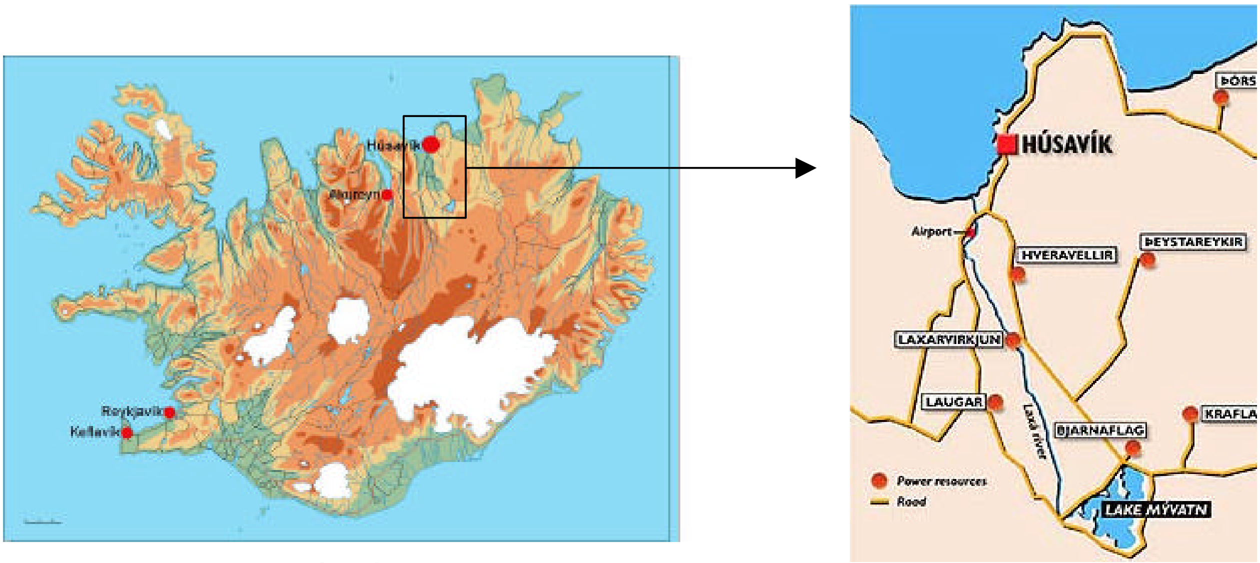
Multiple-use of geothermal energy in Húsavík

Húsavík is the second largest town in the north-east region of Iceland. It has been a site of local trading since 1614 and its inhabitants are now approximately 2,500. The economy has, since Húsavík's time of settlement, been based on fishing and the fishing industry as well as on providing basic services for the surrounding areas. Lately tourism and a variety of small scale industrial businesses have played a greater role in the economic life. In addition to the fishing waters accessible from the harbour, geothermal energy and fresh, pure water provide the town with an abundance of natural resources.



Picture 1 *Iceland - Húsavík*

Fresh water has always been utilised in the fishing industry and during the last few decades for fish farming as well. Despite this increased demand, plenty of fresh water is still disposable in Húsavík, providing various opportunities, especially in the food production sector. Current recourse can give as much as 300 l/s while present usage is merely 90 l/s.

Two geothermal sites are located in the Húsavík area. At Þeistareykir, approximately 25 km east of Húsavík, surface exploration has indicated a high temperature geothermal field of 250-300°C. Originally the Þeistarreykir site was utilised as a sulphur mine but other opportunities are at present being looked into, namely electricity production and various industrial applications. At Hveravellir, 20 km south-east of Húsavík, hot geothermal water has been used for decades to provide energy for greenhouses in the area and to heat nearby farmhouses. The Hveravellir geothermal field is one of the largest, and most powerful, low-temperature (<150°C) fields in Iceland. The geothermal water from Hveravellir is also of a very high quality and especially suited for direct use, both for space heating and as hot tap water.

Uses of Geothermal Energy in Húsavík

The utilisation of geothermal energy in Húsavík can be dated back to 1960 when the local swimming pool was connected to one of the numerous hot water springs in the area. At the same time the drilling of production wells commenced and from 1960-1965 five wells in all were drilled. These wells should have provided Húsavík with half of the hot water needed for district heating but, despite well temperatures ranging from 80°C-110°C, the water quality was not suitable for house heating due to its concentration of salt.

In 1969, Fjarhitun Consulting Engineers was engaged to prepare a feasibility report on district heating in Húsavík. The report concluded that the utilisation of geothermal hot water from the Hveravellir geothermal field was both economical and feasible. The construction of the district heating system, i.e. of the facilities in the geothermal area, the transmission pipeline between Hveravellir and Húsavík and the distribution system in Húsavík, began in 1970.

To begin with only the artesian flow of 100°C hot water from geothermal springs in the area was utilised, but in 1974 a 450 m deep production well was drilled. The artesian flow from the well was 40 l/s of 128°C hot water. Since 1974 the well has provided these 40 l/s and the hot springs approximately 30 l/s. The geothermal water was utilized to heating all buildings in Húsavík and provide them with hot domestic water as well as supplying the town's swimming pool with hot water. Since the altitude difference between Húsavík and Hveravellir is approximately 100 m, Húsavík being the lower area, pumping was not necessary.

A downside to this setup was the considerable amount of energy that was wasted. Approximately 2,2 kg/sec of steam was released into the atmosphere by boiling the 128°C water down to 100°C. In addition losses occurred during the 18 km long transmission of the water to Húsavík since the buried asbestos-cement pipeline was uninsulated. The pipeline's only insulation was the earth that covered the pipes. The temperature loss on the way from Hveravellir was 15°C, resulting in a temperature of 85°C in the distribution network in Húsavík.

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 approximately 60 l/s of 124°C hot water, at a well head pressure of 2 bar.

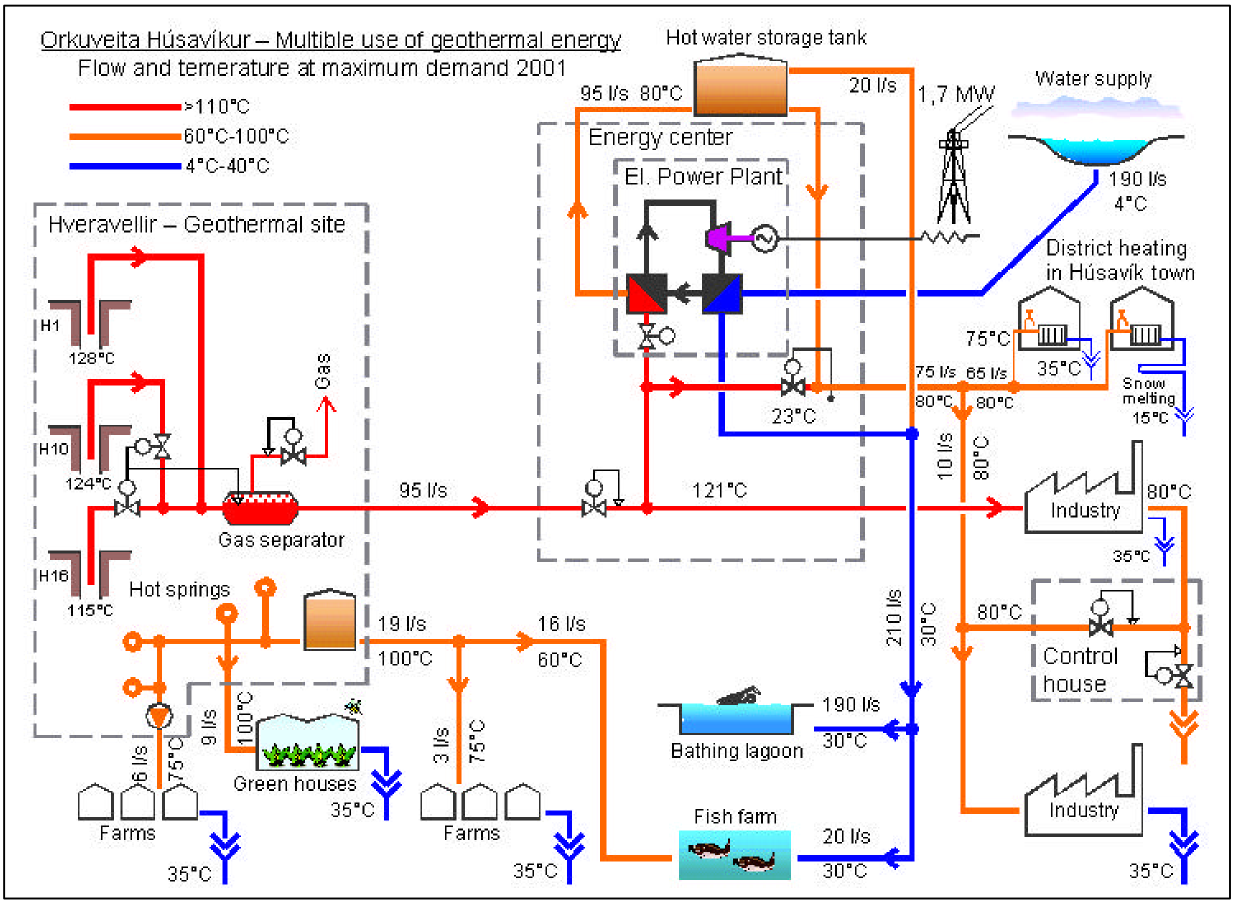
New ideas

During 1998 preparations began for the restoration of the old asbestos-cement pipeline from Hveravellir to Húsavík**.** As mentioned the temperature of the geothermal water at Hveravellir is rather high, so it is possible to use the geothermal energy embedded in it for both space heating and various industrial applications. Thus it was decided to aim for multi- or cascade use of the geothermal energy in connection with the restoration of the transmission pipeline. The benefits of multiple use of the heat energy were many, electricity production would for instance be economically beneficial 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 the utilisation of hot water of various temperatures for space heating, industry and fish farms increases the value of the energy since much less of the heat is wasted.

The main difference between the present setup and the pre-existing one is that the water is piped from the wells to Húsavík in an insulated DN400 steel pipe at the well temperature instead of cooling it down to 100°C by letting it boil. The plan was that once the water arrived in Húsavík it would first be utilised for applications requiring temperatures higher than 120°C (misc. industrial applications and electricity production). Once the water's temperature had fallen to 80°C through these processes it would enter the distribution system and be used in the same manner as previously.

The energy generated from geothermal water depends on the water quantity, the water's 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. Thus considerably more energy can be generated from the geothermal source if it is used in industrial applications than for the production of electricity. However this large difference in efficiency is counterbalanced by differences in market situations. 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.

Picture 2 is a schematic drawing of the new the new geothermal system in Húsavík.



Picture 2 *Húsavík Energy: Multiple-use of geothermal energy – Process diagram*

Electricity Production

In 1998 the decision to build a geothermal electrical power plant in Húsavík was made. Later that same year tender documents for the plant's construction were sent out and offers from three different companies were received. Two of the offers were based on a conventional binary cycle (ORC) power plant, using Isopentan or similar fluids in the internal cycle of plant. Both offers assumed the production of 1,5 MW of electricity. The third offer was based on cutting edge technology, the so-called Kalina technology, in which ammonia and water replace Isopentan in the internal cycle. This offer assumed the production of 2 MW of electricity.

Despite the Kalina technology having been around for a number of years in 1998, it had at this time not managed to achieve recognition. There was thus little experience of its use available. An Icelandic firm of consulting mechanical engineers, VGK, was hired to advise upon a decision and after a very thorough inspection of the system involved it was decided that the Kalina option was both economical and promising. The decision to construct and set up a Kalina power plant, the first of its kind, was thus made.

In 1999 the work on the power plant and the transmission pipeline began and towards the middle of 2000 operation began. The new district heating system has proven to function very well, aside from small problems regarding deaeration of the geothermal water. These problems have now been solved. Quite a number of problems came up at the power plant in the beginning of electricity production. These problems were related to installations within the plant that were not chosen with enough care. Most of the problems were due to a steam separator that did not perform as planned. Water that escaped through the separator damaged blades in the turbine. The separator was replaced towards the end of 2001 and the new separator's performance has been much better than its predecessor's. The power plant is now producing 1,7 MW, a value somewhat lower than the 2 MW promised by the producers. The main reason for this discrepancy is the temperature of the water which is 3°C lower than the design criteria supposed.

The total cost of the Húsavík project amounted to approximately 12 million EUR (1 billion ISK) of which 2/3 (8 million EUR) was spent on renewing the district heating system and 1/3 (4 million EUR) on the power plant.

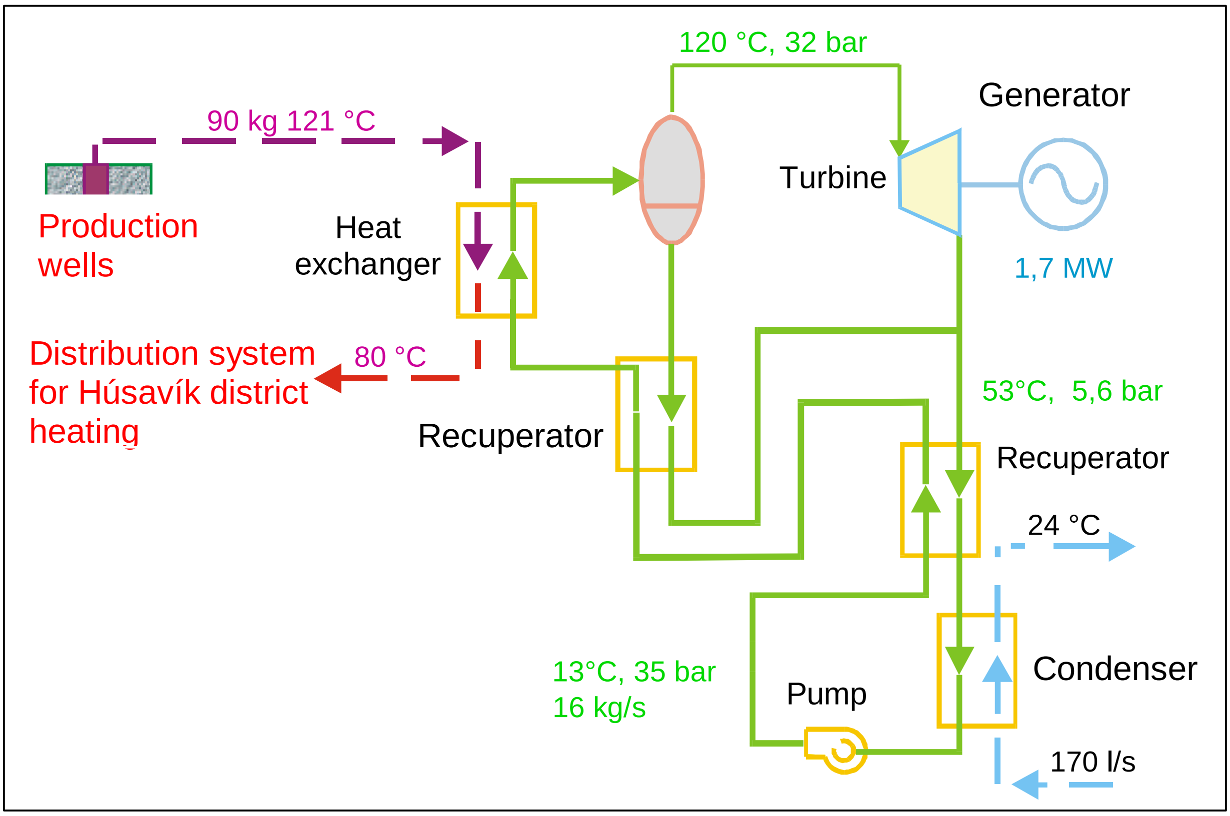
Electricity power plant

The power plant's flowchart can be seen in picture 3. As depicted the water flows from the wells at Hveravellir at a temperature of 121°C into the power plant were it is cooled down to 80°C and used for the district heating system.

The heat extracted by cooling the water from the boreholes is used to heat a fluid medium in a closed circuit. The fluid in question is a mixture of water and ammonia. One of the properties of this mixture 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 water's temperature falls. The condensation temperature of the mixture can be changed 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 it enters a separator in which fluid and steam are separated. The steam, rich of ammonia, is routed through a turbine, expanding as pressure falls. The energy that is produced is turned into electricity in a generator connected to the turbine. The fluid that was separated from the steam before the steam entered the turbine, is used to preheat a fluid mixture that is being routed to the heat exchanger. Following this the separated fluid and steam are again mixed together.

The ammonia/water mixture, now in the form of both steam and fluid, is then sent to a recuperator where it is cooled down. From there it enters a condenser and returned to a fluid state. The condenser is cooled using 170 l/s of 5°C water. This cooling water leaves the condenser at a temperature of 24°C, (23°C-27°C depending on production), a favourable temperature range for fish farming. Once the ammonia/water mixture in the circuit has been condensed a pump is used to raise its pressure and the mixture is routed through two recuperators before entering the heat exchanger and beginning the cycle anew.



Picture 3 *Electrical Power Plant – Process Diagram*

Industry that relies on hot water

The fish farming industry in Húsavík presently uses approximately 4-6 l/s of 80°C hot water in addition to the 20 l/s of the 24°C cooling water from the condenser that the power plant provides. These fish farms currently produce around 1,5 million salmon smolt and 140 tons of trout. A considerable increase in local trout farming is foreseeable and production is assumed to increase to 200 tons next year. Presently the fish farming industry in Húsavík employs 10 persons.

A few years ago a plant for drying hardwood was established in Húsavík. The production uses 80°C hot water to dry the wood in specialised drying compartments and once dry the wood is used to produce timber flooring boards. Today this industry employs 5 persons but during production high season the number of employees rises to 20 persons.

Last year, a company named GPG began processing dried fish in Húsavík. Currently 2,500 tons of fish-heads and other fish parts as well as flatfish are being dried and sold for export to Nigeria. The drying process takes place in specialised drying compartments that use 80°C hot water to heat air before blowing it through the compartments, thereby drying the fish. Around 8-10 persons are employed at the plant which uses approximately 3 l/s of hot water for its drying process.

A company named Glucomed is well under way in preparing the production of glucosamine in Húsavík. The preparations aim at using hot water to produce glucosamine but the compound is used in the pharmaceutical industry for arthritis drugs, amongst others things. A contract signed between Húsavík Energy and Glucomed assumes sales of 7 l/s of 80°C hot water and 2 l/s of 120°C hot water to be used by Glucomed in their production process. The raw material for glucosamine production is by most part chitin, an imported material produced from shrimp and crab shells. The construction of the plant is scheduled to commence in June 2002, when all appointed permits are in place. It is estimated that the plant will provide work for 12-15 persons and that production will begin next fall.

The Icelandic Technological Institution, IceTec, and the ÚA Seafood Group from Akureyri are conducting a study into the feasibility of fresh water fish farming in Húsavík. The study is specifically aimed at a bait-fish called tilapia. Preliminary studies aspire using 170 l/s of 24°C cooling water from the power plant to produce 5.000 tons of tilapia. Since the ideal temperature for tilapia is 27°C, a temperature 3°C higher than that of the cooling water, 10 l/s of 80°C hot water will also be needed to increase the heat of the cooling water. Investors willing to finance a 125 ton experimental plant are currently being sought and financing is expected to be finalised in the beginning of June. A fully operational 5.000 ton plant is expected to cost around 12 million EUR (1 billion ISK) and any analysis needed to reach a decision regarding the plant is scheduled to be complete in the beginning of 2003. If the decision to build the plant is made it is expected to provide work for 50 persons.

Icelandic government policy has been to promote and strengthen the largest urban areas in Iceland, namely the city of Reykjavík and Akureyri. This is done at the expense of other more rural areas. The construction of the geothermal plant and the possibilities it has provided has strengthened the economic life in Húsavík.