Húsavík, Iceland – A model of energy efficiency based on geothermal energy

Mr Hreinn Hjartarson, Orkuveitu Húsavíkur

Mr Lars Gullev, Managing Director, VEKS (West Copenhagen Heating Transmission Company)

Húsavík – a small urban community on the north coast of Iceland, 40 km from the Arctic Circle – is a model of how energy efficiency can be integrated to a unified whole. The geothermal energy is utilised partly for process purposes in the industry and partly for production of heat and electricity in Húsavík's combined heat and power (CHP) plant. Surplus heat from the CHP plant is used for breeding fish. After the hot water has been used for heating houses and institutions, the last of the energy is utilised for "snow melting" at parking areas, streets and footpaths - a system where the energy is exploited to the full, and also creates new jobs.

Húsavík

Húsavík is an old town mentioned for the 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 here. During the 16th century, the activities of the town were concentrated about the discharging of sulphur from the sulphur mines around Mývatn and Theistareykir. As a logical consequence of the wars in Europe at that time, sulphur was a very sought-after product.

Today Húsavík is known primarily for whales, fossils and salmons. For persons with technical interest, the town is also known for its new CHP plant based on utilisation of geothermal energy.

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 400-1000 m deep and produce 120 -130˚C hot water. The wells are among the greatest hot water producers of all low temperature wells in Iceland.

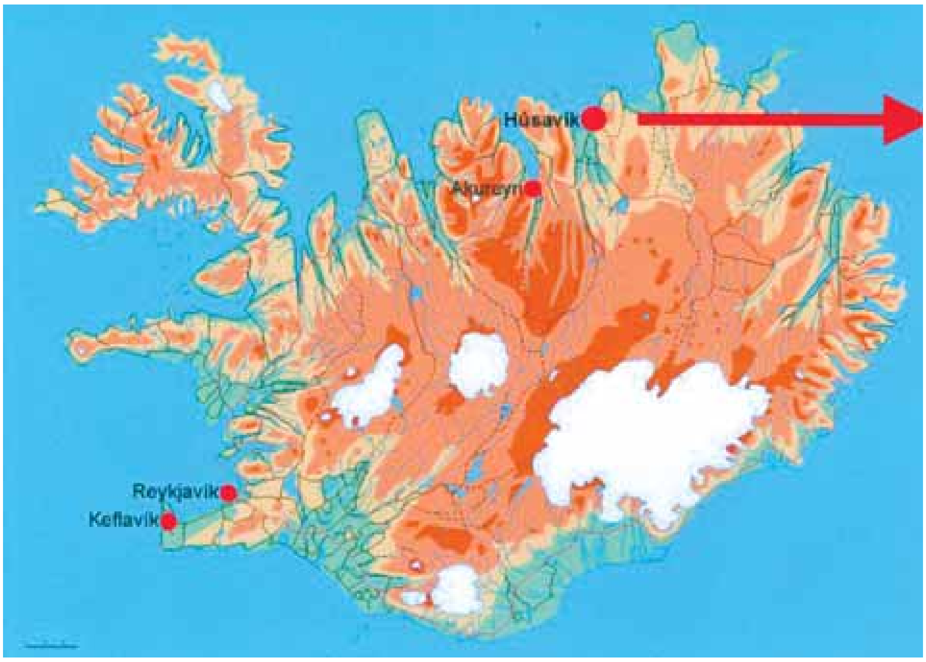
The geothermal area has been explored over a period of decades and is thus well understood. The reservoir's capacity potential has been assessed applying up-to-date reservoir modelling techniques, and the results show that it can sustain a 75-100 MW artesian flow development.

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˚ C hot water was utilised, but in 1974 a 450 m deep production well (flow of 40 l/s and 128˚C) was drilled. The geothermal water was utilized to heat all buildings in Húsavík and to provide 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˚C to 100˚C. In addition to that, there were 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˚C, resulting in a temperature in the distribution network in Húsavík of 85˚C.

Figure 1 and 2. Húsavik.



However, the geothermal fluid in 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˚C to 120˚C hot water both for heating and industrial use. This prompted the idea of expanding the foreseen refurbishing 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 achieve environmental benefits. Combined in a single system, the production of electricity and the provision of suitably hot water for industry, 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 suitable for a multitude of applications close to the consumer location had a great potential for improving the overall economy and employment situation of the inhabitants of Húsavík and its surroundings.

As of 1990, the water supply turned out to be insufficient during the coldest periods of winter. Consequently, a new well was drilled at Hveravellir in 1997. The drilling went as planned and this well now provides around 60 l/s of 124˚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 an amount of 663,000 EURO. In 1999, the construction of the CHP plant and the transmission pipeline started and towards the middle of 2000, the operation began. The concept is as follows:

The high temperature level of the geothermal water at Hveravellir was used 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 economical for Húsavík since the town would no longer need to purchase electricity in addition to creating new jobs and increasing the scope of new jobs. 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 the total energy efficiency increased.

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

Figure 3 depicts in a simplified diagram the new integrated geothermal energy supply system.

Wells and pipeline
The main difference between the new concept and the old 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 made of only one pipe, at the well's temperature of 115˚C-128˚C, instead of being cooled 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 achieved efficiency can be almost 100% in some industrial applications while production of electricity can only provide a 10-12% efficiency at the actual temperature level of 121˚C. The market for electricity is a very stable and safe one, 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 available hot water. 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 Isopentan or similar fluids in the internal cycle of the plant. In this case the electricity capacity was estimated to be 1.5 MW.

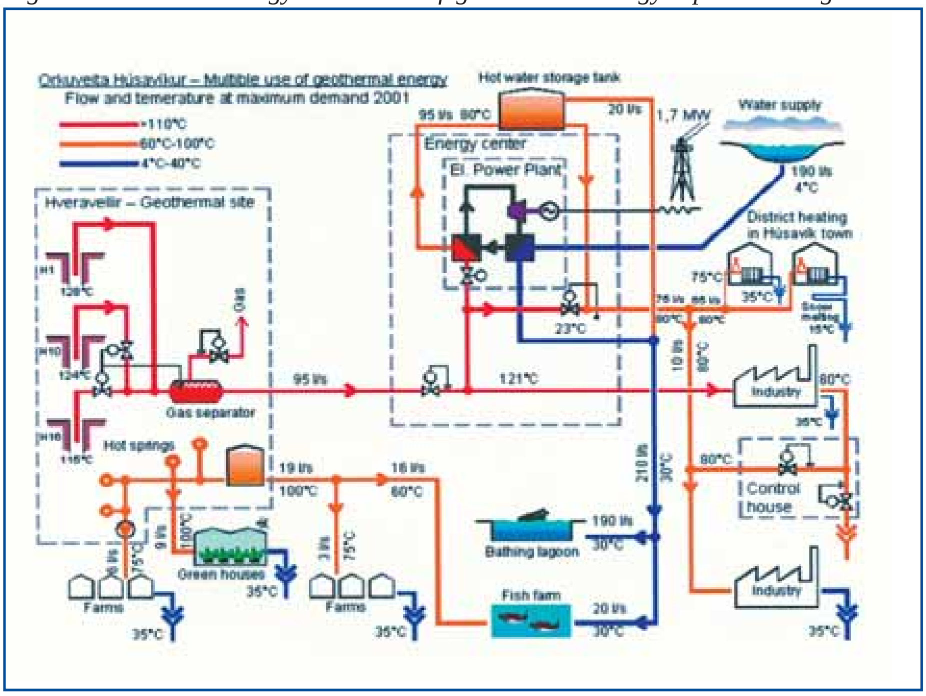
The other concept was based on a new technology, the so-called Kalina technology, in which a mixture of water and ammonia replaces Isopentan in the internal cycle. By using this concept, the electricity capacity was estimated to be 2 MW, which meets about three-quarters of Húsavík's current electricity 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.

The Kalina process
The flowchart of the CHP plant is shown in figure 4. As mentioned, the geothermal water flows from the wells at Hveravellir at a temperature of 124˚C and after a temperature drop of 3˚C, it flows into the CHP. A part of the energy content in the geothermal water (121˚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˚C and thereafter used in the district heating network.

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 by which the temperature of the geothermal water falls. The condensation temperature of the mixture can change by varying the ratio

Figure 3. Húsavik Energy. Multi-use of geothermal energy - process diagram.



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˚C, 32 bar), rich with 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 preheating 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˚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 a fluid state (13˚C). The cooling in the condenser is achieved by using cooling water (190 l/s, 5˚C). The cooling water leaves the condenser at a temperature of 24˚C (depending on production, the temperature varies between 23˚C and 27˚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 been in operation since the middle of 2000. The transmission pipeline has proven to function very well, aside from some small problems regarding deaeration of the geothermal water - and these problems have now been solved.

Quite a number of problems came up at the CHP plant in the beginning of the electricity production. Most of the problems arose due to the steam separator, which did not perform as planned. Fluid and steam were not 100% separated; hence the fluid was sent 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 generating 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 the water (75 l/s, 80˚C) is pumped into the district heating network to households

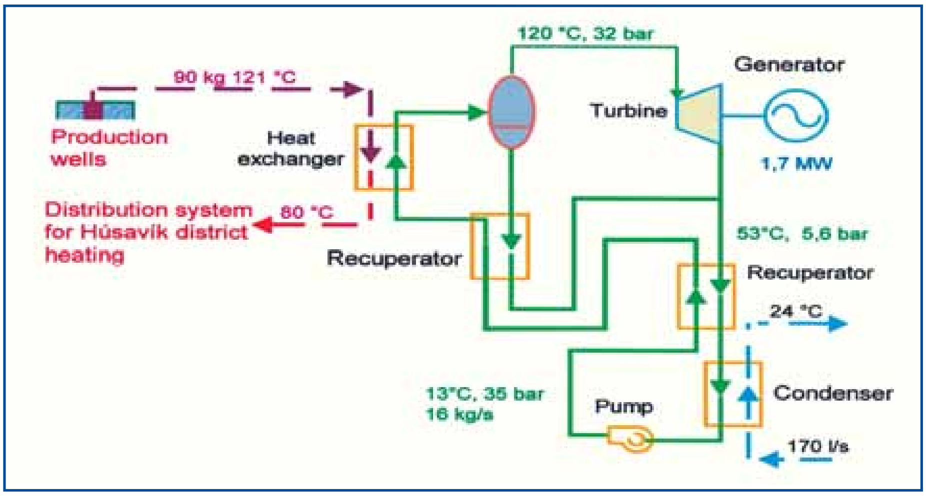


Figure 4. Electrical power plant - process diagram.

and industries requiring low temperature district heating. After the building is heated, the outlet temperature is typically 35˚C. After heating the buildings, some of the water is used for snow melting purposes (15˚C). At the end, all water is sent to the sewer-system.

Among the district heating consumers are several industries:

- A fishing farm presently uses about 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 produces 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 started last summer, and created 15 new jobs. Glucosamine is a compound used in the pharmaceutical industry for arthritis drugs and other purposes. The production requires water in the temperature interval between 80˚C and 120˚C.

At present, 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 estimate 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 necessary to increase the temperature of the cooling water by adding 10 l/s of 80˚C hot water. The financing of a pilot plant with an annual production of 125 tons was finalised last year. A fully operational 5,000-ton plant is calculated to cost around 12 million EUR and will create 50 new jobs, if the decision to build the plant comes through.

As can be seen, the construction of the geothermal CHP and the possibilities it has provided, have 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 amounted to 12 million EURO, of which 8 million EURO were spent on renewing the district heating system and the rest on the CHP plant. The Húsavík Municipality financed about 92%; other project partners financed 2%, and the remaining came from the European Union.

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

For further information please contact:

Orkuveitu Húsavíkur
Att.: Mr Hreinn Hjartarson
Ketilsbraut 7-9
IS-640 Húsavík
Phone +354 464 6130
Fax +354 464 6131
Hreinn@husavik.is

VEKS
Att.: Mr Lars Gullev
Roskildevej 175
DK-2620 Albertslund
Phone +45 43 66 03 66
Fax +45 43 66 03 69
lg@veks.dk