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DISTRICT HEATING IN REYKJAVIK – 70 YEARS EXPERIENCE

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ABSTRACT

District heating in Reykjavik began in 1930, when a 3 km pipe was build from a hot spring area in the city to a school house, the national hospital and some 60 dwelling houses. By 1970 nearly all the houses in Reykjavik were receiving hot water for heating and sales began to nearby municipalities. To day Orkuveita Reykjavikur serves about 150,000 people or 99.9 % of the population of Reykjavik and five neighbouring communities. This is about 58 % of the national population. Four low temperatue geothermal fields and one high temperature field are utilized for the district heating. The water from the low temperature fields is used directly for heating and as tap water. Due to high content of gases and minerals at the high temperature area, water and steam are used to heat frech water. Since 1998 60 MW electrical power has been generated from steam before it is used for heating. The total capacity of the district heating is about 780 MW_t. The cost of the geothermal energy is low comparing to other alternatives and as geothermal replaced burning of fossile fuel for district heating in Reykjavik it has reduced the emission of greenhouse gases dramatically, decades before the international community began contemplating such actions. In Reykjavik geothermal energy has economical and environmental advantages which alternative energy sources can not compete with.

1. INTRODUCTION

Iceland lies in the North Atlantic Ocean, close to the Artic Circle. The climate is oceanic but much milder than might be expected considering the northerly location of the country. The mean annual temperature for Reykjavik is 5°C, the average January temperature being –0.4°C and July 11.2 °C. Heating of building is therefore necessary all the year around.

A continuation of the Mid-Atlantic Ridge crosses Iceland from soutwest to the northeast. The middle of this belt of fractures corresponds fairly well with American and Europian tectonic plates that are diverging at the rate of approximately two centimeters per year. Geothermal activity is closely related to these plate boundaries. There are over 600 hot water springs in 250 low-temperature fields and 28 potential high-temperature areas have been identified. All the high temperature fields are located within the volcanic zones while the main low-temperature fields are found on the flanks of the volcanic zones.

Iceland has been the world's leading country in geothermal district heating developments. More than 86% of the total population of Iceland use geothermal water for space heating. Most of the geothermal production is from low-temperature fields (60-130°C). The water from these fields contain relatively low content of dissolced solids and it can be used directly for district heating.

2. HISTORY OF THE HARNESSING OF GEOTHERMAL HEAT IN REYKJAVIK

In previous centuries, the utilization of geothermal heat was primarily limited to bathing, cooking and laundering. At the beginning of the 20th century, use was first made of geothermal water for heating of dwelling houses. Drilling for geothermal water in Reykjavik began in 1928 and the first district heating system became reality in 1930. The water was piped 3 kilometers to a primary school in the eastern part of the city, which then became the first structure in Reykjavík to be supplied with hot water. Soon more public buildings, including swimming pools, as well as about 60 privite houses were connected to the hot water supply.

These undertakings promoted further interest in the utilization of these natural resources. More geothermal water was needed to fulfil the requriments of the city of Reykjavik. A large geothermal area 17 km east of the city, Reykir area, was considered to be ideal both relatively close and capable of producing great quantities of geothermal water. After acquiring geothermal rights from landowners, drilling commenced in 1933 and in the next decade some 32 boreholes were drilled. Work began in 1939 on laying the pipeline from Reykir to Reykjavik, as well as laying the distribution pipes within the city. The first storage tank was built in 1940. World War II delayed operations so it was not until November 1943 that the first house was connected to the geothermal water distribution from Reykir. Reykjavik District Heating could then deliver 200 litres per second of water at 86°C. By the end of the year some 1300 houses were connected and the following year the number reached 2850.

Test drilling and other research also resulted in more geothermal water being found within the city limits of Reykjavík. In 1957 the state and the city together purchased a more powerful drill rig. That, including the instalment of pumps in existing wells, which increased the efficiency of drilling and water extraction made it possible for more homes to acquire water for space heating. In spite of all this only about half of the residents had access to hot geothermal water in the 40s and 50s.

In the beginning of 1962 as many wells as possible were harnessed and pumps installed to increase their output. It was also necessary to re-drill older wells in Reykir to increase their output. Several wells were drilled between 1967 and 1970 in the geothermal area by the Ellidaar River. Since 1969 all planned districts in Reykjavik have been served by the district heating utility. At the end of 1972, 97% of houses in Reykjavik used geothermal water for heating. Moreover, pipelines were laid to nearby municipalities, which are now supplied with geothermal water through the Reykjavik District Heating system.

3. THE GEOTHERMAL AREAS TODAY

Now, three low temperature fields, and a high temperature geothermal field at Nesjavellir located some 30 km east of the capital (Table 1) are utilized for district heating in Reykjavik. The total installed capacity is about 780 MW. Down hole pumps are used in all production wells in the low-temperature areas. A drawndown of as much as 100 m occurs during maximum load periods in late winter. The water from these fields are low in dissloved solids and is alkaline and it is suitable for direct use, both for heating and as tap water. This water almost fulfils the requierments of drinking water standards (Table 2). Only the sulphide concentration and the pH value are to high.

The water from the high-temperature areas are rich in gases and minerals and cannot be used directly for space heating, but the steam pressure and the high temperature of the water makes it desirable for heating fresh water which can then be utilized.

The Reykjavik municipal authorities decided to build the plant at Nesjavellir in 1986, based on extensive prior research of the area. In 1990 the first stage at Nesjavelllir produced 100 MW_t thermal (Gunnarsson et al., 1992), later increased to 140 MW_t in 1992. Today the steam is used for generation of electricity prior to the water production (Claus et al., 2000). The installed capacity is 200 MW thermal and 60 MW of electrical power.

The geothermal water from the wells in Reykjavik (Laugarnes and Ellidaar) and in Mosfellsbaer (Reykir) comprises about two thirds of the hot water in the distribution system. One third comes from the Nesjavellir field (Figure 1).

4. THE DISTRIBUTION SYSTEM

A simplified flow diagram for the district heating in Reykjavik is shown in figure 2. The water is pumped out of the wells using down hole pumps inserted at about 200 m down the boreholes, connected by drive shafts to surface mounted electric motors. Collecting mains carry the water to the main buster pumping stations, which push the water through transmission mains to distribution pumping stations and storage tanks.

The geothermal water from Reykir flows through a main pipeline to six tanks on Grafarholt, just outside Reykjavik that hold 54.000 m^3. From there the water flows to the storage tanks on Oskjuhlid in mid Reykjavik. Six tanks are located there, four countaining hot water and two with warm returning water. Total effective volume of the Oskjuhlid tanks is 24.000 m^3. The purpose of all the tanks is threefold, compensating the daily load variation in order to minimize number of start-ups of borhole pumps, providing peak energy during cold spells, and provide hot water during failures of power plants. Nine pumping stations distributed throughout the servicing area pump the water to the consumers. The low-temperature geothermal water contain very low quantity of gaseous nitrogene which has to be expelled, otherwise it would accumulate in radiators and block the circulation in the heating systems in the houses.

The water from Nesjavellir flows to two tanks on its way to Reykjavik that hold 18.000 m^3. 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 causes Mg-Silicate scaling.

The total length of the pipelines in the distribution system is about 1300 km. This includes all pipelines from the wells to the consumer. The main pipelines are up to 900 mm in diameter. The pipe from the main line to the consumer is usually 20-150 mm in diameter. No inside corrosion occure and some of the pipes have been in operation for over 50 years. In the earlier days the pipes were insulated with turf and red volcanic scoria. The newer pipes are insulated with foam concrete, urithan or rock wool.

Some 70 % of the distribution system is a single pipe system, the remains is double distribution system. 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 for the distribution. In the single system the backflow drains directly into the sewer system. In the coldest periods the load is up to a maximum of 3.800 l/s. This load is met by the output of the geothermal fields and peak energy is teken from the tanks. Also a 100 MW_t fuel oil boiler plant is installed as peak and reserve power.

Geothermal water usage is measured in cubic meters. Annually up to 60 million cubic meters of water are produced. Figure 3 shows the annual water production from 1944. In 1998 Reykjavik District Heating produced just over 57 million cubic meters of water of which 7 million are backflow waters. The utility serves about 160,000, people living in about 26,000 houses (Figure 4). This is 58 % of the total population of Iceland.

5. BEST UTILIZATION OF THE HOT WATER

Although geothermal energy is sustainable it is necessary to make sensible use of it. It is most important to insulate buildings and to install thermostatic control to conserve the heat. In Reykjavik consumers pay for the water according to the water meter reading. It is therefore to their advantage to use the water effectively. The price of thermal water in Reykjavík is 0.73 US$/$m^3$. That makes the heat cost approximately one third of the price of heating with oil.

Consumers themselves can tell if the amount of hot water they use is within normal limits. In small houses and flats a normal year's consumption may be up to 2 cubic metres for each cubic metre of space. In large buildings normal consumption can be up to 1,5 cubic metres for each cubic metre of space. These values have been decreasing in later years due to better insulation in new buildings (Figure 5). About 85% of the hot water from the Reykjavik District Heating is used for space heating, 15% being used for bathing and washing. The greatest savings come from good insulation and careful attention to radiator operation.

After the hot water has been used in a building it is 25- 40°C hot. In recent years it has become increasingly common to use this to melt snow of pavements and driveways. Some 250.000 m^2 are installed with pipes for snow melting in Reykjavik.

6. ENVIRONMENTAL IMPACT

Before 1940 the main heat source in Reykjavik were burning of fossil fuels, maily coal. At that time it was common to see black cloud of smoke over the city. In 1960-1965 carbon dioxide emission caused by burning of fossile fuels for heating in Reykjavik has been estimated to be around 250,000 tones/year. In 1975 it was down to about 20,000 tones/year and to day it is almost negliable (Gislason, 2000).

The water from the low-temperature geothermal areas has low content of dissolved solids and the content of non-condensable gases is negligible and has no chemical effect on the environment.

The content of chemical components in the fluid from the high-temperature areas is higher, particular hydrogen sulphide, carbon dioxide and silica. Natural outflow exists in geothermal fields before drilling and exploitation. Utilization speeds up the outflow. It has been estimated that the outflow from the Nesjavellir geothermal field has tripled due to exploitation. Compared to other energy alternatives such as coal and oil the geothermal is the best alternative to day.

7. SUSTAINABILITY OF THE GEOTHERMAL AREAS

Throughout the exploitation good record has been kept on reservoir parameters of all the geothermal fields. This includes record on production and water level. All the low-temperature geothermal fields were overexploited for few years before the Nesjavellir plant was taken into operation. Indication of this could be seen in steadily decreasing waterlevel during exploitation in some areas, intrusions of cold and sometime more saline water in other areas (Gunnlaugsson et al., 2000). All the low temperature fields recovered when the production could be reduced after 1990 when operation started at Nesjavellir.

8. BENEFITS OF DISTRICT HEATING IN REYKJAVIK

Clean air is one of the main benefits of utilization of geothermal energy for space heating in Reykjavik and also influenced the health of the inhabitants. Record on number of cold infection in Reykjavik decreased considerably following the installation of geothermal district heating compared to other areas (Figure 6). Clean air and reduction of coal-soot and other particles are undoubtedly the main reason. Other benefits of the use of geothermal energy for district heating is that the energy is domestic, it is relatively cheap and prompt cascading uses such as swimming pools, greenhouses, heated garden conservatories and snow melting.

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Table 1. Summary of the geothermal fields

Field	Temp °C	Capacity l/s	No. of wells
Laugarnes	125-130	330	10
Ellidaar	85-95	220	8
Mosfellssveit	85-95	1700	34
Nesjavellir	250-300		15

Table 2. Chemical composition of thermal and heated groundwater. Concentration in mg/kg.

	Laugarnes	Ellidaar	Mosfells-sveit	Nesjavellir geothermal water	Nesjavellir heated water
°C	130	86	93	290	83
pH/°C	9.45/23	9.53/23	9.68/20	6.2	8.59/24
SiO_2	150.2	67.6	95.0	600	21.8
Na	70.3	46.2	47.9	106	9.8
K	3.5	1.0	1.0	22.1	0.8
Ca	3.7	2.2	1.5	0.1	8.7
Mg	0.00	0.01	0.02	0.00	5.1
CO_2	17.5	26.3	23.7	204	31.4
H_2S	0.3	0	0.9	279	0.3
SO_4	28.7	13.3	20.3	13.2	8.3
Cl	55.6	25.1	12.2	118	8.5
F	0.6	0.18	0.83	0.7	0.08
CO_2 - gas				4000	
H_2S - gas				2100	

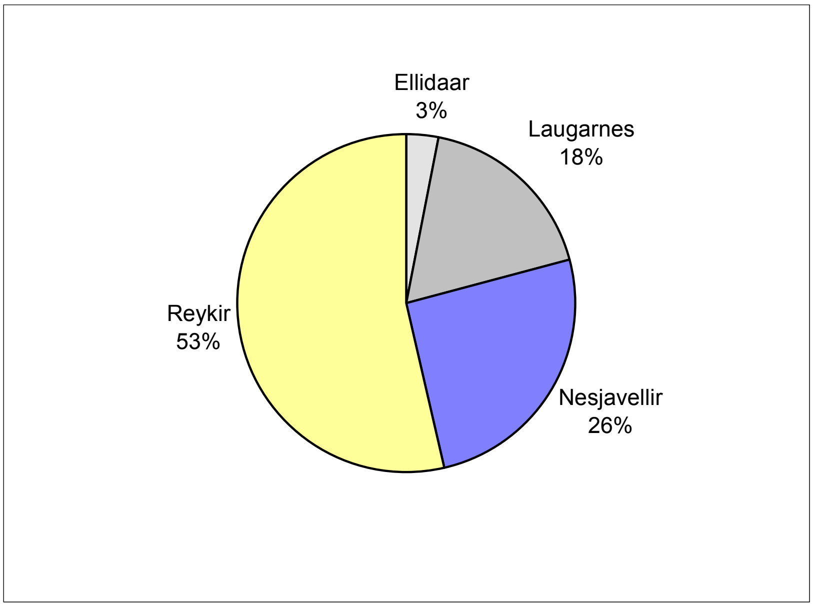

Figure 1. Origin of geothermal energy used for space heating in Reykjavik

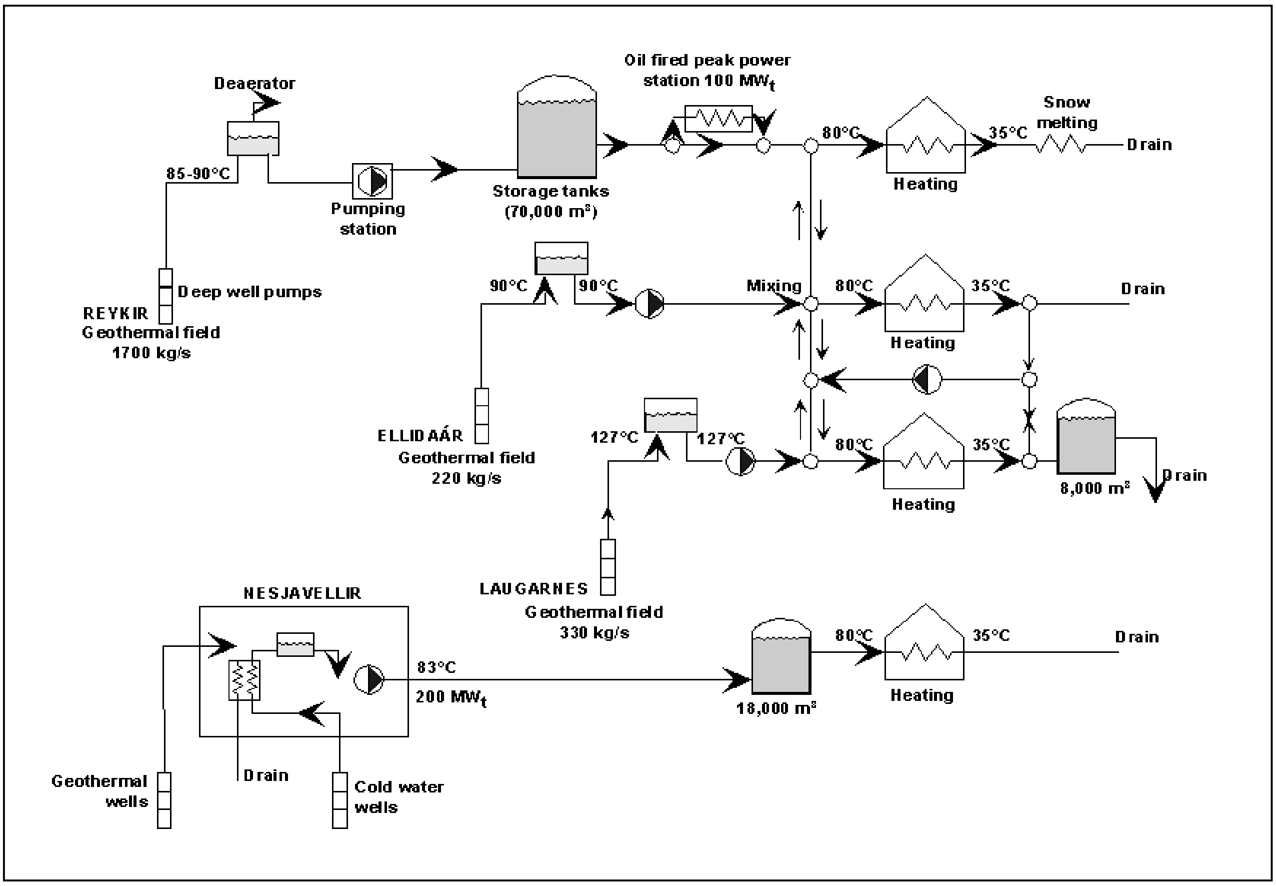

Figure 2. Simplified flow diagram for the district heating in Reykjavik

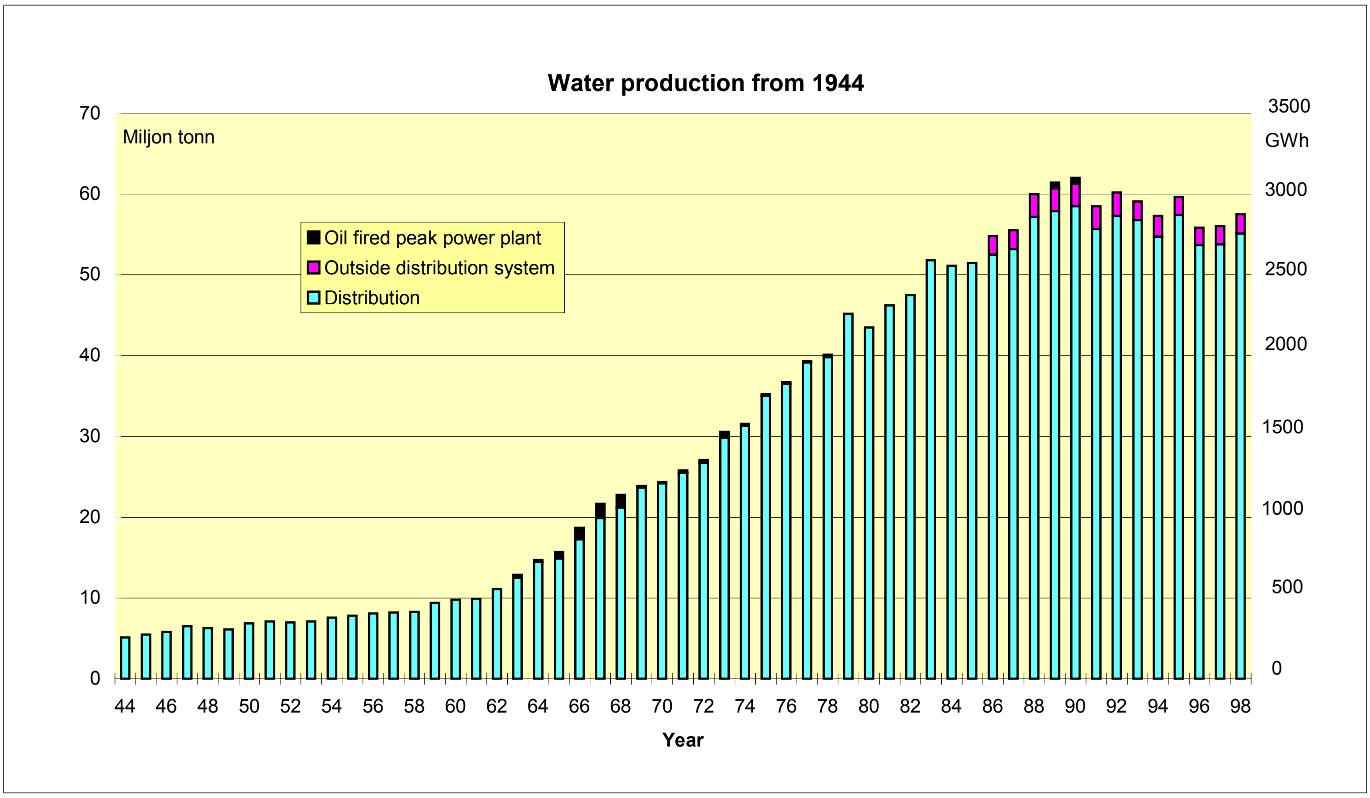

Figure 3. Annual water production from 1944

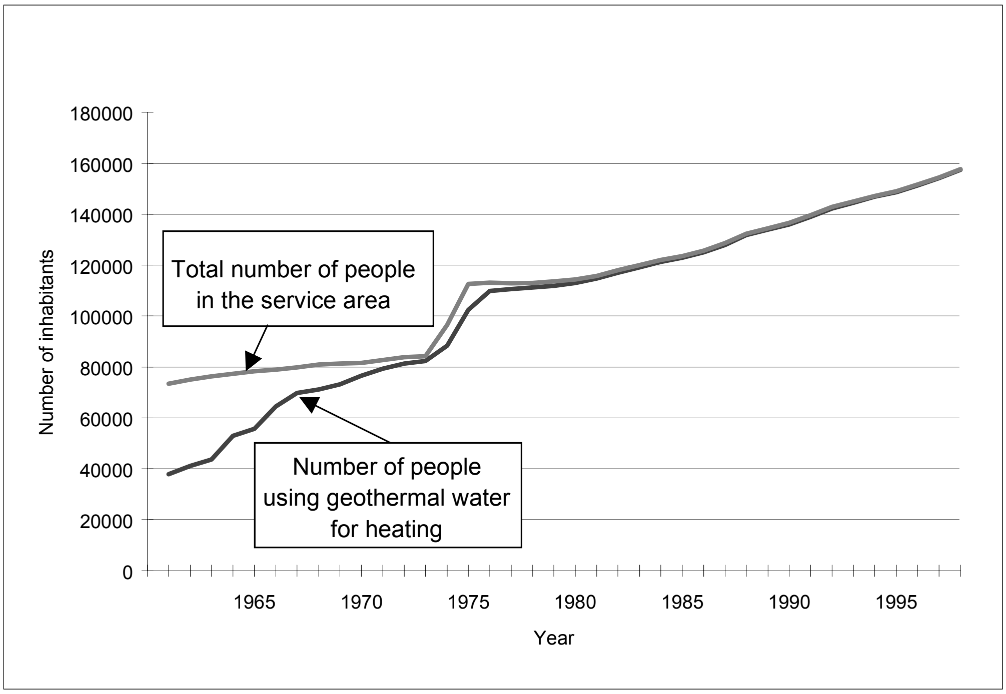

Figure 4. Increase of inhabitants in the service area.

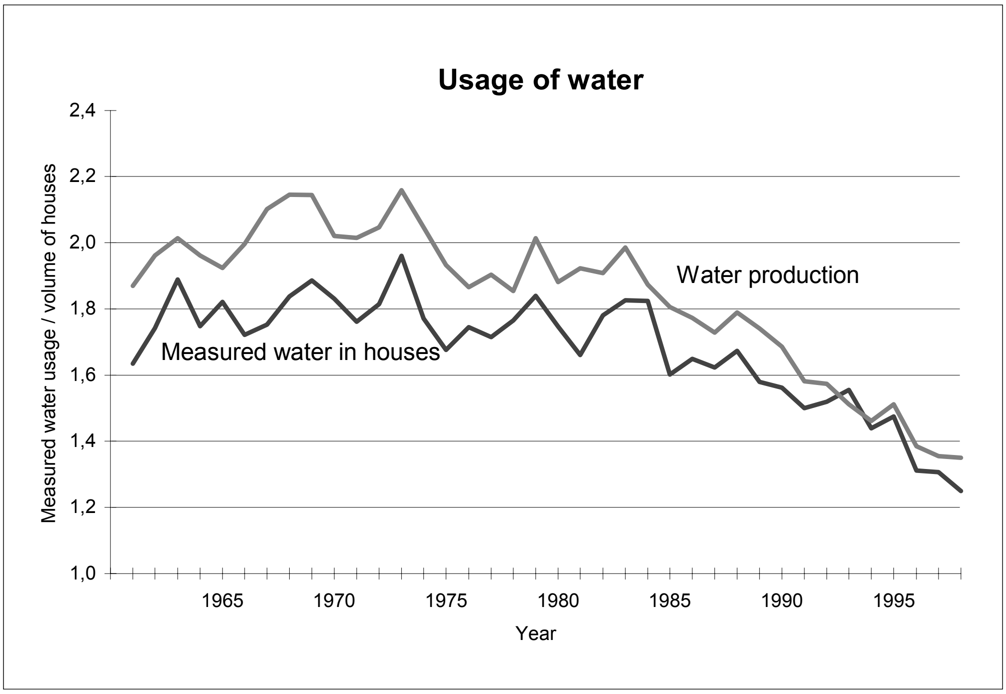

Figure 5. Measured water usage compared to volume of space heated for 1960 to 1998.

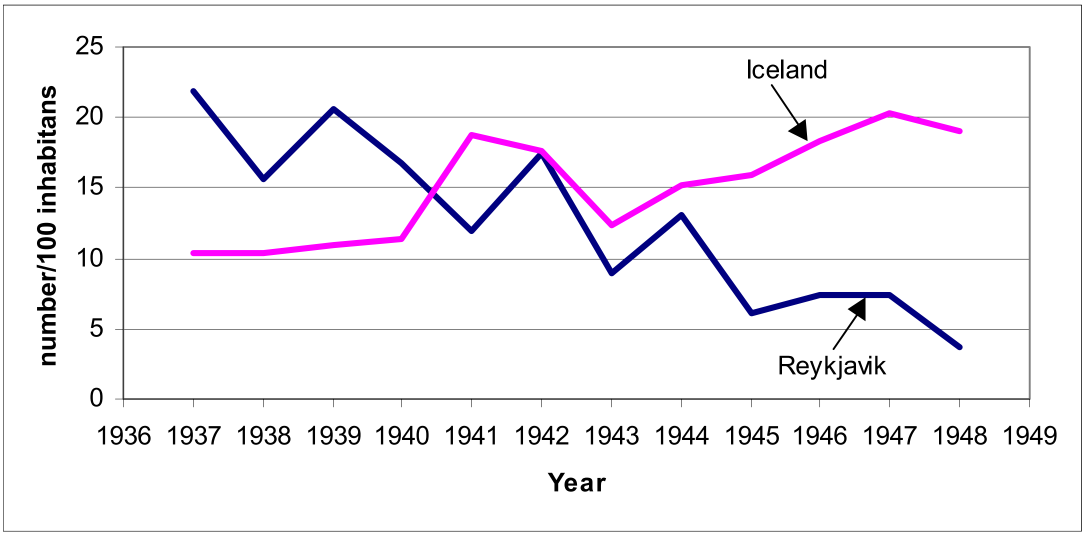

Figure 6. Number of cold infection in Reykjavik during the first years of geothermal district heating in Reykjavik compared to other areas in Iceland.