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REPLACING FOSSIL FUELS BY GEOTHERMAL DISTRICT HEATING - EXAMPLE FROM ICELAND

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ABSTRACT

Geothermal district heating has played a major part in the Iceland's transition from a developing country to a modern society. The first geothermal district heating systems were taken into operation around 1930. The technology used today is still based on the simple and robust solutions developed at that time. Locally manufactured equipment was used to a high degree. Good economics are based on large heat building radiators and low building return water temperature. The distribution system investment cost is kept down by ensuring high temperature differences between the supply and return water(40°C). The supply temperature is governed by the temperature of the geothermal field, but correct building system design can ensure this temperature difference by low return temperature from the building. A geothermal district heating system should be seen as a chain beginning in the geothermal field and ending in the living room of the consumer. If no link in this chain is weak, large oil savings and great improvement in the quality of life can be obtained by geothermal district heating.

1. BACKGROUND AND HISTORY

Iceland was a colony of Denmark for 600 years. The country had agriculture for self-sufficiency and the main export was fish, which made some foreign trade possible. A remote location in the middle of the Atlantic Ocean, however, was not promoting trade. Early, after the settlement, the country was de-forested, so during the middle ages and well into the last century the only fuels available were domestic peat and dried sheep dung. Iceland was thus nothing but a very poor, developing country. As late as 1974 the country was classified as a developing country.

An economic revolution started during the Second World War. The country was occupied, at first by the British military and later by the United States. The number of foreign soldiers during the peaceful occupation is claimed to have been as high as 50% of the local population at peak times. This ensured influx of money, suddenly there was work for everybody and this was paid work.

Iceland is a sparsely populated country with rich energy hydropower and geothermal energy resources.

At the beginning of the last century an energy revolution initiated as well, and geothermal heat was used to heat buildings. The geothermal district heating in Reykjavik operated as early as the late 1920's. The progress of the district heating was slow until the 60's, and around 1970 Reykjavik city was heated by geothermal heat.

Some geothermal resources in Reykjavik were at or very close to the surface, so the first steps for the geothermal district heating were easy. But as early as 1940 an 18 km transport pipeline was built to supply the city´s needs. In the 60's the deepest wells supplying the district heating were over 2000 m deep.

2. GEOTHERMAL DISTRICT HEATING

The main conversion over to geothermal district heating was in the 70's. High oil price stimulated geological and geophysical exploration for resources. The technology was already proven, at that time geothermal district heating systems had been in operation for half a century.

The technology is still very similar to that of the original systems. Due to good water quality and a rich resource a single line network is used, and the water is disposed of into the storm drains at the consumer end point. This leads to low investment cost, and as geothermal systems are typically dominated by very low variable and running cost, with high investment cost, the systems were economical from the beginning.

During the oil crises of the 70's, many of the provincial cities could as well be supplied with geothermal heat. In 1990, the reference year for the Kyoto agreement, most buildings in the country were already heated by geothermal heat and then the geothermal revolution was already over.

The fuel savings due to geothermal district heating are huge, and have been estimated as high as 16-1800 kg of oil equivalent per capita in Reykjavik. This is a major factor in the economy, a major factor in the CO_2 emission reduction for the country, and is not termed "the white gold" without reason.

3. THE TECHNOLOGY

Most of the geothermal resources have clean water, close to drinking water quality, so that the water can be used directly. Rich resource do not require re-injection of the geothermal fluid, and in the poverty of the 1930's, a single line supply system without heat exchangers and with direct tap water use was constructed.

Figure 1 is a simplified schematic of such a system.

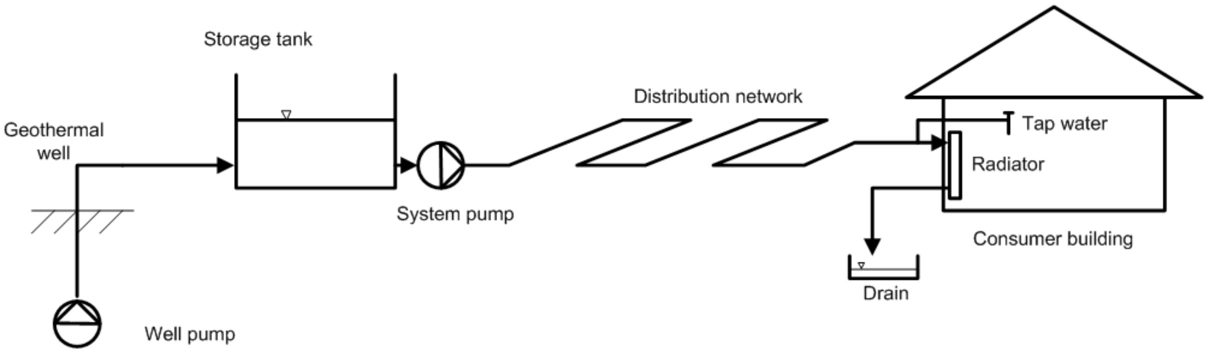

FIGURE 1: Schematic of a single line, direct consumption geothermal district heating system

The water is not re-used, so it was obvious that the water had to be charged for, not the heat. And at that time heat meters were not available on the market, even if the heat should be charged for. The services of the district heating company were thus sold by the amount of water consumed, and volume meters installed at each point of sale to the consumer.

Almost all buildings were heated by a fuel fired radiator system, so the district heating could be connected to the building heating system without many problems. The most common fuel at that time was coal, and later oil.

As a consequence of the water being distributed at a cost, the consumer had an interest in using the water as economically as possible, and this led to a practise of installing large radiators in order to ensure low return temperature. This helps in saving on resource, as the amount of water taken from the reservoir is less.

The system supply temperature is governed by the geothermal field, and cannot be changed. The only flow control in the system is at the consumer end, which means that the radiator or tap water valves of all the consumers are controlling the system flow. The system pump has to ensure sufficient pressure, so that a minimum of 18-20 m head is obtained above the highest consumption point in the entire system.

The system flow is high during the winter and low during the warmer summer. The temperature falls during the low flow in summer, and the distribution network pipes cannot be too large, as this leads to low flow velocity and large temperature drop. The winter condition demand large pipes due to high flow and high pressure loss. The distribution network design has thus to be done with utmost care, in order to satisfy both the summer and winter conditions.

4. CASE STUDY: SELFOSS 1949

Selfoss is a village in southern Iceland. In 1949 the village had around 1000 inhabitants. A well was drilled, and a distribution system was laid out in the village. It was known from the beginning that an upper aquifer delivered oxygen rich water into the well, so the water was known to be corrosive.

Almost all buildings in the village had a boiler and radiator system. The most common fuel was coal. The district heating system was usually connected to the building system by a heat exchanger, installed parallel with thee existing boilers. Building system circulation was commonly at that time by natural means, having large pipes with low flow velocity in the building. In some cases a circulation pump was present.

Figure 2 is a system schematic of such a building system.

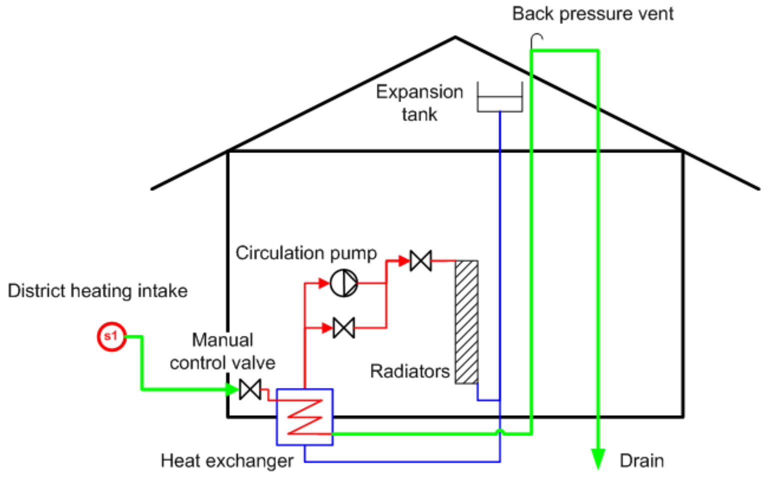

FIGURE 2: Geothermal building system from 1949, Selfoss, Iceland.

Photos from such a system are shown in the following figures. The heat exchanger was made locally. It consists of a spiral tube heat exchanger, with rolled plate shell and conical end plates. The building radiators are cast iron with ample heat exchange surface. Natural circulation is sufficient for the building, even if a circulation pump is installed. It was barely been used during these decades of operation.

The original system from 1949 is still in use, and only a few pipes have been renewed some 15 years ago, when the distribution network was renewed. The associated movement of the intake pipes revealed corrosion, and new pipes were required from the intake to the heat exchanger.

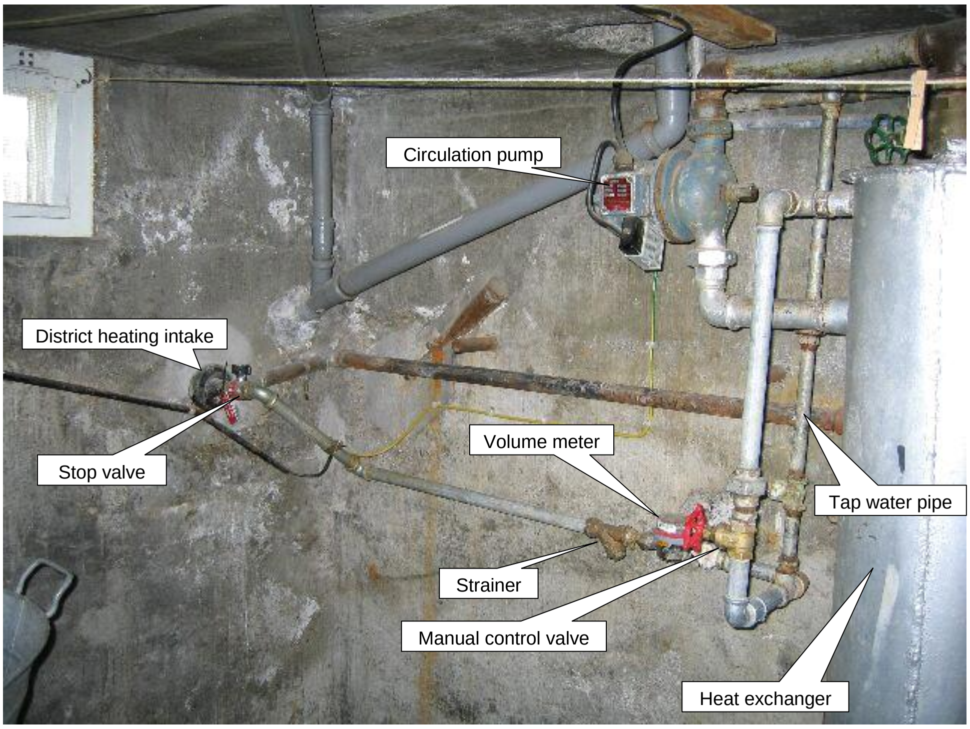

FIGURE 3: District heating intake

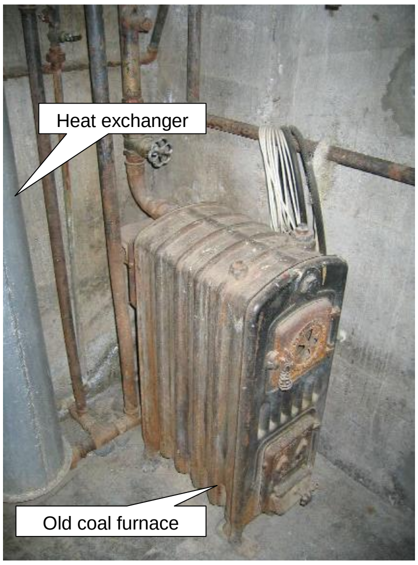

FIGURE 4: Coal furnace

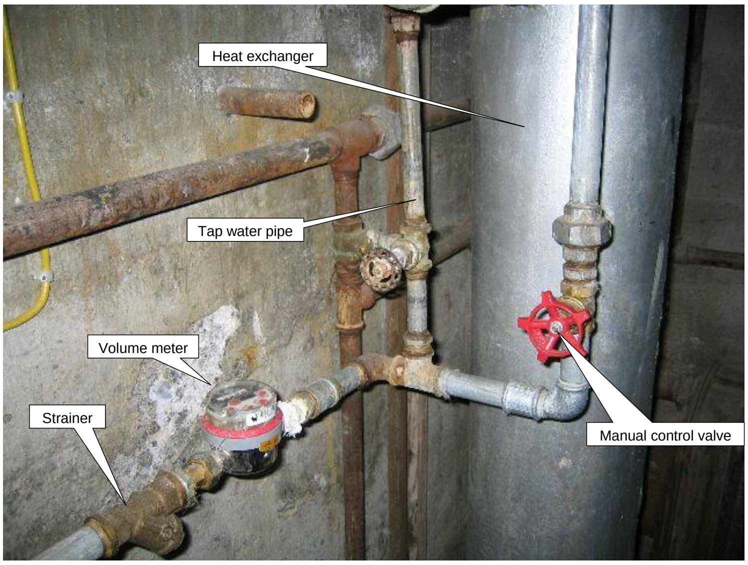

FIGURE 5: Point of sale, volume meter

In some residential homes the radiators are covered with wood in order to make them look better. This will reduce heat transfer from the radiator, reduce the possible cooling of the radiator water and increase the return temperature. This should be avoided if possible.

FIGURE 6: Building radiator

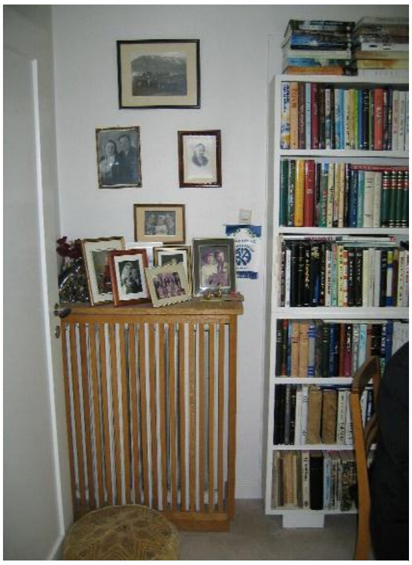

FIGURE 7: Wood covered radiator

5. CONCLUSION

The conversion from fuel fired heating of buildings to geothermal district heating does not require complicated and expensive high technology, as seen from the previous case study. If the conversion is correctly done, it will carry great economic benefit and increase the quality of life for the consumers.

The design of the district heating system has to fulfil certain criteria in order to be successful.

A district heating system can be viewed as a chain, beginning in the geothermal reservoir, through the well, transportation system, distribution system, building system into the living room of the consumer. Every link of this chain is equally important. If one link is weak, the whole chain will fail.

The construction of a heating system is frequently a weak link. The system has to be capable of cooling the heat carrying water to a low return temperature, thereby ensuring good utilisation of the geothermal resource. Floor heating systems assisted by fan coil units, as commonly used in China are elegantly fit for this purpose. The economy of such a system depends heavily on the total investment cost. A large part of this investment is in the transmission and distribution systems. The supply and return temperature in these systems determines the investment cost. The larger the temperature difference, the lower the investment cost, and the better the economy for the consumer. Typically, a good value for the difference between the supply and return temperature is about 40°C. Lower values will hurt the economy of the system.

The system supply temperature is governed by the geothermal field in most cases, and cannot be changed. But the return temperature from the building system is dependent on the building system design and operation. Therefore it is very important to design and operate the building systems in such a way that the return temperature is as low as possible.

The cost for the consumer can be kept low in geothermal district heating systems. The heating cost in Reykjavik for an apartment is similar to the cost of subscription of a newspaper or a subscription to a television channel. The oil saving is great. It has been estimated to be around 1800 kg/year of oil equivalent for every inhabitant. This is the similar amount of oil as would be consumed by a private car, driven 18000 km/year.

The yearly release of CO_2 due to heating of buildings in Reykjavik is shown on Figure 8. This is one of the very few CO_2 release diagrams showing reduction, a very sharp reduction in the release. It has to be kept in mind that the population in Reykjavik has more that doubled during the period shown on the Figure.

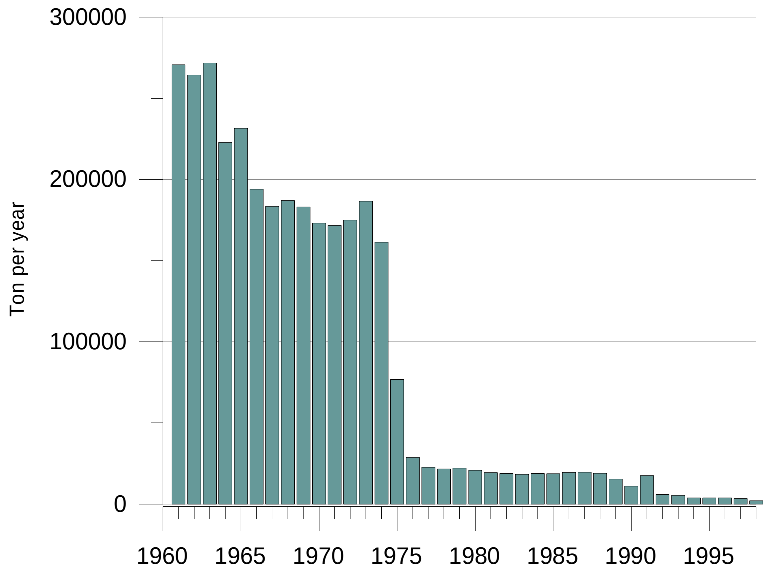

FIGURE 8: CO_2 release in Reykjavik due to heating of buildings