

## Title: Húsavík, Iceland – A model of energy efficiency based on geothermal energy.

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Húsavík – a small urban community on the north coast of Iceland 40 km from the Arctic Circle – is a model how energy efficiency can be integrated to a unified whole. The geothermal energy is utilised partly directly for process purposes in the industry and partly for production of district heating and electricity in Húsavíks combined heat and power (CHP) plant. Surplus heat from the CHP plant is used for breeding fish. The hot water has been used for heating houses and institutions the “last energy” is utilised for “snow melting” at parking areas, streets and footpaths. Altogether an energy system, where energy is utilised “til sidste dråbe”, but also creating new jobs.

### Húsavík.

Húsavík (fig 1) is an old town mentioned first time in the Icelandic Sagas back in the ninth century. The town was an important seaport in the period 1100 to 1260, where 25% of all foreign ships to Iceland loaded and unloaded hear. During the 16<sup>th</sup> century the activities of the town was concentrated about discharging of sulphur from the sulphur mines round Mývatn and Theistareykir. As a logical consequence of the wars in Europe at that time sulphur was a very sought-after product.

To day Húsavík is primary known for whales, fossils and salmons. For persons with technical interest the town is additional known for the new CHP plant based on utilisation of geothermal energy.

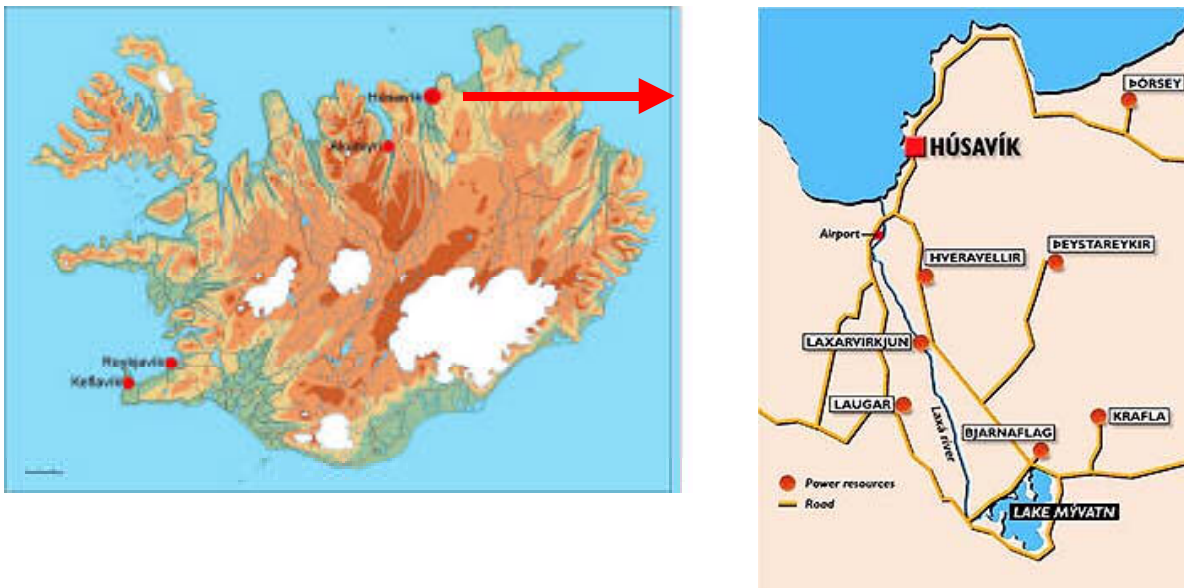


Fig 1. Where to find Húsavík.

### Geothermal area

Located some 20 km south of Húsavík is the Hveravellir geothermal area. From there Húsavík receives geothermal water for the district heating system. There are several natural hot springs and pools in the area that discharge about 100° C hot water. The production wells are from 400 - 1.000 m deep and produce 120 - 130° C hot water. The wells are amongst the greatest hot water producers of all low temperature wells in Iceland.

The geothermal area has been explored over a period of decades and is thus well understood. The reservoir's capacity potential has been assessed applying up to date reservoir modelling techniques and the results show that it can sustain a 75-100 MW artesian flow development.

### **Utilisation of geothermal energy in the past.**

Utilisation of geothermal energy in Húsavík started back in 1960 when the local swimming pool was connected to one of the hot water springs in the area. Húsavík started utilising the geothermal hot water from Hveravellir as early as 1970. To begin with in Hveravellir only the artesian flow of 100<sup>o</sup> C hot water was utilised, but in 1974 a 450 m deep production well (flow of 40 l/s and 128<sup>o</sup>C) was drilled. The geothermal water was utilized to heating all buildings in Húsavík and provided them with hot domestic water. As the altitude difference between Hveravellir and Húsavík is approximately 100 m, pumping was not necessary.

A disadvantage to this set-up was the significant thermal energy lost in the flashing process. More than 2 kg/sec of steam was released into the atmosphere by the temperature drop from 128<sup>o</sup>C to 100<sup>o</sup>C. In addition came the energy losses from the buried uninsulated 18 km long one-pipe asbestos-cement transmission pipeline. The temperature loss on the way from Hveravellir to Húsavík was 15<sup>o</sup>C, resulting in a temperature in the distribution network in Húsavík of 85<sup>o</sup>C. However the geothermal fluid contained within the Hveravellir reservoir was of a quality suited to direct use. In Húsavík the water was used for space heating, drying and also to heat greenhouses and farmhouses in the district.

In recent years it became clear that the old pipeline needed a thorough overhaul. In Húsavík new markets were opening up for 80<sup>o</sup>C to 120<sup>o</sup>C hot water both for heating and industrial use. This prompted the idea of expanding the foreseen refurbishment of the existing system to include diverse cascaded uses. The current highly innovative multi-utilisation development plan for the Hveravellir geothermal resource was primarily conceived to increase its value and reap added environmental benefits. Combining in a single system the production of electricity and the provision of suitably hot water for industrial, fish farming, greenhouses, health centres and heating applications could achieve this. Such an integrated system could improve efficiency in the utilisation of the thermal energy. The provision of inexpensive thermal energy that was suitable for a multitude of applications close to the consumer location had a great potential to improve the overall economy and employment situation of the township of Húsavík and its surroundings.

As of 1990, the supply of water was found lacking during the coldest periods of winter. The impact of this led to the decision to drill a new well at Hveravellir in 1997. The drilling went as planned and this well now provides round 60 l/s of 124<sup>o</sup>C hot water, at the well head pressure of 2 bar.

### **The new concept**

The design of the new integrated energy system started in 1998. The EU Thermie Programme - The Fourth Thermie Framework Programme - supported the project as an innovative demonstration project with a support amounted to 663.000 EUR. In 1999 the construction of the CHP plant and the transmission pipeline began and towards the middle of 2000 operation began. The concept is as follows:

The high temperature level of the geothermal water at Hveravellir made it possible to utilise it for electricity production, space heating and various industrial applications. The benefits of such a multi use of the energy were many; electricity production would be economically for Húsavík since the town would no longer need to purchase electricity in addition to creating new jobs and increasing the variety of employment. Electricity production combined with utilisation of hot water of various temperatures for space heating, industry and fish farms increased the value of the energy since total energy efficiency increased.

The concept was that once the geothermal water arrived in Húsavík it first would be utilised for applications requiring temperatures higher than 115<sup>o</sup>C – electricity production in the CHP plant and various industries. Once the temperature had fallen to 80<sup>o</sup>C through these processes it would be utilised in the district heating distribution system as previously - space heating, industrial purposes and snow melting.

The sketch (fig 2) depicts in a simplified diagram the new integrated geothermal energy supply system:

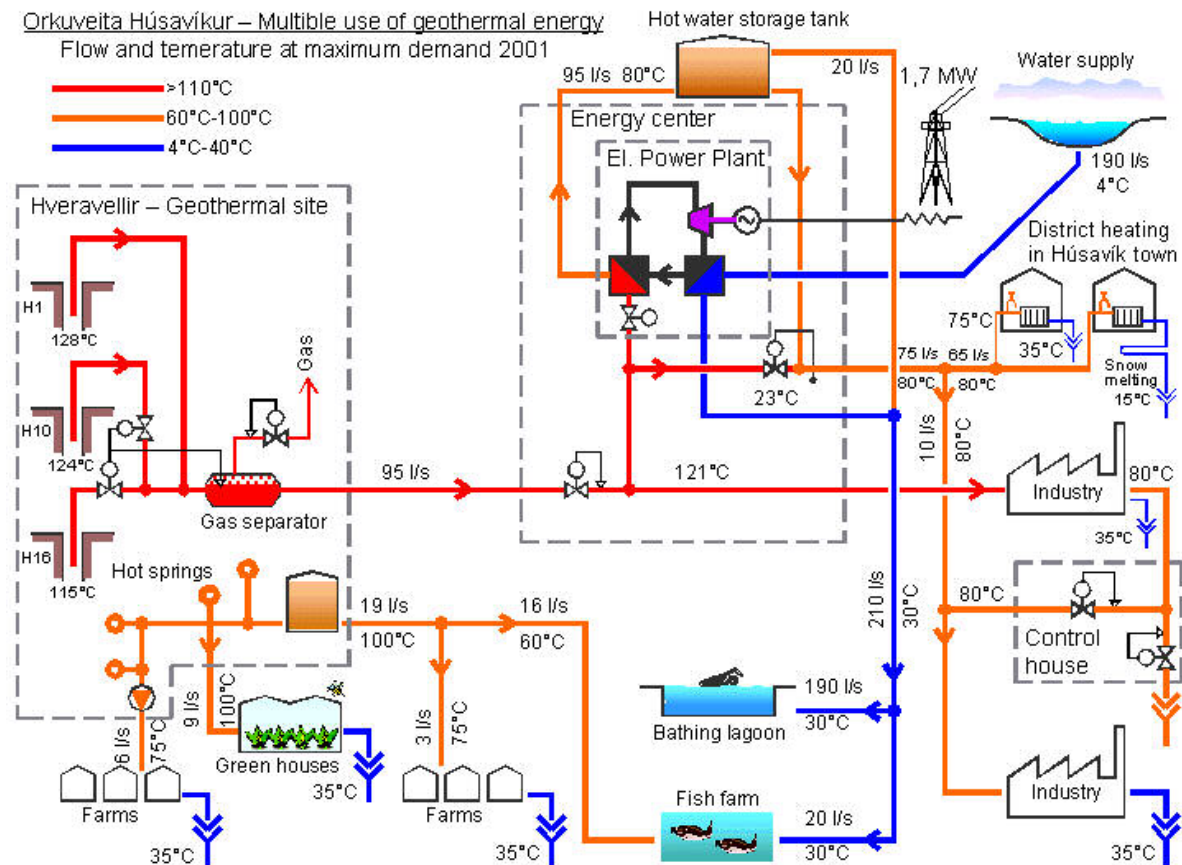


Fig 2. Húsavík Energy. Multi-use of geothermal energy – process diagram.

#### Wells and pipeline.

The main difference between the new concept and the pre-existing one is that the geothermal fluid (95 l/s) from the production wells is piped under pressure from the wells to the Energy Centre located in Húsavík in a pre-insulated DN 400 steel pipeline – only one pipe – at the wells temperature of 115°C-128°C instead of cooling it down to 100°C. The pre-insulated pipeline is buried along the old pipe for most of the way. The temperature loss en route is estimated to be only 3°C.

#### CHP plant.

The energy generated from geothermal water depends on the water quantity, the water temperature and the application in question. The efficiency can be almost 100% in some industrial applications while production of electricity can only provide 10-12% efficiency at the actual temperature level at 121°C. The market for electricity is a very stable and safe market, but the market for hot water in industrial applications is quite limited. In Húsavík at present there is not enough demand from the industrial sector to fully utilise the hot water available. Therefore it was decided to build a geothermal CHP in Húsavík.

Two concepts for the design of the CHP plant were evaluated. One concept was based on a conventional binary cycle power plant using Isopentane or similar fluids in the internal cycle of the plant. The electricity capacity by using this concept was estimated to 1.5 MW. The other concept was based on a new technology, the so-called Kalina technology, in which a mixture of water and ammonia replace Isopentane in the internal cycle. By using this concept the electricity capacity was estimated to 2 MW, which suffices to meet about three-quarters of Húsavík's current electricity demand.

After a radical evaluation of the concepts – both technical and economical - it was decided to construct and set up a CHP plant based on the Kalina concept.

### Kalina process.

The flowchart of the CHP plant is showed in fig 3. As mentioned before the geothermal water flows from the wells at Hveravellir at a temperature of  $124^{\circ}\text{C}$  and after a temperature drop of  $3^{\circ}\text{C}$  it flows into the CHP. A part of the energy content in the geothermal water ( $121^{\circ}\text{C}$ , 90 l/s) is transferred via a heat exchanger to the mixture of water and ammonia in a closed circuit. In the heat exchanger the geothermal water is cooled down to  $80^{\circ}\text{C}$  and afterward used in the district heating network.

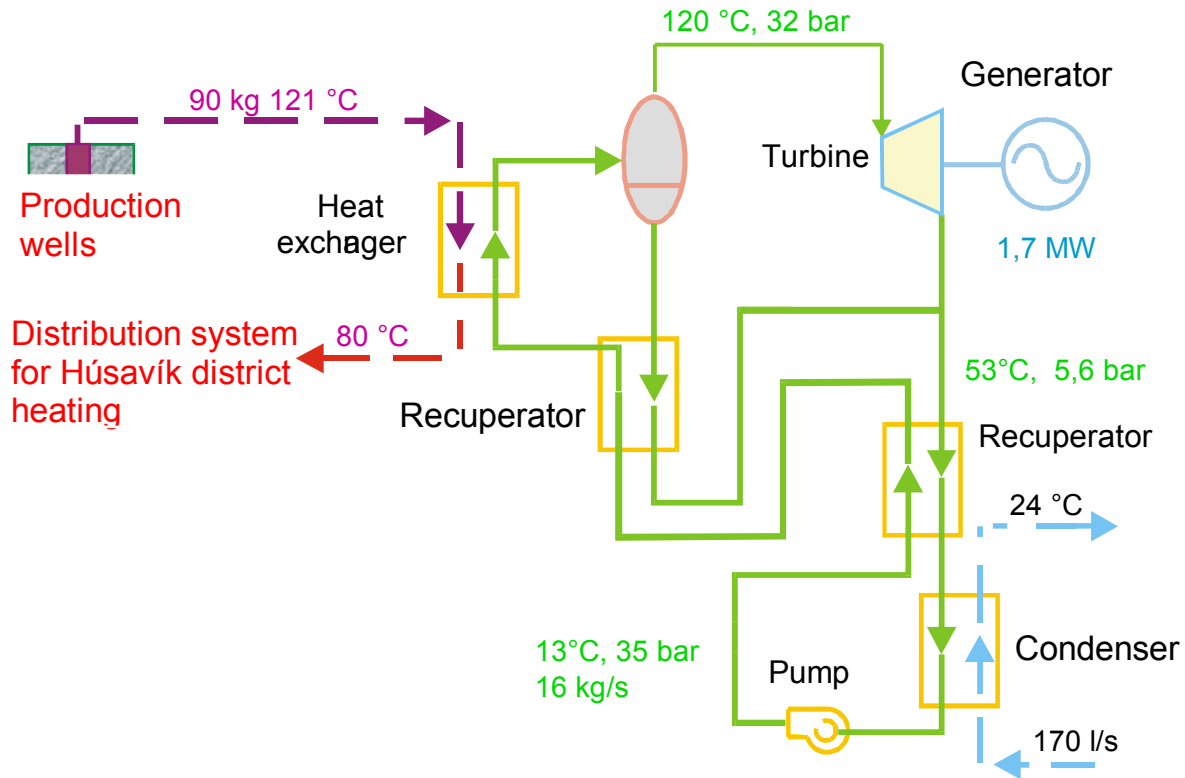


Fig. 3 Electrical Power Plant – Process Diagram

One of the properties of the mixture of water and ammonia is that its temperature changes during boiling and condensation, unlike the steady temperature one encounters when pure matter boils and condenses. The temperature of the mixture thus rises in the heat exchanger, to the same degree that the geothermal water's temperature falls. The condensation temperature of the mixture can change by varying the ratio of water/ammonia in the mixture. The same applies for other fluid characteristics such as its boiling point and temperature of condensation, and their variations can be used to increase production efficiency.

Once the fluid mixture has been heated via the heat exchanger it enters a separator in which fluid and steam are separated. The steam ( $120^{\circ}\text{C}$ , 32 bar), rich of ammonia, is routed through a turbine, expanding as pressure falls. Connected to the turbine is a generator producing the electricity (1.7 MW). The fluid separated from the steam before the turbine is used for pre-heating a fluid mixture that is being routed to the heat exchanger. After the pre-heater the fluid and steam from the turbine are mixed together again ( $53^{\circ}\text{C}$ , 5.6 bar).

The water/ammonia mixture, now in the form of both fluid and steam, is then sent to a recuperator where it is cooled down. Afterwards it enters a condenser where it returns to fluid state ( $13^{\circ}\text{C}$ ). The cooling in the condenser is achieved by using cooling water (190 l/s,  $5^{\circ}\text{C}$ ). The cooling water leaves the condenser at a temperature of  $24^{\circ}\text{C}$  (depending on production the temperature is between  $23^{\circ}\text{C}$  and  $27^{\circ}\text{C}$ ). This temperature is favourable for fish farming.

When the water/ammonia mixture has been condensed a pump is used (13°C, 35 bar, 16 l/s) to raise pressure and the mixture is pumped through two recuperators before entering the heat exchanger and the cycle can begin again.

#### Experience from the new concept.

The new concept has now been in operation since the middle of 2000. The transmission pipeline has proven to function very well, aside from small problems – they have now been solved - regarding deaeration of the geothermal water.

Quite a number of problems came up at the CHP plant in the beginning of the electricity production. Most of the problems were due to the steam separator, which did not performed as planned. Fluid and steam was not 100% separated with the consequence that fluid was send into the turbine and damaged the turbine blades. The separator was replaced at the end of 2001 and the performance of the new separator has been much better. The CHP plant is now producing 1.7 MW, which is less than the expected 2 MW. The main reason for this reduction is the temperature of the geothermal water, which is 3°C lower than the design criteria.

#### Geothermal energy in the district heating system.

The Energy Centre building houses the CHP plant. From the Energy Centre water (75 l/s, 80°C) is pumped out in the district heating network to households and industries requiring low temperature district heating. The outlet temperature after heating the buildings is typical 35°C. After heating the buildings a part of the water is used for snow melting purposes (15°C). All water is at last send to the sewer-system system.

Among the district heating consumers are several industries:

A fishing farm uses presently round 4-6 l/s of 80°C water in addition to 20 l/s of the 24°C cooling water from the condenser at the CHP plant. The annual fish production at the moment is 1.5 million salmon smolt (2 years old salmon) and 140 tons of trout. The trout production is expected to increase to 200 tons next year.

A factory for producing timber-flooring boards uses 80°C hot water to dry the wood in specialised drying compartments.

A factory produce dried fish. Actually the annual production is 2,500 tons and the production is exported to Nigeria. The drying process takes place in specialised drying compartments using 80°C hot water to heat air before blowing it through the compartments.

The construction of a new factory producing glucosamine is scheduled to start summer 2002 and will create 12-15 new jobs. Glucosamine is a compound used in the pharmaceutical industry for – amongst other things - arthritis drugs. The production requires water in the temperature interval between 80°C and 120°C.

Actually a feasibility study concerning fresh water fish farming in Húsavík is under preparation. The study is specifically aimed at a bait-fish called tilapia. Preliminary studies estimates 170 l/s of 24°C cooling water from the CHP plant for an annual production of 5,000 tons of tilapia. Since the ideal temperature for tilapia is 27°C, it is nesseary to increase the temperature of the cooling water by adding 10 l/s of 80°C hot water. The financing of an experimental plant with an annual production of 125 tons is expected to be finalised in 2002. A fully operational 5,000-ton plant is calculated to cost around 12 million EUR and – if the decision to build the plant is made – it will create 50 new jobs.

As it can be seen the construction of the geothermal CHP and the possibilities it has provided has strengthened the economic life in a small urban community as Húsavík.

#### **Project costs and financing.**

The total capital investments in the Húsavík Geothermal Development have been 12 million EUR of which 8 million EUR was spend on renewing the district heating system and 4 million EUR on the CHP plant. The Húsavík Municipality financed about 92 % thereof; other project partners 2% and the remaining came from the European Union.

**Summarize**

The geothermal energy project in Húsavík is an excellent example on how energy efficiency – even in Iceland where enormous resources of relative cheap energy is available – now is integrated in the ideas, when new energy projects are to be realised.

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