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Direct Use of Geothermal Water for District Heating in Reykjavík and Other Towns and Communities in SW-Iceland

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ABSTRACT

The geothermal district heating utility in Reykjavík is the world´s largest geothermal district heating service. It started on a small scale in 1930 and today it serves the capital of Reykjavík and surrounding communities, about 58 % of the total population of Iceland. All houses in this area are heated with geothermal water. Three low-temperature fields, Laugarnes, Elliðaaár and Reykir/Reykjahlíð are used for this purpose along with geothermal water from the high-temperature field at Nesjavellir. 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. The paper will give overview of these utilities and their geothermal fields.

1. INTRODUCTION

Iceland, a country of 300,000 people, is located on the Mid-Atlantic Ridge, a plate margin characterized by high heat flow. Due to the high heat flow hot springs are very abundant in the country. About 1000 geothermal localities have been recognized in Iceland (Fig.1). 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.

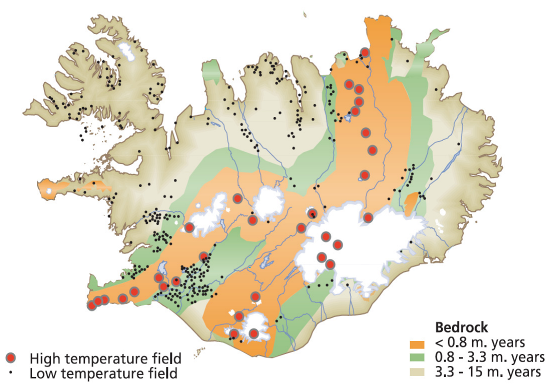

Figure 1: Geothermal activity in Iceland showing distribution of high- and low-temperature fields

2. THE USE OF GEOTHERMAL ENERGY

Iceland's energy use per capita is among the highest in the world and the proportion of this provided by renewable energy source (77%) exceeds that in most other countries. Harnessing the geothermal energy source has been one of the key factors in improving the quality of life in Iceland. It is mainly used for space heating (50%), then electricity generation (34%), fish farming (4%), swimming pools (4%), snow melting (4%), greenhouses (2%) and industry (2%) (Orkustofnun 2008).

3. GEOTHERMAL WATER FOR HOUSE HEATING

In the Icelandic sagas, which were written in the 12th – 13th century A.D., bathing in hot springs is often mentioned. Commonly bath was taken in brocks where hot water from often boiling springs would be mixed with cold water. The famous saga writer Snorri Sturluson lived at Reykholt in west Iceland in the 13th century. At that time there was a bath at his farm but no information about its age, size or structure. There are also implications that geothermal water or steam was directed to the house for heating (Sveinbjarnardóttir 2005).

In a cold country like Iceland, home heating needs are greater than in most countries. The average temperature in January is -1°C and 11°C in July. Due to low summer temperatures, the heating season lasts throughout the year. Iceland is therefore suitable for localized district heating services and they tend to be economically profitable both on a national and individual bases.

By moving from houses made of turf into houses made of wood and concrete at the end of the nineteenth and beginning of the twentieth century Icelanders needed some kind of space heating. Coal imports for space heating began after 1870 and the use of coal increased in the beginning of the twentieth century. Oil for heating first became significant after World War II.

The first attempt to use geothermal energy to heat houses was in 1907 but large scale distribution of hot water for heating houses began in 1930.

4. DISTRICT HEATING IN REYKJAVÍK

4.1 Historical Development

District heating in Reykjavík began in 1930, utilizing water from boreholes in the Laugarnes field close to thermal springs in the area. This was the first district heating system using geothermal water. The water was piped 3 kilometers to a primary school in the eastern part of Reykjavík, which thereby became the first building to be supplied with natural hot water. Soon more public buildings, including the national hospital, a swimming pool, as well as about 60 private houses were connected to the hot water supply. But more water was needed to fulfill the requirements of the town of Reykjavík. A large geothermal area 17 km east of Reykjavík, the Reykir/Reykjahlíð field, was considered to be ideal with respect to its proximity and its capability of being able to produce large quantities of geothermal water. Shallow drill holes were drilled in this area and a pipeline build to Reykjavík. The first house was connected to the distribution system from this area in 1943.

Research and test drilling confirmed that more geothermal water was to be found in the close vicinity of the old thermal springs in Reykjavík. In the beginning of 1962 many wells were harnessed and pumps installed to increase their output. Several holes were drilled between 1967 and

1970 in another geothermal field by the Elliðaár River, within the city limits of Reykjavík. It was also necessary to re-drill older boreholes in Reykir-Reykjahlíð to increase their output. By 1970 nearly all the houses in Reykjavík were receiving hot geothermal water for heating. Moreover, pipelines were laid and sales began to nearby municipalities. Today Reykjavík District Heating serves 99.9% of the population in Reykjavík and neighboring communities, totaling about 187,000 people or about 58.7% of the population of Iceland.

4.2 The Geothermal Fields Today

Today three low-temperature geothermal fields are utilized for district heating in Reykjavík as well as the high-temperature geothermal field at Nesjavellir, where 120 MWe and 300 MWt geothermal plant is operated. Figure 2 shows how the production is divided between the different geothermal areas (Ívarsson 2009).

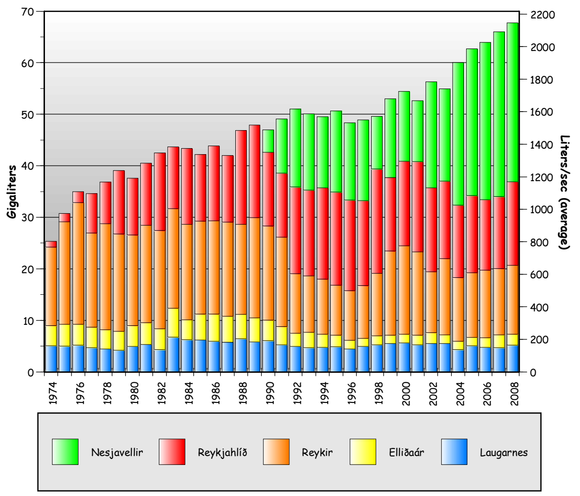

Figure 2: Total water production for the Greater Reykjavík area between 1974 and 2008

4.3 Production and Water Level of the Low-Temperature Geothermal Fields

In the low-temperature fields, there are a total of 52 exploitation wells with a total capacity of about 2400 l/s.

4.3.1 The Reykir – Reykjahlíð geothermal field

Aquifers in the Reykir – Reykjahlíð geothermal field can be correlated to faults and fractures. Prior to drilling, the artesian flow of thermal water was estimated about 120 l/s of 70-83°C water. After redeveloping the field and installation of down-hole pumps in the 34 production wells, the yield from the wells increased to about 2000 l/s of 85-100°C water. Figures 3 and 4 show the production and water level in observation wells from 1985 to 2008.

The water level steadily decreased until 1990 when it became possible to reduce pumping from the field when the new power plant at Nesjavellir started operation. Within a year of the production reduction, the pressure built up and the water level rose again. Only slight changes in chemistry and temperature of the fluid were observed at the south-eastern boundary of the field (Gunnlaugsson et al., 2000). In 2008 the combined production from the Reykir-Reykjahlíð field amounted to 29.6 million tons or almost 44% of the required hot water for the Reykjavík area (Ívarsson 2009).

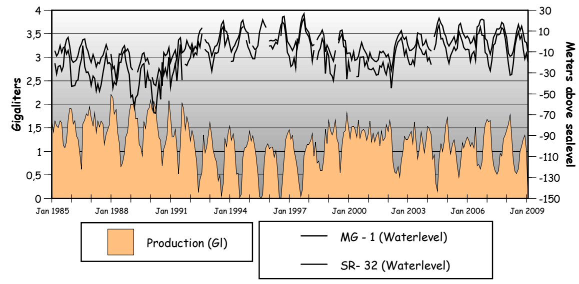

Figure 3: Production from the Reykir field and water level in observation well from 1985 to 2008

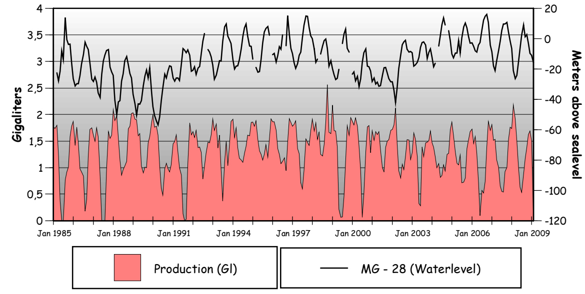

Figure 4: Production from the Reykjahlíð field and the water level in observation well from 1985 to 2008

4.3.2 The Laugarnes Geothermal Field

The Laugarnes geothermal system is located within Reykjavík. In the 1960´s drilling stared in the field and down-hole pumps were used to increase the water production. Ten production wells are used today with a reservoir temperature of 120-140°C. The hydrostatic pressure at the surface in the Laugarnes geothermal field was 6-7 bars prior to exploitation. Exploitation caused a pressure drop in the field, and the water level fell (Fig. 5). Consequently, fresh and slightly saline groundwater has flowed 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. In 2008 the Laugarnes geothermal field produced 5.2 million tons or almost 8% of the required hot water for the Reykjavík area (Ívarsson 2009).

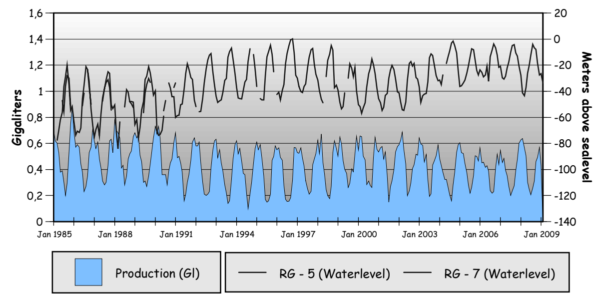

Figure 5: Production from the Laugarnes field and the water level in observation well from 1985 to 2008

4.3.3 The Elliðaár Geothermal Field

The Elliðaár field is the smallest of the low-temperature geothermal fields used for district heating in Reykjavík.

When exploitation started in this area, 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, reducing 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 (Fig. 6) and a decrease in the mixing with cold water. In 2008 the Elliðaár geothermal field produced 2.1 million tons or about 3% of the required hot water for the Reykjavík area (Ívarsson 2009).

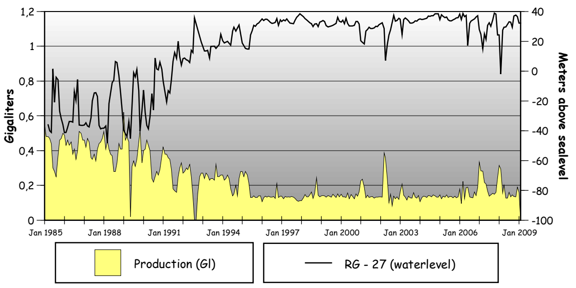

Figure 6: Production from the Elliðaár field and the water level in observation well from 1985 to 2008

4.4 Production and CO_2 Savings by Using Geothermal Water for House Heating

The annual production from 1944 to 2008 is shown in Fig. 7. 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. Then almost all houses had been connected and since 1990 the expansion is only new houses which are connected.

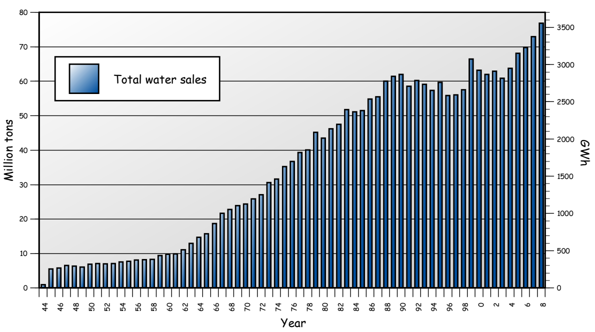

Figure 7: Water sales from 1944-2008

In 2008 the annual water production was about 68 million cubic meters of hot water (plus 9 million cubic meters of backwater for mixing). The total power production of hot water in 2008 was equivalent to 774 MWt with about 55% of the water coming from the low-temperature fields and 65% of the energy. About 85% of the hot water is used for space heating and 15% being used for bathing and washing. The utility serves about 187,000 people or about 58.7% of the total population in Iceland.

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. The gray grime is long gone and the sky is bright blue. 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 (Fig. 8). Geothermal utilisation 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 2004 was 2.8 million tons. 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.

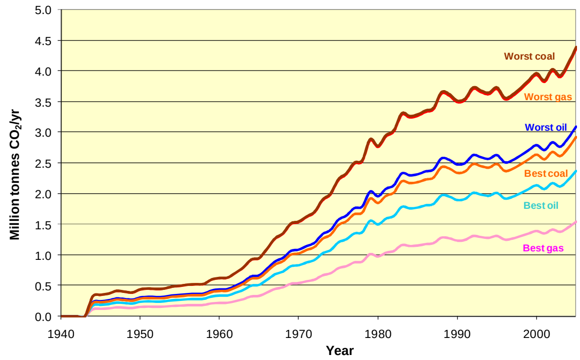

Figure 8: CO_2 savings using geothermal water in Reykjavík compared to other energy sources 1940-2006. Total avoidance, is 90 million to 110 million tons of CO_2 emissions depending on the type of fossil fuel(s) replaced by geothermal resources

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 many cases minute, like in Reykjavík, where the CO_2 content is lower than or similar that of the cold groundwater or about 0.05 mg CO_2 /kWh.

5. OTHER DISTRICT HEATING UTILITIES OPERATED BY REYKJAVÍK ENERGY

Almost 90% of all houses in Iceland are currently heated by geothermal water, and the remainder is heated by electricity generated by hydro (70%) and geothermal (30%). The district heating utility in Reykjavík is far the largest and so far the largest in the world. District heating are in most populated areas in Iceland 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). Fig. 9 shows the distribution of district heating services in Iceland.

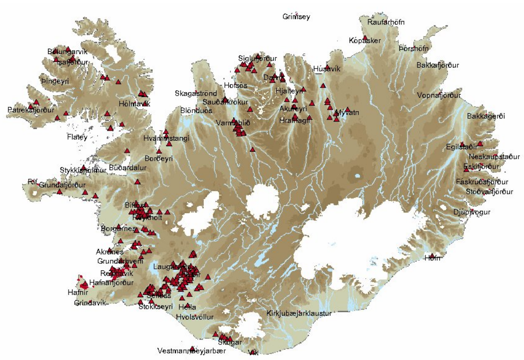

Figure 9: District heating utilities serving about 90% of all houses in Iceland

In SW-Iceland, 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.

Fig. 10 shows the 15 largest district heating services in Iceland ranked according to the water production.

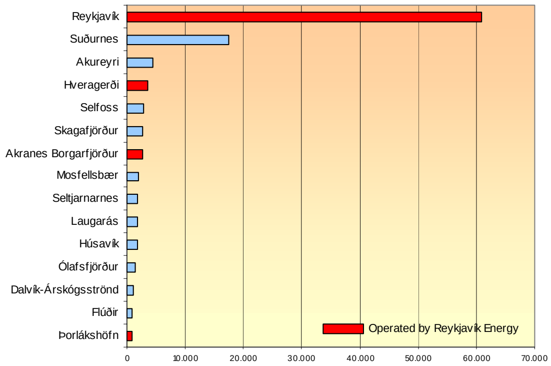

Figure 10: Water production of the 15 largest district heating services in Iceland

5.1 Akranes and Borgarnes

The Akranes-Borgarnes district heating service provides the towns of Akranes (6600 inhabitants) and Borgarnes (1950 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 district heating started operation in 1979. The pipeline was originally built of asbestos but large parts have been replaced by steel pipes. The temperature of the water when it reaches Akranes is 77-78°C. The annual production is on average 4.3 million tons (Oddsdóttir 2008 a).

5.2 Stykkishólmur

Stykkishólmur district heating in Snæfellsnes W-Iceland started operation in 1999. It serves the town of Stykkishólmur (1100 inhabitants) with thermal water which is taken from one production well at Hofsstaðir, located about 5 km from the town. The geothermal system has a reservoir temperature of approximately 87°C. Fig. 11 shows water production and water-level history for the geothermal system. The annual production is near 725 thousand tons and has increased slightly over the last few years (Oddsdóttir 2008 b).

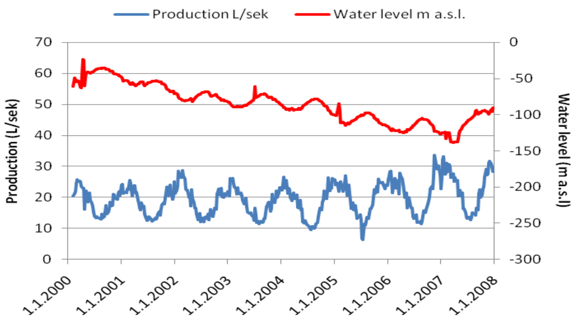

Figure 11: Production from the Hofsstaðir field and the water level from 2000 to 2008

5.3 Hveragerði

Hveragerði is a town in SW-Iceland with nearly 2300 inhabitants. The district heating in Hveragerði started operation in 1946 and Reykjavík Energy took over the operation late 2004. Hveragerði is located in a high-temperature geothermal field with hot springs and fumaroles within the town. The temperature is up to 180°C. Many drill holes have been drilled but seven wells are now in use. There is natural flow from the wells and no down-hole pumps are used. Three distribution systems are in operation. Distribution system I is closed circulation system which serves half of the inhabitants and several industrial companies. In distribution system II geothermal steam is piped to about 25% inhabitants and majority of industrial companies. Distribution system III is single system serving about 25% inhabitants and few industrial and service companies. The temperature of the water in distribution systems I and III are about 80°C but the steam in distribution system II is 150-170°C. All houses except green houses are equipped with heat exchangers due to high temperature of the steam and high content of dissolved solids in the water otherwise forming precipitation in radiators. Due to the complicated system only the production of the distribution system I is well documented. There the annual production is about 472 thousand tons. Plans are to increase the closed circulation system in the near future and close down the old steam distribution system as well as the single distribution system.

5.4 Þorlákshöfn

Þorlákshöfn is a town in SW-Iceland with nearly 1600 inhabitants. The district heating in Þorlákshöfn started operation in late 1979. Today two drill holes are used with temperature from 100-120°C. Yearly production is about 850 thousand tons (Einarsdóttir 2008 a).

5.5 Hella – Hvolsvöllur

The district heating service for the small towns of Hella and Hvolsvöllur in south Iceland began operation in 1982. A total of some 1500 people are served, as well as some 250 persons in the neighboring farming community. Three wells are utilized, one at Laugaland and two at Kaldárholt. A fourth well is used mainly as a replacement well or for reinjection. The reservoir temperature at Laugaland is about 100°C and close to 70°C at Kaldárholt. Annually some 1.8 million tons of water is used by this district heating service (Oddsdóttir 2008 c).

5.6 District Heating for Holyday Homes

It is becoming more and more popular in Iceland to have access to holiday homes in the countryside to relax and find comfort. Holiday home areas are usually built on small sections 5 to 10 thousand square meters, normally in clusters where services such as roads, waterworks and electricity are accessible. Most holiday homes have some space heating appliances, electricity, gas or district heating which is getting more and more common. 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. Other energy sources for the district heating such as electricity and oil are too expensive. Reykjavík Energy operates several district heating services were holiday homes are the principal users.

5.6.1 Grímsnes District Heating Service

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. The district heating service commissioned late 2002 using three drill holes, 80-85°C, at Öndverðarnes geothermal field. Annual production is near 1.1 million tons. Fig. 12 shows the production and water level in observation wells from 2002 to 2009. The full capacity of the field is unknown but it is estimated that the drill holes have sufficient water for at least 1200 holiday homes in total.

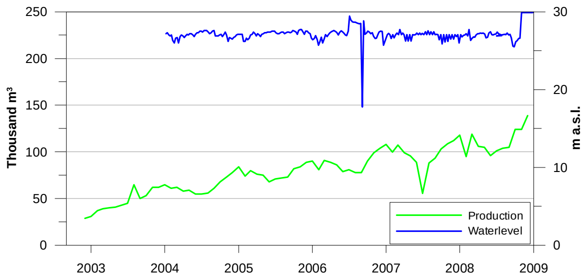

Figure 12: Production from the Öndverðarnes field and water level in observation well from 2002 to 2009

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 (Oddsdóttir 2009).

5.6.2 Munaðarnes District Heating Service

The Munaðarnes holiday home area is located some 100 km north of Reykjavík. There are 160 holiday homes in the area and 90 of them publicly owned by a union. These 90 houses were connected to the district heating service which commissioned mid-year 2004 (Oddsdóttir 2008 d).

5.6.3 Skorradalur District Heating Service

The Skorradalur district heating service was established in 1996. It serves local farms and holiday homes close to the lake of Skorradalsvatn. Only one well is used, which was drilled in 1994 and is 836 meters deep. It produces some 10-15 l/s and the temperature is close to 90°C. Yearly production is close to 320 thousand tons a year (Oddsdóttir 2008 e).

5.6.4 Ölfus District Heating Service

The Ölfus district heating service provide hot water for both shrimp and fish farming businesses, as well as a few farms and summer houses. Two wells drilled in 1977 and 1987 provide some 3-4 l/s, with a reservoir temperature of around 113°C. Total annual production is around 300 thousand tons (Einarsdóttir 2008 b).

5.6.5 Hlíðaveita District Heating Service

Hlíðaveita is a rural district heating service only 10 km south of the Geysir geothermal area in south central Iceland. It serves a farming community with a large collection of summer houses. The only well was drilled in 1988 and 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 (Einarsdóttir 2008 c).

5.6.6 Austurveita District Heating Service

Austurveita 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 270 thousand tons a year (Einarsdóttir 2008 d).

5.6.7 Norðurárdalur District Heating Service

This district heating service provides hot geothermal water for a grouping of summer houses in Norðurárdalur, as well as the university community of Bifröst. Two wells, capable of providing 40 l/s with a temperature between 66°C and 74°C were drilled in the early nineties. Total annual production is around 420 thousand tons (Oddsdóttir 2008 f).

CONCLUSION

Geothermal district heating started on a small scale in Reykjavík in 1930. Since then the utility has expanded and today all houses in the capital area are heated with geothermal water. The use of geothermal water for house heating in Reykjavík has saved CO_2 emission. From 1930 until today the saving is about 100,000,000 tonnes, yearly similar as total CO_2 emission from Iceland. Since all houses in Reykjavík are now heated with geothermal water, Reykjavík Energy has expanded and is now also operating several geothermal utilities in SW Iceland both serving towns and more distributed areas such as holiday homes in the countryside. Monitoring of the geothermal fields is essential for successful operation. Monitoring of the low geothermal fields utilized for district heating in Reykjavík has indicated overexploitation during some period of time. With reduction of production, equilibrium between production and pressure decline has been reached indicating the sustainability of the energy source.

REFERENCES

Einarsdóttir, V., 2008 a: Vatnsvinnsla Hitaveitu Þorlákshafnar. *Orkuveita Reykjavíkur 2008-013.*

Einarsdóttir, V., 2008 b: Vatnsvinnsla Ölfusveitu 2007. *Orkuveita Reykjavíkur 2008-012.*

Einarsdóttir, V., 2008 c Vatnsvinnsla Hlíðarveitu. *Orkuveita Reykjavíkur 2008-016.*

Einarsdóttir, V., 2008 d: Vatnsvinnsla Austurveitu 2007. *Orkuveita Reykjavíkur 2008-015.*

Friðriksson, J.S., 2003: District heating for holiday homes. *International Geothermal Conference, Reykjavík, Sept. 2003.*

Gunnlaugsson, E., Gíslason, G., Ívarsson, G., Kjaran, S.P., 2000: Low temperature geothermal fields utilized for district heating in Reykjavík, Iceland. *Proceedings World Geothermal Congress 2000, Kyushu - Tohoku, Japan, May 28 - June 10, 2000.*

Ívarsson, G., 2009: Hitaveita í Reykjavík. Vatnsvinnslan 2008. *Orkuveita Reykjavíkur 2009-018.*

Oddsdóttir, A. L., 2008 a: Vatnsvinnsla Hitaveitu Akraness og Borgarfjarðar. *Orkuveita Reykjavíkur 2008-011.*

Oddsdóttir, A. L., 2008 b: Vatnsvinnsla Hitaveitu Skorradals 2007. *Orkuveita Reykjavíkur 2008-008.*

Oddsdóttir, A. L., 2008 c: Vatnsvinnsla Hitaveitu Rangæinga 2007. *Orkuveita Reykjavíkur 2008-006.*

Oddsdóttir, A. L., 2008 d: Vatnsvinnsla Munaðarnesveitu 2007. *Orkuveita Reykjavíkur 2008-009.*

Oddsdóttir, A. L., 2008 e: Vatnsvinnsla Hitaveitu Skorradals 2007. *Orkuveita Reykjavíkur 2008-008.*

Oddsdóttir, A. L., 2008 f: Vatnsvinnsla Norðurárdalsveitu 2007. *Orkuveita Reykjavíkur 2008-010.*

Orkustofnun, 2008: Energy statistics in Iceland. *Orkustofnun 2008, 16 pp.*

Oddsdóttir, A. L., 2009: Vatnsvinnsla Grímsnesveitu. *Orkuveita Reykjavíkur 2009-032.*

Sveinbjarnardóttir, G.,2005: The use of geothermal resources at Reykholt in Borgarfjörður in the medieval period: some preliminary results. In *Mortensen, A. and Arge, S.V. (eds.): Viking and Norse North Atlantic. Select Papers from the Proceedings of the Fourteenth Viking Congress, Tórshavn, 19-30 July 2001. Annales Societatis Scientiarum Færoensis. Supplementum XLIV.*