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Environmental Issues Related to the Building of New Power Plants in the Hengill Area

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ABSTRACT

At Reykjavik Energy environmental issues have always played important role when harnessing geothermal energy. Preparation for building a power plant at Hellisheiði began in 2002 by drilling of exploration wells. Recent volcanic fissures stretch through the field from SW to NE. Material from the crates had been used in the 1970´s when a new road was laid through the area. One of the issues described by Reykjavik Energy during EIA was to recreate the craters and volcanic fissure. Old aerial photos were used for the design, making it possible to approach the original form of the craters. Soil dumped from the construction of the power plant was used to reform the craters which were then coved by lava scoria. Research has been carried out with the purpose of finding solution of how to regain the original mountain vegetation.

Emissions of geothermal gasses are a big issue. Attempts to separate the CO_2 and H_2S geothermal gases is been made where the plan is to use the carbon dioxide in sequestration forming calcite minerals and inject the hydrogen sulphide with the separation water.

1. INTRODUCTION

For thousands of years, mankind has been an integral part of the environment and has had similar impact as other animal species. By increasing technology, especially during the last century, this has changed.

Although geothermal energy is generally accepted as being an environmentally benign energy source, especially when compared to fossil fuel energy sources, all geothermal development has some impact on the environment.

Until recently district heating has been the main use of geothermal energy in Iceland. During last years there has been a growing interest in electric energy production from geothermal energy, and currently about 30% of the electricity generated in Iceland is of geothermal origin, the rest being from hydro resources (Orkustofnun, 2008, Ragnarsson, 2010).

Reykjavik Energy is the largest developer of geothermal energy in Iceland. It operates the world's largest geothermal district heating utility, serving Reykjavik and neighboring communities with thermal water (Gunnlaugsson and Ívarsson, 2010). For district heating in Reykjavík the company utilizes four low-temperature fields, located within or close to the city's limit, and one high-temperature field, Nesjavellir, located within the active Hengill volcanic complex. The Hellisheiði power plant also located within the Hengill complex has been generating electricity from fall 2006. Hot water from that power plant will be on line in Reykjavík in the fall of 2010. Further development is planned at that power plant as well as in the vicinity.

2. THE HENGILL GEOTHERMAL SYSTEM

The Hengill geothermal system lies in the middle of the western volcanic zone in Iceland, on the plate boundary between North America and the European crustal plates (Fig. 1).

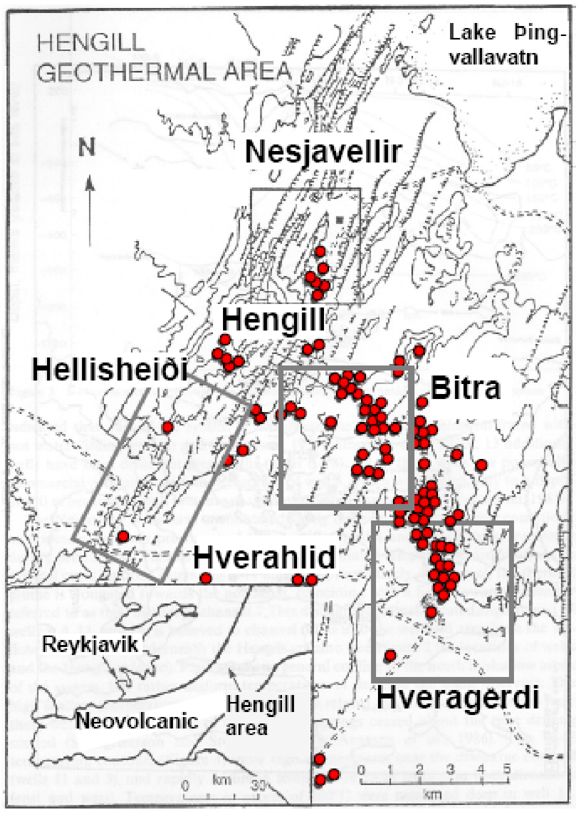

Figure 1: Location of the Hengill geothermal field. Hot springs and fumaroles are indicated by dots (•). The map shows Nesjavellir, Hellisheiði, Hveragerði, Bitra and Hverahlið subfields. (from Sarmiento and Björnsson, 2007).

Resistivity measurements, heat distribution and subsurface measurements indicate an area of around 110 km^2 for the Hengill system. It is one of the most extensive geothermal areas in the country. The bedrock in the Hengill area consists mostly of palagonite formed by volcanic eruptions below glaciers during the last ice ages (Franzson et al., 2010).

Geothermal activity is associated with three volcanic systems of different age within the complex (Fig. 2). Several potential geothermal fields can be distinguished within the Hengill complex. So far only Nesjavellir and Hellisheiði have been developed.

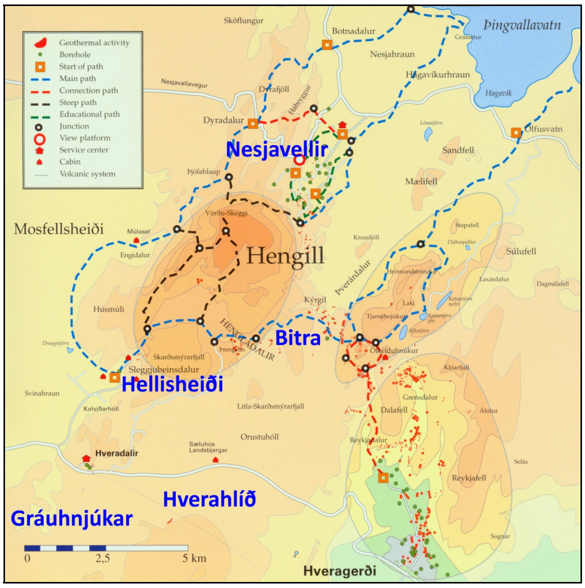

Figure 2: Volcanic systems of the Hengill complex. The map shows the Nesjavellir and Hellisheiði power plants as well as three other locations for possible new power plants.

3. GEOTHERMAL DEVELOPMENT WITHIN THE HENGILL SYSTEM

Environmental issues have always been an integrate part of geothermal development by Reykjavík Energy. During the preparation of Environmental Impact Assessment laws in Iceland, examples from Reykjavík Energy were taking into consideration since environmental issues already played a key role when developing low-temperature as well as in high-temperature geothermal fields.

3.1 The Nesjavellir power plant

The Nesjavellir geothermal power plant (Fig.3) was taken into operation in 1990, following an intensive drilling and testing phase in the 1980's (Gunnarsson et al., 1992). The act on Environmental Impact Assessment became active in 1994. During the preparation for the Nesjavellir power plant all the same research and investigations were done as required for EIA. Research drilling started in 1982 after surface explorations such as geological mapping, resistivity measurements and geochemical exploration. When the plant was commissioned 14 production boreholes had been drilled, and all except one were successful (Gíslason et al. 2005).

Figure 3: The Nesjavellir power plant.

During the preparation period intensive ground water research was undertaken and biological study in the lake Thingvallavatn. The purpose was to determine the initial stage and collect background values. Flora and wildlife was studied and archeological mapping in the vicinity. In 1986 it was decided to build the power plant. Then a meeting open to public was held were the project was described and possible impact on the environment.

Initially the plant produced about 560 l/s of 82°C hot water for district heating (100 MWt), using geothermal steam and water to heat cold groundwater. In 1991 the capacity was expanded to 150 MWt, and in 1998 to 200 MWt. At that time the production of electricity commenced with the installation of two 30 MWe turbines. In the original plan for Nesjavellir power production was less than 50 MWe. Therefore EIA was made for power production prior to installation of turbines.

In 2001 the third turbine was installed, increasing the capacity to 90 MWe. In 2003 the hot water production was increased to 290 MWt and the fourth electricity turbine was online production in 2005, bringing the capacity to 120 MWe.

3.2 The Hellisheiði power plant.

The Hellisheiði power plant is located on the southern side of the Hengill Mountain. It went on line in 2006 generating 90 MWe in two 45 MWe units. Since then it has been extended by two 45 MWe units and a 33 MWe low pressure unit (Geirsson et al., 2010).

The Hengill area is known for hiking and other outdoor activity in the vicinity of Reykjavík. On the southern side of the mountain stretches some volcanic fissures with crater rows from eruptions over the last 10,000 years. Material from many of these craters was used during construction of nearby roads. This part of the area was therefore disturbed and damaged by previous activity. During the preparation phase of the power plant the concept was to work in harmony with nature. Therefore the first approach was to select which area had to be covered to supply geothermal fluid for the power plant. The area lies between the yellow lines in Fig. 4 and runs in a SW-NE direction.

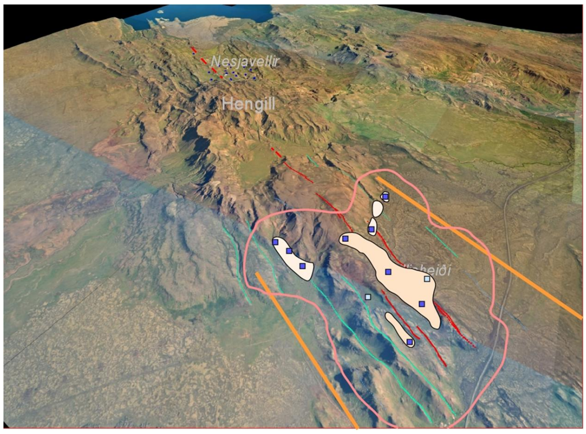

Figure 4: Location of the Hellisheiði well fields. Red lines show the volcanic fissures and green lines the main faults. Between the yellow lines lies the selected production field. The pink area shows where drill holes can be located with minimum impact on the environment. Blue squares indicate the location of well platforms.

Within these lines are the main volcanic fissures. The next step was to map the area, which already had been damaged by previous activity. By locating the drill sites within this damaged area all the selected drill targets could be reached by directional drilling. Furthermore, the drill sites were grouped together to minimize their effect on the environment. Up to 5 wells can be drilled on each of the 11 sites.

Environmental impact assessment for further expansion of the geothermal field was concluded in March 2006. This production field was expanded to Mt. Skarðsmýrarfjall north of the existing production field and closer to the expected up-flow zone. From the size of the field it was estimated that from this extended area further 90-135 MWe could be extracted. Prior to drilling 10 possible drill sites were located and from there it should be possible to reach to all proposed locations.

3.2.1 Drill holes and platforms

Directional drilling has increased last years. The reason is twofold: The main targets for drill holes are near vertical structures such as faults and dikes or volcanic fissures. Therefore it is more likely that directional drill holes hits these structures than vertical wells. Today it is common to drill up to 1200 m from vertical in a well. The second reason for directional drilling is environmental. Using directional drilling it is possible to drill many wells from the same platform with distance of 10-15 m between wells at the surface and therefore reduce the area used under platforms. Fig. 5 shows three dimensional model of the Hellisheiði field.

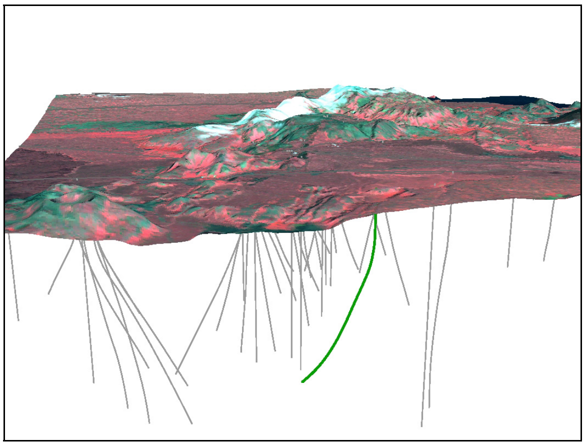

Figure 5: Three dimensional model of the Hellisheiði geothermal field. The direction of drill holes are shown as grey lines. The last drilled hole is shown in green.

After drilling plans are to reduce visual impact by hiding the necessary equipments as possible. The drilling platform can be minimized and filled to the drill holes in such a way that all pipelines to silencer and steam gathering system are underground at the platform (Fig. 6).

3.2.2 Power station

From the beginning the Nesjavellir power plant has been open to visitors. Some 20 thousand guests visit it every year. Due to the location of Hellisheiði power plant, close to the main road to the Southern Lowlands, it was clear that this plant would be an attraction to tourists. To meet this demand it was therefore decided to design the power plant to be able to receive large number of visitors every year (Fig. 7). There the geothermal exploitation is explained as well as information given on the geothermal system, history of the surroundings and nature. During 2008 some 33,500 guests visited the power plant whereof 2/3 was foreign guests and the number of visitors is expected to increase in the future.

Figure 7: The Hellisheiði power plant.

3.2.3 Reconstruction of volcanic craters and fissures

During construction it is important to try to minimize all damage of the land. In the 1970´s scoria from volcanic fissures in the Hellisheiði area was used to build the nearby road. The craters and lava were left with large scars in the landscape.

In the EIA for the power plant it was described how Reykjavík Energy planned to rebuild volcanic craters in the area to its original form. Old aerial photos were used and landscape architects made models of the area (fig. 8).

The land was reconstructed by reshaping the craters with material which had been removed from the foundation of buildings of the power plant. When the form had been reached the land was covered with scoria from the surrounding covering the material of another origin.

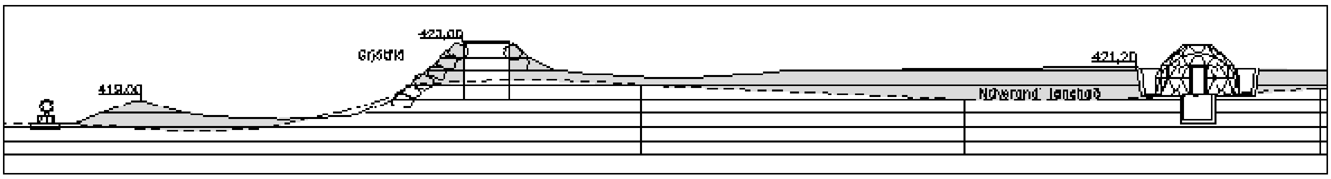

Figure 6: Planned drilling platform after it has been reshaped.

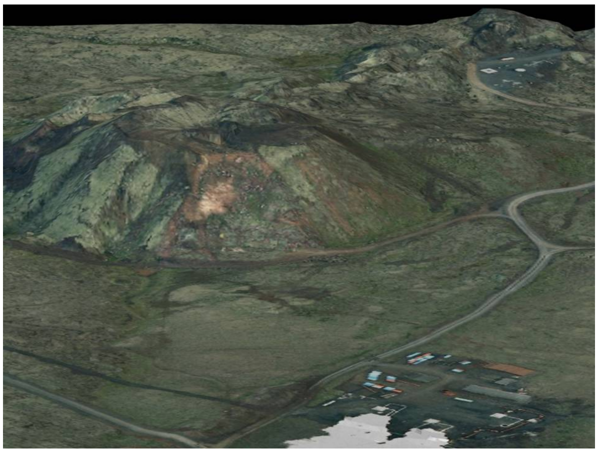

Figure 8: In connection with building of Hellisheiði power plant some volcanic craters which had been damaged in the 1970´s when a new road was laid in the vicinity were re-constructed.

In the Hengill area, especially in the lave fields the vegetation is mainly moss and highland flora. In order to obtain the natural flora some research projects in cooperation with the Agricultural University of Iceland have been taking place in the field. Different methods of planting and restoration of original plants are tested. This work has been undertaken by collage students during their summer vacation (Fig. 9)

Figure 9: Planting of moss and highland flora in scars in volcanic craters.

4. PREPARATION FOR NEW POWER PLANTS

Preparation for two new power plants in the Hengill area has started. The locations are at Hverahlíð and Bitra (Fig. 1 and 2). Three drill holes have been drilled in the Bitra field. Temperature is in the range 210-280°C (Björnsson, 2007). In the Hverahlíð field 4 drill holes have been drilled with highest temperature around 320°C (Franzson et al., 2010).

EIA has been finished for these two fields. The main public concern regarding geothermal development in Iceland in last years have been possible groundwater pollution, visual impact, smell of hydrogen sulphide and that tourism and geothermal development cannot work out together. The last one has on the other hand shown the opposite.

All energy development has some visual impact. Drill holes, pipelines and power plants are the most significant signs of geothermal energy production. The area of activity is on the other hand relatively small. It is possible to reduce the visual impact during the design phase. During the EIA work a special emphases was made to find out the possibility of reducing visual effect, especially drilling platforms, pipelines, access roads and buildings.

Until now all steam transmission pipelines are led above ground with all the bends which are necessary for thermal expansion. In the EIA for the new power plants emphases was to construct the pipes to make them less visual (Geirsson and Hrólfsson, 2010).

In Icelandic high-temperature geothermal fields vegetation cannot be used to hide pipe lines since the flora is mainly moss and grass. Therefore it is necessary to select colors for pipe lines which is similar as the surrounding.

The power station at Hellisheiði was designed to be visitor center to all the power plants in the Hengill area. The architecture was therefore to have the house well visible and attractive to visitors and guests. New power plants in this area can therefore be designed in such a way that they will have minimal visual impact.

Access roads to the drilling platforms have to be designed to carry the heavy load of the drill rig. So far these roads have been high and well visible. Experiments have been made to have the access roads at the same level as the land and the vegetation which had to be removed laid on the side of the road as it is build (Fig. 10). This looks promising and clearly reduces visual impact of roads.

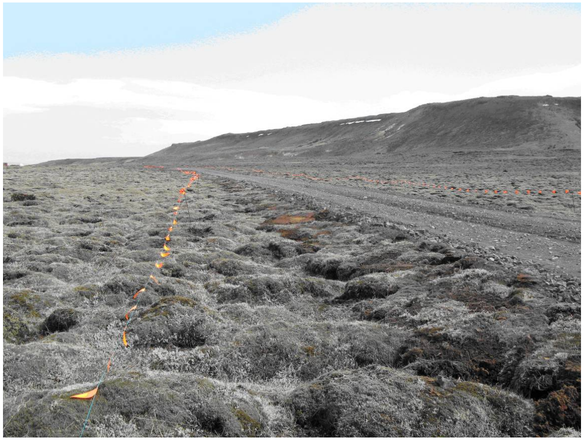

Figure 10: Access road to a drilling platform. The vegetation which had to be removed from the ground is led at the side of the road during construction. The flagged line on both side of the road determines the construction area.

All separated water will be re-injected to the geothermal reservoir to reduce possible pressure draw-down in the system as well as to protect the groundwater system from pollution.

Hydrogen sulphide (H_2S) is the gas most people connect to geothermal fields and the utilization of geothermal energy. The levels of H_2S in the atmosphere in geothermal areas are commonly in the range from 0-0.5 ppm. Humans detect smell at very low concentration. The detection limit of the nose is about 0.005 ppm. The smell of hydrogen sulphide from geothermal power plants in the Hengill area can be found in Reykjavík during cold calm winter conditions. But the smell is unpleasant and therefore it will be removed from the exhaust of the power plant. Carbon dioxide (CO_2) hydrogen sulphide will be separated in gas separated station (Geirsson and Hrólfsson, 2010). The CO_2 will be injected into deeper groundwater systems above the cap rock of the geothermal system, if carbon sequestration project which is now in research phase prove to be successful (Sigurðardóttir et al., 2010). The plan is to re-inject H_2S with the separation water.

5. CONCLUSION

All use of energy has some influence on the environment. Modern society demand large energy sources. The energy sources have to be selected not only from economical point of view but also by taking into account environmental aspects. Geothermal energy is environmental friendly energy source but its utilization can also have influence on the environment and that we have to minimize. By taking that into consideration early in the design phase of the geothermal power plant, try to minimize damages to the environment during construction and perform counter-measure were it is appropriate geothermal power plants will generally be accepted as one of the best option for power production.

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