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A New Geothermal Power Plant in Iceland
The Hellisheiði Project

Asgeir Margeirsson

COO. Orkuveita Reykjavíkur – Reykjavík Energy
Iceland

Keywords

Iceland, Reykjavik, geothermal power, Hellisheidi Project, Reykjavik Energy, geothermal reservoir, energy resources, volcanic eruptions, Hengill, thermal power, chp, geothermal district heating, environmental impact assessment, heat distribution, steam transmission pipes, steam separator stations, cooling towers, steam exhaust stacks, production wells, reinjection, geothermal fluid, drilling, well head silencers, borehole housings, Hellisskard, Kolvidarholl

ABSTRACT

The purpose of this paper is to present the purposed Hellisheiði Geothermal Power Plant in Iceland, now under construction. It describes the technical aspects of the plant, extensive environmental studies carried out, groundwater investigations and shows that the project is regarded as an optimal choice with regards to possible effects on the geothermal reservoir and energy resources.

Orkuveita Reykjavíkur – Reykjavík Energy

Reykjavík Energy entered its first year of operations in 1999 following the merger of the city's Electric Power Works and District Heating Utility. On January 1st 2000, Reykjavik Water Works merged with Reykjavík Energy. All these companies were leading players in the Icelandic energy sector, and merged to create a dynamic new company to handle procurement, sale and distribution of electricity, cold water and geothermal hot water for space heating.

Reykjavik Energy operates the world's largest and most sophisticated geothermal district-heating system - an electricity distribution network and a water distribution system that meets the most demanding international standards for the quality of water and its environment. The area serviced by Reykjavik Energy reaches from Borgarfjörður northwest of the capital and all the way south to Grímsnes, an area where more than half the nation's population lives.

Introduction

Orkuveita Reykjavíkur is constructing a new CHP geothermal power plant in the Hengill region in SW-Iceland, with the first stage to be completed in 2006 and fully operational in 2015. The development area of the project is located on Hellisheiði south of Hengill about 20 km east of the capital area, aprox. 350 meters above sealevel. It is divided into a lower and upper development area connected by the pass Hellisskarð. The main powerhouse will be located near Kolviðarhóll in the western and lower part of the area. A hot water transmission pipe will connect the plant to the OR distribution system.

The objective of the project is to meet increasing demand for electricity and hot water for space heating in both the industrial and domestic sectors.

The capacity of the completed power plant is projected to be 120 MW_e electric and 400 MW_{th} thermal power.

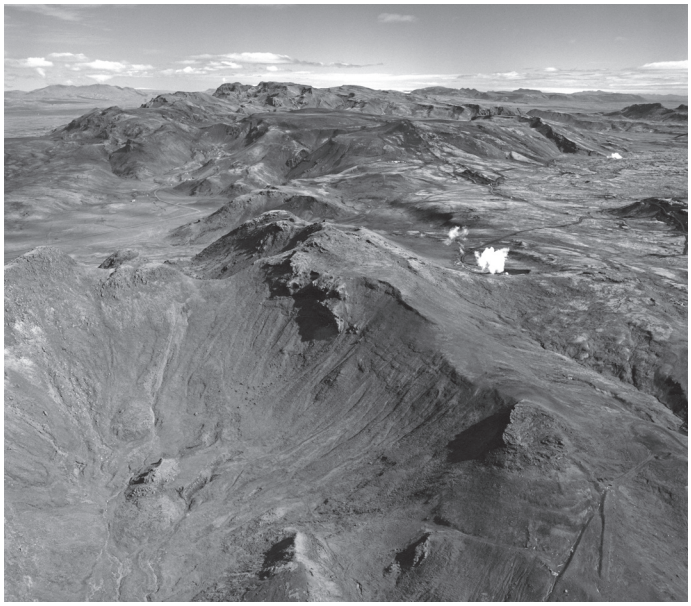

Figure 1. The Hengill mountain area.

Figure 2. Existing geothermal power plant at Nesjavellir, operational in 1990.

The project of building a new geothermal power plant is subject to an environmental impact assessment (EIA) according to Article 5 and item 2 of Annex 1 of the Icelandic Environmental Impact Assessment Act no. 106/2000. The environmental impact assessment of the power plant covers a wider area than the planned development. This applies especially to groundwater investigations that extend from the south coast to Faxaflói in the west, north to the mountain Esja and Þingvallavatn and east to the river Ölfusá.

Technical Description

The proposed geothermal power plant on Hellisheiði will be a cogeneration plant. The capacity of the complete power plant will be 120 MW_e electric and 400 MW_{th} thermal power. The power plant will be built in modular units and units will be added as the market demand increases. The power production capacity of each electric unit will be 40 MW_e and for each thermal unit the capacity will be 133 MW_{th}. The main construction stages are shown in Table 1 the first stage being a 80 MW_e electric power station consisting of two 40 MW_e units.

Table 1. Main construction stages.

Commissioning	2006 Stage 1	2007 Stage 2	2012 Stage 3	2015 Stage 4	Complete power plant
Electric power station	80 MW_e		40 MW_e		120 MW_e
Thermal power station		266 MW_{th}		133 MWt_h	400 MW_{th}

Two possibilities for the organization of the power plant on Hellisheiði were presented in a report on environmental impact assessment of the project, Option I and Option II. In Option I all stages of the electric and thermal power stations will be located in the lower area, close to Kolviðarhóll. Option II allowes for an 80 MW_e electric and a 400 MW_{th} thermal power station near Kolviðarhóll, as well as an 40 MW_e electric power station on the upper area by Gígahnúkur. Orkuveita Reykjavíkur plans to build the geothermal power plant on Hellisheiði according to Option I.

Besides the power house to be built near Kolviðarhóll other main components of the project are: Production wells, well head silencers, access roads, service roads, steam transmission pipes, steam separator stations, cooling towers, steam exhaust stacks, a fresh groundwater supply system, water tanks, a hot-water transmission pipe, discharge transmission pipes and injection areas and connection to the power grid.

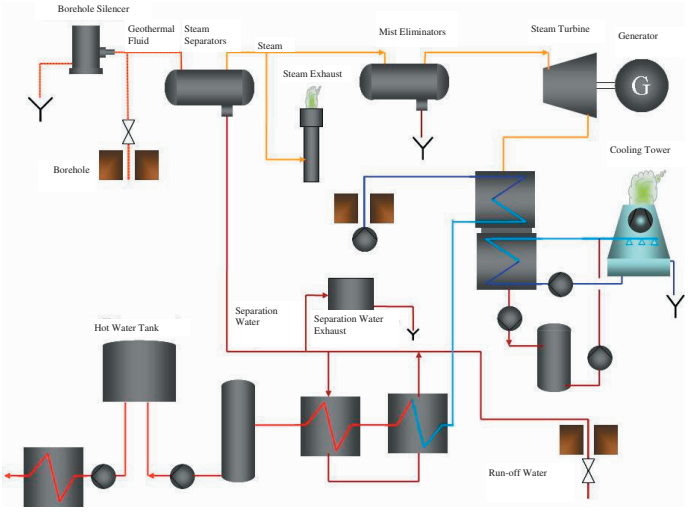

Figure 3. Chart of Production.

Production wells and steam transmission pipes gathering geothermal fluid from the wells into steam separator stations will be constructed on both the upper and lower levels of the development area.

A fresh groundwater supply system will consist of wells by Engidalskvísl, a water pipe from there to water tanks by the Kolviðarhóll building site. A hot water transmission pipe will be installed from the main power house to Reykjavík while discharge transmission pipes will run into the injection area by Lambafell.

The electric power station will be connected to the Landsvirkjun's transmission system through a 220 kV overhead power line that runs through the development area.

Following is a description of the main components of the Hellisheiði CHP geothermal power plant.

Roads

The present Hamragil road will be changed to run west of instead of presently east of Litla Reykjafell and used for accessing the main power house by Kolviðaróll in the lower part of the development area but a new road will be built 2 km east of Skíðaskálinn to access the upper part from the main highway. A road connecting the upper and lower area will be constructed in the pass Hellisskarð. The length of new roads is about 4 km. Service roads about 4 m wide are also needed along steam transmission pipes, the fresh groundwater supply

pipe and hot water transmission pipe for accessing the site for installation and maintenance.

Geothermal Drilling

Orkuveita Reykjavíkur plans to drill ten production wells on Hellisheiði in the years 2004 and 2005. Eight new production wells will be added before commissioning of a second stage of the electric power station in the year 2012. Seven exploration wells in the area have been drilled as possible production wells and will be connected as such to the plant's steam supply system if profitable.

Production wells will be grouped on drilling sites up to 5 wells on each of the 11 sites shown in Figure 1. Boreholes will be up to 3000 m deep and will be both vertical and directional. Well head silencers and borehole housings will be installed at each well.

Geothermal Water and Steam Supply System

Steam transmission pipes will be installed for gathering geothermal fluid from the production wells into two steam separator stations. One station of approx. 500 m^2 is planned above the pass Hellisskarð and the other approx. 250 m^2 will be built west of Þverfell. From the steam separator station above Hellisskarð the steam and water will be transported in four 1000 m long pipes to the power station. Two pipes will be installed for transporting steam and water from the second steam separator station west of Þverfell. Control pressure stations and two to three steam exhaust stacks will be constructed by the main power house within the building plot.

Main Power House

The main power house will be situated within the building plot near Kolviðarhóll in the lower part of the development area. All main equipment will be indoors due to weather conditions. The size of buildings will be approx. 3.400 m^2 and they will be about 15 m high.

Cooling Tower

A cooling tower will be installed southeast of the main power house within the building plot. The cooling tower will be about 18 m high and approx. 1.800 m^2.

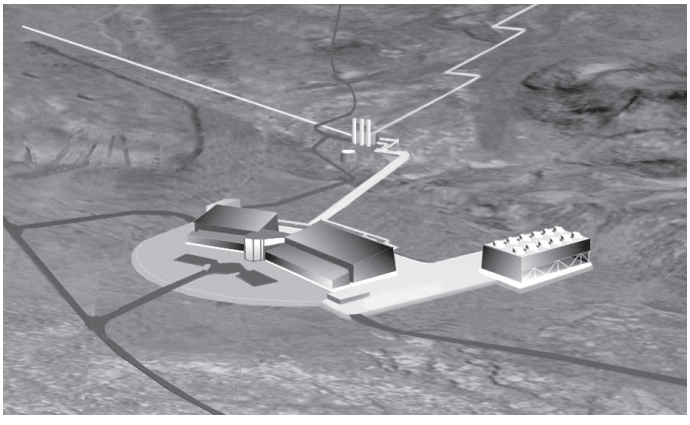

Figure 4. Future site of plant, main house and cooling tower.

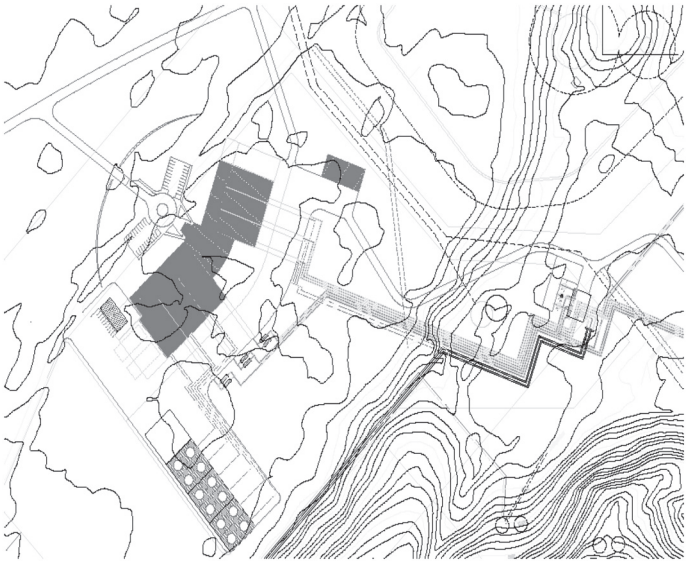

Figure 5. Overview of drilling sites at site of new plant.

Fresh Water Supply System

The estimated fresh water consumption of the complete power plant is 1.700 l/s. Fresh groundwater will be taken from approx. twenty four 100-200 m deep wells and piped from a water supply that is planned at Engidalskvísl 5 km northwest of the power house. The fresh water will be pumped to two water tanks near the power house, each having the capacity of 1.000 m^3.

Discharge System

Estimated fluid discharge from a completed power plant is 750 l/s geothermal water and 150 l/s condensate water. Discharge water will be transported in two pipes to an injection area in Þrengsli located about 3.5 km southwest of the power house. There it will be injected into approx. eleven 800-1.000 m deep boreholes. The discharge transmission pipe will be installed along existing roads and tracks and in culverts where it crosses the highway.

Temporary discharge of geothermal separated water, due to possible closure of discharging operations, will be possible up to three months into shallow sinkholes near the main powerhouse. Discharge water will be transported in buried pipes from the power house to the temporary discharge area.

Hot Water Transmission

An approx. 18 km long buried hot water transmission pipe will be installed from the power house by Kolviðarhóll to Reykjavík to connect the plant to the OR distribution system. The pipe will be located along an existing road the first 4 km and the rest of the distance a service road will be constructed beside the pipe which runs along a power line most of the distance to Reykjavík.

Connection to the Power Grid

The electric power station will be connected to the Landsvirkjun's transmission system through a 220 kV overhead power line that runs through the development area.

Stage 1 80 MW Electric Power Plant

The first stage of the development is construction of a 80 MW_e electric power plant to be commissioned 2006. This stage consists of two modular units and can be divided into the following main components: Geothermal drilling, construction site preparations, installation of the steam supply system 1st and 2nd stage, installation of re-injection system 1st and 2nd stage, building of the centre module of the power house, turbine/generator units and auxiliary systems, control and protection system, see Attachment 5 for overall project plan. Following is a list of the expected tenders for the 1. stage of this project:

HH-I01	Drilling of production wells
HH-I02	Wellhead silencers and measuring tubs
HH-I03	Wellheads and blow-out equipment
HH-I04	Turbine / generator units and auxiliary equipment
HH-I05	Control and protection systems
HH-I06	Road construction and site development
HH-I07	Site facilities
HH-I08	Steam and moisture separators
HH-I09	Geothermal steam and water feeding pipelines
HH-I10	Separator and control pressure stations, cold water storage
HH-I11	Steam exhaust stacks
HH-I12	Prefabrication of pipe supports
HH-I13	Building for equipment storage
HH-I14	Power plant buildings
HH-I15	Steam gathering system 1
HH-I16	Re-injection system
HH-I17	Overhead cranes
HH-I18	Transformers
HH-I19	220 kV / 11 kV distribution
HH-I20	400 V and Dc systems
HH-I21	Pipelines in Power Plant
HH-I22	Installation of electrical equipment
HH-I23	Steam gathering system 2

Environment

General

The Hengill region is a rural mountainous area in the middle of the western volcanic zone in Iceland that runs from Reykjanes in a northerly direction to Langjökull. The bedrock consists mostly of palagonite formed by volcanic eruptions below glaciers during the last ice age. Basalt is present on the fringes of the area. The Hengill region is one of the most extensive geothermal areas in the country. Surface measurements, heat distribution and subsurface measurements indicate an area of around 112 km^2. The region is divided into at least three distinct areas, of which Hengill is one. Recent volcanic structures are common in and near the development area. Three volcanic eruptions are known from the last 11,000 years, the most recent eruption was 2000 years ago. The last eruption in the vicinity occurred in the year 1000 on a fissure west of Hengill, forming the Svínahraunsbruni lava field.

The main characteristic of the groundwater system in the investigated area is that it is divided from southwest to northeast by a range of mountains formed by Hengill, Stóra-Reykjafell, Stórimeitill and Litlimeitill. On the eastern side water flows from Hellisheiði, to the east. Hydrology is a little more complex on the western side, with a characteristic area of 15 km^2 west of Hengill where the level of the groundwater table is around 172 m above sea level. From there, groundwater flows in three directions: West to the Elliðaá catchment area, northeast to Þingvallavatn and to the south until it reaches the sea at Selvogur. Apart from small streams in Sleggjubeinsdalur, from Draugatjörn and in Engidalur there is little surface water in the development area. The river Hengladalsá runs out of Innstadalur in the eastern part of the Hengill region.

Vegetation in the development area is mostly moss, grass and small shrubs. Grassland is less widespread than the moss-covered areas. The land in which the plants fresh water supply, fresh water pipe and hot water transmission pipe will be installed is well vegetated, mostly mossy hillocks and low hills with grass and heather in hollows. About a quarter of the area is lava with a moss covering Wetlands are found only in two places – around Draugatjörn and near the derelict settlement Elliðakot. Animal life is rather scarce, possibly because of shortage of surface water in the area.

The air temperature is on average 2.6°C lower than in Reykjavík. Humidity is higher and the wind speed on Hellisheiði is generally 70% higher than that in the capital area. Rainfall is three times that of Reykjavík.

Cultural remains in the area are particularly linked to transportation and many old trails cross the area. There are no residential houses but two sport clubs have skiing facilities in the Hengill region. The area is popular for recreation and marked footpaths and publication of maps have increased it's accessibility.

Environmental Impact

Careful consideration has been taken to the environmental aspects of the project and its effects. Thus, previously disrupted areas such as gravel pits are being used for drilling sites where possible, existing roads are used and great care taken towards cultural and natural sites in the area.

The conclusion of an environmental impact assessment is that the project will not have a significant effect on the environment.

The conclusion of an environmental impact assessment is that the project will not have a significant effect on the environment. The following is a summary of the results of the EIA of the proposed power plant on Hellisheiði.

The project is regarded as an optimal choice with regard to possible effects on the geothermal reservoir and energy resources, according to numerical reservoir modelling. Exploitation of the Hellisheiði geothermal field is not expected to effect the nearby geothermal areas in Hveragerði, at Ölkelduháls or at Nesjavellir. When production starts a substantial depletion is predicted over time. Orkuveita Reykjavíkur plans reinjection of discharge water which will help to sustain or restore reservoir pressure, when development of suitable methods is complete. The numerical reservoir model predicts low financial risk in constructing a 40 MW_e electric and 133 MWt_h thermal power plant on Hellisheiði. The financial risk increases if construction stages are larger because of uncertainty in the number of

production wells needed. Discharge of separated geothermal water will not increase over the prediction period according to the model. Indications are that geothermal production in the Hellisheiði power plant will be sustainable. If the power plant is shut down after 30 years of operation the pressure and volume of geothermal fluid in the reservoir are predicted to recover quickly and return nearly completely to original levels within a lifetime. The temperature of the reservoir will have reduced from 270°C to 260°C during the 30 year production period, but the area will recover completely in 1000 years assuming there is no external heat injection as a result of volcanic activity. The projects environmental effects on the geothermal reservoir are assumed to be reversible.

Environmental studies included a search for a suitable fresh water supply for producing hot-water in the thermal power plant. An assessment was conducted of the possible effects this extraction of groundwater could have on hydrology of surrounding areas. A suitable site was sought for injection of discharge water into wells and the effect of this discharge on hydrology was also assessed. As is described above the hydrology of the area proved to be rather complex and the area investigated was therefore extensive. Numerical modelling, among other techniques, was performed to analyze the data and assess the effects on hydrology. Samples of geothermal fluid were analyzed to assess whether fluid discharge from the power plant could have an effect on groundwater. This analysis shows that condense water contains no substances exceeding allowed limits. However, levels of three substances in the separated geothermal water were found to be above limits for drinking water and amounts of arsenic were considered unacceptable for the biota in surface waters. For this reason surface discharge of separated geothermal water is not considered as an option because of possible effects on water supplies and biota.

Sufficient freshwater for hot water production in the power plant can be obtained from the proposed water supply at Engidalskvísl west of Húsmúli. An area surrounding the fresh water supply will be defined as a protected water catchment area. According to groundwater investigations and numerical modelling, the most appropriate location for injection of geothermal separated water into 800-1000 m deep wells is in the a proposed discharge area in Þrengsli west of the main powerhouse. In this way the water supplies of Þorlákshöfn, of the power plant on Hellisheiði and for the capital area will not be affected by this discharge. Temporary discharge of geothermal separated water into shallow sinkholes near the main powerhouse due to possible closure of discharging operations does not appear to have any effect on groundwater.

The completed power plant on Hellisheiði will cause increase in carbon dioxide emissions in Iceland of around 24,300 tonnes per year, or approximately 0.74% compared with 2001 levels. Emissions of methane will increase by about 16 tonnes annually or around 0.1%. Efficient use of natural resources in the power plant through cogeneration of electric and thermal power leads to very low greenhouse gas emissions per produced kWh. Discharge of hydrogen sulphide from geothermal power plants in Iceland will increase by 2,500 tonnes per year, or 16% compared with 2001 figures. It is expected that a negligible fraction of this will oxidize to form sulphur oxides while most will fall to the ground during periods of rain and form sulphate or sulphur. Hydrogen sulphide is expected to be washed out of the atmosphere because of the high precipitation and strong winds in the area. Risks are considered low of hydrogen sulphide affecting the environment, although under certain conditions a sulphurous smell can be expected in the area.

The landscape in this part of the Hengill region are not highly valued and the area is already considerably disturbed. For this reason it is considered that the project will not have a significant effect on the landscape. Construction in recently formed lava fields, will effect a type of landscape that is protected according to nature conservation legislation. As far as possible, construction sites have been chosen to avoid affecting protected areas. Certain geological features in the area have been defined and will not be disturbed. Grouping production wells on each specified drilling site will reduce the number transmission pipes and service roads needed and minimizes the disturbance of land. Excavated material that is discarded and will be used for filling up the old quarries at Gígahnúkur and in front of Hamragil. Mitigating measures will help to minimize any effect on the landscape and areas of geological interest.

The surroundings of the proposed power plant will be subject to some changes. Buildings such as the powerhouse, cooling towers and steam exhaust chimneys will be clearly visible, as will surface transmission pipes, borehole housings and new roads. In most cases these effects will be permanent, although some will be temporary such as steam exhaust from wells while testing and during construction of transmission pipes as well as quarrying.

The general public opinion of exploiting the geothermal resources in the Hengill region is positive. Results of surveys indicate that the construction of a power plant will not reduce the number of visitors coming to the Hellisheiði and Hengill areas. On the contrary, the results indicate that the number of visitors pursuing outdoor activities in the area will increase rather than decline.

The project is not expected to lead to increased traffic on Hellisheiði. The most likely impact will be that traffic will increase at the junctions of the National Highway and the two roads used to access the upper and lower part of the development area.

Monitoring

Monitoring of possible effects of the geothermal installation on Hellisheiði will be, where appropriate, carried out in a similar manner to that employed in the Nesjavellir area. The control system software of the power plant collects information on principal factors of production. Additionally, the geothermal area will be monitored and inspected regularly, this includes possible land deformation due to exploitation, impact on fauna, flora and hydrology and changes to discharges.