uses of geothermal energy in Iceland 2001.

District heating in Reykjavik began in 1930 when water from a hot spring area in the city was piped 3 km to a primary school. Soon after the national hospital, a swimming pool and some 60 private houses were connected. In 1943 geothermal water from a large geothermal field located about 17 km from the city, the Reykir area, was piped to Reykjavik. Reykjavik Energy utilizes now four low-temperature areas within and in the vicinity of Reykjavik as well as the high-temperature field at Nesjavellir, about 27 km away. The water from the low-temperature fields is used directly for heating and as tap water, but due to high content of gases and minerals the water and steam from Nesjavellir is used to heat fresh water. Today Reykjavik Energy serves about 177,000 people or practically the whole population of Reykjavik and four neighbouring communities, as well as two towns in a separate system in West-Iceland.

Besides Reykjavik there are district heating systems in about 30 towns and villages in Iceland, most of them municipally owned. Geothermal heating is now applied in all areas in Iceland where geothermal resources have been located. Resent developments in thede fields include district heating in Stykkisholmur, Drangsnes and Budardalur with a total number of about 1,700 inhabitants.

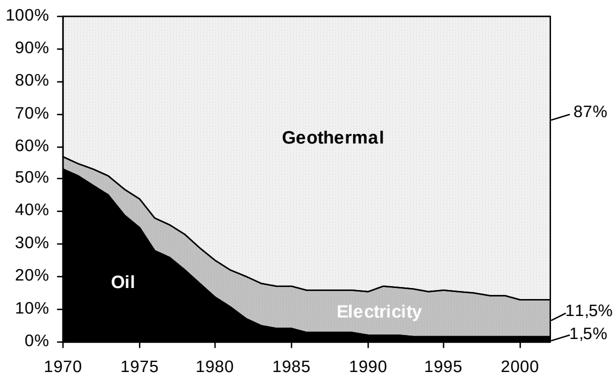

Figure 2: Space heating by sources 1970-2002.

The government subsidizes heating of dwelling houses by electricity and oil in order to keep heating costs comparable over the whole country. To encourage installation of new geothermal heating schemes and expansion of older ones the government gives grants to this type of installation. The amount granted is the equivalent sum of expected subsidies over the next five years to the houses involved, as it would have been in case of continuing electrical heating.

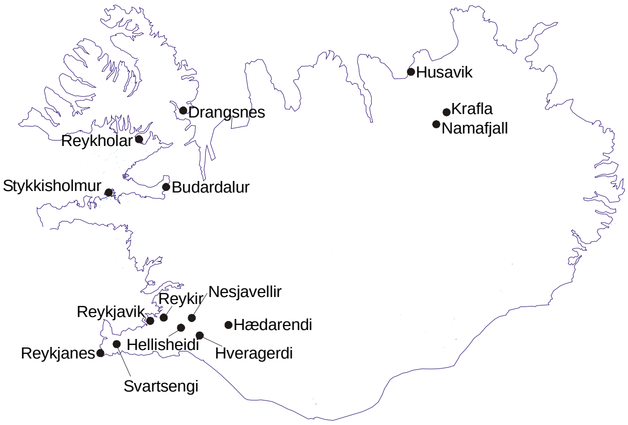

Figure 3: Location of geothermal utilization sites mentioned in the paper.

3 Other direct uses

Following is a brief description of other geothermal utilization sectors than space heating.

3.1 Swimming pools

From the time of settlement of Iceland some 1,100 years ago until early in the 20th century the use of geothermal energy was limited to bathing, cooking and laundering. Some of these uses are today still significant and heating of swimming pools is one of the most important utilization sectors in the country. There are about 100 public swimming pools and about 30 pools in schools and other institutions heated by geothermal energy with a combined surface area of 28,000 m^2. This comprises about 90% of all swimming pools in Iceland. Most of the public swimming pools are open-air pools in constant use throughout the year.

Swimming is very popular in Iceland and the pools both serve for recreational use and for swimming instruction. In the grater Reykjavik area there are about ten public outdoor pools and five indoor ones. The largest of these is the Laugardalslaug, having a surface area of 1,500 m^2 and five hot tubs in which the water temperature ranges from 35 to 42°C. The Blue Lagoon at Svartsengi and the Health Facility in Hveragerdi, comprising geothermal clay baths and water treatments, are also very popular.

The number of visitors in swimming pools has increased in the last years reaching 4.7 million visits last year, which is equivalent to 16 visits per inhabitant. A new swimming pool of average size is using similar amount of geothermal water as 80-100 private houses.

3.2 Snow melting

The use of geothermal energy for snow melting has been widespread for a long time. It has become increasingly common to use return water from the houses, at about 35°C, for de-icing of sidewalks and parking spaces. Most systems have the possibility to mix the spent water with hot water (80°C) in periods when the load is high. Under an extensive rehabilitation of streets in downtown Reykjavik a few years ago, a snow melting system was installed under pavements and streets covering about 40,000 m^2. Many streets in a new construction area in the eastern part of Reykjavik are having snow-melting system installed.

The total area covered by snow melting systems in Iceland is estimated to be about 740,000 m^2, of which about 460,000 m^2 are in Reykjavik. The total geothermal energy used for snow melting is estimated to be 320 GWh per year. Of that about 55% come from spent water from the houses and the rest from 80°C hot water.

3.3 Industrial uses

The use of geothermal energy for industrial uses began on a large scale in 1967 with the establishment of Kisilidjan, a diatomic plant at Myvatn near the Namafjall high temperature geothermal field. It is still the largest industrial user of geothermal energy in the country. The raw material is diatomaceous earth from the bottom of the lake Myvatn. The annual production is about 27,000 tonnes per year of diatomite filter aids for export. The annual steam consumption is about 270 thousand tonnes at 10 bar absolute for drying.

A seaweed processing plant at Reykholar uses geothermal water for drying. The annual production of seaweed and kelp is 2,000 to 4,000 tonnes and the processing plant is using 28 l/s of 107°C hot water.

On the Reykjanes peninsula a salt plant was in operation for more than 20 years, but it was closed down in 1994. From geothermal brine and seawater the plant produced salt for the domestic fishing industry as well as low-sodium health salt for export. Part of the plant was restarted in 1999 on a small scale.

At Hædarendi in Southern Iceland, a plant for the commercial production of liquid carbon dioxide has been in operation since 1986. The plant uses 6 l/s of geothermal water at 160°C with high gas content. The annual production is about 2,000 tonnes of CO_2, which is used in greenhouses, soft drink production and other food industries.

Geothermal energy has also been used for other industrial purposes such as drying of hardwood at Husavik which started in 1986, drying of fish at several locations, retreading of car tires in Hveragerdi and production of cements blocks at Myvatn.

3.4 Greenhouses

Geothermal heating of greenhouses started in Iceland in 1924, but prior to that naturally warm soil had been used to grow potatoes and other vegetables. The total area under glass is about 195,000 m^2. Of this area about 55% are used for growing vegetables (tomatoes, cucumbers, paprika etc.) and 45% for growing flowers for the domestic market (roses, potted plants etc.). In addition it is estimated that about 105,000 m^2 are used for soil heating. It has the main benefit of early thawing of the soil and the vegetables can be brought to market sooner.

The majority of the greenhouses are in the southern part of Iceland. Most of them are glass covered with heating installations made of unfinned steel pipes hung on the walls and over the plants. Undertable or floor heating is also common.

Artificial lighting has increased considerably in the last years, doubling the crop yield and allowing year-round production, but with increasing expenses in electricity. Enrichment of CO_2 gas in greenhouses during the winter has increased last years.

3.5 Fish farming

At present there are about 50 fish farms in operation in Iceland. The total production has been slowly increasing the last years and is now about 4,000 tonnes per year. Salmon is the main species with about 70% of the production but arctic char and trout are also raised. Geothermal water, commonly 20-50°C, is used to heat fresh water in heat exchangers from 5 to about 12°C. It is mainly used in the hatchery state of the fish production. A great expansion is expected in this sector with a considerable increase in utilization of geothermal energy.

4 Electricity generation

The electricity demand has increased considerably in Iceland in the last years due to a large expansion in the energy intensive industry. This has been met partly by increased geothermally produced electricity. Of the total electricity generation of 8,411 GWh in 2002 1,433 GWh or 17% came from geothermal energy, 82,9% from hydro and 0,1% from fuels. Figure 4 shows the geothermal generation of electricity in Iceland in the period 1970-2002. The total installed capacity of geothermal power plants is now 200 MW.

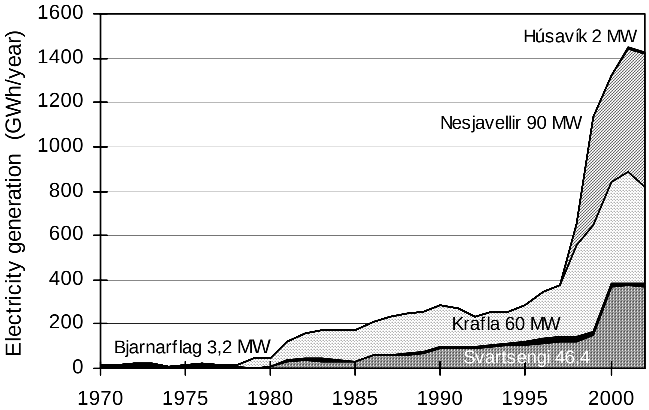

Figure 4: Geothermal generation of electricity in Iceland 1970-2002.

The first geothermal power plant with 3 MWe started operation in 1969 in Namafjall in North-Iceland. It has been in operation since, except for three years in 1985-1987 when the plant was closed mainly due to volcanic activity in the area. The reservoir temperature is about 280°C. Steam is separated from the water, at 9.5 bar absolute, to provide a steam flow rate of 12.5 kg/s to a single flash turbine.

The Krafla power plant in North-Iceland has been in operation since 1977. For the first 20 years it was generating 30 MWe in a double flash condensing turbine. Volcanic activity in the area caused inadequate steam supply in the beginning so expansion to the originally planned capacity was delayed. The capacity was increased to 60 MWe in 1997 by installing a second turbine. The reservoir temperature is ranging from 210 to 350°C. Steam is separated from the water in two stages, at 7.7 and 2.2 bar absolute, to provide 120 kg/s high pressure steam and 30 kg/s of low pressure steam. As a result of exploration drilling activity in the area the last years, further increase of 40 MWe are under preparation. Also it will be considered to build a new plant in the area in the future.

The Svartsengi co-generating power plant has been producing both hot water and electricity since it started operation in 1977. It is located on the Reykjanes peninsula, 40 km from Reykjavik, and serves about 16,000 people. The geothermal reservoir fluid is a brine at 240°C with high salinity. The geothermal heat is transferred to freshwater in several heat exchangers. An expansion of the plant was completed in 1999 by installing a new 30 MWe turbine. The total installed capacity is now 200 MWt for hot water production and 46 MWe for electricity generation, of that 8.4 MWe come from binary units using low-pressure waste steam.

The effluent brine from Svartsengi is disposed of into a surface pond called the Blue Lagoon, where it has for a long time been used by people suffering from psoriasis and other forms of eczema, who seek therapeutic effects from the silica rich brine. Also it is very popular among tourists, especially after the opening of new facilities a few years ago.

At Nesjavellir high-temperature field, Reykjavik Energy is operating a co-generating plant. The plant started operation in 1990 with production of hot water for the Reykjavik area 27 km away. Freshwater is heated by geothermal steam and water in heat exchangers. At the end of 1988 the power plant started electricity generation of 60 MWe in two 30 MWe turbines. The working pressure of the turbines is 12 bar (190°C). The third 30 MWe turbine was installed in the year 2001 bringing the total installed capacity to 90 MWe. Further expansion of the plant to 120 MWe is under consideration.

At Husavik, located in the northern part of Iceland, the generation of electricity began in the year 2000 by installing a binary plant of Kalina type. Geothermal water of 120°C is used to generate 2 MWe of electricity and hereby cooling the geothermal fluid down to 80°C. The electricity generated is enough to provide more than half of the electrical demand of the town. The 80°C water from the power plant is then used for district heating of the town.

5 Geothermal exploration

During the past five years the Ministry of Industry has been running a programme to encourage geothermal exploration for domestic heating in areas where geothermal resources have not been identified, so-called “cold areas”. A total amount of 150 million ISK (1.9 million US$) have been granted for this purpose and used mainly for drilling 50-100 m deep thermal gradient exploration wells. This method has proven to be a successful exploration technique in Iceland.

Reykavik Energy has the last years been drilling several exploration wells on Hellisheidi where they plan to build a new power plant for both electricity and hot water production. Also at Nesjavellir new wells have been drilled as a preparation for expansion of the existing power plant.

At Reykjanes Hitaveita Sudurnesja has been carrying out exploration drilling in connection with plans to utilise this high-temperature field for power production. There they plan to build a power plant of 40 MWe in the first stage. The company has also been involved in drilling activity at Trölladyngja, which is another high-temperature field on the Reykjanes peninsula.

A consortium of Icelandic energy companies is preparing the drilling of a 4-5 km deep drillhole into one of the high-temperature hydrothermal systems to reach 400-600°C hot supercritical hydrous fluid at a rifted plate margin on a mid-ocean ridge. The main purpose of the project is to find out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions. A feasibility report was completed in May 2003 and further proceeding of the project will depend on the financing available.

Figure 5 gives an overview of the geothermal drilling activity in Iceland since 1970.

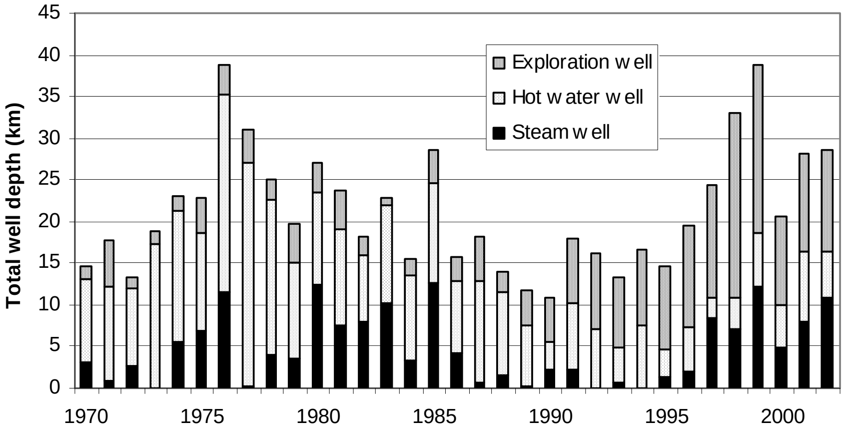

Figure 5: Total depth of geothermal wells drilled annually in Iceland 1970-2002.

6 References

Gunnlaugsson, E., Ragnarsson, A. and Stefansson, V. (2001). Country update 2001. Geothermal Energy in Iceland. Presented at the *International Symposium in Izmir*, Turkey, 4-5 October 2001.

Ragnarsson, A. (2000). Geothermal development in Iceland 1995-2000. *Proceedings of the World Geothermal Congress,* Japan, May 28 – June 10, 2000.