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# Geothermal Energy in Iceland

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## Introduction

Energy use in Iceland differs from other counties. The energy use is there higher per capita than in any other country in the world and the ratio of sustainable energy sources is also higher. Geothermal energy pays an important rule in the energy supply of Iceland but other sources are hydropower and imported fossil fuel. The ratio of domestic energy has increased considerably during last decades.

The geothermal resources in Iceland are closely associated with the country's volcanism, with the 26 high-temperature geothermal fields located within the active volcanic zone running from Southwest to Northeast, while the low temperature areas are mostly in the areas flanking the active zone. About 250 separate low temperature areas with over 600 hot springs have been located.

## Primary Energy Supply

The annual primary energy supply in Iceland, which has a population of about 283,000 was 138 PJ or 492 GJ per capita for the year 2000. This is a higher value than in any other country and can mainly be explained by Iceland's main industries, fishing and heavy industry. The primary energy sources for the year 2000 are shown in table 1 but figure 1 shows the changes and development from 1940. The figure shows clearly how the oil crisis affected the primary energy sources by increasing the use of geothermal energy for house heating. About 70 % of the primary energy supply are domestic sustainable energy sources while about 30 % are imported fossil fuels mainly used for fishing and transport where the domestic energy can not be used. This may change in the future if hydrogen can replace fossil fuels to some extent. Of the 70 % of the sustainable energy sources geothermal is over 52 % further showing its importance in the energy supply in Iceland. The availability of geothermal energy has strongly influenced the standard of living in Iceland with economical and environmental benefits. It has been estimated that using geothermal for space heating instead of fossil fuels saves annually about 100 million US$ in imported oil.

***Table 1.*** Primary energy supply in Iceland in 2000

| | PJ | % |
|---|---|---|
| Hydro | 22.9 | 16.5 |
| Geothermal | 73.6 | 53.2 |
| Oil | 37.7 | 27.3 |
| Coal | 4.0 | 2.9 |
| **Total** | **138.2** | **100** |

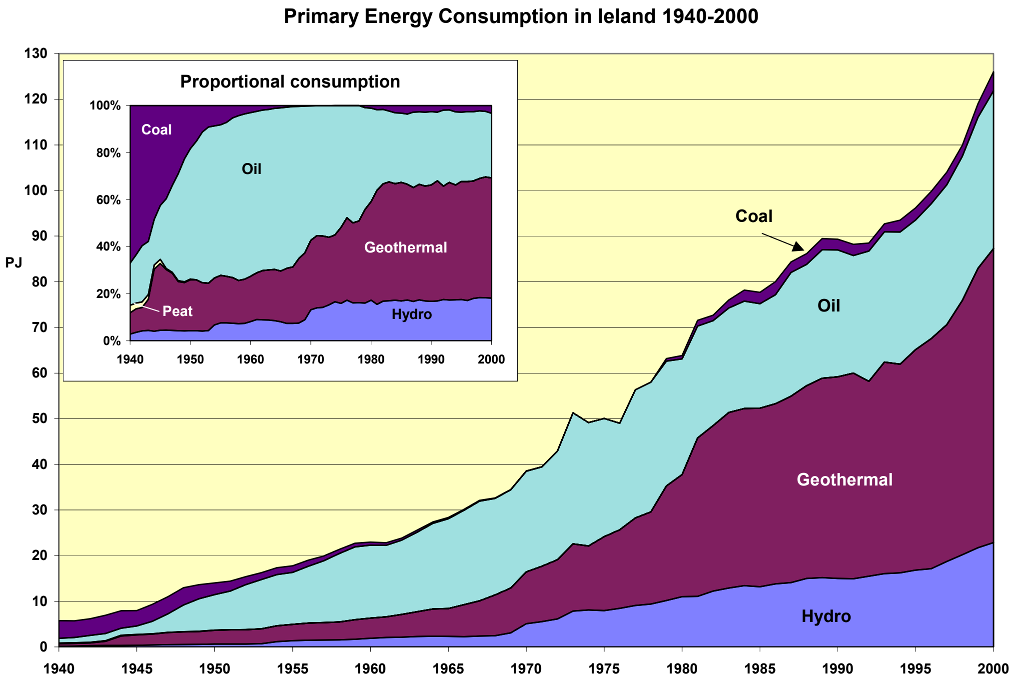


*Figure 1*. Primary energy use in Iceland from 1940 to 2000.

## Utilization of geothermal energy

For centuries, geothermal energy was only used for bathing and washing. In the late nineteenth century first attempts were done to use geothermal energy in gardening and in early twentieth century first greenhouses were heated with geothermal water. At the same time the first houses were heated with geothermal water and steam. Figure 2 shows the geothermal utilisation in Iceland classified by sectors for the year 2000. Direct use of geothermal energy for this year for space heating was 20,400 TJ or 5,650 GWh and the

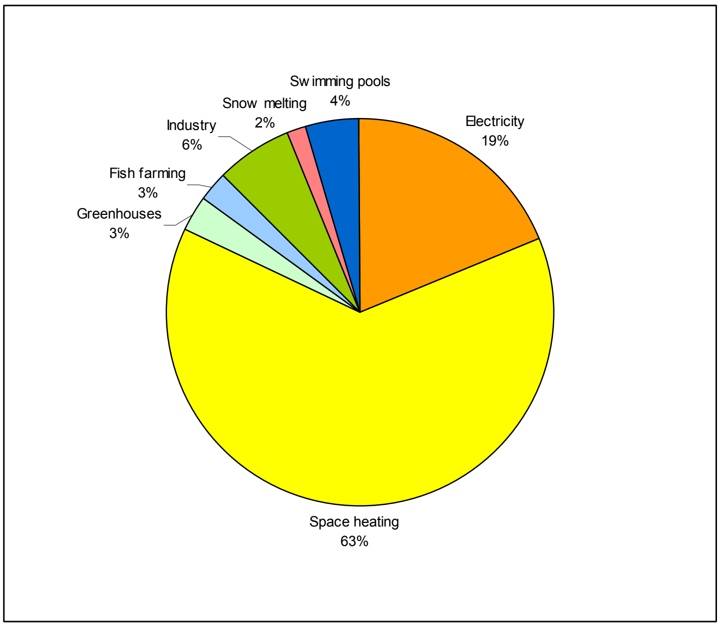


*Figure 2*. Geothermal uses in Iceland, classified by sectors

electrical generation was 1,323 GWh. As can be seen on the picture the main use of geothermal energy in Iceland is for space heating, about 63 % with 19 % electrical production in the second place.

***District heating*** using geothermal energy began in 1930 when the first house, a schoolhouse, in Reykjavík received hot water from wells close to the old thermal springs in Reykjavík. Soon after the main hospital, a swimming pool and about 70 private houses were connected. In 1943 geothermal water from a very large thermal field located about 17 km from the city was piped to Reykjavík. At the end of 1944 total 2850 houses had be connected to the district heating utility in Reykjavik. Following the oil crises in the 1970$^{th}$ the use of geothermal energy for space heating increased considerably. This development can be seen on figure 3. In 1970 geothermal accounted for 43 % of the energy used in Iceland for heating houses but to day it is 87 %. Now there are 26 municipally owned district heating system in Iceland, the largest one in Reykjavík serving 58 % of the total population of Iceland. The newest geothermal district heating system is for the village Stykkishólmur with 1,300

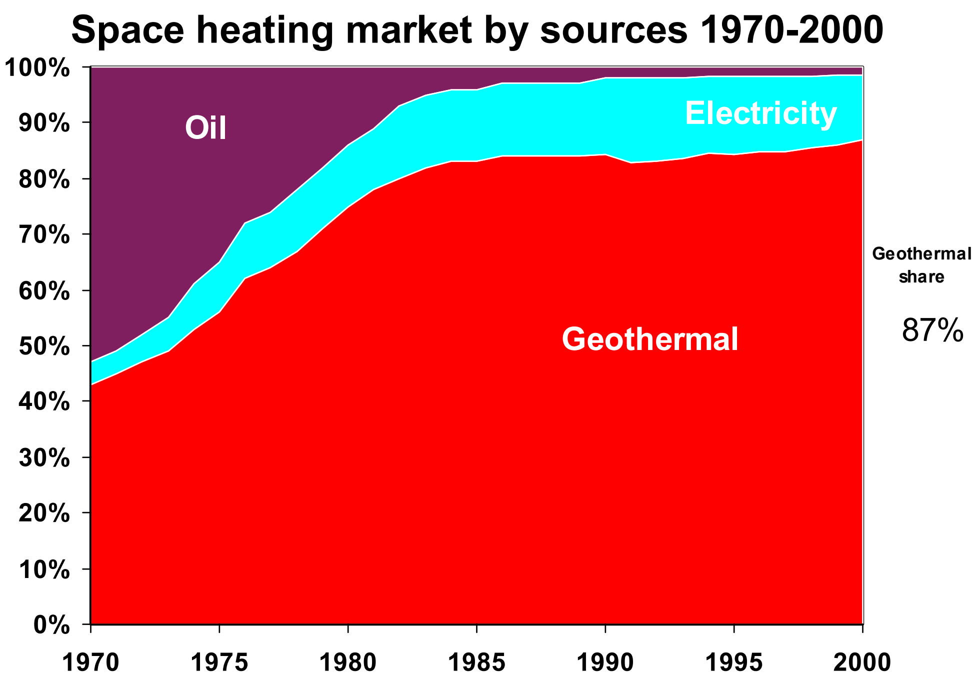


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***Figure 3***. Energy sources for space heating 1970 - 2000

inhabitants. Geothermal heating is now applied in all areas in Iceland where geothermal resources have been located. Relative increase of the geothermal heating is now taking place by discoveries of "hidden geothermal resources" (Stykkisholmur).

Today heating of swimming pools is the third most important direct use of geothermal water in Iceland. There are about 160 ***swimming pools*** in operation the majority or 130 using geothermal water. Most of the public swimming pools are open-air pools in constant use through out the year. Based on the surface area, 89 % are heated with geothermal, 7 % with electricity, and 4 % with oil. Swimming is very popular in Iceland and in Reykjavík area there area about 30 % of the swimming pools in Iceland. The number of visitors have increased in last years reaching 4.2 millions visits last year which is equivalent to 15 visits per inhabitant. New swimming pool of average size is using similar amount of thermal water as 80 – 100 private houses.

The use of geothermal energy for ***snow melting*** has been widespread for last 15 to 20 years. Spent water from heating of houses, about 35 °C, is commonly used 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 Reykjavík 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 Reykjavík are having snow-melting systems installed.

The total area now covered by snow melting systems in Iceland is estimated to be at least 350,000 $m^2$ , of which about 250,000 $m^2$ are in Reykjavík. The annual energy consumption is dependent on the weather conditions, but in average it is estimated to be about 325 $kWh/m^2$. Of that about two third come from spent water from the houses and one third from 80 °C hot water. The total geothermal energy used for snow melting is estimated to be 410 TJ per year.

Geothermal heating of ***greenhouses*** started in Iceland in the 1924, but prior to that naturally warm soil had been used to grow potatoes and other vegetables. The total area under glass is about 183,000 $m^2$. Of this area about 55 % are used for growing vegetables and 45 % for growing flowers for the domestic market. Artificial lighting has increased considerably in the last years, doubled the crop yield and allowed year-around production, but with increasing expenses in electricity. Enrichment of $CO_2$ gas in greenhouses during the winter has increased last years.

At present there are about 50 ***fish farms*** in operation in the country. The total production has been slowly increasing last years and is now about 4,000 tonne per year. Geothermal water commonly 20-50 °C is used to heat fresh water in heat exchanger from 5 to about 12°C and it is mainly used in the hatchery state of the fish production.

The use of geothermal energy for ***industrial uses*** began on a large scale in 1967 with the establishment of Kísilidjan, 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 pressure for drying. This corresponds to an energy use of 521 TJ per year.

A seaweed processing plant at Reykhólar uses geothermal water for drying. The annual production of seaweed and kelp is 2000 to 4000 tonnes and the processing plant is using 28 l/s of 107 °C water.

On the Reykjanes peninsula, a salt plant was in operation for more than 20 years, but it was closed down in 1994. Part of the plant was restarted in 1999 on a small scale.

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 2000 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 in the North which started 1996, drying of fish at several locations, retreating of car tires in Hveragerdi in the south and production of cements blocks at Myvatn in the North.

## *Production of electricity*

Last years there has been a large expansion in the energy intensive industry in Iceland that has increased the electricity demand considerably. At the end of 2001 the total installed capacity of electrical power plants in Iceland were 1,470 MW, 1,150 MW in hydropower plants, 200 MW in geothermal and about 120 MW using oil.

The total electricity generation in the year 2000 was 7,679 GWh or 27,317 kWh per inhabitant. This is higher than in most other countries and is expected to increase in the next years. Table 2 shows the origin of electricity in Iceland in the year 2000. Hydro is encounting for about 82.8 % and geothermal energy for 17.2 %. Fossil fuel is only used as back-up energy.

***Table 2***. Production of electricity in Iceland in 2000.

| | **GWh** | **%** |
|---|---|---|
| Hydro | 6,352 | 82.8 |
| Geothermal | 1,32 | 17.2 |
| Oil | 4 | 0.1 |
| **Total** | **7,679** | **100** |

Production of electricity using geothermal energy has increased considerably during the last years. Figure 4 shows the geothermal generation of electricity in Iceland in the period 1970-2000. The total installed capacity of geothermal power plants is now about 200 MW.

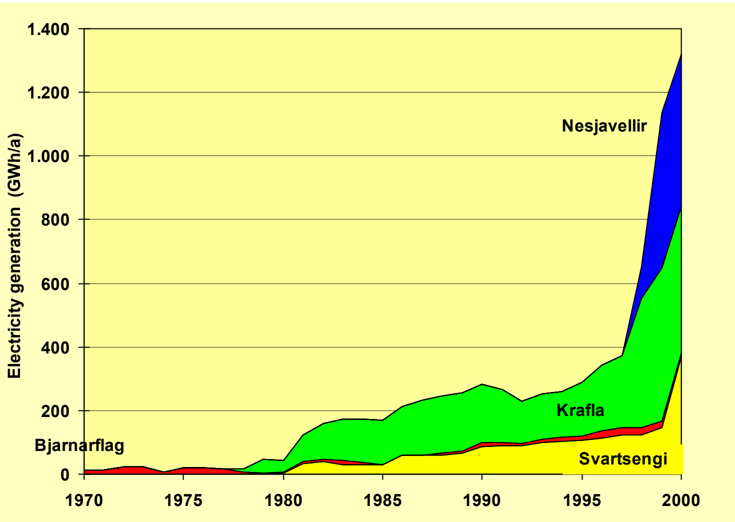


***Figure 4.*** Development of electrical production from geothermal 1970 – 2000

The first geothermal power plant with 3 MWe started operation in 1969 in Námafjall in the North. 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 Krafla power plant has been in operation since 1977. For the first 20 years generating 30 MWe but was increased to 60 MWe in 1997. Further increase of 40 MWe are under preparation.

The Svartsengi co-generating power plant has been producing both hot water and electricity since it started operation in 1977. In 1999 a new 30 MWe turbine was installed increasing the capacity to 46 MWe. Of that 8.4 MWe come from binary units using low-pressure waste steam.

At Nesjavellir high temperature field, Reykjavík Energy is operating a co-generating plant. The plant started operation in 1990 with production of hot water for the Reykjavík area. At the end of 1998 the power plant started electricity generation of 60 MWe in two 30 MWe turbines. In the year 2001, the third 30 MWe turbine was installed bringing the total installed capacity to 90 MWe.

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 125 °C is used to generate 2 $MW_e$ of electricity and hereby cooling the geothermal fluid down to 80 °C. The electricity generated is enough to provide 75 % of the electrical demand of the town. The 80 °C water from the power plant is then used for district heating of the town.

## $CO_2$ emission from geothermal industry

The environmental issues are paying important rule in all modern society. The emission of greenhouse gasses has to be reduced. Geothermal energy is important as it is renewable and environmentally friendly energy source. In Iceland 83 % of the greenhouse gasses are $CO_2$. The largest share, or 70 %, originate from the use of fossil fuels. This shows the importance of energy in the reduction of $CO_2$. In the year 2000 the total emission of $CO_2$ in Iceland was 3.3 million tonnes. Of which 36 % came from industry, 31 % from transport (excluding international flights), 26 % from the fishing fleet, 5 % from high temperature geothermal plants, 1 % from homes and 1% from other sources.The use of geothermal energy has reduced the $CO_2$ emission considerably since 86 % of the total population in Iceland is now using geothermal energy for space heating which replaced fossil fuels mainly in the years 1960-1980.

Table 3 shows the $CO_2$ emission form the high temperature geothermal fields in utilisation in Iceland. It should also be kept in mind that emission from geo-thermal fields is not production of greenhouse gasses this emission is taking place naturally in all high temperature geothermal fields although the utilisation is increasing the rate on a short time scale.

***Table 3.*** $CO_2$ emission from utilized high temperature geothermal fields 2000

| | **g/kWh** |
|---|---|
| Krafla | 173 |
| Námafjall | 210 |
| Svartsengi | 181 |
| Nesjavellir (electricity) | 28 |
| Nesjavellir (co-generation) | 10 |

## Future prospects

At present, the majority of town and villages in the geothermal regions in Iceland are using geothermal energy for space heating. It is not expected to grow much further in the coming years. The use of geothermal energy for generating electricity has increased greatly in the last years and is likely to increase further in coming years.

Exploratory drilling in the high temperature geothermal area on the southern side of the Hengill Mountain is now taking place. Two wells are drilled this year and three wells will be drilled in the year 2002. If the result turnes out to be positive the first power plant can be in operation there in 2005.

New exploratory well in the Trölladyngja thermal field is promising and future development is expected there in the next years.

Environmental impact studies are now conducted for three geothermal power plants, i.e. for the extension up to 100 MW of the Krafla power plant and two new power plants, one at Reykjanes and the other in Námafjall.

Industrial uses of geothermal energy are also under consideration, mainly as cascading applications to the electrical production.

Experiments to replace fossil fuel with renewable energy sources for transport and the fishing fleet are now taking place. For this purpose hydrogen produced with electricity seem to be most promising.

## References

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