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85 Years of Successful District Heating in Reykjavík, Iceland

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ABSTRACT

The use of geothermal water for house heating in Reykjavík stared in 1930 by use of artesian flow of water from shallow drillholes within Reykjavík. This was a great success and more people wanted access to hot water. That led to piping of low temperature water from other geothermal fields in the vicinity of the capital and building of a distribution system. A major development was in late 1950’s when a large drill rig was purchased and pumping started from deep drillholes. This led to lowering of water level in the fields and all hot springs disappeared. A new equilibrium was reached between production and water level. If pumping is now stopped from the low temperature fields the water reaches the surface within one or two years. The fields are therefore used in a sustainable manner. Today three low-temperature fields, Laugarnes, Elliðaaár and Reykir-Reykjahlíð are used for district heating in Reykjavík. When still more water was needed for heating in Reykjavík in late 1980’s the high-temperature fields at Nesjavellir and Hellisheiði were developed where groundwater is heated with geothermal fluid and pumped to the capital area. The district heating utility in Reykjavík serves the capital of Reykjavik and surrounding communities, about 60 % of the total population of Iceland. Geothermal district heating in Reykjavík has had enormous benefits on the environment, economy and living standard of Icelanders. Using geothermal water for heating instead of burning of fossil fuels has saved 100 million tons of CO_2 emission. Geothermal heating saves annually 3-4 million tons of CO_2 emission compared to emission from burning of oil. This is similar as the total annual CO_2 emission from Iceland. Heating cost has followed CPI despite of significantly more expensive technical solutions. Other alternative for heating is to use fossil fuels like coal and oil which have to be imported. The price of heating with geothermal water is low comparing to heating by oil. It has been estimated that cumulative oil savings is 22 billion USD or 5 times the Icelandic treasury budget. During the 85 years of district heating in Reykjavík the citizens have experienced numerous benefits related to the use of geothermal water for house heating. The air-quality is now much better and houses are better which are always kept comfortable warm. This has led to better health of the people and people are better off due to low energy cost. Reykjavík Energy is also operating district heating utilities in 7 other towns outside the capital area with total 15.000 thousand inhabitants and 7 other utilities serving farmhouses and holiday homes.

1. INTRODUCTION

Iceland is rich of energy resources, both hydro and geothermal. The geothermal resources are closely associated with the volcanic activity. Geothermal water is generally of meteoric origin, i.e. it is rainwater which has fallen to earth and sinks deep beneath the earth´s surface where it is heated up by hot substrata and magma intrusions. About 1000 geothermal localities have been recognized in Iceland (Figure.1). Traditionally the geothermal fields in Iceland are divided into low-temperature fields and high-temperature fields. The division is based on temperature and geological characteristics of the areas. We generally define low-temperature resources as those having temperature less than 150°C at a depth of about 1000 meters. These fields are characterized by warm and hot springs with little or no alteration around the springs. In the high-temperature areas the water temperature is not less than 200°C at a depth of 1000 meters. The surface activity of the high-temperature areas is much more diverse than that of the low-temperature areas. Fumaroles are found along with boiling hot springs, mud pots and geysers. Generally the soil is very acidic making it inhospitable to vegetation.

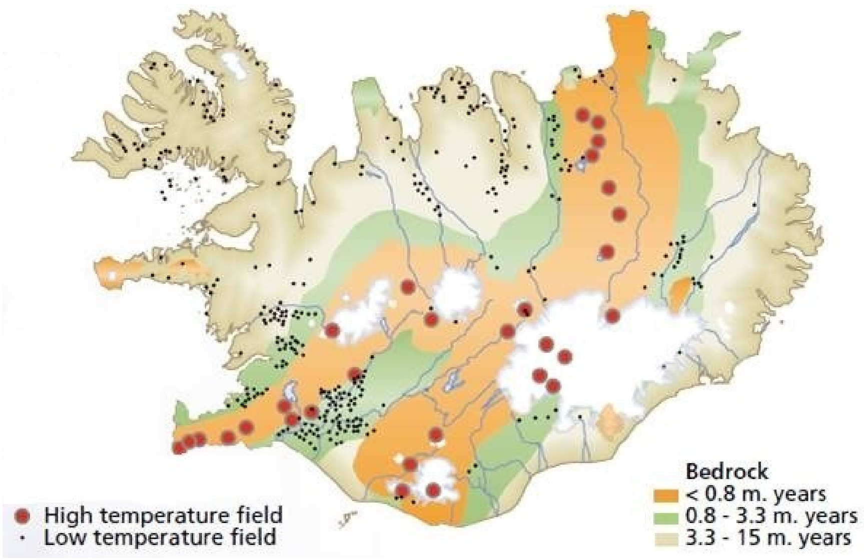

Figure 1: Geothermal activity in Iceland showing distribution of high- and low-temperature fields.

Some 30 high-temperature fields have been identified in Iceland, all within the active volcanic zone. The low-temperature areas, total a few hundred, are are mainly on the flanks of the volcanic zones but some low-temperature resources are found in most parts of the country. Many are without a doubt former high-temperature geothermal fields that have drifted out of the active volcanic zones and cooled.

2. THE USE OF GEOTHERMAL ENERGY FOR HEATING HOUSES IN ICELAND

Harnessing of this energy source has been one of the key factors in improving the quality of life in Iceland. The geothermal energy is mainly used for space heating but electrical generation has increased in the past few decades. Other uses include fish farming, balneology, horticulture, snow melting and industry.

For centuries, the utilization of geothermal heat was primarily limited to cooking, bating and laundering. In the Icelandic sagas which were written in the 12th – 13th century A.D., bathing in hot springs is often mentioned, such as one in Rekholt, where the famous saga writer Snorri Sturluson lived in the 13th century. There are implications that geothermal water or steam was conducted to the house for heating (Sveinbjarnardóttir 2005).

When Icelanders moved out of a houses made of turf into houses of wood or concrete at the end of the nineteenth and the beginning of the twentieth century the need for space heating of some sort was necessary. At first it was fulfilled by burning coal or peat in stoves or ovens. In many houses central heating with coal furnaces was installed. Coal for space heating was first imported after 1870 and the use of coal increased in the beginning of the twentieth century. Soon after the introduction of coal furnaces the idea of utilizing geothermal heat for space heating popped up. Experiments proved that it was technologically possible and could be advantageous (Jónason and Þórðarson 2007). The first attempt to use geothermal heat to heat houses was in 1908 but the first large scale heating using geothermal water was initiated in 1930 (Björnsson 2007).

Almost 90% of all houses in Iceland are currently heated by geothermal water, and the remainder is heated by electricity generated by hydro (71%) and geothermal (29%). The district heating utility in Reykjavík is by far the largest in Iceland. It is also the largest in the world. District heating are in most populated areas where geothermal water can be found in the vicinity. The country's larger district heating services are owned by their respective municipalities. Some 200 smaller heating utilities have been established in rural areas. Recently, district heating is also becoming popular for holiday homes (Friðriksson 2003). Figure 2 show the distribution of district heating services in Iceland.

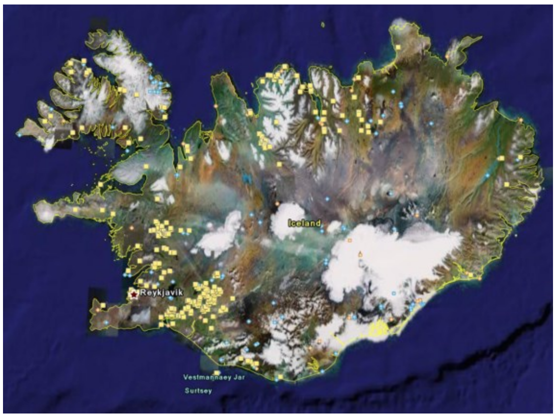

Figure: District heating utilities serving about 90% of all houses in Iceland.

3. REYKJAVÍK ENERGY AND DISTRICT HEATING IN REYKJAVÍK

Reykjavík Energy is multi-utility, owned by three municipalities. It was founded in 1999 by merging of Reykjavík District Heating and Reykjavík Electricity. In the following year Reykjavík Water Work was included in the Reykjavík Energy. It therefore stands on old roots distribution of cold water started in 1909, then production and distribution of electricity, in the beginning from hydropower started in 1921. Distribution of geothermal water for district heating in Reykjavík started 1930. In 2015 is 85 years of continuous service of hot water and with a great success. Reykjavík is also operating district heating utilities in 7 other towns outside the capital area with total 15.000 thousand inhabitants and 7 other utilities serving farmhouses and holiday homes). Reykjavík Energy took over the sewage services in Reykjavík in 2006 and operates fiber optics services for data transmission from 1999. To-day the company provides electricity to about 56 % of the population of Iceland, hot water to about 68 % of the population of Iceland and cold water to about 42 % of the population of Iceland.

3.1 Historical background of geothermal utilization in Reykjavík

For hundreds of years, the residents of Reykjavík used the thermal springs in Reykjavík to wash their laundries. District heating in Reykjavík began in 1930, utilizing water from boreholes in the vicinity of the thermal springs in Reykjavík. The yield of these boreholes was about 14 l/s of 87°C water. This location is part of the Laugarnes geothermal field which still is one of the fields used for district heating in Reykjavík. The water was piped 3 kilometers to a primary school in the eastern part of Reykjavík, which thereby became the first building in Reykjavík to be supplied with natural hot water. Soon more public buildings, including the national hospital, swimming pool as well as about 60 private dwelling houses were connected to the hot water supply.

It was clear from the beginning that more geothermal water would have to be found to fulfill the requirements of the town of Reykjavík. One of the largest low temperature geothermal fields in SW Iceland is located about 17 km east of Reykjavík. This field, the Reykir-Reykjahlíð field, was considered to be ideal as it is close to the city and capable of producing large quantities of geothermal water. In the 1940's shallow drillholes were drilled and pipeline build to Reykjavík. The first house was connected to the distribution system from this area in 1943. From the beginning the distribution system was interconnected and then the Reykjavík District Heating could deliver 200 l/s of water of 86°C. By the end of the following year the number of connected houses reached 2850.

By 1970 nearly all the houses in Reykjavik were receiving hot water for heating. Moreover, pipelines were laid and sales began to nearby municipalities. Reykjavík Energy serves 99.9% of the population in Reykjavík and surrounding communities with hot water for house heating.

3.2 Geothermal fields used for district heating in Reykjavík

The district heating utility in Reykjavík is utilizing hot water from three low-temperature geothermal fields, i.e. the Laugarnes geothermal field, the Elliðaár geothermal field and the Reykir-Reykjahlíð geothermal field. There is also production in the high-temperature fields at Nesjavellir and Hellisheiði in the Hengill area. At Nesjavellir, the heating capacity is about 290 MW_{th} co-generated with 120 MW_e and at Hellisheiði power plant the heating capacity is about 133 MW_{th} co-generated with 303 MW_e. About half of the heat used in Reykjavík and surrounding communities comes from the high-temperature power plants and half from the low-temperature geothermal fields.

3.3 Sustainable utilization of the low temperature geothermal fields

3.3.1 The Laugarnes field

Prior to exploitation the hydrostatic pressure at the surface in the Laugarnes geothermal field was 6-7 bars, corresponding to a free water level 60-70 m above the land surface. For the first 30 years mainly artesian flow from drillholes was used. Around 1960 use of down-hole pumps started that has caused a pressure drop in the field, and the water level has fallen (Figure 3). In 1985 to 1990 fresh and slightly saline groundwater has flown into the pressure depression and mixed with the geothermal water. A slight change in chemistry was noticed in some wells without changes in the fluid temperature. The mixing of different water types resulted in disequilibria of calcite and formation of that mineral. Reduced pumping after 1990 has reduced the pressure drop and the mixing of groundwater. Last decades new equilibrium between production and water level has been reached showing sustainable utilization of this geothermal field (Figure 4).

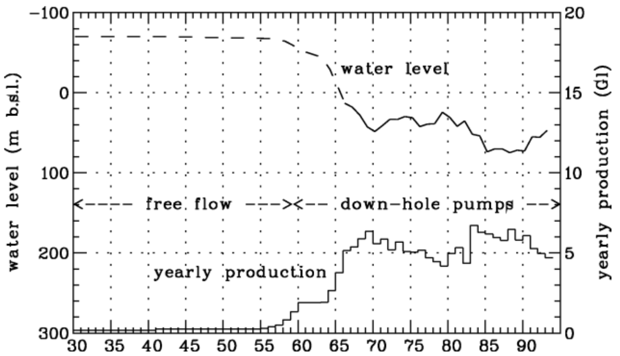

Figure 3: Water level and production history of the Laugarnes low-temperature field up to 1995.

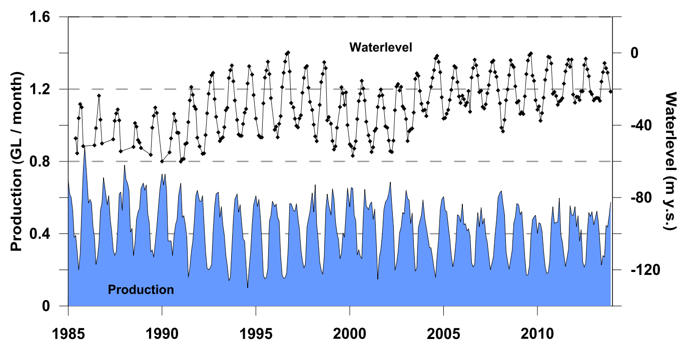

Figure 4: Production from the Laugarnes field and the water level in observation well from 1985 to 2013.

3.3.1 The Elliðaárfield field

The Elliðaár field is the smallest of the low-temperature geothermal fields used for district heating in Reykjavík. The field had minor surface manifestations before drilling with maximum temperature of 25°C. Drilling began in the area in 1967 finding aquifers with 85-110°C. The exploitation area covers 0.08 km^2 but the manifestations cover 8-10 km^2. When exploitation started in this area using down-hole pumps, the temperature was in the range of 95-110°C. Production caused a pressure drop and consequent cooling of the field. Cold groundwater from the surroundings mixed with the geothermal water, reduced the temperature, and affected the chemistry of the water. Chemical changes can often be seen before noticeable changes in temperature are observed.

Reduction of production in 1990 resulted immediately in higher water levels in the area (Figure 5) and a decrease in the mixing with cold water. Last decades only one or two drillholes are used but other can be added for short period of time during cold spell during the winter.

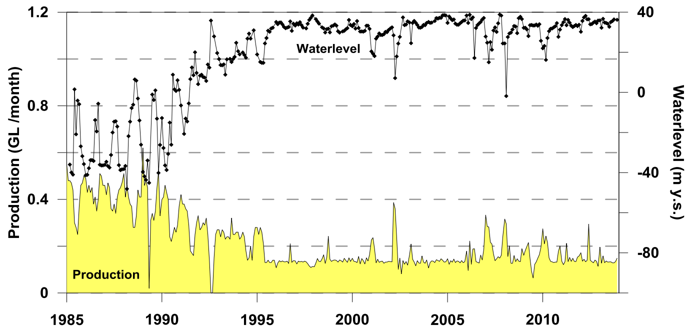

Figure 5: Production from the Elliðaár field and the water level in observation well from 1985 to 2013.

3.3.1 The Reykir-Reykjahlíð field

The Reykir-Reykjahlíð field which is about 5.5 km^2 is geographically divided into sub-areas, Reykir and Reykjahlíð. It is located between two calderas and the stratigraphy consists of lavas and hyaloclastite layers cut by numerous faults and fractures. Prior to drilling the artesian flow of thermal springs was estimated to be about 120 l/s of 70-83°C water. After drilling of shallow drillholes in the 1930´s about 200 l/s of 86°C water were available for heating houses in Reykjavík. After redeveloping of the field and installation of down-hole pumps in the 34 production drillholes, the yield increased to about 2000 l/s of 85-100°C water.

Annual variation in production is reflected in the water level (Figures 6 and 7). The water level was steadily decreasing until 1990 when it became possible to reduce pumping from the field when a new power plant at Nesjavellir started operation. Immediately after the reduction of production the pressure built up and the water level rose again. Changes in chemistry and temperature of the fluid were only observed at the south-eastern boundary of the field. After 1990 balance between production and water level has been reached showing sustainable utilization of this geothermal field. Production can be increased during short period of time if needed during cold winter spells.

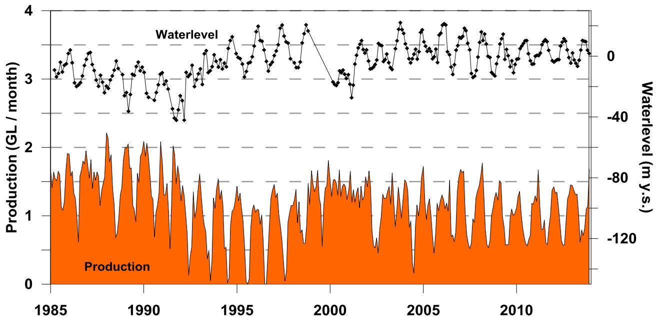

Figure 6: Production from the Reykir field and the water level in observation well from 1985 to 2013.

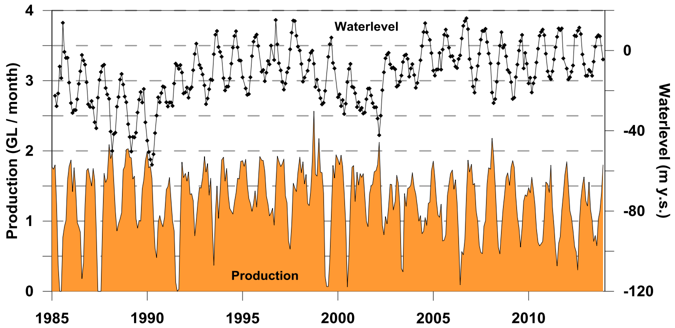

Figure 7: Production from the Reykjahlíð field and the water level in observation well from 1985 to 2013.

3.3 Distribution system and water production

The average temperature in Reykjavík in January is -1 °C and 11°C in July. Due to the low summer temperature, the heating season lasts throughout the year and is therefore suitable for district heating of houses.

The distribution system is either a single or a double distribution system (Figure 8). In the double system, the return flow from the consumer runs back to the pumping stations. There it is mixed with hotter geothermal water and serves to cool that water to the proper 80°C, before being re-circulated. In the single system, the backflow drains directly into the sewer system. During the coldest period of the year the consumers use about 18,400 m^3/hour of water for space heating.

The water from the low temperature geothermal fields can be used directly for district heating without any treatment. It is free of dissolved oxygen but it contains small quantities of hydrogen sulphide that helps to keep the water free of dissolve oxygen and the water is therefore not corrosive to steel. Hydrogen sulphide reacts with copper and therefore copper and copper alloys are not suitable material. On the other hand water from high temperature geothermal fields contain relatively high content of minerals and gasses and can therefore not be used directly for district heating. Thus cold water has to be heated up in the high temperature fields and treated before it is used for district heating.

The geothermal water from Reykir-Reyjahlíð field flows through main pipelines to six tanks in the eastern part of Reykjavík that hold 54 million liters. From there, the water flows to five storage tanks on Öskjuhlíð in mid-Reykjavík, holding 20 million liters. Distribution pumping stations located throughout the servicing area pump the water to the consumers.

The water from Nesjavellir and Hellisheiði high-temperature fields flows to three tanks on the way to Reykjavík that hold 27 million liters. From there, the heated water flows along a main pipeline to the southern part of the servicing area. The heated fresh water and the geothermal water are never mixed in the distribution system, but kept separated all the way to the consumer. Mixing of these water types will cause scaling of magnesium silicate. The total length of the pipelines in the distribution system is more than 3000 km. This includes all pipelines from the wells to the consumer. After the hot water has been used in a building, it has a temperature of 25-40°C. In recent years, it has become increasingly common to use this run-off water to melt snow of pavements and driveways. The use of geothermal water for melting snow has been increasing during the last three decades.

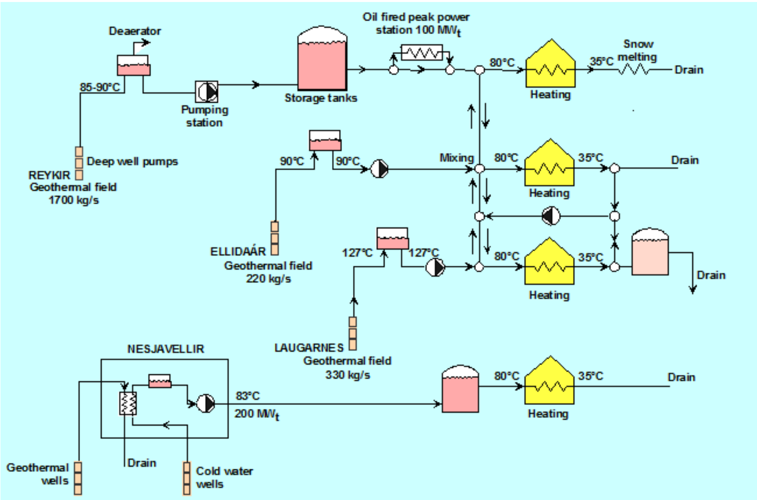

Figure 8: Simplified flow diagram for the district heating in Reykjavík.

The annual production from 1974 to 2014 is shown in figure 9. For the first years the production was below 10 million tons per year but from about 1960 to 1990 there was an increase in production as the system expanded to new areas. After that almost all houses had been connected and since 1990 the expansion is only new houses which are connected. In 2013 the annual water production was about 71.1 million cubic meters of hot water. The total power production of hot water in 2013 was equivalent to 430 MWt with about 48 % of the water coming from the low-temperature fields. About 85% of the hot water is used for space heating and about 15% being used for bathing and washing.

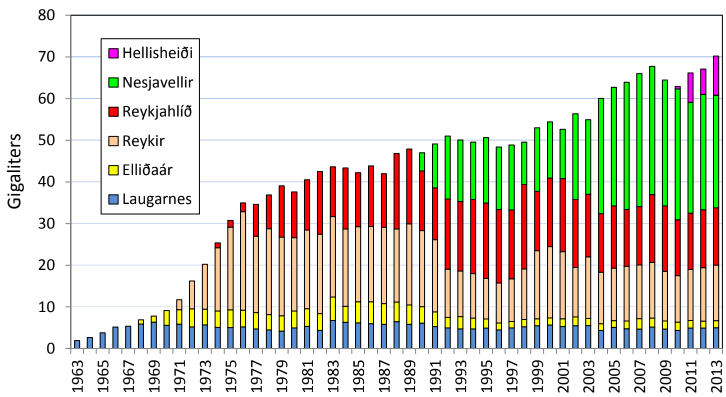

Figure 9: Total water production for the capital area between 1974 and 2014 (Source: Ívarsson 2014).

3.5 Other district heating utilities operated by Reykjavík Energy

Beside district heating in the capital area, Reykjavík Energy is also operating 12 heating utilities outside the capital area serving towns and rural areas (Figure 10). The towns are Akranes, Borgarnes and Stykkishólmur in the west and Hveragerði, Þorlákshöfn, Hella and Hvolsvöllur in South Iceland.

Figure 10: Location of district heating utilities operated by Reykjavík Energy.

3.5.1 Stykkishólmur

Stykkishólmur district heating in Snæfellsnes W-Iceland started operation in 1999 serving the town of Stykkishólmur (1100 inhabitants) with thermal water. The water is taken from one production well located about 5 km from the town. The reservoir temperature is about 87°C. The annual production is near 855 thousand tons and has increased slightly over the last few years.

3.5.2 Akranes and Borgarnes

The Akranes-Borgarnes district heating service in Western Iceland provides the towns of Akranes (6700 inhabitants) and Borgarnes (1830 habitants) with geothermal water, as well as some farmhouses along the 63 km long pipeline from the Deildartunga hot spring. This hot spring is one of the world's largest hot springs with some 180 l/s natural flow rate with temperature of 98-99°C. The temperature of the water when it reaches Akranes is 77-78°C. The annual production is around 4.3 million tons.

3.5.3 Þorlákshöfn

Two drill holes with temperature from 100-120°C serve the town of Þorlákshöfn with population about 1900 inhabitants. Yearly production is about 900 thousand tons.

3.5.4 Hella and Hvolsvöllur

This district heating service serves began operation in 1982 serving the small towns of Hella and Hvolsvöllur. A total of some 1500 people are served, as well as some 250 persons in the neighboring farming community. Two geothermal fields with reservoir temperature about 100°C and 70°C respectively are utilized. The annually production is around 2.2 million.

3.5.5 Hveragerði

The district heating in Hveragerði, a town with nearly 2300 inhabitants started operation in 1946 and Reykjavík Energy took over the operation late 2004. Hveragerði is part of the Hengill high-temperature geothermal system with hot springs and fumaroles within the town. The temperature in drillholes in the town is up to 180°C. There is natural flow from the wells and no down-hole pumps are used. There the annual production is about 1230 thousand tons.

3.5.6 District heating for farms and holyday homes

Holiday homes in the countryside are popular in Iceland. More and more people enjoys the quietness of the countryside to relax and find comfort. Holiday homes are often built in clusters where services such as waterworks and electricity are accessible. The holiday homes with geothermal water have greater attraction than those without geothermal water since there are usually hot water tubs or spas. Many holiday home areas are located in the vicinity of geothermal resources that can easily be harnessed. Reykjavík Energy operates several district heating services were holyday homes are the principal users.

Norðurárdalur. It serves the university community at Bifröst and summer houses. Two wells are used, capable of providing 40 l/s with a temperature between 66°C and 74°C. Total annual production is around 430 thousand tons.

In the *Munaðarnes* holiday home area, located some 100 km north of Reykjavík there are 160 holiday homes and 90 of them publicly owned by a union. Total annual production is around 205 thousand tons.

Austurveita is located east of the town Hveragerði. It serves less than 100 houses and farms. Three wells, one at 37°C, the second at 103°C and the third at 115°C provide some 9 l/s. Total production is around 440 thousand tons a year.

The *Ölfus* district heating service provides hot water for fish farming businesses, as well as a few farms and holiday homes. Reservoir temperature is about 113°C and the total annual production is around 48 thousand tons.

The *Grímsnes* holiday home area is located 60 km east of Reykjavík. Some 1500 holiday homes have been built in the area and half are connected to the heating service. Three drill holes are used with temperature 60-85°C. The supply temperature measured at the holiday homes ranges from 55° to 80°C, depending on the distance from the geothermal field and the number of connected holiday homes in the vicinity. Annual production is near 1.78 million tons.

Hlíðarveita is located about 10 km south of the Geysir geothermal area. It serves a farming community with a large collection of summer houses. One well is used is capable of providing some 20-25 l/s of almost boiling water. The wellhead temperature is between 140-150°C and the steam phase is used to power a small steam turbine that produces around 70 kW, enough to power the pump for the district heating service. Annual production is near 700 thousand tons.

4. BENEFITS OF DISTRICT HEATING

During the course of the 20th century, Iceland went from one of Europe's poorest countries, dependent upon peat and imported coal for its energy, to a country with a high standard of living where practically all stationary energy and roughly 82% of primary energy comes from indigenous renewable sources (62% geothermal, 20% hydropower). District heating has now been in Reykjavík for about 85 years. The citizens have experienced numerous benefits related to the use of geothermal water for house heating. The air-quality is now much better than before and the use of geothermal water has reduced emission of carbon dioxide. The houses are better built and the indoor temperature is always kept comfortable warm. This has led to better health of people.

4.1 Economic benefits of geothermal space heating

The price of heating with geothermal water is different from one place to another. In Iceland it is very well compatible with other alternatives. Over the period 1970-2009 the retail price of imported heating oil has at all times been higher than the price of geothermal energy per unit of deliverable heat energy. For some years, the use of oil for heating was only 2 times as expensive as heating by geothermal, but in 1979 and 2008, it became almost 10 times as expensive (Haraldsson et al. 2010, Haraldsson 2014). The accumulated savings customers over this 40 year period amount to 9,510 million USD, more than three times Iceland's national budget. It has been estimated that cumulative oil savings is 22 billion USD or 5 times the Icelandic treasury budget (Friðriksson, 2013). The total economic benefit from geothermal in 2010 has been estimated to be in the ranges of US$ 480 to 830 million. This is equal to 4-6% of gross domestic product of Iceland. This includes benefits for space heating, related industry benefits and social impacts (Friðriksson, 2013). Figure 11 shows estimated cost of heating houses with oil compared to the price of geothermal heating from 1975 to 2012. Large variation is in the price of oil but the price of heating with geothermal water is more or less constant.

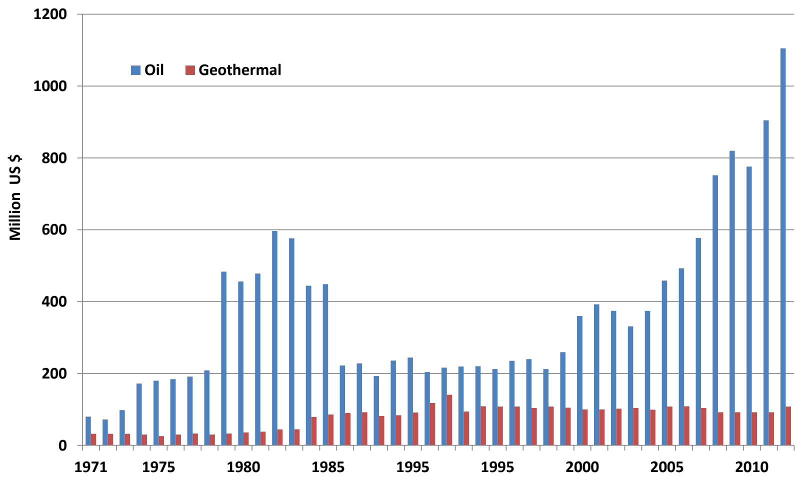

Figure 11: Revenues of heating utilities of geothermal heating compared to cost of heating with oil (Source: Orkustofnun 2014)

The hot water in Reykjavík is sold by volume of water. The price of 1 m^3 of hot water is about 1.147 US$. Typical monthly cost of heating 200m^2 house is equal to 72 US$ or similar as a subscription to two newspapers.

Figure 12 shows the price of average heating prices in Europe, the United States and Korea. The data is based on data from Euroheat & Power, 2014. Iceland has the lowest price of 3.54 USD/GJ. Out of 20 surveyed countries, the highest price is in Denmark and the second highest in Norway. The Nordic countries all have cold climates and therefore a need for heating. This difference is therefore of special interest. It is probable that the reasons are not only economic but also political. In general, taxes tend to be high in Nordic countries and countries with limited domestic energy resources may want to keep energy prices high in order to promote efficiency and reduce consumption.

4.2 Environmental benefits of geothermal space heating

Reykjavík is one of the cleanest capitals in the world, thanks to geothermal district heating. In the 1940s the majority of houses were heated by burning coal but today they are heated with geothermal water. Heating with polluting fossil fuels has been eliminated, and about 100 million tons of CO_2 emissions have been avoided by replacing coal and oil heating by geothermal (Figure 13). Geothermal utilization has reduced CO_2 emissions in Iceland by some 2-4 million tons annually compared to the burning of fossil fuels. The total release of CO_2 in Iceland in 2010 was 3.4 million tons (Hallsdóttir et al. 2012). The reduction has significantly improved Iceland's position globally in this respect. Iceland has therefore reduced its greenhouse gas emission dramatically, decades before the international community began contemplating such actions. Many countries could reduce their emissions significantly through the use of geothermal energy. The gas emissions from low-temperature geothermal resources are normally only a fraction of the emissions from the high-temperature fields used for electricity production. The gas content of low-temperature water is in most cases very small, like in Reykjavik, where the CO_2 content is lower than or similar to that of the cold groundwater (about 0.05 mg CO_2 /kWh). In sedimentary basins, such as the Paris basin, the gas content may cause scaling if it is released. In such cases, the geothermal fluid is kept at pressure within a closed circuit and re-injected into the reservoir without any de-gassing taking place. Such systems have zero emission.

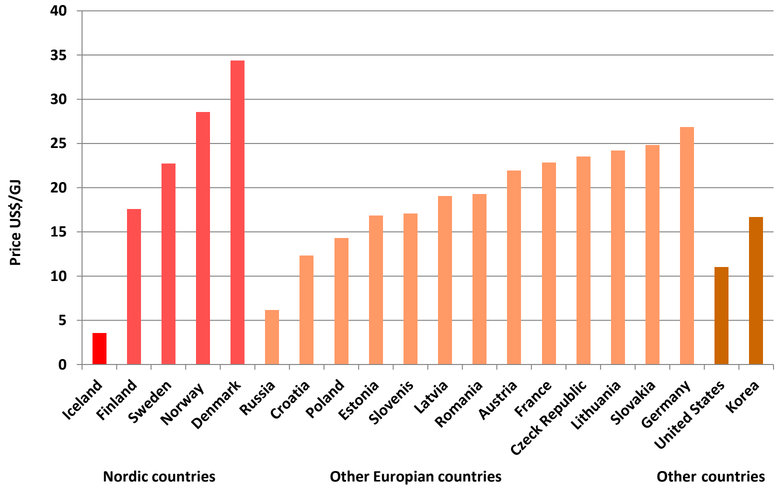

Figure 12: Average district heating prices in Europe, the United States and Korea. (Source: Euroheat & Power 2014)

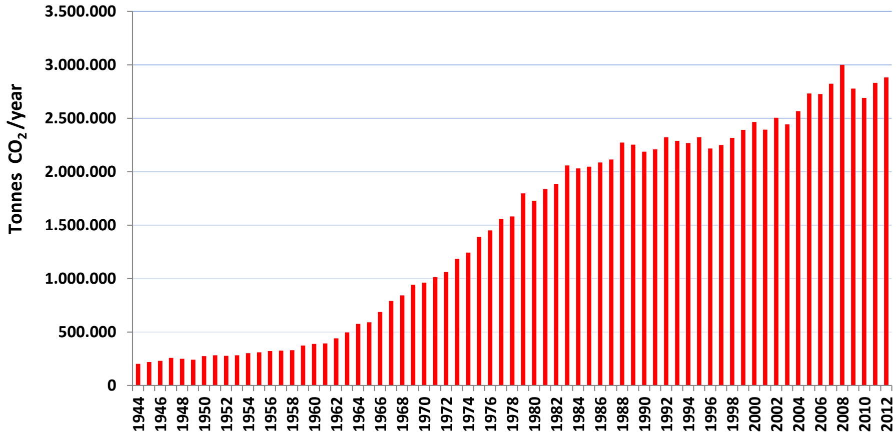

Figure 13: CO2 savings using geothermal water in Reykjavik (Iceland) compared to other energy sources 1944-2012. Total avoidance is about 100 million tonnes of CO2 emissions.)

No systematic collection has been made on CO_2 emission data from geothermal district heating systems in the world. The CO_2 emission from low-temperature geothermal water can be regarded negligible or in the range of 0-1 g CO_2/kWh depending on the carbonate content of the water. Galanta in Slovakia is an example of replacing fossil fuels by geothermal water, although on a smaller scale. A district heating system using natural gas with about 9,000 GJ/yr heat productions was modified. The natural gas was replaced as a heat source by carbonate rich geothermal water. The replacement resulted in the reduction of CO_2 emission by about 5,000 tonnes annually (Galantaterm, 2014). Although this geothermal water is rich in carbonate, its CO_2 emission is negligible (about 0.3 g CO_2/kWh).

4.3 Other benefits of geothermal space heating

Geothermal energy has not only improved the economy and the environment in Iceland but also improved the quality of life of the people significantly. The houses are better built with good insulation and double glass in windows and all rooms are kept comfortable warm. This has led to better life and health of the people.

Geothermal heating has encouraged building of swimming pools that are very popular in Iceland. Around 150 outdoor swimming pools open around the year in Iceland with comfortable pools for swimming and hotter pools where people can sit down and relax and discuss the news, politics or just the weather.

In Iceland there are long winters and short summers. Therefore, it is common to build heated garden conservatories heated by geothermal water for the purpose of growing tropical plants and flowers.

When the hot water flows through the radiators of the houses it is cooled down to 20-40°C. After that is common to let the water flow through tubes under driveways and walkways to melt snow. Almost all new buildings in the capital area have such snow melting system.

6. CONCLUSIONS

Geothermal is one of the cleanest energy sources available. It can be utilized in sustainable manner and has to be well operated, properly monitored and done in respect to the environment. The use of geothermal water for house heating in Reykjavík and other areas in Iceland has greatly influenced the economy of the country and the live and health of the people. The total annual economic benefit from geothermal is in the ranges of US$ 480 to 830 million that is equals to 4-6% of gross domestic product of Iceland. The use of geothermal water for heating houses in the Reykjavík area has saved some 100 million tonnes of CO_2 emissions.

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