Geothermal Sustainability Assessment Protocol

ORKA NÁTTÚRUNNAR

Hellisheidi Geothermal Project

Iceland

Project Stage: Operation

Assessment Date: 26/01/2018 to 02/02/2018

Final

Report Date: 05/06/2018

Client: Orka Náttúrunnar

Lead Assessor: Dr Joerg Hartmann, Independent Consultant

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Project size: 303 MW_e and 133 MW_{th}

Cover page photo: Hellisheidi main power plant (ON photo)

Acronyms

Acronym	Full Text
ASÍ	Icelandic Confederation of Labour
BAT	Best Available Technology
CEO	Chief Executive Officer
EU	European Union
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EMS	Environmental Management System
GPS	Global Positioning System
ISO	International Organisation for Standardization
ÍSOR	Iceland Geosurvey
NIB	Nordic Investment Bank
OH&S	Occupational Health and Safety
OHSAS	Occupational Health and Safety Assessment Series
ON	Orka Náttúrunnar
OR	Orkuveita Reykjavíkur
SA	Confederation of Icelandic Employers

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Executive Summary

This report presents the findings of an assessment of the Hellisheidi Geothermal Project, using the Geothermal Sustainability Assessment Protocol. Hellisheidi is a 303 MW geothermal power plant, combined with a 133 MW hot water plant for district heating, with potential for future expansion. It is one of the largest geothermal plants in the world, and is owned by Orka náttúrunar (ON), a subsidiary of Orkuveita Reykjavíkur (OR), a public utility serving south-western Iceland. The assessment was carried out over an 8-month period, with a planning visit in September 2017, an on-site assessment in January 2018, an internal workshop in March 2018 and a stakeholder meeting in April 2018.

Iceland has significant geothermal potential and an installed capacity of some 750 MW, in six major power plants. The project has benefitted from the combined experience of the three main power companies, the National Energy Authority (Orkustofnun), the Environmental Agency (Umhverfisstofnun), the Planning Agency (Skipulagsstofnun), other government agencies, as well as specialised companies, such as consulting and drilling companies. The geothermal sector in Iceland is also supporting geothermal development abroad.

This assessment is the second test of the draft Geothermal Sustainability Assessment Protocol. The main objective was to learn about the applicability of a sustainability protocol, modelled on the Hydropower Sustainability Assessment Protocol, to geothermal power projects. Other objectives were to gain insights into the performance of the specific project under assessment, and to identify opportunities for improvement of this and other geothermal projects in Iceland.

The assessment focuses on the operation stage of the project, which was commissioned in stages, starting in 2006. OR/ON have been able to deal with a range of legacy issues related to the design of the project in the 2000s, a time when there was less awareness of risks in the Icelandic geothermal sector, related primarily to resource availability, finances, and environmental effects. The results of the assessment show that Hellisheidi has low adverse environmental and social impacts, and important positive socio-economic effects, primarily by supplying clean and low-cost power to the national electricity grid and hot water to serve heat demand in the capital area of Reykjavík and neighbouring communities. District heating in particular makes an important contribution to the quality of life in Iceland.

These issues are reflected in the findings of this assessment, and in a range of high scores that summarise the findings. Hellisheidi meets Proven Best Practice on six topics: O-3 Environmental and Social Issues Management, O-5 Asset Reliability and Efficiency, O-8 Project Benefits, O-14 Biodiversity and Invasive Species, O-15 Induced Seismicity and Subsidence, and O-16 Air and Water Quality.

The project exceeds Basic Good Practice on six topics, each of these with one significant gap against Proven Best Practice: O-1 Communications and Consultation, O-2 Governance, O-6 Public Health and Safety, O-7 Financial Viability, O-12 Labour and Working Conditions, and O-13 Cultural Heritage.

The project meets Basic Good Practice on two topics: O-4 Geothermal Resource Management, and O-9 Project-Affected Communities and Livelihoods.

Two topics, Resettlement and Indigenous Peoples, are Not Relevant to Hellisheidi. The scores for all topics are summarised in the following Sustainability Profile and Table of Significant Gaps.

Sustainability Profile

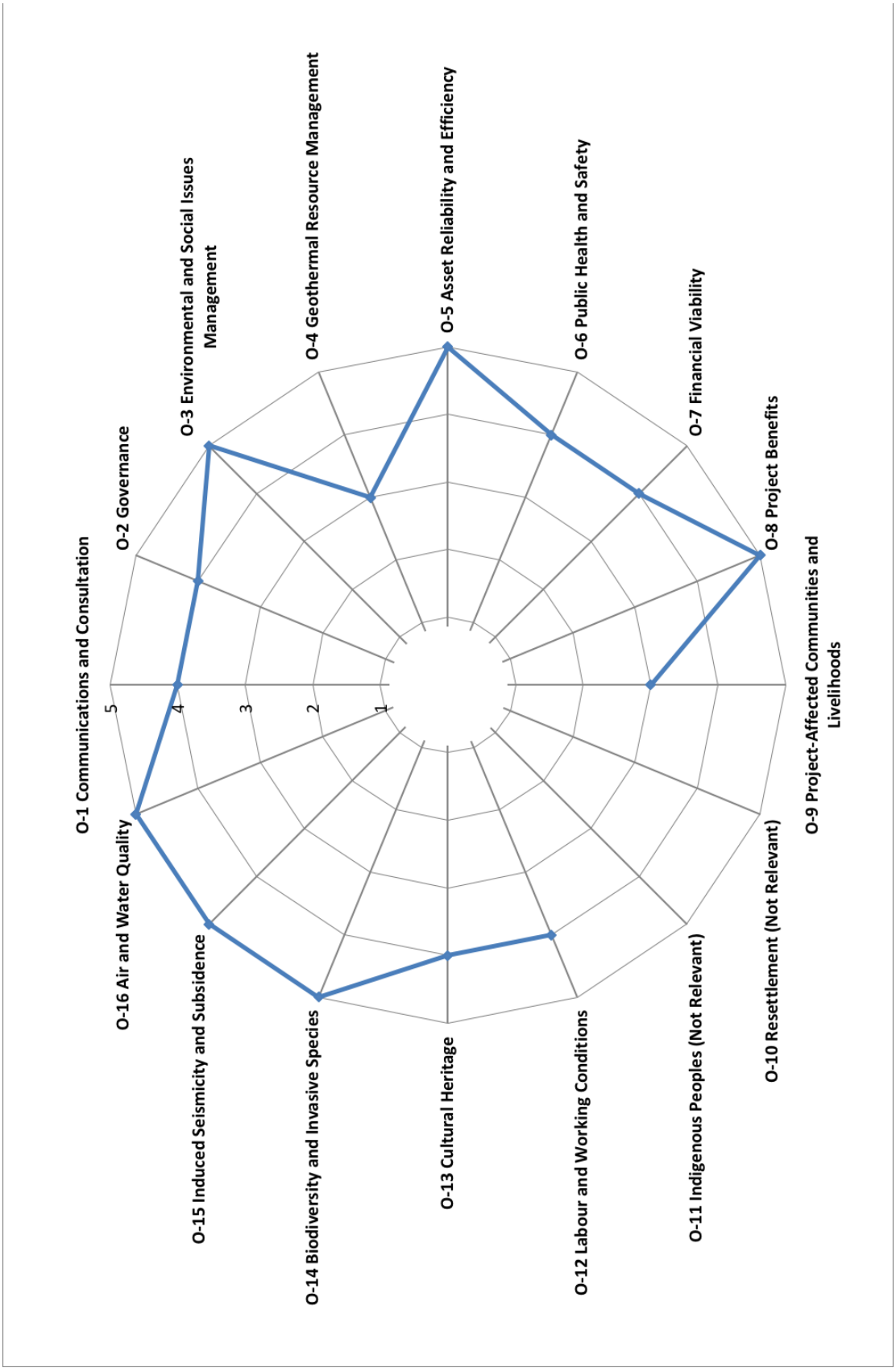


Table of Significant Gaps

	Level 3: Significant Gaps against Basic Good Practice	Level 5: Significant Gaps against Proven Best Practice
Assessment	No significant gaps	O-7: The original assessment of resource capacity and environmental impacts was inaccurate and uncertainties were not taken sufficiently into account, which has required substantial unforeseen and ongoing expenditure and has contributed to relatively low returns on investment.
Management	No significant gaps	No significant gaps
Stakeholder Engagement	No significant gaps	O-1: There is a lack of personal and regular interaction with residents in the Hveragerdi community through proactive contacts and targeted information dissemination. O-9: There is no effective process for involving project-affected communities in decision-making on relevant issues. O-12: Feedback to workers before the process to change shift schedules started again in June 2017 was insufficient, which has contributed to some dissatisfaction and departures in the operations team.
Conformance/ Compliance	No significant gaps	O-4: ON informed the National Energy Authority too late of a rapid pressure drop at a Hverahlíd well. O-4: There are repeated non-compliances in relation to the utilization licence conditions on surface releases of geothermal water. O-13: Damage to a protected historic stone wall by a contractor was notified to ON, but has not yet been rectified.
Outcomes	No significant gaps	O-2: Current governance arrangements do not support an equitable treatment of municipalities. O-6: There is a lack of active promotion of research into H_2S exposure-response relationships. O-9: There are uncertainties around positive livelihood outcomes for parts of the community in Hveragerdi.

Introduction

The Geothermal Sustainability Assessment Protocol

The Geothermal Sustainability Assessment Protocol ('Protocol') is a framework to assess the performance of geothermal power projects according to a defined set of sustainability topics, encompassing environmental, social, technical, and financial issues.

The Protocol was developed by a working group of Icelandic power companies and government agencies. It is modelled on the Hydropower Sustainability Assessment Protocol, developed by the International Hydropower Association (IHA) in partnership with a range of government, civil society and private sector stakeholders (www.hydrosustainability.org). Iceland was one of the early supporters of the hydropower Protocol and is now an active user. The work of the hydropower sector in pioneering sustainability assessments and developing the necessary tools is gratefully acknowledged, and it is hoped that other renewable energy sectors will follow suit.

The Protocol is in a development stage, and this assessment of the Hellisheidi project was its second test. It should currently be considered a draft, with additional input to be requested from geothermal sector stakeholders. Tools for the Preparation and Operation stage have been developed; and other tools for other stages in the project cycle (early stage/project selection, and implementation) may be developed over time. Following the example of the hydropower sector, objectives for the geothermal Protocol are that it should be (i) globally applicable, i.e. can be used on all types and sizes of geothermal projects, anywhere in the world; and (ii) consistent, i.e. with quality controlled to ensure reliability of assessment findings. Currently, there is no quality control system for the geothermal Protocol. For the test assessments, accredited Lead Assessors from the hydropower Protocol were contracted.

Applying the Protocol delivers an evidence-based assessment of performance in each topic, with a set of scores providing an indication of performance in relation to basic good practice and proven best practice. The scoring system is as follows:

5	Meets basic good practice and proven best practice;
4	Meets basic good practice with one significant gap against proven best practice;
3	Meets basic good practice with more than one significant gap against proven best practice;
2	One significant gap against basic good practice;
1	More than one significant gap against basic good practice.

Assessments rely on objective evidence to support a score for each topic that is factual, reproducible, objective and verifiable. Scoring is an essential feature of the Protocol, providing an easily communicated and replicable assessment of the project's strengths, weaknesses and opportunities. The scoring system has been devised to ensure that a Protocol Assessment cannot provide an overall 'pass' or 'fail' mark for a project, nor can it be used to 'certify' a project as sustainable. The Protocol provides an effective mechanism to continuously improve sustainability performance because results identify gaps that can be addressed, and the findings provide a consistent basis for dialogue with stakeholders.

Assessment Objectives

- To identify areas for improvement of the Hellisheidi project, and other OR/ON geothermal projects
- To facilitate a discussion within OR/ON, with stakeholders, and with other working group members about sustainability in geothermal projects
- To test the Operations tool of the draft Geothermal Sustainability Assessment Protocol

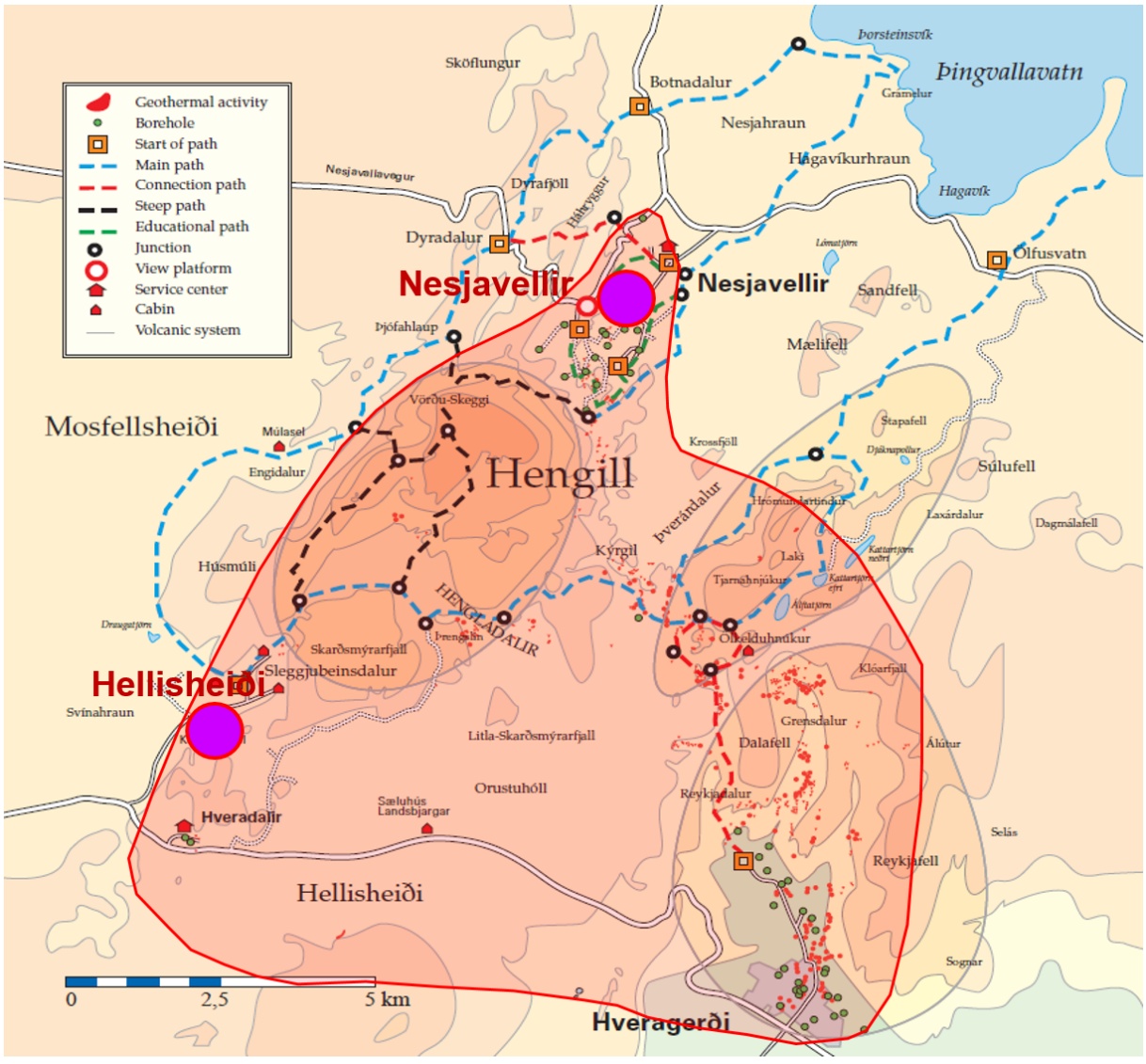
Project Description

The Hellisheidi power plant is located on the southern side of the 803 m high Hengill volcano, about 25 km southeast of Reykjavík. The Hengill high-temperature field has an extension of about 110 km^2. Hellisheidi is OR/ON's second geothermal plant, after the Nesjavellir plant commissioned in 1990, at a distance of 11 km on the northern side of the volcano. Like Nesjavellir, Hellisheidi is a cogeneration plant for heat and power, and was built up in modular units.

Research drilling started in 1985 with one well and again in 2001 with two wells. Environmental impact assessment was carried out in two steps; initially for a 120 MW_e power generation and 400 MW_{th} thermal production design (finalized in 2003); and afterwards for a 303 MW_e and 133 MW_{th} design (finalized in 2005).

The geothermal field supplying the plant consists of three main areas: the upper area above the Hellisfjördur mountain pass, the lower area below the mountain pass and the Skardsmýri mountain, and the Hverahlíd area, which was originally intended to supply its own power plant, but was later decided to be connected to Hellisheidi. The total footprint of the project is approximately 820 ha.

Figure 1. ON's Geothermal Production Area



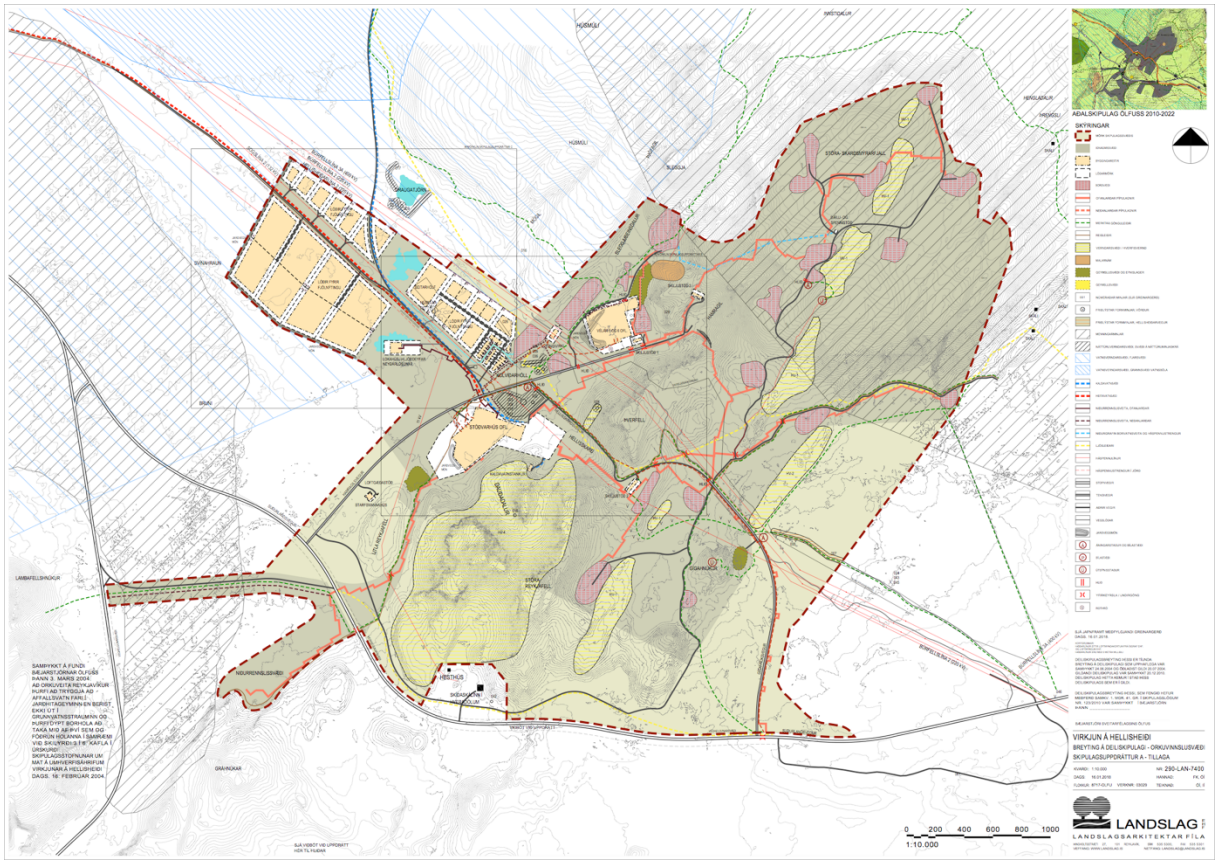
Construction started in early 2005, and the first two turbine units were commissioned in late 2006. The annual output increased steadily in the coming years as more turbines were added. At the end of 2010, the thermal

station began operations and in October, 2011 the final phase of electricity production, in a separate powerhouse called Sleggja, just north of the main powerhouse.

The power generation process can be divided into several steps: collection of geothermal fluids from wells; separation of steam and water; collection and heating of cold water; electricity production; disposal of fluids and gases largely through re-injection; and connection to the national power grid and the Reykjavík district heating system, respectively.

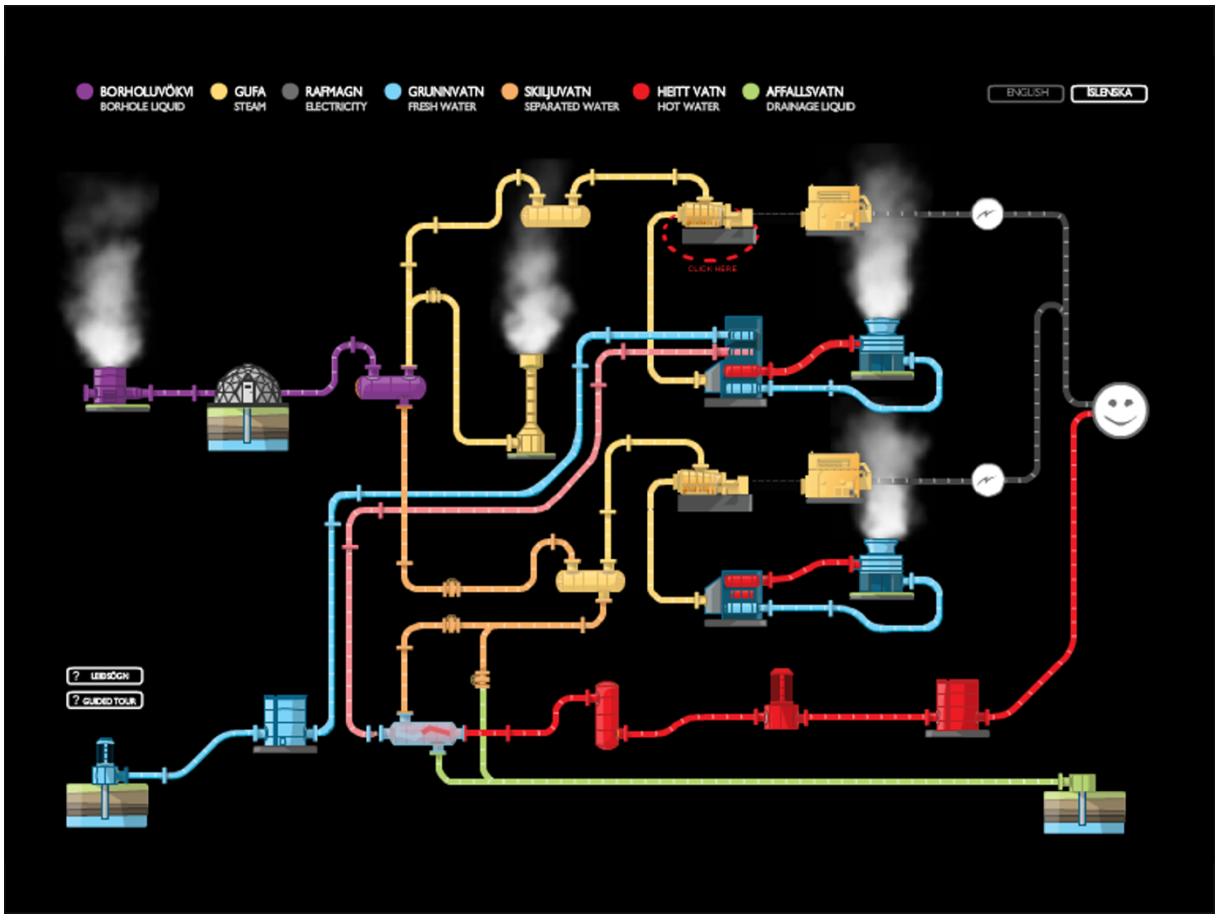
64 boreholes have been drilled at Hellisheidi and approximately 40 wells are in operation. The depth of the wells is often about 2.000 meters and their length up to 3.000 meters. Wells are drilled vertically or directionally, to minimise surface impacts. Collection pipes carry the mixture of steam and water from the boreholes to the separation stations. Separated water and steam are transported via pipeline to the plant. Collection pipes and pipelines are above ground, insulated and lined with aluminium.

Figure 2. Current Site Plan for the main part of the Hellisheidi plant (including new geothermal resource park, but without Hverahlíd steam supply area)



Six high-pressure steam turbines (45 MW each) and one low-pressure steam turbine (33 MW) are used to utilise the steam pressure. Units 1 to 6 are supplied with steam after a single stage flash separation process, and condensate from the first stage flash process then goes to a second stage flash separation to produce lower pressure steam for Unit 11. All turbines are equipped with steam condensers, which maximise the utilisation of the steam. The steam condensers are cooled either by preheating the cold freshwater for district heating purposes, or by circulation of cooling water from cooling towers to allow for flexibility in both power and heat production.

Figure 3. Process Schematic



The hot water station went into operation in November 2010. The fresh water supply was investigated by drilling 23 exploration wells into ground water aquifers west of Hellisheidi. Six boreholes in the Engidalskvísl area, at a distance of 5.5km, with a total capacity of 1,100 l/s are connected to the plant. Freshwater is preheated in the condensers, and then heated to 85°C in four heat exchangers. The installed capacity of the heat exchangers is 133 MW_{th}, equivalent to 650 l/s of 85°C water. The hot water is de-oxygenized (through physical de-aeration and addition of H_2S) to prevent pipe corrosion in the district heating system.

The hot water pipeline from Hellisheidi is approximately 26 km in length and up to 1,000 mm in diameter. It runs from the hot water tank by the Hellisheidi power plant and connects with a control centre at Reynisvatnsheidi, where the water mixes with hot water from the Nesjavellir plant. It takes the water around 6 hours to reach Reykjavík. The pipeline is already designed for a hot water station with a capacity of 1,600 l/s. According to the license, the plant could be expanded up to 400 MW_{th} in the future, in two or three stages dependent upon the need for hot water in the metropolitan area. This would be equivalent to 2,000 l/s, and the sustainable groundwater yield would be re-evaluated before expansion.

The power plant began operations in 2006. The effluent water from the plant has been pumped back into the geothermal reservoir to ensure the sustainable status of the project and to protect the groundwater. The groundwater is monitored in over 40 wells, to measure the effects of the power plant on the environment. No significant increase in chemicals in the wells has been recorded. Procedures for pumping water back into the system have been reviewed and revised, following earthquakes that occurred when reinjection began in a new area near Húsmúla in late 2011. The regularity of the tremors has gradually been reduced. Construction of the power plant has mostly been completed, and the focus has shifted to the restoration of the surroundings and of the local vegetation.

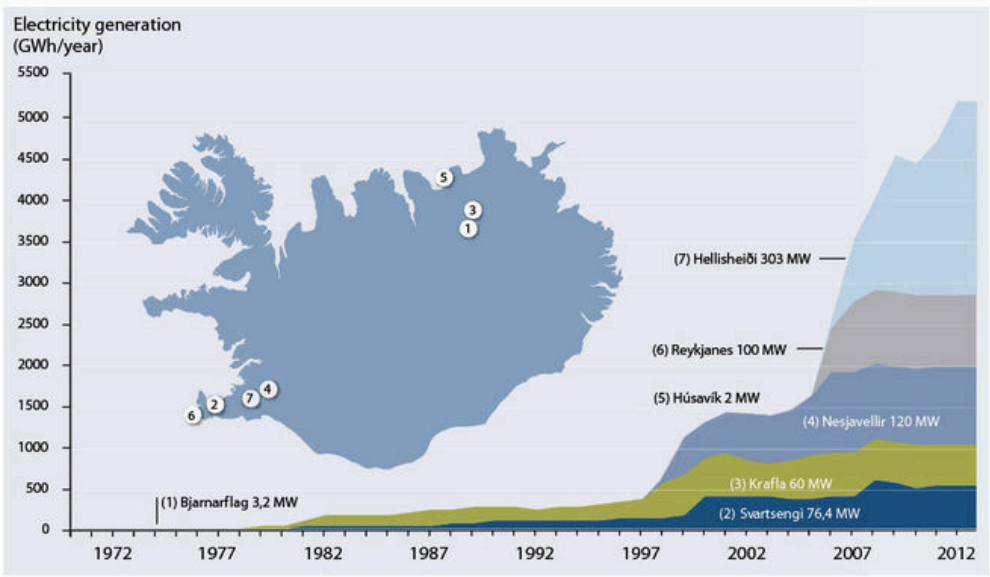
The development of geothermal energy production in the Hengill area has resulted in an increase in gas emissions, relatively close to urban areas. OR has in recent years worked to find a solution to deal with the greenhouse gas carbon dioxide (CO_2), and the pollutant hydrogen sulphide (H_2S), which can be toxic in high concentrations. In the spring of 2012, the three main power companies OR, Landsvirkjun and HS Orka began to work together to find environmentally friendly and cost-effective solutions to reduce the concentration of H_2S in the air. Work is in progress to reduce gas emissions through the SulFix and CarbFix projects, by reinjecting the geothermal gases back deep into the rock layers, where they mineralize.

Assessment Process

The Hellisheidi assessment was carried out over a 7-month period, with a planning visit in September 2017, an on-site assessment in January 2018, and workshops in March and April 2018. It is part of an ongoing initiative by a group of Icelandic government agencies and power companies (National Energy Authority, Environmental Agency, OR/ON, Landsvirkjun, HS Orka) to support the development of a Geothermal Sustainability Assessment Protocol.

Previously, a Preparation stage tool was tested, on the Theistareykir project under development by Landsvirkjun. That assessment report has been published at https://www.landsvirkjun.is/Media/gsap-theistareykir-assessment-reportfinal-3-may-2017-4.pdf. It was decided to use Hellisheidi for the test of the Operation stage tool, because it is the last geothermal project commissioned in Iceland before Theistareykir, and one of the largest geothermal projects worldwide.

Figure 4. Development of Geothermal Generation Capacity in Iceland over Time



The on-site assessment was conducted in January 2018 by two accredited lead assessors for the Hydropower Sustainability Assessment Protocol. It involved one week of site visits and 48 interviews with internal and external stakeholders in Reykjavík and at the project site in Hellisheidi. Following the on-site assessment, the assessors developed a draft report, which was discussed during follow-up workshops in March and April 2018, with internal and external stakeholders. After the workshops, the assessors finalized the report, supported OR/ON in the development of an action plan to address the identified gaps, and provided recommendations for the revision of the draft geothermal Protocol.

Assessment Experience

The project manager for this assessment was Gísli Sveinsson (Assistant of CEO, ON), supported by a project team consisting of Marta Rós Karldóttir (Managing Director of Natural Resources, ON), Heida Adalsteinsdóttir (Planning Specialist, OR), and Magnea Magnúsdóttir (Environmental and Restoration Manager, Power Plant Operations). Although this was the first sustainability assessment for OR/ON, it was very well prepared, with a broad range of internal and external stakeholders and an exceptionally large number of documents.

Layout of this Report

This report consists of sixteen sections numbered in direct correspondence with the sixteen topics of the Protocol's Operation tool. Three appendices are provided, detailing the items of visual, verbal and documentary evidence referred to under each topic.

For each topic (except O-10 Resettlement and O-11 Indigenous Peoples, which are Not Relevant), findings are provided according to the criteria used in the Protocol's methodology: Assessment, Management, Stakeholder Engagement, Stakeholder Support, Conformance / Compliance, and Outcomes. Findings are presented against a statement of 'basic good practice' and a statement of 'proven best practice' for each, with a 'Yes/No' indication of whether the scoring statement is met. A summary of the significant gaps against the scoring statement, the topic score and a brief summary are presented at the close of each topic section.

1 Communications and Consultation (O-1)

This topic addresses ongoing engagement with project stakeholders, both within the company as well as between the company and external stakeholders (e.g. affected communities, governments, key institutions, partners, contractors, geothermal area residents, etc).

The intent is that stakeholders are identified and engaged in the issues of interest to them, and communication and consultation processes maintain good stakeholder relations throughout the project life.

1.1 Background Information

There is a broad range of project stakeholders from local to national levels. Directly-affected stakeholders are defined in the Protocol as 'those with substantial rights, risks and responsibilities'. On the basis of this definition, this assessment considers the following to be directly-affected stakeholders:

- The municipalities of Ölfus and Hveragerdi and their residents and businesses;
- OR and ON staff;
- The National Energy Authority, Environment Agency, Planning Agency, Environmental and Public Health Authority of South Iceland, Landsnet (the national transmission company), and several other government agencies;
- The owners of OR and ON, i.e. the municipalities of Reykjavík (93.5%); Akranes (5.5%) and Borgarbyggd (1%);
- Power and hot-water customers;
- Consultants, contractors and other service providers (including ON's sister company Veitur, the utility which delivers much of the power and hot water produced by the project), businesses operating on Hellisheidi power plant's property or utilising resources resulting from the operation of the plant.

Important stakeholders who are not directly affected include:

- Environmental NGOs such as INCA (Iceland Nature Conservation Organisation) with around 2,000 members; Landvernd (Icelandic Environment Association), which is an umbrella organisation with over 40 members, mostly other NGOs that have almost 5,000 individual members;
- Other municipalities in south-west Iceland;
- Domestic and international tourists;
- Other power-generation companies in Iceland.

1.2 Detailed Topic Evaluation

1.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Ongoing or emerging issues relating to geothermal facility communications and consultation have been identified; requirements and approaches are determined through a periodically updated assessment process involving stakeholder mapping; and effectiveness is monitored.*

The stakeholder map is a 'living' document held at OR which is constantly updated as needed, but more formally reviewed on an annual basis. It is integrated with the Customer Relationship Management system (CRM), and contains descriptions of the stakeholders, roles, importance to the project, contact address/number, responsible person assigned (each major stakeholder has one dedicated contact person in OR/ON) and any possible issues

that have been or are being dealt with. The system links directly to stored information such as e-mails; letters etc.

The mapping exercise is based on corporate aspects, project aspects and individual issues. The most recent example is a standards-based mapping as all standards in Iceland now have a stakeholder component. The most important stakeholders in terms of communication needs are owners, licensing agencies, nearby communities/municipalities as well as the general public in the capital area.

Communication effectiveness is measured at regular intervals by polling consumers and business markets, regular meetings with environmental NGOs, media analysis and public satisfaction polls. The company won a customer-satisfaction award during 2017.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, the stakeholder mapping takes broad considerations into account.*

Communications are handled at both national and local levels, inter-relationships between stakeholders are well-identified and managed, and there are monthly meetings held with the key affected municipalities, the Environmental and Public Health Authority of South Iceland, National Energy Authority and Environmental Agency.

However, there is evidence that some stakeholders feel that OR/ON are not fully sensitive to their stated interests, and fail to engage on issues of concern. This is covered under O-9 and not assessed here.

Criteria met: Yes

1.2.2 Management

Analysis against basic good practice

Scoring statement: *Communications and consultation plans and processes, including an appropriate grievance mechanism, are in place to manage communications and engagement with stakeholders; these outline communication and consultation needs and approaches for various stakeholder groups and topics.*

The OR group has communication/consultation-related policies and associated processes on e.g. communication, customer service, records, ethics, IT, information security and OH&S. OR/ON's own communication directed at stakeholders is becoming more and more web-based and the 2017 Annual and Environmental reports will be published as web-based documents. OR and ON have separate web sites and publish a wealth of information, some of which is also available in English.

The stakeholder map outlines the needs and approaches necessary for the different groups, and a grievance mechanism is built into the CRM, where each issue raised by a complainant is assigned to an individual responsible person in the company and followed up. It is possible to lodge anonymous complaints (a so called 'whistle-blower' mechanism) via phone, without revealing one's name or through using the on-line question function without divulging one's own name and contact information.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, communication and consultation plans and processes show a high level of sensitivity to communication and consultation needs and approaches for various stakeholder groups and topics; and processes are in place to anticipate and respond to emerging risks and opportunities.*

The OR group uses modern means of communication and hosts highly informative web sites, one for OR as well as a separate one for ON. ON operates a Facebook page where news and current events are published. This is

highly proactive and as an example publicised the recent fire at Hellisheidi. The OR group organises a Science Day where research projects are put on display together with presentations on geothermal energy, its utilisation and impacts. Company representatives also engage frequently in international contexts and cooperation ventures and have given presentations on various aspects of operations, where the CarbFix and SulFix projects are of particular note, see O-16.

The Geothermal Exhibition located at Hellisheidi power plant receives around 100,000 visitors per year and disseminates knowledge about geothermal energy to groups and individuals from all over the world.

The cooperation with Arbaejarskoli is a pro-active approach to spreading information among young people about geothermal energy and technical and trade professions in general, see O-8. There is also a summer-jobs programme which aims at young locals, as well as high-school internships.

One person stationed at the power plant is the dedicated liaison with the two nearby municipalities. This provides a direct line of contact which serves as a mechanism to anticipate and respond to emerging risks and opportunities at the local level. Those stakeholders interviewed confirm that it is always easy to get hold of the ON representative.

A strategic goal for the external communication is to focus on one or a few strong messages. During 2017, the chosen topic was land rehabilitation.

Criteria met: Yes

1.2.3 Stakeholder Engagement

Analysis against basic good practice

Scoring statement: *The operation stage involves appropriately timed and scoped, and often two-way, engagement with directly affected stakeholders; engagement is undertaken in good faith; ongoing processes are in place for stakeholders to raise issues and get feedback.*

Most stakeholders attest to positive experiences from their communication with OR and ON. Project representatives are described as available, open and quick to respond to concerns with good-quality feedback. The direct personal contact and availability is particularly appreciated. The organisational emphasis on guaranteeing feedback is managed through a call-back policy, valid for every complaint/contact.

The monthly meetings with the Ölfus and Hveragerdi municipalities, the Environmental and Public Health Authority of South Iceland, National Energy Authority and Environmental Agency are a robust mechanism for key stakeholders to raise issues and get feedback.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, engagement is inclusive and participatory; negotiations are undertaken in good faith; and feedback on how issues raised have been taken into consideration has been thorough and timely.*

While the Hellisheidi plant is not located in the Hveragerdi municipality, the town is the nearest significant settlement to the plant and an area where residents have expressed negative impacts from the plant, and evidence shows that there is some resentment towards the project and ON in the community.

The feedback is considered good to excellent by almost all stakeholders. It is, however, apparent that feedback on some issues has not reached part of the target stakeholders, given the lingering resentment in the Hveragerdi community, and evidence of different understandings between stakeholders and ON/OR on the situation for a number of issues and developments. This is alleged by some stakeholders to be caused by a lack of openness and proactive communication regarding e.g. air and water emissions and safety-related aspects, but the relevance of this information is difficult to ascertain. OR/ON provides the bulk of its highly detailed information on these

issues to the public on the Internet, which has to be regarded as a standard and fully viable approach in 2018 in a country as "connected" as Iceland. To reach the level of proven best practice, this approach would, however, have to be combined with a more personal and regular interaction with residents in the community through proactive contacts and targeted information dissemination on subjects of concern. This is considered a **significant gap**.

Criteria met: No

1.2.4 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives relating to communications and consultation have been and are on track to be met with no major non-compliances or non-conformances, and communications related commitments have been or are on track to be met.*

Communications and consultation processes and objectives are on track without major non-compliances or non-conformances. Some issues with reporting and/or responsiveness towards authorities are not systemic communications issues and are dealt with under other topics, notably O-4 and O-13.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

There are no non-compliances or non-conformances.

Criteria met: Yes

1.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There is a lack of personal and regular interaction with residents in the Hveragerdi community through proactive contacts and targeted information dissemination.

1 significant gap

1.3 Scoring Summary

OR/ON has a well-developed and managed system for Stakeholder mapping which is updated continuously with formal reviews on an annual basis. A clear majority of the stakeholders, including environmental NGOs, attest to a positive communication climate with thorough and timely feedback provided both by individuals employed in the company, and by the company at corporate level.

Monthly meetings with the two main project-affected municipalities of Ölfus and Hveragerdi and key government agencies function as a regular mechanism for capturing and responding to emerging risks and opportunities. However, there is evidence of complaints and dissatisfaction from some residents in the Hveragerdi community, and there is a lack of personal and regular interaction with residents in order to resolve the issues. This is a significant gap, resulting in a score of 4.

Topic Score: 4

1.4 Relevant Evidence

Interview:	1, 5, 7, 8, 11, 14, 15, 16, 17, 18, 24, 26, 27, 30, 31, 32, 36, 39, 48
Document:	1-6, 48-50, 53-55, 135-137, 491
Photo:	68, 96, 97, 98

2 Governance (O-2)

This topic addresses corporate and external governance considerations for the operating geothermal facility.

The intent is that the owner/operator has sound corporate business structures, policies and practices; addresses transparency, integrity and accountability issues; can manage external governance issues (e.g. institutional capacity shortfalls, political risks including transboundary issues, public sector corruption risks); and can ensure compliance.

2.1 Background Information

Orkuveita Reykjavíkur (OR) is a utility company owned by the three municipalities Reykjavík (93.539%), Akranes (5.528%) and Borgarbyggd (0.933%). The company was established under acts by the national Parliament (most recently Act no. 136/2013), and the owners have formulated a Partnership Agreement and an Owners' Policy. These set out the corporate structure and responsibilities of OR and its subsidiaries. One of these is Orka Náttúrunnar (ON Power Ltd), established in 2014.

OR provides services across southwestern Iceland, where more than two thirds of the country's population live. It owns and/or operates cold water supply, hot water supply (district heating), sewerage, electricity generation and distribution, and fiber-optic network assets. ON covers the competitive activities of the company, primarily power and hot water generation. Iceland applies the EU Energy Market legislation through the Electricity Act no. 65/2003 and subsequent regulations, with the National Energy Authority (Orkustofnun) as the main regulator. ON is the second-largest producer of power in the country, and the largest producer of geothermal power. It competes with other generating companies, primarily Landsvirkjun and HS Orka, in the wholesale market and the market for large industrial customers. ON's largest single power customer is the Nordurál aluminium smelter; its only hot water customer is its sister company Veitur.

Various regulatory frameworks apply to OR and more specifically, the operation of geothermal power and hot water generation plants. Developers generally need to obtain

- if not on their own land, research permits for exploration drilling, from the Ministry of Industry
- development consents from the municipality (in the case of Hellisheidi, the municipality of Ölfus), based on an EIA process organised by the Planning Agency, which is subject to review and comments by a range of other government agencies, and a public consultation process; the development consent also requires that the project is compatible with the municipal zoning plan and a site development plan
- building permits, also issued by the municipality
- any special permits from the Cultural Heritage Agency or other agencies, if required
- permits for power utilization from the National Energy Authority
- operating licenses from the regional Public Health and Environment Authorities (in the case of Hellisheidi, the South Iceland office)
- agreements with private and/or public landowners (unless the developer owns the required land, as in the case with most of the land in Hellisheidi)

Some of these regulatory responsibilities have been introduced since the first stages of the Hellisheidi plant were built. The two key regulatory bodies today are the National Energy Authority, which authorizes research and utilization of geothermal and groundwater resources (based on the Act on Survey and Utilisation of Ground Resources, no. 57/1998), and municipalities, which authorize the construction and operation of power plants and associated infrastructure, and supervise operations through the regional Public Health and Environment offices, which are formed by groups of municipalities.

OR/ON are also subject to a range of other laws and regulations that apply to all companies or to specific groups of companies, such as taxation, public procurement, and access to information laws.

2.2 Detailed Topic Evaluation

2.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Ongoing or emerging political and public sector governance issues, and corporate governance requirements and issues have been identified, and monitoring is being undertaken to assess if corporate governance measures are effective.*

The Legal Affairs unit maintains a register of all relevant laws and regulations. This register is regularly updated, enabling the OR group to respond to all relevant changes. All license conditions that are managed by ON are contained within a quality document (LBX-505), under the responsibility of the Records Manager and the head of Environmental Affairs. Relevant documents are accessible for all staff in a specially developed database, and also distributed directly to specific staff concerned.

The identification and management of risks of non-compliances as well as broader governance issues is the responsibility of all unit managers, who get support from legal, quality, risk and strategy units as well as the internal audit function. There is a comprehensive management process for both operational and market risks, and risks and mitigation actions are regularly reported and discussed at various levels in the company. At the highest level, one of the key monitoring mechanisms is the annual report to OR's owners, on compliance with the owners' policy, which is presented to owners at a shareholders meeting each November.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no significant opportunities for improvement in the assessment of political and public sector governance issues and corporate governance requirements and issues.*

The importance of a continuing assessment of external governance issues depends on a number of factors. For the OR group, it is important because the company depends directly on decisions made by its owners and regulators. After the financial crisis, the owners considered a sale of the competitive components of the company, including the power plants, and recently an offer from a private group has been made for purchase of the Hellisheidi project. The unbundling of the group, into regulated and competitive components, was originally triggered by the EU's Energy Directive, which was introduced into Icelandic law through the Electricity Act, but the owners had to request several delays from the authorities before the unbundling could be completed in 2014. Political issues also play a role because the city of Reykjavík and particularly the national level, have seen frequent changes in government with different agendas. However, there have been no major problems for OR, probably because the company is well governed internally, is well connected in the small Icelandic community, and there is a high degree of continuity and competence in the public sector. Iceland generally scores very highly on international governance indicators, although data show (http://info.worldbank.org/governance/wgi/) that the gap between Iceland and the rest of Europe on the different categories (voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption) has narrowed in recent years.

Through its membership in associations such as Samorka (association of Icelandic power companies and utilities), SA (Confederation of Icelandic Enterprises), and Festa (Icelandic Center for Corporate Social Responsibility), the OR group can obtain additional insights into emerging governance issues. A membership in the Icelandic Chamber of Commerce is under consideration.

There is a well-established internal process for strategic projects, which can and often do encompass governance improvements that require some analysis and extended time. The annual portfolio of OR's strategic projects is

built from the bottom up and is approved by the Board, which also receives bi-monthly updates on implementation.

Work on a database for external reporting, primarily to regulators, is ongoing.

Criteria met: Yes

2.2.2 Management

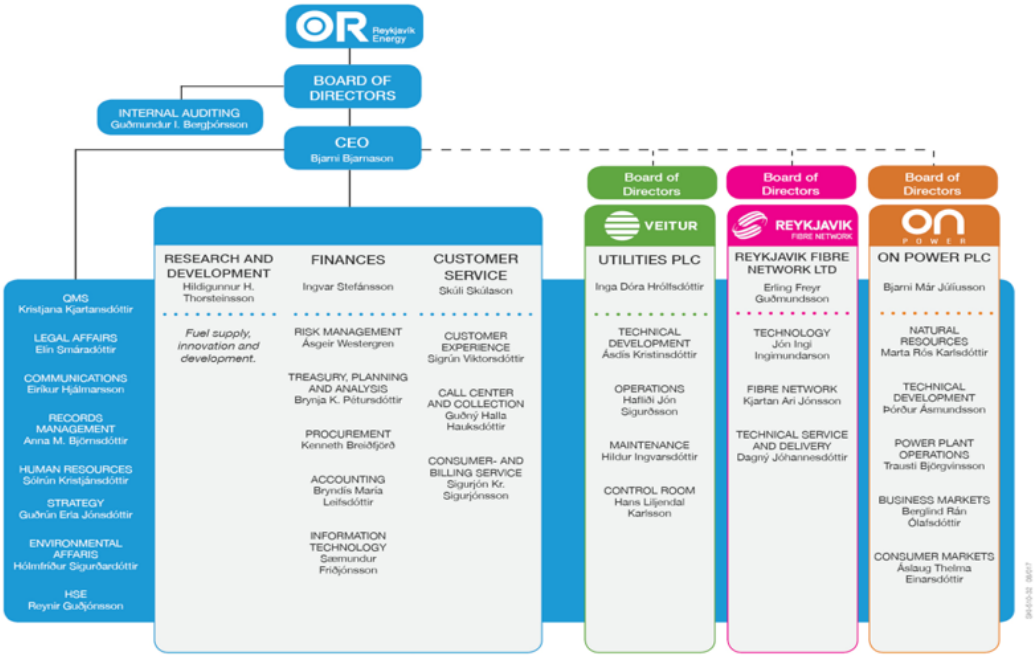
Analysis against basic good practice

Scoring statement: *Processes are in place to manage corporate, political and public sector risks, compliance, social and environmental responsibility, procurement of goods and services, grievance mechanisms, ethical business practices, and transparency; policies and processes are communicated internally and externally as appropriate; in case of capacity shortfalls, appropriate external expertise is contracted for additional support.*

The structure of the OR group is shown in Figure 5 below, and fulfils two basic functions:

- Oversight can be provided by the owners, the directors they appoint to the Board, and by the internal audit function that reports to the Board, while not interfering in the day-to-day management of the company. (The internal auditor position is currently vacant, and the City of Reykjavík's internal audit will provide that function on an interim basis.)
- Regulated utility services (principally provided by the Veitur Utilities PLC subsidiary) are separated from services in competitive markets (principally provided by ON). These services are subject to a number of different laws and overseen by different regulators.

Figure 5. OR Organization Chart



The owners of OR, through the chairpersons of the three municipal councils, oversee the company and take certain strategic decisions. For example, investments worth more than 5% of the equity book value and those that require environmental impact assessment, require approval by the owners. The Partnership Agreement lays out procedures and protects the minority owners. The annual General Meeting and other owner meetings are opportunities for high-level discussions.

The Board of OR consists of six voting members and one non-voting observer (representative of Borgarbyggd) appointed by the municipal councils, and the CEO as a non-voting member. It comprises members with various

backgrounds including environmental, economic, legal and engineering. The Board has established Rules of Procedure which are in line with the Corporate Governance Guidelines established by the Icelandic Chamber of Commerce, in collaboration with SA and Nasdaq OMX Iceland. The Board defines the corporate strategy, approves policy and process documents and business decisions within a prescribed range, and establishes key performance indicators (KPIs).

The boards of subsidiary companies consist of five members, with a mix of expertise, genders, and internal vs external perspectives. ON's board consists of the CEO, the head of environment and the head of R&D from OR, plus two external members, an academic geothermal specialist and a business leader. This board also has extensive Rules of Procedure. Staff from Legal Affairs act as board secretaries, at the group and subsidiary level.

The OR group has a comprehensive set of corporate policies, guidelines, and procedures, some of which apply to the entire group and others to specific subsidiaries. For ON, for example, there are policies on Service, Competition Law, Environment and Resources, Quality, Risk, Procurement, Information Technology and Information Security, and several human resources policies (see O-12). All staff have to adhere to a Code of Ethics. The management system is a set of procedures to implement these policies, that lays out responsibilities for all core business processes and support processes; planning, performance objectives and budgeting; risks, controls and corrective action; and regular meetings and reporting. Decisions are well documented, and the document management system allows easy location and referencing of documents.

These processes are supported by a number of staff from legal, quality, risk and strategy units. Procedures are easily accessible through the intranet and organized in handbooks, including an extensive handbook and database on operational risks. Irrespective of how issues are identified (through external or internal audits, or through observations from staff), they are processed through the integrated risk management process, and staff from the quality unit support operational units in the improvement of processes. Quality management in the group is supported by external ISO 9001 auditing. The first stage of the current audit has recently been completed and did not identify non-conformities. There are regular training courses including induction courses for new employees and a 36-page brochure with an overview. Legal staff also provide a regular basic course on laws and regulations relevant to OR.

Corporate social and environmental responsibility is not subject to separate policies or reporting, but embedded within the OR group's core policies, processes and reports. Reporting is further addressed below, under Stakeholder Engagement.

Concerns, grievances and complaints can be brought through a variety of channels, including the Ministry of Industries and Innovations, the National Energy Authority, the municipalities, the Environmental Agency, the Planning Agency, and the review committee for the Act on Access to Information (No 140/20120. They can also be taken directly to OR/ON (see above under O-1).

The company regularly uses external expertise for support, for a broad range of issues, for example on aluminium price risks. The decision-making checklist for ON's board includes a question on the need to get external input.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, contractors are required to meet or have consistent policies as the developer; procurement processes include anti-corruption measures as well as sustainability and anti-corruption criteria specified in pre-qualification screening; and processes are in place to anticipate and respond to emerging risks and opportunities.*

OR generally follows public procurement guidelines and conducts open tenders, as far as possible (about half of all procurement by volume in 2016 was conducted through open tender, if internal transactions are excluded). ON as a competitive business has its own Procurement Policy, which requires that 'safety, health, quality and environmental considerations as well as cost are taken into account'. If products are comparable in other

respects, the supplier with the least impact and/or with a certified quality system should be chosen; and compliance of suppliers with laws and regulations should be enforced.

Tender documents include a number of requirements for contractors, including some related to social and environmental responsibility. Under Icelandic regulation no. 340/2017 on procurement by public water, energy, transport and postal service entities, tenderers that have been convicted of particular offences (such as participation in a criminal organisation, corruption, fraud, terrorist offences or offences linked to terrorist activities, money laundering or terrorist financing, child labour and other forms of trafficking in human beings) are excluded. ON's tender documents contain a self-declaration by tenderers to this effect.

OR/ON generally does not perform contractor screening or pre-qualifications, but this is not seen as a significant gap, as 1) contractors are supervised and a lack of performance in previous projects (including on health, safety and environmental matters) can be a ground of non-eligibility to participate in tenders, 2) legal requirements for businesses in Iceland and regulatory supervision are relatively strong, and 3) there is an expectation to rely more on EU-wide pre-registration of contractors in the future.

The risk management process has triggered a number of improvements in procurement processes. For example, in order to more clearly impose its own policies as well as compliance with laws and regulations on suppliers, OR/ON now includes clauses for cancellation of contracts, including liability for non-compliances of subcontractors.

Criteria met: Yes

2.2.3 Stakeholder Engagement

Analysis against basic good practice

Scoring statement: *The business interacts with a range of directly affected stakeholders to understand issues of interest to them; and the business makes significant project reports publicly available, and publicly reports on project performance, in some sustainability areas.*

The OR group and its subsidiaries are well integrated in the capital region, primarily known as providers of utility services, and regularly interact with most households and businesses. The primary concerns of stakeholders are reliable services at low costs and with high quality, and customer satisfaction has been high, as evidenced by the 1st rank among utilities in 2016. Other important issues are air quality, seismicity, and the financial performance of the company and the associated risks and opportunities. These issues are reflected in the owners' perspectives, and are not expected to change drastically after the upcoming municipal elections in 2018. The owners have seen financial consolidation after the crisis as a priority, and the ability to pay dividends as secondary (see O-7).

As required by the owners' policy, OR and ON operate with a high degree of transparency. Policies, reports and proceedings of the OR Board (including both minutes of meetings and supporting documents) are accessible through the website. The annual reporting includes general business, financial, environmental and social responsibility matters. Since 2015, reporting is organized according to the Global Reporting Initiative (GRI) G4 Core criteria. While not the entire GRI information is independently verified, its financial and environmental components are audited (see O-7 and O-3). OR and ON's website are well designed and organized, and have received various national and international recognitions.

Stakeholders can access additional information through informal requests or under the Access to Information Act (no. 140/2012), which applies to most of the OR groups documents, with some exceptions related to commercial confidentiality and to privacy considerations. Internal routines are in place for the handling of such information requests, and the right to access is described on the website, along with a request form.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, the business makes significant project reports publicly available and publicly reports on project performance in sustainability areas of high interest to its stakeholders.*

Public surveys have focused on customer satisfaction in general and customer services in particular, as well as on the satisfaction of visitors to the Geothermal Exhibition at Hellisheidi. Surveys from a marketing perspective have shown that for only a minority of electricity customers, environmental management is an important element in their choice of supplier. Beyond that, there has not been no formal materiality process to identify the sustainability areas of highest interest to stakeholders. This may be an opportunity for improvement but is not considered a significant gap, given the generally high degree of transparency and the comprehensive, GRI-compliant reporting.

Criteria met: Yes

2.2.4 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *The project has no significant non-compliances.*

No non-compliances with laws and regulations related to governance have been identified by regulators, by the internal auditor and legal affairs units of OR, or by the City of Reykjavík Audit Committee. The Hellisheidi project has all required licenses and is also compatible with the municipal zoning plans. A number of non-conformances with internal procedures are regularly identified and corrective actions defined, but these are not non-compliances in the sense of the scoring statement.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *The project has no non-compliances.*

As stated above, there are no non-compliances.

Criteria met: Yes

2.2.5 Outcomes

Analysis against basic good practice

Scoring statement: *There are no significant unresolved corporate and external governance issues identified.*

The governance arrangements comply with modern expectations and set out clear rules and responsibilities for owners, board members, and managers in the OR group. They provide for mitigation of potential conflicts of interest, particularly those between corporate managers and shareholders; and ensure that assets are used in the best interests of owners and other stakeholders. Governance arrangements represent a large improvement over the situation of about 10 years ago, when governance problems caused a large crisis for OR.

No significant unresolved governance issues were identified.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no unresolved corporate and external governance issues identified.*

The frequent changes in the national government have delayed the resolution of a number of policy issues which had been identified over the years. One among these is the discussion whether users of government-owned natural resources, including geothermal resources, should pay resource taxes or royalties. Currently there is no

such requirement. The lack of resolution of this issue has also hindered the fulfilment of one requirement in the owners' policy, namely that OR 'should annually calculate and make an official assessment the value of resource utilization, depending on the type of resources, whether owned by the company or others'. While this is a gap, it is not considered significant as it is not expected to materially affect the financial position of OR.

The responsibility of relatively small municipalities for permitting and supervising major power projects has been an issue in other projects in Iceland, but is primarily a problem during the preparation stage, not during operations. As described under O-8 and O-9, positive and negative impacts from Hellisheidi are also unevenly distributed between the municipalities in the area. It is broadly recognized that this could be addressed through reforms to the regulatory framework, or a further consolidation of municipalities. The fact that the current governance arrangements do not support an equitable treatment of municipalities, is a **significant gap** against proven best practice.

Criteria met: No

2.2.6 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

Current governance arrangements do not support an equitable treatment of municipalities.

1 significant gap

2.3 Scoring Summary

The OR group is publicly owned and subject to regulation by several government agencies, so that an understanding of external governance and compliance issues is important. Both public governance in Iceland and the corporate governance of the OR group are of a high standard. The structure of the company reflects the need to provide effective oversight by owners, and to separate the strongly regulated utility business from the competitive market business, to which the Hellisheidi project belongs. The company has a range of policies and processes which establish clear rules and responsibilities. It operates with a high degree of transparency and complies with all governance-related laws and regulations.

There are opportunities for improvement regarding the framework under which municipalities interact with major power projects. This is a significant gap against proven best practice, resulting in a score of 4.

Topic Score: 4

2.4 Relevant Evidence

Interview:	1, 11, 15, 23, 30, 31, 40-42, 44, 47
Document:	7-103
Photo:	--

3 Environmental and Social Issues Management (O-3)

This topic addresses the plans and processes for environmental and social issues management.

The intent is that negative environmental and social impacts associated with the geothermal facility are managed; avoidance, minimisation, mitigation, compensation and enhancement measures are implemented; and environmental and social commitments are fulfilled.

3.1 Background Information

Typical environmental and social impacts associated with geothermal development in Iceland are: geological changes including the impact on the geothermal reservoir; use of cold water resources for cooling and as basic resource for delivery of hot water to customer (after heating by geothermal water in heat exchangers); landscape and aesthetic effects; tourism and recreation; biological resources; noise, air and water pollution; and impacts on cultural heritage.

The EIA process is managed by Skipulagsstofnun, the National Planning Agency, a state authority under the Ministry for the Environment and Natural Resources, responsible for the administration and implementation of the Planning Act, the EIA Act and the Strategic Environmental Assessment Act. The agency's main role is quality control of EIAs, by taking screening decisions based on the EIA Act, approving EIA scoping documents, interacting with developers during the elaboration of the EIA, recommending improvements, and issuing an opinion on the developers' final EIA documents. This opinion has to be taken into account by the municipalities which are the authorities that grant development permits.

The Hellisheidi project has been subjected to two EIA processes, the original one and then one for an extension of the plant. The first EIA statement was sent to the National Planning Agency in November 2003 and the National Planning Agency approved it in February 2004. The second EIA statement was sent to the National Planning Agency in December 2005 and the National Planning Agency approved it in March 2006. The first EIA was for 120 MW of electricity generation and 400 MW of hot-water production. The second EIA was for an increase of the electric capacity to a total of 303 MW, divided between six 45 MW high-pressure units and one 33 MW low-pressure unit. The initial thermal capacity of the plant is 133 MW, delivering 650 l/s of hot water, which will be expanded as heat demand grows in the capital region. The conclusion of the assessments was that the project will not have a significant impact on the environment if conditions are fulfilled. There was an additional EIA conducted for a geothermal power plant at nearby Hverahlíd, approved in 2008. This project has not been constructed as originally planned, but the geothermal resource is now utilised to sustain generation at Hellisheidi. This change in approach to utilisation was approved under a regulation for screening of changes in projects, without the need for an additional EIA.

The regulatory body for power generation is the National Energy Authority, and the present utilisation licence dates from 2015. The project is also subject to licensing by the Environmental and Public Health Authority of South Iceland, a regional regulatory body working on behalf of 14 municipalities in the region. This licence is dated 2016.

The current utilisation licence from the National Energy Authority is valid for 40 years (until 2055) and contains a number of requirements, including:

- No surface discharge of geothermal water except for short-term testing and due to major (emergency) failures;
- Under normal conditions all separated water and up to 30% of the condensate shall be reinjected into boreholes at least 800 metres deep;

- Compliance with all recommendations for mitigation and monitoring made by the EIAs and the National Planning Agency's ruling on the EIAs, including that on the Hverahlíd extension.

The operating licence from the Environmental and Public Health Authority of South Iceland is valid for 12 years (until 2028). The authority can take the initiative to review activities and licence compliance at their own initiative, whenever they choose to do so, also during the license's validity period.

The main licence conditions are:

- any change to the project has to be reported (for evaluation by the authority and possible amendments to the licence);
- H_2S and groundwater monitoring;
- regarding the management of separated geothermal water, the licence refers to the National Energy Authority's licence conditions;
- minimisation and management of pollution on aspects such as sewage, oils, PCB, other air emissions, and general and hazardous waste;
- environmental performance targets to minimise energy and water use;
- the operator may (non-mandatory but encouraged) choose to have a third-party-certified Environmental Management System (EMS), such as either ISO 14001 or EMAS (EU Eco-Management and Audit Scheme);
- staff-related spaces such as dining rooms, toilets etc., have to fulfil health regulations;
- the operator is obliged to use Best Available Technology (BAT).

The two licencing agencies essentially regulate two different aspects of project operations. There is, however, one area where the licences have some overlap. This is in regards to surface-water releases, which are regulated by the National Energy Authority from the point of view of its impact on geothermal-reservoir management and by Environmental and Public Health Authority of South Iceland from the point of view of the releases as an emission into the environment.

This topic overlaps with a number of other topics. In general, the overall management aspects of the Environmental Management System are reviewed under this topic, while all specific aspects are reviewed under the respective specialist topic such as O-1, O-4, O-6, O-8, O-9 and O-12 through O-16.

3.2 Detailed Topic Evaluation

3.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Systematic processes are in place to identify any ongoing or emerging environmental and social issues associated with the operating geothermal facility, utilising appropriate expertise; and monitoring programs are in place for identified issues.*

Comprehensive monitoring programmes are in place at the power station and in other key areas of potential impact such as air quality monitoring close to residential areas and a network of boreholes for sampling of groundwater quality. Objectives, methodology, frequency and reporting requirements are well understood, documented and followed up in the EMS. Several key monitoring programmes are implemented by senior external professionals from organisations such as Vatnaskil, Vista, the University of Iceland, the Agricultural University of Iceland, Iceland GeoSurvey (ÍSOR), and the Icelandic Institute of Natural History. Details of these monitoring efforts are given under their respective topics below.

Regular audits and inspections are implemented by authorities, principally the Environmental and Public Health Authority of South Iceland. Review of changing regulatory conditions is an inherent part of the management system and is described under O-2.

One relevant issue which has been identified is that of radon contamination of the mist eliminators. The Icelandic Radiation Safety Authority has decided that these will be kept in adequate storage for three years until they can be safely disposed of in an approved manner, see also O-6.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes to identify ongoing and emerging environmental and social issues take broad considerations into account, and both risks and opportunities.*

As a publicly-owned company, the board takes a keen interest in broad considerations of sustainability and environmental responsibility is considered an issue of particular importance. The board is well-placed to practice oversight and risk awareness as they are mainly appointed as experts, see also O-2 above. The focus on risk identification is further reinforced by the acknowledgement that one of the higher risks to the company is loss of licence due to non-compliances.

Risk assessment at the operational level has been substantially upgraded over the last few years and is organised with a "bottom-up" perspective where everyone has access to all information in order to avoid that issues fall between cracks, and managers are responsible for all risks within their areas. Identification of risks and opportunities is generally managed through regular meetings at corporate level as well as through the comprehensive monitoring programmes, some implemented by external actors.

OR/ON took the initiative to organise monthly meetings with key stakeholders in order to capture emerging risks and opportunities. Stakeholders included in these meetings are the Environmental and Public Health Authority of South Iceland, the National Energy Authority, the Environmental Agency of Iceland and the municipalities of Hveragerdi, Ölfus (where Hellisheidi is located) as well as Grímsnes and Grafningshreppur (where ON's other major geothermal power plant Nesjavellir is located).

Projects in the pipeline with potential environmental impact are identified and analysed. 2018 will see among other projects, investments in one new reinjection well, new pipelines for reinjection and an effort to reduce the power consumption at the plant itself.

Criteria met: Yes

3.2.2 Management

Analysis against basic good practice

Scoring statement: *An environmental and social management system is in place to manage measures to address identified environmental and social issues, and is implemented utilising appropriate expertise (internal and external).*

The EMS is a comprehensive ISO 14001:2015 system described in more detail below. The system for management of ON's environmental and social issues is fully integrated with the systems of its parent company OR and its two other subsidiaries, Veitur (the utility for electricity, cold and hot water supply, and sewerage) and Reykjavík Fibre Network. The management system has a compliance register, and a register for reporting requirements is being developed. Actual compliance is reviewed as part of internal audits as well as an integral part of third-party audits of the EMS.

The staff of OR's Environmental Affairs and Research and Development departments and ON's Natural Resources, Operations and Technical Development departments are all highly qualified. The internal methodology and technology development which has resulted in the CarbFix and SulFix technologies as well as the impressive land-reclamation activities undertaken clearly demonstrate the expertise of the internal staff. External experts are frequently used for specific tasks; examples are leading consulting companies such as Vatnaskil for water management, Vista for air-quality management and various universities and institutes such

as (but not limited to): the University of Iceland; the Agricultural University of Iceland; ÍSOR; and the Icelandic Institute of Natural History as well as research programmes involving multiple foreign universities from several countries.

All new employees are given an induction course to all company policies, including those relevant to environmental and social issues, and are part of a mentoring programme.

Contractors are closely supervised and audited every two weeks, and if found non-compliant or non-conformant with regulations and contract requirements can be barred from future services procurements. The company has developed guidelines for contractors in Icelandic, English and Polish and these guidelines include detailed training and handbooks for excavation and land rehabilitation.

ON reports to the National Energy Authority on resource use annually (latest 1 May each year), and emissions data shall be published latest one year after their respective measurement. Some of this data shall be made available to the public.

ON reports to the Environmental and Public Health Authority of South Iceland on an annual basis regarding licence compliance and the authority monitors ON's hazardous waste management.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities; and plans and processes are embedded within an internationally recognised environmental management system which is third party verified, such as ISO 14001.*

ON's parent company OR holds certificates for the entire OR group. Specifically for environmental and social issues management, the company is certified according to ISO 14001: 2015, valid through the 11th of March, 2021. The application of the EMS is entirely embedded in OR's and ON's online management system with clear environmental goals and a clickable structure for governing documents in response to all listed aspects. As mentioned under O-12, OR is also certified in accordance with OHSAS 18001:2007, with some relevance for environmental management.

The OR group has an Environmental and Resource Policy which is valid for the parent company and all its subsidiaries. In addition to this there are group-level policies for Corporate Social Responsibility, Ethics and "Climate-Friendly Transport". The Environmental and Resource Policy outlines five key areas as: responsible resource management; value of utility operations; impact of emissions; impact on society; and operations. 22 significant environmental factors are defined as part of the policy document. Out of these, ON is solely responsible for six and shares responsibility with the parent company and/or fellow subsidiaries for a further nine. Responsible management of water resources and the minimisation of H_2S emissions are singled out as the two most important aspects.

Apart from the Policy, other key management processes and documents include the "EMS Handbook", a "living" Stakeholder map, a routine for management review, incident-management routines, key performance indicators, emergency-response procedures etc.

A wealth of environmental information is included in the annual environmental report for OR. Examples are: chemical composition of the groundwater near the Hellisheidi plant; waste inventory; GHG emissions; induced seismicity; a number of different H_2S metrics; and trace elements (including heavy metals) in geothermal water.

OR also makes sure that the EIAs are kept available to the public on their public web site. The Hverahlíd EIA, together with the Planning Agency's decisions on all three EIAs are available on the Planning Agency's public web site and an English-language summary of the EIAs and Planning Agency's decisions is available on the web site of the European Investment Bank (EIB).

Criteria met: Yes

3.2.3 Stakeholder Engagement

Analysis against basic good practice

Scoring statement: *Ongoing processes are in place for stakeholders to raise issues and get feedback.*

A clear majority of stakeholders attest to positive experiences from their communication with OR and ON regarding environmental and social issues management. Project representatives are described as available, open and quick to respond to concerns. The direct personal contact and availability is particularly appreciated. The CRM system (see O-1) assigns a responsible OR/ON employee for each issue, and feedback is tracked.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, feedback on how issues raised have been taken into consideration has been thorough and timely.*

However, there are also stakeholders who are not satisfied with information and feedback on, especially, the H_2S emissions issue. There is an apparent feeling of mistrust among some stakeholders, notably some residents in Hveragerdi, about ON's communication and intentions, and the monthly meetings mentioned above under Management do not appear to be enough engagement. This is not considered a significant gap against these criteria under this topic, as it is not a systemic stakeholder issue for this topic. It is, however, also identified under O-1, where it is considered significant.

Criteria met: Yes

3.2.4 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives in environmental and social management plans have been and are on track to be met with no major non-compliances or non-conformances, and environmental and social commitments have been or are on track to be met.*

All plans and commitments are either met or on track to be met. Ongoing issues include the year-by-year improvement in the fractions of H_2S and CO_2 that are reinjected, as well as ongoing methodology development to reach the target of no surface discharge for separated geothermal water.

All reporting commitments are met.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

At present, given the variable nature of geothermal energy generation, the Environmental and Public Health Authority of South Iceland is allowing time for the project to improve technology, with a view to advancing BAT in terms of reinjection. In this context it is noteworthy that the other regulator, the National Energy Authority, is contemplating a change of the licence requirements in relation to surface discharge of separated geothermal water, making it more consistent with the other licence.

The Environment Agency is considering to introduce limits for total annual air emissions (notably H_2S), in addition to the short-term limits already in place.

There have been non-compliances in the past but at the time of the assessment, there were no current non-compliances or non-conformances.

Criteria met: Yes

3.2.5 Outcomes

Analysis against basic good practice

Scoring statement: *Negative environmental and social impacts associated with geothermal facility operations are avoided, minimised and mitigated with no significant gaps; and land disturbance associated with development of the geothermal project is rehabilitated or mitigated.*

Land rehabilitation in the area was not a priority during construction and in the initial period after commissioning, with an unnecessarily large footprint from today's perspective, but over the recent past there has been a turn-around that demonstrates best practices. It could even be argued that best practices have been advanced for sub-arctic/arctic environments through the work of ON staff. The approach adopted, which has been awarded with a prize, focusses on turf transplantation, moss distribution, seeding with hay transfer and planting of willow cuttings. All of this work uses strictly indigenous species. This has resulted in first-rate recovery of indigenous vegetation over large areas which were previously entirely stripped of vegetation, hence subjected to erosion mainly from wind, a widespread problem of national importance in Iceland. Municipal representatives attest to the fact that ON's land reclamation has contributed to rehabilitate also areas outside its own impacts, as the area around the power plant was in a state of severe degradation caused by mining and quarrying activities. Initially this was accomplished by support to a municipal Land Reclamation Fund in the Ölfus municipality, which OR funded between 2006 and 2012. A total 75 million ISK was paid out. This support ended in 2014 but the municipality is maintaining the fund and now allocates its own funds to various land-reclamation projects from it.

The EIA failed to predict two key negative impacts of the project's operations. While the amount of H_2S was predicted with acceptable accuracy, the odour, corrosion and potential health issues associated with these emissions were overlooked. The induced seismicity which followed as a result of reinjection of separated geothermal wastewater was also unexpected. In both cases OR/ON have worked with authorities and neighbouring communities to develop avoidance, mitigation and minimisation protocols. As a result, less than one third of the H_2S from the operations was released into the atmosphere during 2017 while the rest was injected into deep boreholes (see O-16 for details), and induced seismicity is being managed as described under O-15.

The residual negative impacts are either avoided, minimised or mitigated with no significant gaps. The impacts from H_2S and induced seismicity are described in more detail below.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, negative environmental and social impacts associated with geothermal facility operations are avoided, minimised, mitigated and compensated with no identified gaps.*

The impacts from H_2S perceived by the local communities, especially in Hveragerdi but also in the capital region, as well as the worry experienced by the communities in Hveragerdi and Selfoss regarding induced seismicity have been addressed and reduced, but cannot be said to have been mitigated or compensated. This is a significant gap, but it is covered under O-9 and will not be double-counted here.

ON has had to assume responsibility for illegal garbage dumping by third parties in a disused mine in the Hellisheidi area.

The negative aesthetic impacts from the plant and in particular the pipelines, especially those constructed early in project development, are minimised and work is ongoing to address remaining issues. Mitigation measures include the choice of colours that blend with the background as well as routing away from exposed view-fields.

Criteria met: No

3.2.6 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There are no significant gaps against proven best practice.

0 significant gaps

3.3 Scoring Summary

The EIAs conducted for the project did not identify the two key negative impacts later realised, emissions to the air of, primarily, hydrogen sulphide as well as the induced seismicity caused by one of the project's most important environmental and operation mitigation measures – the reinjection of geothermal water. This has been addressed by the project and at the time of this assessment, monitoring of all significant environmental parameters is carried out in a satisfactory manner, often by OR/ON-external professionals such as consultants and/or universities.

OR is certified in accordance with ISO 14001, a certificate which is also valid for its subsidiaries, and the system's implementation is intranet-based.

The project holds two main licences and at the time of the assessment, is compliant with both.

Land reclamation in the project is state-of-the-art, and most negative impacts are avoided, minimised or mitigated. There are concerns in some project-affected communities regarding health, safety and livelihood impacts. This gap is assessed and scored under O-6 and O-9. Hence there is no significant gap affecting this topic.

Topic Score: 5

3.4 Relevant Evidence

Interview:	1, 2, 3, 5, 6, 7, 8, 9, 11, 14, 15, 16, 20, 22, 26, 29, 30, 31, 32, 34, 36, 37, 39
Document:	102-207, 417, 418, 421, 422, 424-427, 430, 431, 433-438, 443-448, 461-465
Photo:	9, 20, 24, 25, 26, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 56, 64, 92, 94

4 Geothermal Resource Management (O-4)

This topic addresses the level of understanding of the geothermal resource and the assessment of the geothermal production capacity. Also, predicted and actual response to the planned production and generation efficiency based on the assessed geothermal conditions and utilization strategy.

The intent is that energy generation planning and operations take into account a good understanding of the geothermal resource availability, renewability and reliability in the short- and long-term, as well as efficient utilization of the geothermal resource.

4.1 Background Information

Geothermal reservoirs store heat that is continuously recharged by the earth, through conduction (the slow process of heat transfer through solid rocks) and convection (the fast process of heat transfer by mass motion of a fluid). The sustainability of utilization of a geothermal reservoir is basically a function of not extracting more heat and not reducing the pressure by more, than can be provided by the resource and by (re)injection, over the course of an extensive project lifetime (National Energy Authority guidelines suggest 100 years). If a reservoir is used excessively, its yield may be reduced. However, because of increased recharge following a period of excessive production, geothermal systems are generally able to recover, allowing for longer-term production cycles.

A variety of disciplines and approaches contribute to understanding the amount of resource available and the limits of recharge, and designing the most effective and efficient utilization, including geology, geophysics, geochemistry, reservoir modelling, and reservoir engineering. In Iceland, the experience in predicting reservoir yields and responses to utilization has been increasing over time, among specialized government agencies, power companies and consultancies. Utilization technologies are also evolving, allowing for example deeper and directional drilling, and enhancing the permeability and therefore the heat flow in the reservoir. Local reductions in yield within a geothermal reservoir are expected and can be compensated for by drilling make-up wells.

Iceland is a young country geologically and one of the most tectonically active regions on earth, resulting in a large number of volcanoes and hot springs, with frequent small earthquakes. Within Iceland's volcanic zone, along the mid-Atlantic ridge that stretches from the south-west to the north-east, there are at least 20 high-temperature areas containing steam fields with underground temperatures reaching 250°C within 1,000 m depth. About 250 separate low-temperature areas with temperatures not exceeding 150°C in the uppermost 1,000 m are found mostly in the areas flanking the active zone. There are also over 600 hot springs (with temperatures over 20°C).

The high-temperate area around the Mt. Hengill volcano in the south-west is of particular interest due to its proximity to Reykjavík, and has seen the most intensive development of any area in Iceland. The volcano is approximately 400,000 years old and last erupted 2,000 years ago. The most productive part of the Hellisheidi field is a relatively narrow strip (about 1 km wide and 4 km long) in the fracture zone southwest of Mt. Hengill, as well as the separate Hverahlíd area. The main heat sources in the current production field are now assumed to be relatively shallow, dispersed and smaller, instead of one large up-flow under the central volcano.

4.2 Detailed Topic Evaluation

4.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Monitoring is being undertaken of geothermal resource production capacity and reliability, and ongoing or emerging issues have been identified; inputs include field measurements, testing of wells,*

appropriate statistical indicators and geothermal reservoir models, issues which may impact geothermal availability or reliability have been identified and factored into the geothermal models.

The geothermal reservoir at Hellisheidi was initially more difficult to understand than the one at Nesjavellir, as it had very few surface manifestations. A first well at Kolvidarhóll had been drilled in 1985. The decision to build the plant was made in 2002, on the basis of additional research drilling to assess the capacity of the field, completed in 2001. A conceptual model of the reservoir was developed over the years, and a 2005 paper by OR and ÍSOR geologists summarizes the knowledge at the time, based on data from the first 10 deep wells. The model was further developed and revised, based on the results of the intensive drilling program (total of 64 wells) until today. In 2010, new summaries were provided by ÍSOR, suggesting three separate upflow zones beneath Reykjafell, Gráuhnúkar and Hverahlíd. On the basis of the new model, OR produced forecasts of the reservoir response to utilization.

By 2012, as the Hellisheidi plant had entered full operation, it became clear that the yield from the wellfields was declining and not able to support the full capacity of the plant, requiring further adjustments to the reservoir model. Since then, the annual expected decline of the existing wells has been calculated to determine the number of necessary make-up wells. The annual decline was initially estimated as equivalent to 7 MW, later increased to 20 MW which proved to be inaccurate, and thus recently reduced again to 7-13 MW.

A similar experience regarding over-optimistic modelling was made with regards to the Hverahlíd wellfield. This was originally planned to support its own 90 MW power plant, but in 2013 a decision was taken to instead connect it to Hellisheidi, to provide approximately 50 MW of additional steam. Also in this case, the original model had to be modified to better represent rapidly declining yields.

The growing understanding of the reservoir has been supported by well measurements, tracer experiments to investigate the effects of reinjection, micro-seismicity (see O-15) and other data.

There are three main types of well measurements; well-head pressure data, production flow data and downhole logging. Well-head pressure has been measured weekly for each well since it was taken into production; the intention is to move to continuous measurement via fiber-optic cables. Production flow measurements measure the flow and enthalpy of the fluid in each well, generally during operations. Measurement intervals have been increased to twice a year. They are now done twice every year for every well, but before they were only done once a year and not on all wells. Downhole logging monitors pressure and temperature developments at different depths in strategically selected wells. If production wells have to be used for this purpose, they have to be taken offline for two weeks before the measurement, so this is preferably done while there are planned maintenance outages at the power plant. Chemistry of all wells is also analysed bi-annually. Well monitoring data are easily accessible.

Tracer experiments were undertaken during 2013-2015 to determine possible cooling effects from reinjection of colder water into a number of reinjection wells. There were no significant cooling effects in the production wells that showed the greatest tracer recovery. Tracer experiments were also undertaken in connection with the CarbFix and SulFix projects. By now, tracer experiments are undertaken for all new reinjection wells.

An additional operational problem is that the reinjection capacity of wells, which is also monitored, was originally overestimated and has been declining over time.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, issues that may impact on steam and fluid availability, renewability and reliability have been comprehensively identified; and scenarios, uncertainties and risks including reservoir drawdown, average well production decline and geothermal system response are routinely and extensively evaluated over the short- and long-term.*

Given the critical importance of better understanding of the reservoir, OR has invested considerable resources in research and development activities, has closely monitored operational experience, and conducted multiple experiments. For example, it has been tested whether the injection of colder water can increase fracturing and thereby the permeability of the rock around wells, which would be useful both for production and for reinjection wells. It has also been explored what the optimal pressure levels are, as reducing pressure can increase the steam fraction in the geothermal fluid. Tests on the well response to flexible operations (reducing steam production during hours of low power demand) have been conducted. Drilling plans for additional wells are routinely updated based on new insights.

While the original understanding of the field was flawed, this is not any more the case, and is not considered a gap under Assessment. Rather it was the management decision to develop the field rapidly, without waiting for a gradually improved understanding, that caused the current problems, and this is addressed under Management below.

Criteria met: Yes

4.2.2 Management

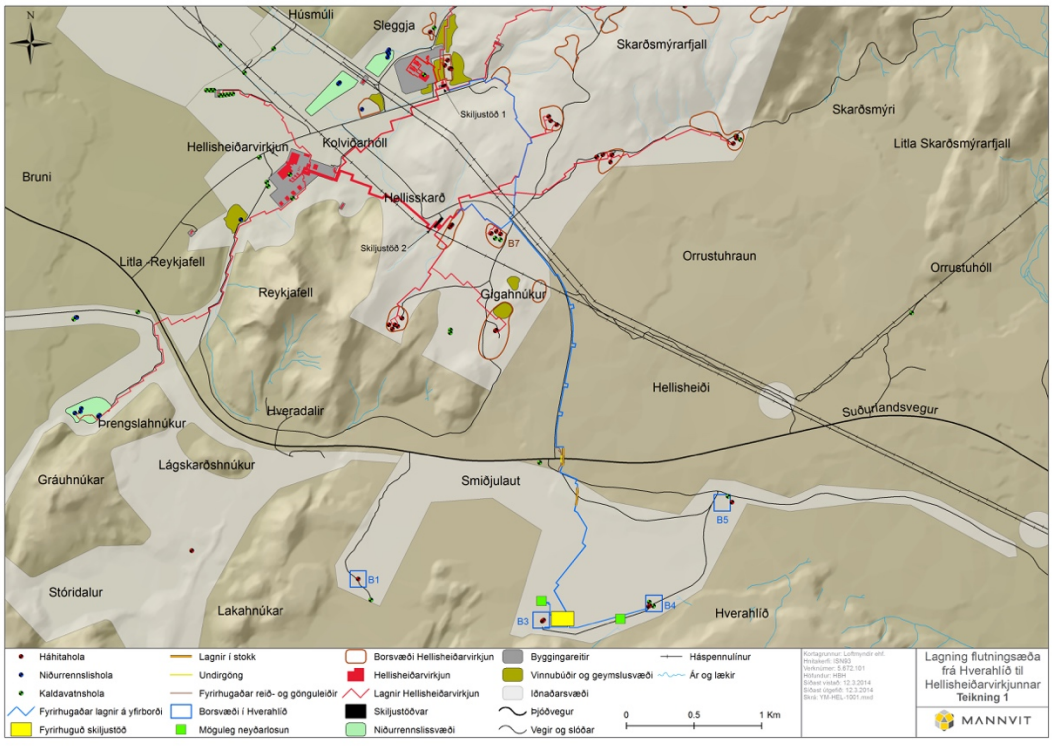
Analysis against basic good practice

Scoring statement: *Measures are in place to guide generation operations that are based on analysis of the geothermal production capacity, a range of scientific and technical considerations, an understanding of power system opportunities and constraints, and social, environmental and economic considerations.*

The main operational parameters for generation are the use of existing and additional wells for production and reinjection, which will also determine the status of the geothermal reservoir.

Geothermal production capacity is increasingly well understood, as described above under Assessment, and ON is aiming to reach a sustainable level of reservoir utilization while making full use of the installed plant capacity, in order to be able to fulfil its power delivery and debt service obligations. The most significant step towards expanding steam supply is the development of the Hverahlíd wellfield.

Figure 6. Steam Supply from Hverahlíd Wellfield



The development of additional production wells, such as in the Hverahlíd wellfield where a separate EIA was done, takes multiple considerations into account. Reinjection also serves a dual purpose, maintaining pressure in the reservoir as well as reducing the environmental effects of surface disposal. Reinjection is necessary because of the high production density at Hellisheidi. It is estimated that reservoir pressure would drop more than 10 bar annually, assuming no natural recharge or reinjection. The main reinjection zones for the Hellisheidi power plant are Gráuhnúkar in the south-west of the field (since 2006) and Húsmúli in the north-west (since 2011) and; additionally a number of production wells have been converted to reinjection wells, for in-field reinjection.

Utilization of the geothermal resource is subject to a number of ON guidelines, including processes for resource monitoring, changes in utilization, surface water disposal, and compliance with the utilization license. Under a process titled 'From Natural Resource to Customer', there are frequent coordination meetings between resource, operations and sales managers. Power system opportunities and constraints are well understood. ON generally has to purchase additional energy on the market, and thus sales are not a relevant constraint on generation planning.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, generation operations planning has a long-term perspective; shows exemplary energy efficiency; and comprehensive monitoring of the effect of operation on the resource is performed and conceptual and numerical models are well maintained to ensure that geothermal fluid and energy balance can be achieved in the long run and goals of sustainable yield will be met, e.g. with reinjection as applicable. Predictions are presented with quantified and well supported uncertainty boundaries.*

The original generation planning was based on significantly over-optimistic scenarios, that did not take potential long-term yield decline into account. While today's generation planning is based on more careful long-term projections, as described below, there is a broad consensus that the Hellisheidi plant was developed too rapidly and may be too large and expensive for the geothermal field that it relies on. It has proven to be preferable to develop fields step-wise or in stages, to take into consideration the individual conditions and response of each geothermal system.

The flaws in the original plant design impose significant operational constraints on ON, the financial consequences of which are addressed under O-7. The flaws were not just the responsibility of an overambitious management at OR, but also of licensing agencies, banks, power purchasers and other parties that did not undertake sufficient due diligence. Today the National Energy Authority sees it as one of their roles to protect the good reputation of Iceland as an investment destination for power intensive industries, by avoiding technically unsustainable projects that could not fulfil their power supply contracts.

To compensate for the shortfalls in steam supply and reach a sustainable yield, OR/ON have undertaken a series of planning exercises, to expand the wellfields, modify areas designated for reinjection and production, and explore additional wellfields, most likely to the south of Hellisheidi. All available data are taken into account, including resistivity and seismic measurements, geochemistry and geophysics, and geological mapping. In 2010, it was estimated that 34 wells would be needed between 2010 and 2040 to maintain steam supply. A drilling plan for 2012-2026 (the end of the main Nordurál contract) foresaw the need for 32 wells. A 2013 memo lays out options in more detail, and also compares them to additional alternative such as 'do nothing' (which requires purchasing power from third parties), and constructing a sea outfall to reduce the problems with reinjection and be able to use the Gráuhnúkar field (with high permeability) for production instead of reinjection. It was on the basis of this analysis that the decision to develop the Hverahlíd wellfield was taken.

These plans have been further updated, through a strategic project called 'Fjallid' (The Mountain). This has taken new information from well measurements into account and has rearranged the order in which new wells are drilled. The estimates of the number of additional wells needed and the associated costs have been reduced.

Different scenarios have been prepared, depending on drilling success. The latest drilling tender was launched in 2017, for seven plus an option for three more wells. The first well under the current drilling campaign appears promising. One of the Hverahlíd wells shows the highest temperature of any well at Hellisheidi, 337° C.

Drilling additional wells will provide more operational flexibility. For example, 'wetter' wells with a higher water content in the geothermal fluid are more useful in the winter, when more water is needed for the heat exchangers, and 'drier' wells are more useful in the summer.

Other alternatives currently under consideration include adding a back-pressure turbine of approximately 6 MW at the Hverahlíd separator station, where steam pressure has to be reduced before steam is sent to the power plant, and drilling wells deeper than before.

Drilling success at Hellisheidi (63% currently) has been in line with general experiences in Iceland and worldwide, according to a recent publication by the National Energy Authority. Also, the average yield of all wells, at 5-5.5 MW, has been in line with global averages.

All generation planning exercises are subject to remaining uncertainties, which are clearly addressed in the planning documents, such as the latest internal memo on steam supply options from August 2017.

Connecting additional wellfields to Hellisheidi may depend on the status of those areas in the national generation expansion masterplan.

Criteria met: No

4.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Objectives for operating regulatory requirements for the geothermal resource have been and are on track to be met with no significant non-compliances or non-conformances.*

The regulatory requirements regarding geothermal resource management are laid out in the utilization license. ON submits an annual report to the National Energy Authority, which is laid out according to the requirements in the license. This contains, for example, data on production or injection for each well, as well as steam pressure and temperature measurements.

The National Energy Authority also participates in the monthly meetings with stakeholders and receives specific reports from ON. For example, in February 2018 an update to the Hverahlíd reservoir model was submitted, and for each major change to reinjection procedures, a risk assessment for induced seismicity is submitted.

Compliance on other issues related to reservoir management is also addressed under other topics. This includes compliance with the agreed protocols for reinjection (see O-15) and compliance with surface disposal conditions (see O-16).

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances with operating regulatory requirements for the geothermal resource.*

According to the National Energy Authority, while ON is generally in compliance with the utilization license, there are three minor issues.

Firstly, the original power plant license from the Ministry of Industry only covers the use of groundwater for district heating, not for associated projects like GeoSilica. There is agreement that the volumes used by GeoSilica are minor by comparison with the hot water plant, and the application for a license change was sent to the National Energy Authority in February 2018.

Secondly, ON informed the National Energy Authority too late of a rapid pressure drop at a Hverahlíd well (HE-21), which could affect meeting the license requirements. ON is of the opinion that it would have been premature to inform the National Energy Authority when the pressure drop was first detected in 2016, because for a number of reasons, the measurements were inconclusive until August 2017. The measurements have now been confirmed and the National Energy Authority has been fully informed. Nevertheless, even if there were good reasons for the delay in information, it is considered a **significant gap**, because the Energy Authority would have preferred to receive earlier, informal indications of the issue, which would help building a cooperative relationship with the regulator.

Thirdly, there are repeated non-compliances in relation to the utilization licence conditions on surface releases of geothermal water. For example, in 2015 and 2016, 7% and 5% of all water was released on the surface, which is more than intended by the licence. Although this has been tolerated by regulators, it is considered a **significant gap** because it is an ongoing issue. It is recorded here under O-4 and not under O-16, because it is a non-compliance against the utilization licence from the National Energy Authority, with the primary purpose of guaranteeing a prudent management of the geothermal resource. The National Energy Authority is considering raising the utilization licence requirements, but this has not yet happened. Environmental implications are discussed under O-16. ON is developing alternative operational approaches which may contribute to a resolution of this issue.

Criteria met: No

4.2.4 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

ON informed the National Energy Authority too late of a rapid pressure drop at a Hverahlíd well.

There are repeated non-compliances in relation to the utilization licence conditions on surface releases of geothermal water.

2 or more significant gaps

4.3 Scoring Summary

The management of the geothermal reservoir at Hellisheidi presents significant challenges to ON. These are related to over-optimistic assumptions in the original evaluation of the field, but also to the fact that design and investment decisions were taken rapidly, without being informed by initial reservoir responses. The resulting design flaws are making today's generation planning difficult. However, the understanding of the field has substantially improved, and there is active management - including the drilling of multiple additional wells - to overcome these constraints.

ON is generally in compliance with its utilization license but from the perspective of the regulator, could have provided more timely information on a possible problem with meeting license requirements on pressure drawdown, and is releasing more geothermal water than intended on the surface, rather than reinjecting it. These are two significant gaps against proven best practice, resulting in a score of 3.

Topic Score: 3

4.4 Relevant Evidence

Interview:	3, 7, 11, 20, 25, 26, 29, 31, 34, 37, 38
Document:	208-234
Photo:	16, 18, 20, 24-31, 59, 66, 100, 103, 104

5 Asset Reliability and Efficiency (O-5)

This topic addresses the reliability and efficiency of the geothermal facility and associated network assets. The intent is that assets are maintained to deliver optimal performance in the short- and long-term in accordance with the overall energy generation and supply strategy of the owner/operator.

5.1 Background Information

Reliable and efficient power and hot water supply from the Hellisheidi project is highly important, as it provides an important share of the capital city area's heating and power supply, and an important share of OR/ON's assets and revenues. Also, much of the power generated at Hellisheidi is sold to the Nordurál aluminium smelter. Aluminium smelters can suffer significant damages from supply outages that last beyond a few hours, and outages caused by the supplier can have financial and reputational repercussions, beyond lost sales. Outages can also affect the operations of other customers. Finally, reliability is also an issue in the general market, where ON aims to compete on service quality, and to reduce outages as far as possible.

The Hellisheidi plant was built in stages, and its components have now been in operation for about 10 years on average:

- 2 x 45 MW high-pressure turbines Mitsubishi 2006
- 1 x 33 MW low-pressure turbine Toshiba 2007
- 2 x 45 MW high-pressure turbines Mitsubishi 2008
- Hot water plant (133 MW) 2010
- 2 x 45 MW high-pressure turbines Mitsubishi (Sleggja plant) 2011

In parallel, the wellfields have been developed and connected to the plant, with the Hverahlíd field in 2015 as the latest expansion. The capacity of the hot water plant is to be expanded soon.

Together with ON's other projects (the Nesjavellir geothermal co-generation plant and the small Andakíl hydropower plant), Hellisheidi is operated by the Power Plant Operations department. The department has a total of approximately 45 staff in several units for planning, operations, mechanical maintenance, electrical maintenance, safety and environment.

5.2 Detailed Topic Evaluation

5.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Routine monitoring of asset condition, availability and reliability is being undertaken to identify risks and assess the effectiveness of management measures; and ongoing or emerging asset maintenance and management issues have been identified.*

The most basic elements of routine monitoring are daily visual checks in the power plant and the continuous supervision of the performance of key components from the control room in the power plant and/or remotely from the operations centre at OR headquarters in Reykjavík.

Maintenance is based on the DMM system (Dynamic Maintenance Management, an Icelandic software platform that is used across the power sector). This platform is becoming more powerful, both through software improvements and because it has become an integral part of the work culture. It enables a systematic approach to preventive maintenance, repairs, work safety issues, and record keeping.

Major inspections of the generating units (that last about one week) were initially scheduled at yearly intervals, and with increasing confidence are now scheduled every two years. In addition, there is condition monitoring at

more frequent intervals, and there are major turbine overhauls (initially every four years, now every five years, see below). Each overhaul is documented through a comprehensive report. One issue that was found is that some 40% of the steam is already condensing in the turbines, increasing the wear. This has been taken into account in the approach to overhauls.

Other components are also regularly inspected and tested; for example, transformer gas analysis is conducted every 6 months. Major generator inspections are scheduled every five years, and overhauls every 10 years.

External reviews by an auditor for the insurers have been undertaken in 2014 and 2017. The auditor's observations are analysed and taken on board if it is deemed economical to do so, for example because the action results in a reduction in premiums. The last insurance loss event was in 2005, at Nesjavellir. All other issues at the two power plants have been below the deductible threshold.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging asset maintenance and management issues takes into account both risks and opportunities.*

There are a number of examples for taking risks and opportunities into account.

The reliability of supply in emergency situations has been considered. For example, if the hot water supply pipeline to Reykjavík were to be interrupted, at peak load there would be a supply deficit in the hot water system of approximately 1,600 m^3/h. Existing hot water storage in the city is 26,700 m^3 (not counting any water left in the pipeline, a maximum of 4,000 m^3) so that there would be at least 17 hours of reserves. After that, a curtailment plan would need to be activated, and supplies reduced by about 10% until the pipeline is repaired.

Many components in the plant are redundant to increase reliability, and with an emergency generator the plant has black start capability.

The shift schedule for the plant originally provided for continuous presence of operational staff, to respond to urgent matters. An analysis of calls from 2005 to 2007 (a total of approximately 250 for Hellisheidi) showed that 82% had low urgency and could be attended to in the next day shifts, and 50% could be resolved remotely from the operations centre in Reykjavík. For the others, time-to-failure and reaction time was reviewed; workers can arrive within the hour. The upcoming change in the shift system (see O-12) is based on this analysis.

Criteria met: Yes

5.2.2 Management

Analysis against basic good practice

Scoring statement: *Measures are in place to address routine monitoring and maintenance requirements of the operating facility in accordance with the overall energy generation and supply strategy of the owner/operator.*

The overall generation strategy for electric power is to maximize generation subject to resource availability (see O-4), sales (see O-7) and availability of the plant. The units operate continuously at high load, and only have around five starts on average each year.

There are approximately 1,000 maintenance work orders in the DMM system per year, two thirds of which are for Hellisheidi, ON's most complex plant. Sources for work orders are 1) automatic intervals, 2) flagged observations, 3) individually planned projects. There is an annual maintenance plan for major work orders, which is also shared with the TSO (Landsnet) so that planned machine outages can be integrated into national-level generation planning. Maintenance slots are then confirmed by the TSO. The TSO is also informed of any unscheduled maintenance work that results in unavailability of machines.

During the initial phase of the financial recovery plan (see O-7), a significant part of the workforce (about 200 staff) were laid off. Maintenance was prioritized according to an A-B-C categorization, reflecting the importance for safety and operational aspects, and where possible deferred. A service provider (Deilir) was contracted to support part of the maintenance. Deilir currently works with approximately 20 staff, is ISO 9001 certified since 2017, and is fully integrated into ON's O&M, using DMM and the same OH&S processes. In an initiative to save costs and reduce maintenance downtime, a turbine rotor workshop was established in cooperation with the maintenance contractor. Since the financial situation has stabilized, maintenance is no longer deferred. ON and Deilir staff typically work inside the power plant, while outside work is outsourced to other contractors.

Turbine overhauls involve disassembly, cleaning, non-destructive testing of rotor, replacement of defective and repair of worn parts, setting of diaphragm and seals, and assembly. The time for major overhauls of turbines has been reduced from 5-6 to 3 weeks, as more parts available for immediate exchange and work is done in two shifts. As the manufacturer's guarantee on the units has expired, ON is free to source parts domestically and to repair rotors in its own workshop, which is fully equipped including some self-developed tools. An Icelandic machine workshop (Vélvík) is now able to produce rotor blades, for example, that have been reverse-engineered from the original machines. Some of the repairs actually result in higher quality (e.g. harder alloys, with less wear and tear). Having a workshop on-site has resulted in large savings, higher availability, and increased technical competence and confidence.

O&M staff are familiar with the plant and critical systems that require more attention, such as the compressed air system. In hindsight, some components of the plant should have been designed differently, and adjustments are made on an ongoing basis. For example, to reduce scaling in the heat exchangers, a number of options were considered and are being tested, including the options to dilute separated water with condensate water, and to inject gases to change the acidity.

Some special operational challenges and risks are related to the environment. These include

- winter conditions, which affect access to the plant and the ability to do outdoor work (see O-12), and storms which have also damaged equipment such as the cooling towers,
- the presence of H_2S which is corrosive (see O-16), and
- the risk of earthquakes and volcanic eruptions.

Geothermal power plants have a lower inherent fire and explosion hazard than a conventional thermal plant (lower steam temperatures and limited quantities of fuel on site). The Hellisheidi plant has fire detection and suppression systems on site; the insurance auditor has made a number of observations for possible improvements to fire suppression. The January 12 fire required external fire-fighting support. The police are responsible for conducting an investigation of the fire.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities; and asset maintenance management plans include a long-term program for efficiency improvements and asset upgrades.*

Monitoring of components has shown a number of issues that are now being more closely monitored, with the intention of scheduling repairs when they become necessary (for example, regarding corona discharge on one of the stators, and elevated CO and CO_2 levels in the transformers).

One general objective is to simplify operations, where possible. Hellisheidi is a highly interconnected plant, that may become even more complex with the establishment of the Geothermal Park.

Several options regarding the rotor workshop are being reviewed. The main objectives are 1) to ensure in-house competence on turbine condition assessments (by adding two internal staff positions), 2) to utilize the equipment at the rotor workshop for ON as a first priority (by keeping ownership of the equipment, and keeping options

open for future changes), and 3) to ensure competitive maintenance costs (by tendering out maintenance works, so that prices can be compared with the present service provider Deilir). Insourcing complex maintenance tasks such as turbine maintenance also contributes to work satisfaction (see O-12). There are only a few comparable workshops for geothermal turbines worldwide, so that the technical capacity of this workshop represents a high value. There have been some concerns that the upcoming tender for maintenance works might result in a loss of knowledge, but the insourcing of jobs is intended to mitigate that risk.

OR/ON's asset management programmes are based on ISO 55001, although the company is not certified to this standard. Major rehabilitation and investment projects are prioritized according to their costs and return on investment, as well as to their contributions to safety and environmental improvements. A long-term plan for machine overhauls up to 2030 has been established. New technologies are being developed and tested, in cooperation with other companies and universities. The level of efficiency of the installed key components is generally high, and there is no intention to upgrade them in the foreseeable future. Instead, efficiency improvements are expected to result from incremental changes to O&M.

Criteria met: Yes

5.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives relating to asset maintenance and management have been and are on track to be met with no major non-compliances or non-conformances, and any asset related commitments have been or are on track to be met.*

No non-compliances or non-conformances have been identified. Regarding ON's own KPIs, the load factor across the three ON power plants in 2017 dropped to between 80% and 85% in two months (June and August), which is in the yellow band (the green or target band is above 85%, the red band below 80%). However this is not considered a non-conformance, as the factor did not fall into the red band, and was in the green band for 10 months, and even 80% to 85% is a high plant efficiency by international standards.

There are no external asset related commitments, for example in contracts with major customers.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

No non-compliances or non-conformances have been identified.

Criteria met: Yes

5.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *Asset reliability and efficiency performance is in line with the objectives of the owner/operator and any asset performance guarantees with only minor gaps.*

The plant has been operating reliably for a number of years. The availability of machines at Hellisheidi during 2017 was 99.5% or above, within the target range of 99%-100%.

The load factor as discussed above is a function of planned and unplanned outages, as well as resource constraints. The overall generation from Hellisheidi is currently capped at 284 MW (average over the year). This provides some flexibility to schedule maintenance, which would otherwise be very difficult in a plant running at close to capacity.

The insurance auditor considers Hellisheidi to be an Above Standard Risk from a machinery breakdown perspective, Standard Risk from a property/fire perspective, and Above Standard Risk from a business interruption perspective (business interruption is not currently insured).

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *Asset reliability and efficiency performance is fully in line with the objectives of the owner/operator and any asset performance guarantees.*

The plant's own power consumption (for example, for pumping water) is considerable and has been increasing because of increased hot water production and other changes (e.g. the CarbFix and SulFix projects). This has been recognized by ON and measures to increase efficiency are included in the current investment plan, hence this is not considered a gap. All other reliability and efficiency objectives are being fully met.

Criteria met: Yes

5.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There are no significant gaps against proven best practice.

0 significant gaps

5.3 Scoring Summary

The Hellisheidi project is closely monitored, and ON in cooperation with local contractors have developed strong capacities in operation and maintenance, including complex repairs. Opportunities for improvements in reliability and efficiency are regularly evaluated, and a number of them have been realized. The overall load factor is above 80% and the overall availability of generating units is above 99%. There are no significant gaps, resulting in a score of 5.

Topic Score: 5

5.4 Relevant evidence

Interview:	3, 4, 13, 23, 26, 43, 47
Document:	236-258
Photo:	1-21, 26-31, 43-95

6 Public Health and Safety (O-6)

This topic addresses management of hazardous and polluting impacts from geothermal operations and other health and safety issues for the public and neighbouring communities.

The intent is that life, property and the environment are protected from the consequences of the geothermal energy harnessing and facility operation and other associated health and safety risks.

6.1 Background Information

Key aspects of geothermal projects with potential impacts on public health and safety with relevance for Iceland include: psychological disorders, mercury or heavy-metal bioaccumulation, impacts from emissions of hazardous gases from operation of the facility, seismic and volcanic risks, extreme noise, contamination of drinking-water sources by geothermal effluents, electric shock, injury from hot water or steam, road accidents, etc.

Public safety and civil protection fall under the Ministry of Justice and are delegated to the National Commissioner of the Icelandic Police (NCIP). The NCIP has a Department of Civil Protection and Emergency Management which has the day-to-day responsibility. Other important actors are the Fire Department and the volunteer Mountain Rescue Service. The Environmental and Public Health Authority of South Iceland is responsible for environmental health.

Iceland has a very well-developed and publicly-funded health system. The health status of the Icelandic population is better than the already high European average, and the life expectancy as determined by the World Health Organisation (WHO) in 2015 was the 5th-longest in the world. The nearest hospital to the power plant is located in Selfoss, approximately 25 km to the south-east, and there is a clinic in Hveragerdi and a general-practitioner nurse stationed in Thorlákshöfn, the capital of the Ölfus municipality. Hveragerdi is a spa town, centred on the geothermal area with its hot springs.

Some risks are covered under other topics. Occupational health and safety risks to workers are covered under O-12. The actual induced seismicity and subsidence are covered under O-15, and the actual emissions and contamination from geothermal effluents, releases and spills are covered under O-16, but the impacts on the public are covered here. Impacts on the project-affected communities in terms of general discomfort experienced from either exposure to low and safe levels of emissions, or from worries over potential safety issues are covered under O-9.

6.2 Detailed Topic Evaluation

6.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Routine monitoring of health and safety issues related to the operating facility and other infrastructure is being undertaken to identify risks and assess the effectiveness of management measures; and ongoing or emerging health and safety issues have been identified.*

The main public health and safety issues identified which directly relate to the Hellisheidi plant are:

- Human exposure to H_2S emissions for the plant;
- Induced seismicity resulting from the reinjection of geothermal fluid;
- Impacts on groundwater quality as a result of contamination from surface releases of geothermal water;
- Public safety concerns relating to plant-related infrastructure such as pipelines, the plant site itself, project-specific roads etc.

H_2S emissions are well monitored as described under O-16. The potential health impacts of such emissions are not well understood, but as described under O-16, Iceland has implemented stricter regulations than those recommended by the WHO, by a factor of 3. There have been reports about increased cancer risks from the exposure to high-temperature geothermal areas in Iceland. One comprehensive study found an increased risk of just over 1% for all cancers in the high-temperature-area population as compared with the control population. The highest increased hazard was for non-Hodgkin's lymphoma at just over 3%. The authors of the study concluded that there are indications of an exposure-response relationship, as the risk was elevated but that more precise information on chemical and physical exposures are needed to draw firm conclusions from the findings. Research has also been conducted on the negative impacts on people who suffer from respiratory illnesses such as asthma. The impacts were measured by using the increase in medicine sales and emergency hospital visits in the days following significant increases in H_2S concentrations in the air as indicators. The findings indicated significant increases of between 1-2% per 10 $\mu g/m^3$ increase in H_2S concentration, for 5 and 3 days respectively. The conclusions of the authors was: "Our findings indicated that intermittent increases in levels of particle matter from traffic and natural sources and ambient H_2S levels were weakly associated with increased dispensing of drugs for obstructive pulmonary disease in Iceland's capital area. These weak associations could be confounded by unevaluated variables hence further studies are needed."

The main actor responsible for warnings related to natural hazards, notably earthquakes, avalanches, floods, wind and extreme precipitation events, is the Icelandic MetOffice. Whenever there is a concern for public safety, the MetOffice issues a warning to the national-level Department of Civil Protection authorities, which in turn is responsible for contacting local police as and when appropriate.

Iceland GeoSurvey (ÍSOR) operate a significantly denser network of seismic monitoring stations than that used by the MetOffice, but this is mainly orientated towards improving the scientific understanding of seismic conditions, rather than addressing public-safety concerns.

Each municipality has a Civil Protection Committee whose primary responsibility is preventive work on emergency planning.

Groundwater quality is monitored as described under O-16, and the Vatnaskil consulting company constantly updates and re-evaluates the groundwater model used to predict potential impacts to domestic water supplies, importantly for the capital region.

The Icelandic Radiation Safety Authority (IRSA) have assessed levels of natural radioactivity in scale formations in geothermal power plants in Iceland in, among other places, Hellisheidi. The concentration is low and the maximum exposure to humans is far below the permissible levels for workers' exposure, 1 mSv/year.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging health and safety issues for the public and neighbouring communities takes into account consideration of a broad range of scenarios and both risks and opportunities.*

Iceland has a world-class publicly-funded health system which is well-placed to identify any negative impacts to the population as a result of typical hazards of geothermal power generation.

The NCIP is responsible for monitoring and for supporting research and studies related to risk factors and natural catastrophes.

OR/ON support research by academic institutions in order to improve the tools available for the analysis of public-health issues, including H_2S exposure.

Criteria met: Yes

6.2.2 Management

Analysis against basic good practice

Scoring statement: *Hazardous and polluting geothermal impact and other health and safety management plans and processes have been developed in conjunction with relevant regulatory and local authorities with no significant gaps, and provide for communication of public health and safety measures; emergency response plans and processes include awareness and training programs and emergency response simulations.*

In accordance with the protocol on induced seismic activity developed in cooperation between the project, the National Energy Authority and the project-affected municipalities, procedures are in place for management response and the issuance of alerts to the public, see O-15.

The earthquake readiness and response planning is not specific to the Hellisheidi project but is rather general for South Iceland. An improved plan is under preparation. Municipal representatives express some concern regarding too many alerts, as this might affect the community negatively for no reason.

There is a system called “one force”, which links Civil Protection, the 112 emergency number system and the volunteer Mountain Rescue services. In case of a situation the “one force” goes into a joint “command station” readiness. This system was tested in practice when the fire occurred at the Hellisheidi plant in early January, 2018. Regular training of emergency response is carried out twice a year with the local fire brigade and the Mountain Rescue.

Some signage and fencing is done around the facilities, and the project has recently created a new map of public exclusion zones around the plant and is in the process of implementing strengthened rules on road access to project installations. However, there is a stated policy to leave areas as open as possible, which is a common approach in Iceland.

Staff at the Hellisheidi plant take part in the University of Iceland studies into the long-term effects on the dose-response relationships for human exposure to H_2S.

The mist eliminators contaminated by radioactive scale formations are stored for three years or until their radioactivity has been reduced to permissible levels. Following this, they will be cleaned and the scale formations will be disposed of in a manner consistent with recommendations by IRSA.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities; and public health and safety measures are widely communicated in a timely and accessible manner.*

Overall, there are well-functioning processes for the anticipation and response identification for public health and safety issues in place and these are also communicated in a timely and accessible manner. A good example is the communication with various outdoor-focussed stakeholders such as snowmobile clubs, ski clubs etc. resulting in the entire pipeline network being put into a GPS system and made available on Garmin Maps. Snowmobilers skiers, snowboarders and winter off-road drivers can utilise this in order to avoid having accidents with pipelines hidden by the snow cover. Additionally, the trail maintenance in the Hengill area focusses on tourist safety and has also included the reclamation of old mining pits which were previously a safety concern to tourists in the area.

Some stakeholders express concerns regarding communications between project and Government staff as well as some academic experts on one hand, and the project-affected communities on the other. The communities do not consider the communication on public health and safety issues to be appropriate to them. This is a

significant gap against these criteria, but is considered the same gap as that identified under O-1 above, and will not be double-counted here.

Criteria met: No

6.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives relating to public health and safety have been and are on track to be met with no major non-compliances or non-conformances, and health and safety related commitments have been or are on track to be met.*

All processes and objectives, as well as commitments have been or are on track to be met, without major non-compliances or non-conformances.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

There are no non-compliances or non-conformances.

Criteria met: Yes

6.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *Health and safety risks have been avoided, minimised and mitigated with no significant gaps.*

All identified risks have been either avoided, minimised or mitigated without significant gaps at this level. The implementation of GPS registration of the pipeline network of the plant's infrastructure is a significant step towards improved public safety.

In the case of perceptions of the project-affected communities, facts are of the utmost importance and the lack of knowledge about the impacts to humans from H_2S exposure is a serious issue in need of attention. The contribution by OR/ON to research into this issue is positive but appears to be in need of significant increase as the issue is a high-profile one suffering from inconclusive studies, see below.

Only one real public-safety incident has been registered at the Hellisheidi plant, when a visitor burned a foot in a geothermal hot spring, a natural hazard in the environment at the plant.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, health and safety risks have been avoided, minimised and mitigated with no identified gaps; and health and safety issues have been addressed*

All identified risks have been either avoided or minimised or mitigated without gaps, except the perception of risk on the part of project-affected communities, especially Hveragerdi, but also people in the nearby town of Selfoss and in the capital region. Evidence indicates that there is low trust among some project-affected communities in the information disseminated on, especially, health risks associated with H_2S releases. The lack of active promotion of research into exposure-response relationships in order to resolve the issue of health hazards caused by the H_2S emissions is a **significant gap**.

The sparse signage and fencing create avoidable risks to the public, but this issue is being actively addressed as part of an ongoing assessment of non-labour safety management.

Criteria met: No

6.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There is a lack of active promotion of research into H_2S exposure-response relationships.

1 significant gap

6.3 Scoring Summary

The main significant public health risk is exposure to H_2S emissions and the main safety risk relates to the project infrastructure and the accident hazards with e.g. pipelines hidden by snow in winter.

Safety issues are managed in close cooperation with the responsible authorities, led by the National Commissioner of the Icelandic Police and the MetOffice as responsible agencies for monitoring and warning on natural hazards. Regular training is conducted with the local first responders, supported by the volunteer Mountain Rescue Service.

Some studies have been conducted on health risks such as cancer and respiratory illnesses, but they have yielded low and inconclusive results. OR/ON do support some research into the health aspects of H_2S emissions, but given the high profile this issue has in the project-affected community, and the time that has passed since the impacts were discovered, there could be a more concerted effort to encourage and support research able to resolve this issue.

There is one significant gap, resulting in a score of 4.

Topic Score: 4

6.4 Relevant Evidence

Interview:	2, 8, 9, 11, 15, 16, 20, 32, 34, 36, 39
Document:	135-137, 155-158, 190, 259-275, 478-481, 483, 484, 487, 488, 490, 491, 499, 500, 502-505
Photo:	13, 19, 23, 31, 60, 92, 94, 100, 101, 102, 103, 104

7 Financial Viability (O-7)

This topic addresses financial management of the operating geothermal facility, including funding of measures aimed at ensuring project sustainability, and the ability of the project to generate the required financial returns to meet funding requirements as well as to optimise its financial opportunities.

The intent is that the operations of the geothermal facility are proceeding on a sound financial basis that covers all funding requirements including social and environmental measures and commitments, and that it is aware of and responding to market trends which may influence its long-term viability.

7.1 Background Information

The economic crisis in Iceland in the late 2000's, in combination with aggressive investments and a lack of cost control, led to a very difficult financial position for OR. In 2011, a plan for financial recovery was agreed with the owners. It included reductions in operating costs and investments, sale of assets, loans from owners, and increases in revenues, and targets for the 2011-2016 period have been achieved ahead of schedule. Comparing the 3rd quarter of 2009 with the most recent data, up to the 3rd quarter of 2017,

- Operating revenues increased by 74%,
- Net debt decreased by 47%, and the
- Equity ratio increased from 14% to 44%.

The owners prioritise a further financial consolidation, and a gradual increase in dividends.

Hellisheidi is the largest single asset of OR, accounting for between 1/5th and 1/6th of total value. The capital cost of the original Hellisheidi plant, before the Hverahlíd expansion, was estimated by OR in 2012 as USD 800 - 810 million, with the following general categories: general costs 6.7%, drilling and steam supply system 36.7%, electrical power plant 36.7%, thermal power plant 11.2%, exhibition area 0.6% and interest during construction 8.1%. The annual operational cost was estimated to be about 2.75% of the investment cost, where the largest component is the drilling of make-up wells during the lifetime of the plant (at an average cost of USD 3 million per well).

The project was primarily financed through long-term multilateral loans from the European Investment Bank (EIB), the Council of Europe Development Bank (CEB) and the Nordic Investment Bank (NIB). At the end of 2016, OR's long-term liabilities included 73% bank loans, 9% subordinated loans from the owners, and 17% bonds.

Additional costs that arose after 2012 include the Hverahlíd expansion and other measures to increase steam supply to the plant and maintain a high load factor, and the technical changes related to emissions mitigation. The costs for increasing steam supply over 6 years were reported as USD 263 million in 2016. In 2012, it was estimated that the cost of H_2S mitigation could be approximately USD 41.1 million.

Revenues from the plant include sales of power and hot water, as well as minor additional revenues.

7.2 Detailed Topic Evaluation

7.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Routine monitoring of the operating geothermal facility's finances is being undertaken to identify risks including decline of yield over time and assess the effectiveness of management measures; and ongoing or emerging financial management issues have been identified.*

Routine monitoring of expenditures at Hellisheidi is undertaken, covering both basic operational and maintenance (O&M) costs (i.e. the costs of Power Plant Operations unit) and costs of major projects (i.e. the costs of the Technical Development unit). These costs as well as those of other support units are only partially caused by Hellisheidi, as these units service all three power plants, but each of these is treated like a separate cost center. The same applies to the cost of OR's debt service (as financing is handled at the group level) and also to ON's revenues, which are not separated by assets.

Regular updating of cost data for Hellisheidi is required because the price of one of the products (hot water) has to be approved by a regulator. The costs therefore have to be either directly attributed to the products, or allocated according to a formula (see also below under Conformance/Compliance).

Regular monitoring of risks includes market risks and operational risks, both expressed in terms of their financial consequences. Currently ON's major market risks (liquidity, exchange rates, aluminium price) as well as associated management measures (e.g. hedging) are within their target ranges. Decline of yield and therefore, generation over time, as well as the effectiveness of measures to maintain yield are also monitored (see under O-4).

At the corporate level, financial monitoring is also undertaken through annual external audits (by KPMG in 2016) and periodically by external ratings agencies (Moody's, Fitch and Reitun, the Icelandic ratings agency).

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging financial management issues takes into account both risks and opportunities including confirmation of resource capacity based on monitoring and resource modelling as well as factors and trends that might influence future demand for electricity and ancillary services.*

OR/ON have a broad view of ON's operational risks, which are ranked according to their estimated probability (return period) and financial consequences. Risks include loss of operating license to environmental incidents; a significant increase in Landsnet transmission tariffs; failures of turbine, generator or transformer; cold water shortage; fire hazard at Hellisheidi; H_2S exposure of operational staff; electricity transmission system failure for more than 6 hours; volcanic eruption resulting in a production stops for a week; earthquake (7-8 on Richter scale); hacking of SCADA system; and transport interruptions to power plant. Mitigation measures are covered throughout this report, under the respective topics.

The original assessment of resource capacity and environmental impacts was inaccurate and uncertainties were not taken sufficiently into account, which has required substantial unforeseen and ongoing expenditure and has contributed to relatively low returns on investment (see O-4, O-16 as well as below under Outcomes). This is considered a **significant gap**. Resource capacity is now constantly monitored and modelled and understanding of the resource has much improved, although there is some remaining uncertainty over the costs of the drilling program to maintain steam supply to the power plant. Similarly, there is much better understanding of impacts but some remaining uncertainty over the costs of gas and wastewater mitigation.

General demand trends and associated risks and opportunities are broadly discussed in the Icelandic power and utilities sector. Demand for hot water is increasing steadily and will enable expansion of hot water production already in the short term. The National Energy Authority has estimated a potential increase in demand of 50% by 2050, based on population growth, increased residential space that requires heating, and commercial and industrial use (for example, for greenhouses). Demand for electricity is more difficult to estimate, as most of it depends on power intensive industries which are quite mobile in the long term, and the uncertain prospects of a submarine interconnector to Europe. In the medium term, sales by ON to power intensive users are expected to be stable, while retail sales in the Icelandic market sales are expected to grow by 1.5% p.a., and ON intends to keep up with that growth, if necessary by purchasing power on the market.

7.2.2 Management

Analysis against basic good practice

Scoring statement: *Measures are in place for financial management of the operating geothermal facility.*

Annual budgets are prepared and approved for ON's O&M costs and major projects. During the initial phase of the financial recovery plan, costs for O&M were also cut, by prioritizing or postponing maintenance projects. Currently the annual operational costs include as the largest item, the costs of the Power Plant Operations unit, with approximately 40 staff. Major projects for 2018, for a total of ISK 4.3 billion, include for example, the drilling of 4-5 additional wells, a new reinjection pipeline, improvements to steam pipe insulation, reductions in the plant's own power consumption, utilization of older low-productivity wells, and some work on buildings. Some repairs of damages from the January 12 fire at Hellisheidi need to be added. These costs are for all of ON's investments, not just for Hellisheidi.

OR/ON also prepare a medium-term 5-year rolling forecast of costs and revenues, which is frequently updated. Major projects over the 2019-2023 period are estimated at ISK 21.4 billion. This is prepared according to the so-called 'Beyond Budgeting' method of strategic forecasting, involving a broader range of managers and other staff, who can base their decisions on documented financial targets. From this year, OR's budget for the year 2018 and forecast for 2019-2023 will also be integrated into the consolidated budget of the City of Reykjavík.

Sales of hot water to Veitur are based on a long-term arrangement, at a regulated price. Sales of power are conducted through two ON units, Consumer Markets and Corporate Markets. All power customers in Iceland can choose their supplier.

Consumer Markets is currently serving 73,000 residential users and 10,000 businesses. ON's market share in Iceland is 33%, and 80% in its direct service area. ON is generally trying to avoid competing on price, and is seeking differentiation from competitors on service and on the image as a sustainable company. ON is also rolling out the largest network of electric vehicle charging stations in Iceland, with a view to benefitting from strong future demand.

Corporate Markets is serving individual large power-intensive users. This currently includes two long-term contracts with Nordurál ehf (an aluminium smelter north of Reykjavík at Grundartangi, owned by Century Aluminium) which will begin to expire in 2026, and one contract with Landsvirkjun (the largest power company in Iceland, for resale also to Nordurál, expiring in 2019). These contracts make up a significant share of power sales (~75%) at low prices (in the case of Nordurál, roughly USD 20/MWh including transmission) which are partially linked to aluminium prices.

The Corporate Markets unit is aiming to maintain and increase sales, by

- Renegotiating expiring contracts, which in the case of Nordurál is due to start in 2023. Other power companies that have renegotiated such contracts recently, have been able to achieve significantly improved conditions.
- Attracting new, smaller high-tech clients with high potential such as data centres (the first contract with a data centre has been concluded, with deliveries starting in November 2018) and firms that can locate at the Geothermal Park at Hellisheidi, using different resource streams and products. General guidelines for firms at the Park are under development.
- Developing a pipeline of contacts with international power-intensive industries.
- Annual agreements with Invest in Iceland, jointly with other power companies, to promote Iceland as an investment destination.

Since 2012, ON's own generation has been approximately 3.1-3.5 TWh per year. It is higher during the winter (approximately 390 MW) than during the summer (between approximately 310 MW and 360 MW), when

overhauls of equipment are planned because purchasing of power is cheaper, due to slightly reduced demand and high inflows into hydropower reservoirs. The overall average generation from Hellisheidi is currently capped at 284 MW, due to resource constraints (see O-4). The own generation is generally sufficient to supply power consumption in the plants (for example, to pump cold water through heat exchangers), sales to power intensive customers, the transmission system operator (TSO), and wholesalers, plus sales in the general market during night time. During day time (peak hours), the general market customers require additional supplies. These are purchased by ON's trading desk, generally from Landsvirkjun which is the only major supplier in the market. The trading desk also participates in the short-term balancing market, the quarterly tenders by the TSO, and the sale of 'guarantees of origin' for renewable energy, in the European market. Sales in 2018 are expected to range between approximately 350 MW and 580 MW.

Financing of ON is through OR. The equity ratio of OR has been increasing and is expected to further increase to 59% by 2023. Repayments of debt over 2017-2023 are expected at ISK 98 billion, while new borrowings (for refinancing of debt) will amount to ISK 57 billion. The refinancing strategy is therefore still important. It is the intention to reduce currency risks by relying more on financing in ISK (in particular with local bonds, OR first returned to the bond market in 2016), and to replace variable rate loans by fixed interest financing.

Other routine measures include the management of taxes, as all of ON's operations are subject to income tax, VAT and property taxes. Insurances are managed by the risk unit of OR. The Hellisheidi plant is insured for a value of USD 624 million against property damage.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities; and financial contingency measures can be implemented for environmental and social management plans if required.*

The owners of OR provide guarantees and have established a Dividend Policy which only allows dividend payments if a number of conditions are met.

Internally, OR/ON apply a number of analyses to understand and manage risks. There are targets for major market risks, and sensitivity analysis is conducted regularly to calculate, for example, the impact of a 20% drop of aluminium price or an interest rate increase by 300 bp, on equity. There are also targets for hedging major market risks, and the share of risks that are hedged is tracked. The risks of large, long-term contracts have been identified (among other things, through internal audits), and a formalized process has been introduced, where a committee with representatives from finance, risk, legal and trading prepares ON board decisions on contracts. Business interruption risks have been analysed and insurance options explored, but not pursued due to high premiums. Counterparty risks for major customers have been reviewed.

A number of risks are well understood but difficult to control. The risk of major customers such as a smelter leaving Iceland may be low, but it is a possibility that can only be partially mitigated by building of a pipeline of potential customers. In the shorter term, in a poor water year the main supplier in the market (Landsvirkjun) may have limited availability, which may require maximizing ON's own generation, curtailing some customers (starting with secondary power deliveries), or purchasing in the balancing market (which can be expensive).

OR/ON are also constantly exploring a number of financial opportunities that are relevant for Hellisheidi, for example the option to insource drilling projects by purchasing a drill. The cost of this was compared to the external bids in the last major drilling tender. Similarly, different options to organize maintenance at Hellisheidi are being compared (see O-5), and a decision to save costs by changing the shift system has been taken (see O-12). On the financing side, multiple options are compared, including loans through Municipality Credit Iceland (MCI), a loan fund owned by the municipalities, and pooling borrowing with the City of Reykjavík. Regarding the Geothermal Park, the costs for providing different products to potential clients have been estimated, to guide commercial discussions which have started with 3 out of 4 interested parties.

The three owners each have to approve loan guarantees if these are required by lenders or otherwise advantageous (guarantee fees are exempt from taxes, while dividends are not). After an approval by the City of Reykjavík on a guarantee for EIB and NIB loans took a long time, an agreement has been found to work more closely together, to achieve timely decisions.

Environmental management measures are not separated out among the operational or investment costs at Hellisheidi. Many of the investments are at least partially motivated by environmental concerns. For example, investments for 2018 include ISK 150 million for further improvements to gas extraction, currently focused on producing clean CO_2 for use in the Geothermal Park. There are no special contingency funds for such measures, but they are part of the approved medium-term investment envelope.

Criteria met: Yes

7.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives relating to financial management have been and are on track to be met with no major non-compliances or non-conformances, and funding commitments have been or are on track to be met.*

There are no indications for any non-compliances with financial regulations, non-conformances with OR/ON's financial plans or management processes, or problems with debt service.

There is a long-standing, unresolved disagreement with the regulator National Energy Authority over the appropriate allocation of costs at Hellisheidi, between the regulated product (hot water) and the unregulated product (electricity). There is a generic allocation formula developed by the National Energy Authority, and one developed by OR/ON. OR's auditors have deemed the OR/ON formula appropriate, and it is being used on an interim basis, but a final decision by the National Energy Authority is pending. The lack of resolution is not a compliance issue, however.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

There are no non-compliances or non-conformances.

Criteria met: Yes

7.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *The operating geothermal facility or the corporate entity to which it belongs can manage financial issues under a range of scenarios, can service its debt, and can pay for all plans and commitments including social and environmental.*

Recent changes of ratings and outlooks by external agencies have all been positive, reflecting progress in implementing the financial recovery plan. OR is currently rated at Ba2/positive by Moody's, BB+/stable by Fitch, and i.AA3/positive by Reitun. The medium-term objective is to return to investment grade, thus lowering refinancing costs.

Positive factors from the ratings agencies' perspectives include OR's strong market position in the capital region; Iceland's strong macroeconomic environment; likely government support in case of financial difficulties; moderate dividends, as the owners' main priority is financial consolidation; high predictability of the major part of the cash flow, from regulated activities; recent positive developments of aluminium prices, exchange rates

and interest rates; and the asset base with predictable and low levels of capital investments. Negative factors included OR's still significant financial leverage; the foreign currency risk; and exposure to unregulated business and volatility in the price of aluminium.

OR/ON's finances are managed prudently, in order to be prepared for a range of scenarios. Legacy issues related to the highly risky financial conduct in the 2000s, in terms of investments, sales, and financing, are being overcome. The rate of return on ON's geothermal assets was 5.4% on electricity and 7% on hot water, according to the 2016 Financial Statements, which is comparable to the weighted average cost of capital assumed at the time of the investment decision (6.3% before tax). The profitability of the project is thus low, but this is not a gap under this criterion. Under reasonable assumptions OR will be able to service its debt and to pay for all plans and commitments related to Hellisheidi.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, the operating geothermal facility or the corporate entity to which it belongs can manage financial issues under a range of scenarios, and has optimised or is on track to optimise its market position with respect to supply and demand for energy and ancillary services.*

OR/ON are applying considerable foresight and creativity to optimising their positions in various markets. Examples are the charging stations for electric vehicles, a potentially large future market; the preparation of industrial-scale technologies to supply several products to new clients at the Geothermal Park, serving new and potentially large markets; the conclusion of a new contract with a data centre, also a rapidly growing sector; and the sale of certificates of origin for renewable energy. They aim to be market leaders in a number of new areas, as they were historically with district heating in Reykjavík.

The diversification of clients and markets will give OR/ON more options for the upcoming negotiations with its largest customer. The cost of power for Nordurál is among the lowest for any smelter in the world, so that there is a significant upside potential.

Criteria met: Yes

7.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

The original assessment of resource capacity and environmental impacts was inaccurate and uncertainties were not taken sufficiently into account, which has required substantial unforeseen and ongoing expenditure and has contributed to relatively low returns on investment.

1 significant gap

7.3 Scoring Summary

Financial management of the Hellisheidi project is fully integrated into the finances of the OR group. There are a number of financial legacy issues from the time when Hellisheidi was built, including high debt leverage and currency, interest rate, and aluminium price risks. Ongoing investments which were not originally foreseen, are required to maintain steam supply and to comply with environmental requirements, and also to develop the Geothermal Park for new clients.

With more prudent financial management, the financial position of the group has steadily improved and is expected to further improve over the medium term. In the longer term, there is considerable upside potential from the end of the contract with the main power customer. OR/ON have a good understanding of financial risks and opportunities, and are actively mitigating risks and pursuing opportunities.

There is one significant gap, resulting in a score of 4.

Topic Score: 4

7.4 Relevant Evidence

Interview:	1, 2, 12, 13, 17-19, 21, 23, 30, 31, 40
Document:	276-330
Photo:	7, 10, 14, 21, 59, 67, 69, 76-78, 95, 98

8 Project Benefits (O-8)

This topic addresses the benefits that were committed to alongside development of the geothermal facility.

The intent is that commitments to additional benefits and benefit sharing strategies are fulfilled, and that communities affected by the geothermal development have benefitted.

8.1 Background Information

Aspects covered under this topic do not include benefits that are created or necessitated by the main purpose of the facility, such as generated energy, delivered hot water, necessary access roads and transmission infrastructure. To be included under this topic, benefits also have to be additional to any mitigation and/or compensation to project-affected communities, which are addressed under O-9.

The Hellisheidi project contributes to the local/regional economy mainly through direct municipal revenues through payments of property taxes, and also pays rent to the IR sports club for a small plot of land owned by them, close to Kolvidarhóll. Some power-plants employees live in Hveragerdi, contributing to employment and tax revenue. In the future, with an improving financial status of the company (see O-7), corporate income taxes and dividends may also accrue at significant levels for the owner municipalities in the capital region.

OR/ON maintain a 110 km network of tourism trails and associated shelters in the Hengill area, which are used for hiking, biking, skiing and horse-riding by residents and visitors, and which support related businesses as well as annual races.

The project also generates income from employment and local contracts for goods and services.

The Geothermal Park is a concept devised to utilise by-products from the generation of power and hot water for innovative new enterprises. It presently consists of:

- The Carbfix project (see O-16), a collaborative research project started in 2007 and led by OR with CNRS (the French national centre for scientific research at the University of Toulouse), the University of Iceland, and Columbia University in the USA. In the 2011-14 period, the project received EU funding and added partners from Amphos21 in Barcelona, Spain, and the Nano Science centre of Copenhagen University in Denmark. The project is now in its second phase, which aims at demonstrating the economic viability of industrial-scale application. This second phase also has funding from the EU and the partners involved are OR, the University of Iceland, CNRS, Amphos 21 and the Climeworks company from Switzerland.
- Algaennovation is an Israeli company which experiments with using the CO_2, clean water and energy available at Hellisheidi to produce algae that would ultimately make food for animals and humans. Initially the aim is to produce fish food for aquaculture production.
- The GeoSilica company was founded in 2012 with support from the Icelandic Technology Development Fund. The concept is utilising geothermal water from the Hellisheidi plant. The products aim at skin, hair and nail care as well as treating osteoporosis and bone and connective-tissue injuries associated with e.g. sports injuries.

An innovation closely associated with CarbFix is the SulFix project described in more detail under O-16 as it is a mitigation measure to reduce the negative impacts of H_2S emissions. The development of the world-leading technology necessary for that project is not just a national but global benefit generated by the Hellisheidi project.

8.2 Detailed Topic Evaluation

8.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Monitoring is being undertaken to assess if commitments to project benefits have been delivered and if management measures are effective; and ongoing or emerging issues relating to delivery of project benefits have been identified.*

The benefits identified during the planning of the project mainly consist of the taxes and other fees paid to Ölfus municipality. These do not need special monitoring or management beyond regular financial management to pay fees and taxes in accordance with Icelandic Law, see also O-7. The property tax amounts to approximately 100 million ISK per year, about 7% of the municipal budget.

The ongoing and emerging issues are mainly related to the Geothermal Park and additional plans for tourism infrastructure in the area and are monitored in cooperation with, mainly, the Ölfus municipality.

ON is also leading the roll-out of fast-charging stations for electrical vehicles, mainly in the capital region, including in the two project-affected municipalities, but also around Iceland on the main national ring road.

An important and well-known issue, and the source of some discontent, is associated with the distribution of tax revenue associated with the project. The Ölfus municipality receives all property taxes from the Hellisheidi power plant as it is located in Ölfus, while the Hveragerdi municipality receives no taxes in spite of suffering a greater burden from the plant's emissions.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging issues relating to project benefits takes into account both risks and opportunities.*

The issue regarding equity in the distribution of taxes is due to the national legal/regulatory framework, as discussed under O-2. Changes in laws and regulations are monitored and evaluated at the corporate level by OR.

The Hellisheidi project has realised some opportunities in relation to the training of youth and the encouragement of choosing technical and trade careers. Together with the Arbaejarskoli in Reykjavík a programme has been developed which allows 16 students, 8 of each gender, to visit and study the power plant, geothermal energy, and technical and trade professions in general. There is also a summer-jobs programme in the land-reclamation activities for youths above the age of 17.

The maintenance of the plant (see O-5) provided an opportunity for the creation of Deilir, a local company with around 20 staff, and further expanding.

Criteria met: Yes

8.2.2 Management

Analysis against basic good practice

Scoring statement: *Measures are in place to deliver commitments to project benefits, and to manage any identified issues relating to these commitments; and commitments to project benefits are publicly disclosed.*

Measures are in place to deliver commitments to benefits, including payment of required taxes. The cooperation with Arbaejarskoli is managed cooperatively by a human resources person from ON and a representative of the school. The summer-jobs programme is managed from OR's headquarters. The tourism-related benefits, both the Geothermal Exhibition and the tourist trails, are managed from the plant. During the maintenance season,

the company employs five assistants and a manager and also use contractors for some maintenance work. Sign-posting is maintained in order to make sure tourists do not wander off-trail, causing damage to sensitive volcanic geology and flora. The potential environmental damage done by tourism is a concern to some local residents who see the plans for a large new hotel in the area as an opportunity for mitigation, as larger operations have better resources and motivation to educate its guests on responsible behaviour.

ON actively manages the development of the Geothermal Park (see also O-7). All material flows are inventoried along with the processes for utilising them. The goal is to find 5-6 commercially viable applications.

Commitments are well-known to the public, and many are either parts of municipal budgets or included in local zoning plans.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to risks and opportunities.*

The Icelandic system (which resembles that of many other countries) with most legislated benefits flowing only to the municipality in which the main structure of the project is located, inherently creates risks for community relations, as nearby communities that do not benefit from these revenue streams, can develop resentment of those who do benefit. This is seen as a significant gap but is scored under O-2 above.

In general terms, the frequent direct contacts between nearby municipalities and the project, anchored in the monthly meetings with regulators, serve to identify risks and opportunities for improvements.

Some stakeholders express a desire for ON to be more actively involved in the support of community activities, but this is an approach that been criticised in the past as OR/ON are publicly owned companies, hence should not spend money in this manner, nor should they run the risk of being perceived as “buying support” for their activities.

Criteria met: No

8.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives in place to manage project benefits have been and are on track to be met with no significant non-compliances or non-conformances, and commitments have been or are on track to be met.*

No non-conformances or non-compliances have been identified and all commitments made to the Ölfus municipality and other stakeholders have been met.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

There are no non-conformances or non-compliances.

Criteria met: Yes

8.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *Communities directly affected by the development of the geothermal facility and any other identified beneficiary of the facility have received or are on track to receive benefits.*

Both main project-affected municipalities have received benefits. Ölfus municipality is by far the greater recipient, as property taxes are only paid to the municipality in which a project is located. Hveragerdi has received and continues to receive benefits through the tourism-related initiatives in the Hengill area in general, and the Reykjadalur valley in particular. The valley and the geothermal features are the main tourist attractions in the town.

The municipalities in the capital region who are also project-affected derive some benefits from the project, but mainly in relation to the project's purposes, e.g. increased delivery of hot-water services. As an additional attraction, the Geothermal Exhibition contributes to increased tourism in the wider area, and also offers an information and education opportunity for capital-region inhabitants on geothermal energy.

The Geothermal Park and the fast-charging stations for electrical vehicles are significant benefits generated by the project and by ON in general.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, benefits are significant and sustained for communities affected by the project.*

Benefits are clearly highly significant and sustained for the Ölfus municipality, over the operation period of the Hellisheidi power plant. The situation is different for the Hveragerdi municipality. Not being a recipient of tax revenue from the power plant, the benefits are largely restricted to the tourism aspects but are still significant and sustained.

Criteria met: Yes

8.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There are no significant gaps against proven best practice.

0 significant gaps

8.3 Scoring Summary

There are significant direct and indirect benefits accruing to the main project-affected communities and also to to the wider Icelandic society. The Ölfus municipality, through the direct tax benefits, is the largest recipient of benefits and the other main project-affected community of Hveragerdi receives tourism-related benefits. There are no significant gaps, resulting in a score of 5.

Topic Score: 5

8.4 Relevant Evidence

Interview:	1, 9, 11, 14, 15, 16, 27, 32, 36, 39
Document:	104, 331-336, 501
Photo:	7, 10, 14, 67, 69, 79, 96, 97, 98

9 Project-Affected Communities and Livelihoods (O-9)

This topic addresses how impacts of development of the geothermal facility on project-affected communities have been addressed.

The intent is that livelihoods and living standards impacted by the project have been improved relative to pre-project conditions for project-affected communities with the aim of self-sufficiency in the long-term, and that commitments to project-affected communities have been fully fulfilled.

9.1 Background Information

This topic focusses on the potentially negative impacts from the project on project-affected communities and their livelihoods, and the efforts of OR/ON to avoid, minimise, mitigate and compensate those impacts. Typical negative impacts of geothermal plants on project-affected communities include emissions to air and water, both surface and groundwater, and impacts on local businesses and their employees. Many of these businesses are associated with the tourism sector. The EIAs for the Hellisheidi plant identified aesthetic impacts, an important aspect as Icelandic citizens put a very high importance on both protection of, and access to, wilderness. The issue mainly concerns the pipelines, but also the plant itself and necessary new or reinforced roads to the wellfields. Impacts on the tourism sector were assessed as both positive and negative, but the negative impacts were expected to be overshadowed by the positive. The EIAs did not identify H_2S emissions or induced seismicity as significant impacts.

A number of other topics relate to the issue of impacts on project-affected communities. Public health and safety impacts are covered in O-6, and O-8 focusses on potential positive impacts. If people had needed to be physically relocated because of the project, and if indigenous people had been affected, O-10 and O-11 would have been relevant. This is not the case for the Hellisheidi project. Impacts on ON/OR staff are covered under O-12, impacts on cultural heritage under O-13, and the physical changes that can affect local communities under topics O-15 (seismicity and subsidence) and O-16 (emissions).

The municipalities that are most affected by the project are Ölfus and Hveragerdi. The Hellisheidi power plant is located in Ölfus, but the town of Hveragerdi is the nearest settlement to the plant.

Ölfus is a large municipality with an area of 737 km^2, and an approximate population of 2,000 people out of which around 1,500 live in the municipality seat, Thorlákshöfn. The population density is low at approximately 2.7 inhabitants/km^2. The main economic activities are the fish-processing plants, the port and tourism.

The Hveragerdi municipality is, by contrast, very small. It encompasses only the town with the same name, and not even all residents of the settlement reside inside the municipality border. The area is 9 km^2, population around 2,500 and the population density 276 inhabitants/km^2, or 100 times that of Ölfus. The main economic activities are horticulture (utilising geothermally-heated greenhouses) and recreation and tourism, centred on the hot springs and geothermal area in the town as well as a popular hiking destination, Reykjadalur, north of the town.

Other affected municipalities include the seven located in the capital area with a combined population of over 200,000 or two thirds of the entire country's population. These seven, together with a number of additional municipalities located near the capital region, are sometimes affected by H_2S from the Hellisheidi plant. Reykjavík, Akranes and Borgarbyggd municipalities are the owners of the OR group, hence potentially affected by the financial results of the group. This relationship is covered under O-2, O-7 and O-8.

9.2 Detailed Topic Evaluation

9.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Monitoring is being undertaken to assess if commitments to project-affected communities have been delivered and if management measures are effective; and ongoing or emerging issues that affect project-affected communities have been identified.*

Monthly meetings are held with the two key affected municipalities and the regulators at the Hellisheidi power plant where any issues can be discussed, emerging issues identified and necessary management measures agreed upon.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging issues for project-affected communities takes into consideration both risks and opportunities, and interrelationships amongst issues.*

Monitoring of identified issues is comprehensive (see O-15 for monitoring of induced seismicity and O-16 for monitoring of air emissions). The inter-relationship between the need for reinjection of separated geothermal water and the induced seismicity is well understood. A programme to determine where and how H_2S emissions reach the community in Hveragerdi is about to be started. This will hopefully result in a better understanding of cause and effect, and provide a basis for future discussions between the project and the affected community.

The staff managing the tourist trails follow developments along the trails closely and respond to needs for improvements in order to sustain the tourists' appreciation of the area.

The community liaison officer is in regular contact with the communities as needed and the monthly meetings serve the need for identification of emerging risks and opportunities.

Criteria met: Yes

9.2.2 Management

Analysis against basic good practice

Scoring statement: *Measures are in place to deliver commitments to project-affected communities, and to manage any identified issues relating to these commitments; and if there are any formal agreements with project-affected communities these are publicly disclosed.*

The monthly meetings at the plant allow stakeholders to talk to each other, which is of the utmost importance as the different perspectives of the Hveragerdi and Ölfus municipalities on the project need close attention and proactive management by ON.

The planned initiative to investigate H_2S background values in Hveragerdi town is long overdue but will help establish the actual impact caused by the emissions from the Hellisheidi plant.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to risks and opportunities.*

The monthly meetings allow issues to be identified, as well as a joint evaluation of risks and opportunities.

OR/ON support recreation and tourism in the Hengill area through a network of hiking trails they have established and now maintain. The trails were started as mitigation for the construction of the Nesjavellir plant, to encourage people to use the area and to show that power generation was compatible with recreation. There is also an educational trail around the Nesjavellir plant, and the trail system includes the highly popular tourist destination of Reykjadalur, north of Hveragerdi. There are tourism operators in the town that utilise these trails for their business. Important historical/cultural and geological features (such as cairns, craters and hot springs) have been identified and restored (for example, from previous impacts of road construction unrelated to the project), and the project has cooperated with the municipalities to have them included in local plans for protection.

Criteria met: Yes

9.2.3 Stakeholder Engagement

Analysis against basic good practice

Scoring statement: *Ongoing processes are in place for project-affected communities to raise issues and get feedback.*

Community representatives unanimously attest to well-functioning communication processes, including feedback on issues raised. ON staff members at the plant are the principal contact point.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, feedback on how issues raised are taken into consideration is thorough and timely, and project-affected communities have been involved in decision-making around relevant issues and options.*

A clear majority of interviewees consider ON's feedback as both thorough and timely. However, not everybody residing in the Hveragerdi community is equally satisfied, and there are some indications of an unsatisfactory information flow and understanding concerning a number of relevant issues, and a perceived lack of involvement in decision-making. Examples of such issues include: H_2S emissions and their seriousness; induced seismicity risks and their seriousness; the purchase of the hot water utility in Hveragerdi (operated by ON's sister company Veitur); and differences in expectations surrounding e.g. a potential hot-water pipeline to Thorlákshöfn.

There is no effective process for project-affected communities to be involved in decision-making on relevant issues. This is a **significant gap.**

Criteria met: No

9.2.4 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives in place to manage delivery of commitments to project-affected communities have been and are on track to be met with no significant non-compliances or non-conformances, and commitments have been or are on track to be met.*

There are no significant non-compliances or non-conformances identified at the time of the assessment.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

All commitments, processes and objectives are met without non-compliances or non-conformances.

Criteria met: Yes

9.2.5 Outcomes

Analysis against basic good practice

Scoring statement: *Livelihoods and living standards impacted by the project have been or are on track to be improved; and economic displacement has been fairly compensated, preferably through provision of comparable goods, property or services.*

The project has not resulted in any identified economic displacement.

The impacts on livelihoods and living standards show significant differences between different communities. The Ölfus municipality report significant improvements while all other municipalities, principally Hveragerdi, consider the comfort- and odour-related impacts from the H_2S emissions to be significantly negative. As Hveragerdi is located in a very active geothermal site and the baseline H_2S concentration was not established by the EIA, it is difficult to ascertain what the net negative impact from the project really is. A study about to be started should establish this in the near future. The SulFix project described under topic O-16 has gradually reduced the impact, and the continued increase of the fraction of H_2S that is reinjected will further reduce any negative impacts experienced by the communities, both Hveragerdi and the more distant ones in the capital area.

Communities in the capital region, and notably including the Reykjavík Public Health Authority, express concerns with the odour and comfort impacts caused by the H_2S emissions from the plant. The pressure to reduce emissions as fast as ever possible is strong.

The communities of Hveragerdi and Selfoss both express concerns regarding the induced seismicity initially caused by the reinjection of the separated geothermal water from the project. This impact has been addressed in cooperation between the project, the concerned communities and the National Energy Authority, and is covered under O-15.

Livelihoods and living standards in Iceland, mainly the south-western part, have been improved by the project, but not without also causing significant issues and there are individuals who feel that their quality of life has been negatively affected. This is not considered as a significant gap at this level of scoring.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, the measures put in place to improve livelihoods and living standards are on track to become self-sustaining in the long-term.*

The overall improvements to Icelandic livelihoods and living standards created by the project are on track to be self-sustaining.

This is, however, not the situation for all residents in the Hveragerdi municipality. Hveragerdi interviewees consider the project to have a small economic impact on their community, with improvements to some residents' livelihoods due to employment at the plant or because of additional visitors to the area related to the plant and the Hengill trails (see O-8). However, others are concerned about impacts on the reputation of Hveragerdi as a spa town, where people go for recreation and health treatments. There is no analysis conducted of the project's potential to improve local livelihoods and living standards in the long term. The uncertainties around positive livelihood outcomes for parts of the community in Hveragerdi constitute a **significant gap**.

Criteria met: No

9.2.6 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There is no effective process for involving project-affected communities in decision-making on relevant issues.

There are uncertainties around positive livelihood outcomes for parts of the community in Hveragerdi.

2 or more significant gaps

9.3 Scoring Summary

Most project-affected interviewees express satisfaction with the overall impacts of the project and ON's management of these. The Ölfus municipality has experienced a considerable improvement in revenues, and livelihoods and living standards in the capital region are also improved, even if the negative impacts from H_2S emissions are considered significant by most residents there.

The lack of effective processes for involving communities in decision-making on relevant issues, as well as the concerns about Hveragerdi's reputation which could impact livelihoods, constitute two significant gaps against proven best practice, resulting in a score of 3.

Topic Score: 3

9.4 Relevant Evidence

Interview:	11, 14, 15, 16, 20, 29, 30, 32, 36, 39
Document:	104, 332-336, 501
Photo:	97, 99

10 Resettlement (O-10)

This topic addresses how the physical displacement arising from development of the geothermal facility has been addressed.

The intent is that the dignity and human rights of those physically displaced have been respected; that these matters have been dealt with in a fair and equitable manner; that livelihoods and standards of living for resettlees and host communities have been improved; and that commitments made to resettlees and host communities have been fully fulfilled.

This topic is not relevant in the case of the Hellisheidi project, because the population density in the project area is very low and the project was able to avoid any physical displacement of people.

11 Indigenous Peoples (O-11)

This topic addresses the rights, risks and opportunities of indigenous peoples with respect to the geothermal facility, recognising that as social groups with identities distinct from dominant groups in national societies, they are often the most marginalized and vulnerable segments of the population.

The intent is that the operating facility respects the dignity, human rights, aspirations, culture, lands, knowledge, practices and natural resource-based livelihoods of indigenous peoples in an ongoing manner throughout the project life.

This topic is not relevant in the case of the Hellisheidi project, because the native Icelandic population is considered homogenous, with no ethnic minorities.

12 Labour and Working Conditions (O-12)

This topic addresses labour and working conditions, including employee and contractor opportunity, equity, diversity, health and safety.

The intent is that workers are treated fairly and protected.

12.1 Background Information

Iceland's labour market is characterized by a high participation rate and high demand for labour, with an unemployment rate of 3%. There is a strong general awareness of labour rights and a high proportion of trade union membership, at around 85%. Collective bargaining between unions and/or their federation (Icelandic Confederation of Labour, ASÍ) on the one side, and companies and/or the Confederation of Icelandic Employers (SA) on the other hand, cover most employment contracts.

OR has a total of 510 employees (357 men and 153 women), while ON has 75 employees (60 men and 15 women). The largest division within ON is Power Plant Operations, with 45 positions (some of which are vacant). Additionally, a number of contractors have staff at the Hellisheidi plant (currently mainly drilling and maintenance contractors), and there is a small but potentially growing number of staff working for businesses associated with the power plant, such as GeoSilica and Algaennovation.

Some of the occupational health and safety (OH&S) risks associated with a geothermal project are regular construction and electrical industry risks. In addition, there are specific risks associated with working outside, particularly in winter conditions, and with the specific characteristics of geothermal energy, particularly with gas emissions, drilling, high pressure and high temperatures.

12.2 Detailed Topic Evaluation

12.2.1 Assessment

Analysis against basic good practice

Scoring statement: *A periodically updated assessment has been undertaken of human resource and labour management requirements for the operating facility, including occupational health and safety (OH&S) issues, risks, and management measures, with no significant gaps; monitoring is being undertaken to assess if management measures are effective; and ongoing or emerging labour management issues have been identified.*

Human resource issues are monitored and evaluated on an ongoing basis by OR's Human Resources unit, for individual staff, work units, subsidiaries, and the entire OR group. Some indicators are tracked through periodic reviews by external specialists. For example, job satisfaction is surveyed by MMR each December, with 60 or 20 questions in alternating years. The overall index increased from 4.12 in 2013 to 4.39 in 2016 and has been consistently above the Icelandic average (4.07 in 2016), and compares well with other companies in the power and utilities sector. However, satisfaction in ON's Power Plant Operation department has dropped to 3.91, and is even lower in the operators' unit, with 3.36 (see below under Stakeholder Engagement).

Regarding gender equality, the 'unexplained' gender wage gap came down from 8.4% in 2008 to -0.1% in 2018. These data are externally verified by PWC, and OR has received the 'Golden Seal' in these PWC Equal Pay audits for several years in a row. Achieving pay equality has been supported by an internal pay analysis work procedure. The percentage of female managers has increased from 17% in 2005 to 49% in 2018, and 45% of board members at OR and its subsidiaries are now female.

OH&S is another focus of continuous monitoring and evaluation, on the basis of systematic reporting of issues. A specific OH&S database is used since 2013 to record dangerous conditions, procedures, work environment and equipment, as well as near accidents and accidents. Entries can be made by each staff member (in fact, a new KPI is that each staff member should enter at least five observations per year) and are quality controlled. There are currently 193 entries from the Power Plant Operations department. The database has proven very valuable and is now also used to track health, environment and information security. All data are easily accessible and indicators are displayed through 'dashboards'. OH&S indicators include a new summary Safety Index which allows tracking of conditions at each work site over time. Safety measures increase the index value, while incidents (including such incidents as missing a weekly safety meeting) decrease it.

Additionally, OH&S issues that are considered systemic (such as the risks from H_2S exposure) are entered into the operational risk database, together with analyses of incidents.

Some OH&S risk appraisal methods include risk assessments for individual assets or work procedures. Regular management safety walks are conducted, and safety observations entered into DMM where they are automatically prioritized and turned into work orders.

For major individual projects, indicators such as lost-time incidents are also tracked. For example, the last major project at Hellisheidi, the construction of the steam system for the Hevrahlíd expansion, with over 700,000 work hours, was achieved without lost-time incidents.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging labour management issues takes broad considerations into account, and both risks and opportunities.*

There are multiple examples of assessments that take broad considerations into account.

The scope of the surveys among employees is very broad, with up to 60 questions, and allows detailed analysis over time and by work unit. It has shown, for example, that while satisfaction with equal opportunities has gone up in the OR group overall, it has slightly declined in ON.

OR has introduced a new analysis tool, which allows prediction of the pay equality impacts of different remuneration decisions for individuals and groups.

Regular voluntary health assessments of all staff are conducted by an external company (Vinnuvernd ehf) and in collaboration with the Administration of Occupational Health and Safety (Vinnueftirlit). The last assessment in the spring of 2017 expanded the scope and had a focus on mental health.

External experts are regularly brought in to support work safety and where appropriate, they are provided with OR's risk analysis approach so that their analyses are compatible. Some examples from 2017 include:

- The fire alarm system was last appraised by Securitas in October 2017.
- Verkís conducted a generator fire and explosion risk assessment in November 2017.
- A contract with Vedurvaktin (Weather Watch) was concluded in January 2017 to provide warnings on weather conditions that could affect operations (including indirectly, for example through increased H_2S concentrations).
- The last insurance audit in August 2017 included work safety observations, including on fire risks. Most of the observations were previously known and had been assessed and approved; for example a temporary wooden partition wall.

Another example for broad considerations was support for an academic study that found a significant relationship between internal CSR (employee related), external CSR (customer, local community and business partner related), and the motivation of employees.

12.2.2 Management

Analysis against basic good practice

Scoring statement: *Human resource and labour management policies, plans and processes are in place to address all labour management planning components, including those of contractors, subcontractors, and intermediaries, with no significant gaps.*

OR/ON's human resource and labour management are guided by Icelandic labour laws as well as a number of corporate policies. Policies at OR and ON are equivalent. There is an overall human resources policy and specific policies on remuneration and other terms of employment, equal rights, OH&S, and workplace harassment, all supported by relevant procedures and KPIs. The surveys and appraisals mentioned above under Assessment, are followed up in a systematic way.

For example, for equal rights and in particular gender equality there is a committee with its own procedures, annual reports and action plans, to implement the company's own policy and to ensure compliance with the Act on Equal Status and Equal Rights of Women and Men No. 10/2008, as well as subsequent legislation, including a new law from 2018 that requires employers to demonstrate equal pay. The 2017/2018 action plan includes a broad range of actions regarding wage equality, recruitment, career development, board membership, gender stereotypes, family-friendly workplace, sexual harassment and bullying, and attitudes and knowledge. There is still a strong imbalance at the level of power plant operators, who are almost exclusively male.

OH&S is another priority. The policy emphasises that everybody is responsible for their own safety, and managers are responsible for the safety of their team. The group's OH&S unit act as advisers and trainers, and provide data and analysis. Work units appoint safety officers and there are four safety committees in OR, including elected workers' representatives; one of these covers ON's power plants. The general approach is that no unsafe work is allowed. Even jobs that are often considered dangerous, such as drilling, can be made safe with the appropriate work procedures and safety behaviour. In recent years emphasis has been on changing the safety culture, moving towards behaviour-based safety, and looking after other people's safety as much as on one's own safety.

There is a range of practical management measures:

- Frequent and regular safety-specific meetings at all levels (additionally, safety is regularly addressed at other meetings)
- Safety protocols and contingency plans for specific kinds of work and specific sites
- Preparing individual work orders with safety checklists and hazard assessments
- Evacuation plans with alarms, signage, assembly areas
- Standardized reporting and follow-up procedures for safety observations
- PPE including personal H_2S warning devices
- Defibrillators, breathing masks and other emergency equipment
- First aid courses and first aid station in powerhouse
- Hearing protection talks
- Contract for support by Árnessýsla fire brigade
- Emergency procedures, including communications channels
- Lock-and-Label procedure for work on dangerous equipment
- Rules to always work in pairs in dangerous areas
- Remote camera supervision

The personal warning devices ensure that workers receive warnings before they reach the personal H_2S exposure limits of 5 ppm as the 8-hour average, and 10 ppm as the 15-min average. In the past, a few workers and contractors have disregarded H_2S safety protocols, and two people have fainted. An elevated H_2S concentration

in a part of the plant occurred during the site visit for this assessment, and the source was identified with portable gas detectors.

All contractors that work for the OR group are required to follow its safety handbook and/or provide their own, equivalent handbook. Contractor staff are offered safety courses, which since 2016 are delivered by an external training provider. Contractors and related businesses with staff on site (e.g. GeoSilica) confirmed that they are fully integrated into OR/ON's work safety processes. Many contractors are in the plant for longer periods of time. In fact, after an accident of a contractor during repairs on a cooling tower, the courts ruled that OR/ON's insurance company had to pay for health care and work loss, as the long employment time on site gave him the same rights as those of an employee.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities.*

The work satisfaction surveys are providing insights into multiple components of satisfaction, many of which can be addressed in operational decisions (for example, the costs and benefits of outsourcing maintenance vs. keeping that capacity and competence in-house).

Shift work and long working hours in operations has been identified as an obstacle to recruiting younger workers, as well as a source of safety hazards. Analysis has shown that it is acceptable to not require continuous presence at the power plant (see O-5), and changes to shift schedules have been decided to foster a safer and more family-friendly work environment. This is further discussed under Stakeholder Engagement below.

Health assessments and work satisfaction surveys have resulted in an increased focus on employee health. OR is now offering multiple health activities, including workplace massages, fitness classes in OR's own gym and a personal trainer, mindfulness courses; and staff can apply for grants for physical training and for sustainable transport, which includes cycling and walking to work.

Safety managers from the different power and utility companies in Iceland (organized in Samorka) meet regularly to share lessons learnt and discuss new safety protocols and technologies. There are examples for approaches that OR adopted from the other participants, and vice versa. One opportunity identified through cooperation with Landsvirkjun is an app for easy reporting of safety incidents and observations, which will be further improved. Quantitative benchmarking is also undertaken but is not strictly comparable between companies.

Criteria met: Yes

12.2.3 Stakeholder Engagement

Analysis against basic good practice

Scoring statement: *Ongoing processes are in place for employees and contractors to raise human resources and labour management issues and get feedback.*

There are various options for employees to raise issues. Periodic 'employee conversations' between employees and their direct managers are the primary option. A key part of these conversations is discussing career objectives, skills development and training, which OR/ON will normally support (financially and in terms of absence from work). There are guidelines and training for managers on conducting these conversations. Other options include the Human Resources unit and, in sensitive cases, an external psychologist.

Most staff are trade union members, and OR negotiates collective agreements with eight unions. The union representatives are known to their members, and they are also available on the intranet, as well as links to the different unions and collective agreements. The union representatives are another option for staff to raise issues, and are generally involved in discussing operational changes.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, feedback on how issues raised have been taken into consideration has been thorough and timely.*

In general, as can be seen from the surveys and interviews, OR/ON staff are increasingly satisfied with workplace communication and feedback on issues raised. The operators unit is also satisfied with material work conditions (tools, work clothing, food etc.). However, overall satisfaction in the operators unit has been low. There are some explanations for this drop, including some personal conflicts and reports of bullying. However, the most relevant issue appears to be the change in shift schedules which will take effect shortly and will reduce night and weekend shifts, which provided significant extra pay for the operators. Instead operators will be more frequently at home on call, and are expecting an overall pay reduction.

A number of discussions were held about this change with the unit, and ON offered a number of compromises including reducing the length of regular shifts and reducing the pay gap between shift work and on-call time (resulting in an increase in pay per hour worked), and a 6-month adjustment period. Nevertheless, a number of workers have left or are considering leaving. One factor that contributed to dissatisfaction was the unnecessarily long uncertainty, and the impression on part of some of the workers that their concerns were not taken into account. The intention to change shift schedules was first discussed about 2 years ago, but decisions were delayed because of an organizational audit and a change in the manager of operations position. Feedback to workers during this time was insufficient, which is a **significant gap** against proven best practice. After the process of changing the shift plan started again in June 2017, there has been active engagement with shift workers over the upcoming changes.

Criteria met: No

12.2.4 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives relating to human resource and labour management have been and are on track to be met with no major non-compliances or non-conformances, and any labour related commitments have been or are on track to be met.*

The Administration on Occupational Health and Safety does periodic site inspections, but in companies with strong safety records such as OR/ON, focuses on machinery such as cranes, forklift trucks and pressure vessels. No observations have been made recently.

Similarly, the Environmental and Public Health Authority of South Iceland which is among other things, responsible for hygienic working conditions and food safety, considers the power plant to have high standards and has had no observations regarding working conditions recently.

No other non-compliances with any labour-related regulations have been identified.

The aspirational goal of OR is to have zero accidents (for workers, contractors, and members of the public). As this is almost impossible to meet, indicators are frequently outside the target zone, but this is not considered a non-conformance. For example, the newly introduced Safety Index fluctuated strongly in 2017, as three incidents lowered the value into the red zone of below 400. The most serious incidents in 2017 were a finger injury from a sledgehammer, a snowmobile accident from hitting a rock, and a burn from steam. In each case, corrective action was taken to avoid repeat accidents; for example in the case of the finger injury, a hydraulic wrench was purchased. Internally, safety managers use standard indicators such as lost-time incidents per million work-hours, across all of OR (incident numbers for ON are too low to be meaningful). This indicator has come down gradually (at the end of 2016 it stood at 7.8) and has now plateaued.

OR is certified in accordance with OHSAS 18001:2007 and audited twice yearly.

Other objectives, such as employee retention and satisfaction, have been met with the exception of the power plant operations team, but this is discussed above (Stakeholder Engagement).

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

No non-compliances or on-conformances have been identified. A workers' safety representative at Hellisheidi had not yet completed the required introductory course with the Administration on Occupational Health and Safety, but this is in the process of being corrected.

Criteria met: Yes

12.2.5 Outcomes

Analysis against basic good practice

Scoring statement: *There are no identified inconsistencies of labour management policies, plans and practices with internationally recognised labour rights.*

Iceland has ratified all 8 fundamental conventions of the International Labour Organization (ILO). These labour rights are embedded in laws, regulations, collective bargaining agreements, and individual employment contracts, and there are no indications of any inconsistencies in the Hellisheidi project.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, labour management policies, plans and practices are demonstrated to be consistent with internationally recognised labour rights.*

There is no separate analysis of consistency. While this a gap, it is not significant given the high standards of labour rights in Iceland. OR/ON achieve high marks on labour satisfaction, work safety, and non-discrimination.

Criteria met: Yes

12.2.6 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

Feedback to workers before the process to change shift schedules started again in June 2017 was insufficient, which has contributed to some dissatisfaction and departures in the operations team.

1 significant gap

12.3 Scoring Summary

The OR group aims to be an attractive and competitive employer, and employees generally report high rates of job satisfaction. There are comprehensive systems of analysis and management of labour issues. From the point of view of OR/ON employees, changes in the safety and gender culture of the company have been some of biggest shifts, and quantitative indicators show low accident rates and a remarkable elimination of the pay gap

between men and women. There is some dissatisfaction in the unit operating the Hellisheidi plant, linked to insufficient engagement while a change in shift schedules was being prepared. This is a significant gap, resulting in a score of 4.

Topic Score: 4

12.4 Relevant Evidence

Interview:	3, 4, 10, 12, 13, 23, 27, 43, 44, 47
Document:	259-261, 266, 272, 274-275, 337-402
Photo:	5, 47, 51, 60-65, 72-75, 83-91, 93

13 Cultural Heritage (O-13)

This topic addresses cultural heritage, with specific reference to physical cultural resources, associated with the geothermal facility.

The intent is that physical cultural resources are identified, their importance is understood, and measures are in place to address those identified to be of high importance.

13.1 Background Information

According to Act no. 80/2012, cultural heritage includes evidence of the nation's history such as archaeological heritage, cultural landscape, church relics, memorials, buildings and other structures, ships and boats, art relics and utensils. Minjastofnun, the Cultural Heritage Agency, is tasked with the protection of cultural heritage. All archaeological sites, artefacts, and buildings 100 years or older, as well as others assessed on a case-by-case basis, have protected status.

The Hellisheidi area is at an elevation of 260-600 m and therefore too high to establish permanent farms and settlements. Cultural relics found in the area are primarily historic trails between the Reykjavík area and the south coast with shelters, cairns, and remains of a homestead and guesthouse at Kolvidarhóll.

13.2 Detailed Topic Evaluation

13.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Ongoing or emerging cultural heritage issues with respect to physical cultural resources have been identified, and if management measures are required then monitoring is being undertaken to assess if management measures are effective.*

OR commissioned a number of studies during the preparation of the Hellisheidi project, starting in 1997. Among these were several archaeological surveys as well as related studies on geological features and landscape value. These were summarized in the EIAs (see O-3), which stated that the Hengill region had an unusual amount of cultural remains for Icelandic highlands, because of its close proximity to coastal settlements and use for summer grazing and transport. Additional surveys and/or EIAs were conducted for additional wellfields, such as Gráuhnúkar and Hverahlíd. No concerns were raised that known cultural remains would be at direct risk from the development.

A small number of cases were identified where a pipe or cable would cross a historic trail, or another component of the plant would be close to a cairn or similar feature. In these cases, consultation with the Cultural Heritage Agency would be required to define mitigation measures in detail. There is no need for specific monitoring beyond construction supervision.

The surveys were taken into account in the site plans which are developed with the municipality of Ölfus. These contain the locations of all cultural remains, and it is thought that the most detailed cultural heritage surveys in the municipality have probably been on OR's land. Ölfus has access to all reports prepared for OR and is reportedly planning a survey for the entire municipality, which will benefit from the project surveys.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging cultural heritage issues takes broad considerations into account, and both risks and opportunities.*

At Kolvidarhóll, there was a refuge hut and later a guesthouse between 1844 and 1977, as well as a graveyard. The remains are surrounded by power plant infrastructure. While they are protected from direct impact, as defined in the EIA, the impression of a historical site is partially lost, which would probably not be acceptable today. Also, excavation of at least part of the site would probably be required today and is considered a missed opportunity by the Cultural Heritage Agency. This is an ongoing cultural heritage issue that cannot be changed now, but is not considered a gap, as this was accepted practice at the time, and OR/ON have identified various initiatives to promote the Kolvidarhóll site (see under Management).

In a broader sense, OR/ON through their support for the Hengill trail network (see O-8) have identified an opportunity to make cultural heritage much more accessible. The trail maps and signs identify sites of particular cultural interest.

Criteria met: Yes

13.2.2 Management

Analysis against basic good practice

Scoring statement: *Measures are in place to manage identified cultural heritage issues.*

In their Code of Ethics, OR/ON have defined a general responsibility of all their employees to respect cultural heritage.

During construction works, ON informs and/or supervises contractors to ensure that cultural heritage mitigation measures are implemented, where necessary.

ON maintains the Kolvidarhóll homestead by painting and repairs when needed, mowing the lawn etc. There was also a special exhibition on Kolvidarhóll at the Hellisheidi Geothermal Exhibition at, and an interactive display was included in the permanent exhibits until recently, when it was taken out because of technical reasons. An update is under preparation by a media studio.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities.*

When the plant is expanded (for example, by connecting new wellfields), the Cultural Heritage Agency, municipality and other agencies are involved for prior review, site visits and approvals. The latest planned expansion of the Hellisheidi plant, the Resource Park, is located to the west of the access road to the plant, and will have no impact on Kolvidarhóll. The site plan is currently undergoing public consultation and review by the Planning Agency. No other emerging risks or opportunities are known.

Criteria met?

13.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives in place to manage cultural heritage issues have been and are on track to be met with no significant non-compliances or non-conformances, and cultural heritage related commitments have been or are on track to be met.*

The Cultural Heritage Agency has a well-defined role in the approval of works in Iceland and has been consulted by OR/ON before the development of each new wellfield and other greenfield developments. Where required by the Agency, archaeological surveys were done. There has been no further engagement with the Agency in recent years.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

There is a minor non-compliance in that a stone wall which is older than 100 years and therefore protected, was damaged by a contractor. Although this was noticed and commented upon by the representative of the Cultural Heritage Agency, the damage has not been rectified at this stage. There may have been a communications issue and the message may not have been clearly received, but nevertheless this is seen as a **significant gap**.

Criteria met: No

13.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *Negative cultural heritage impacts arising from activities of the operating geothermal facility are avoided, minimised, mitigated and compensated with no significant gaps.*

With the exception of the Kolvidarhóll homestead with the visual impacts addressed above under Assessment, and the damage to the stone wall addressed above under Compliance/Conformance, there are no reports of negative impacts.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, where opportunities have been identified, measures to address cultural heritage issues beyond those impacts caused by the facility have been or are on track to be achieved.*

One observation from the Cultural Heritage Agency is that the multiple archaeological surveys have not been pulled together to present one comprehensive report of the area. However, it is unclear whether this has been discussed as an opportunity with OR/ON.

As described above, the trail network has made cultural heritage in the Hengill area more accessible, the Kolvidarhóll homestead is being maintained by ON, and there are plans to re-introduce cultural heritage elements into the Geothermal Exhibition.

Criteria met: Yes

13.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

Damage to a protected historic stone wall by a contractor was notified to ON, but has not yet been rectified.

1 significant gap

13.3 Scoring Summary

The Hellisheidi project is not located in an area with major cultural heritage values. The mitigation measures required in the EIA and in subsequent reviews of expansions by the Cultural Heritage Agency have been implemented, but there has been no pro-active engagement with the Agency. A number of opportunities have

been identified to make cultural heritage more accessible to visitors of the area. There is one minor non-compliance which is considered a significant gap, resulting in a score of 4.

Topic Score: 4

13.4 Relevant Evidence

Interview:	6, 15, 33
Document:	403-417
Photo:	97

14 Biodiversity and Invasive Species (O-14)

This topic addresses ecosystem values, habitat, species and specific issues such as threatened species in the geothermal development areas and surrounding, as well as potential impacts arising from pest and invasive species associated with the operating geothermal facility.

The intent is that there are healthy, functional and viable aquatic and terrestrial ecosystems in the area that are sustainable over the long-term; that biodiversity impacts arising from the operating geothermal facility are managed responsibly; that ongoing or emerging biodiversity issues are identified and addressed as required; and that commitments to implement biodiversity and invasive species measures are fulfilled.

14.1 Background Information

Iceland's ecosystems are comparatively young, as the country was entirely covered by ice until the end of the last ice age around 10,000 years ago. Together with the country's geographic isolation in the north Atlantic and the climatic conditions (sub-arctic to tundra), this has resulted in ecosystems with relatively few native species (e.g. 1 land mammal – the arctic fox, 6 fish, 75 breeding birds and around 1,400 insects). Ecosystems are diverse but relatively simple, in terms of communities and food-webs. Since human settlement started in the late 9th century, the indigenous biodiversity has been affected by deforestation, overgrazing and, as a result, large-scale erosion. There is some biodiversity specifically associated with geothermal surface manifestations, including vegetation, invertebrates, and micro-organisms but the area around the project does not have the richness in geothermal surface manifestations common in many places in Iceland.

About 21% of Iceland's land area is protected and the area near the Hellisheidi project is home to the country's first national park, Thingvellir, only about 10 km to the north, and one of Iceland's two UNESCO World Heritage sites. There is also a country park or "common" ("fólkvangur" in Icelandic) to the west and south-west of the project site. The UNESCO classification of Thingvellir is done on cultural and historic basis, and not for reason of biodiversity conservation.

The topic of Biodiversity and Invasive Species is closely linked to the reclamation of disturbed areas. That aspect is covered under topic O-3, above.

14.2 Detailed Topic Evaluation

14.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Ongoing or emerging biodiversity issues have been identified, and if management measures are required then monitoring is being undertaken to assess if management measures are effective.*

The Environmental Impact Assessment procedures for the components of the Hellisheidi plant were undertaken in several steps, see under O-3.

The biodiversity-related impacts predicted in the EIAs were principally construction-related, mainly disturbance to bird populations from noise. Excavation-related impacts to vegetation was also identified as a negative impact, in this case partially permanent. The significance of both these impacts was judged as low. Apart from this, the limited footprint of the project (see above in the Project Description) together with the lack of any identified sensitive areas and/or species in the impact areas meant that the EIAs did not register any serious concerns. The EIAs and the Planning Agency's review and decision resulted in limited biodiversity monitoring. The main aspect monitored and evaluated is vegetation changes, focussing on mosses as these were judged most sensitive,

especially to H_2S emissions. Some studies of other aspects have also been implemented, some by international universities from e.g. the UK, USA and Denmark in cooperation with Icelandic academic institutions. One significant example is the temperature-dependency of aquatic biota in geo-thermally affected water courses. Several studies of bird populations were implemented by Icelandic experts as part of the EIA. Further, inventories of thermophilic plants and microbes living in, and adapted to, high-temperature areas, often also subjected to geo-thermal gas emissions, were conducted in 2002 and 2006 by Icelandic experts, also as a part of EIA-related work. There has also been a study on changes to micro-organism communities in the Hellisheidi geothermal reservoir, investigation whether reinjection has any impacts. No negative impacts could be conclusively identified.

Invasive species, which are a significant issue on Iceland in general, are not a problem in the area affected by the project.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging biodiversity issues takes into account both risks and opportunities.*

The regular monitoring is designed to capture any emerging risks, and the approach most often adopted by the Icelandic power sector of utilising external and independent experts for monitoring provides independence from the project and its owners and an additional process for the identification of emerging risks and opportunities.

Cumulative impacts are difficult to assess and address, as there is limited scientific knowledge about the floral and faunal communities affected. This is an issue that can only be addressed by further research into these fields and is not considered a gap against the scoring statement.

Criteria met: Yes

14.2.2 Management

Analysis against basic good practice

Scoring statement: *Measures are in place to manage identified biodiversity issues.*

Vegetation monitoring is conducted every five years with the first campaign conducted in 2012 (reported in 2013) and the second in 2017. The report from this second monitoring campaign will be published during 2018. Apart from the monitoring, no other issues requiring management have been identified. The monitoring programme is outsourced to competent outside agencies such as the Icelandic Institute of Natural History and the Agricultural University of Iceland.

Apart from the monitoring and the related reporting and evaluation of results, the only other biodiversity issue identified as needing management was the impact on a wetland at Ellidakotsmyrar. As a response to the first EIA, the Planning Agency required OR to recover an equal amount of wetland in south-west Iceland as the project would affect. This was done through the restoration of wetlands at Ulfljotsvatn close to the Nesjavellir power plant.

OR's land ownership in protected areas as well as protected species present in operation areas are listed as appendices in the annual Environmental Report.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities.*

As described above under Assessment, a tailor-made monitoring programme is in place and implemented by external agencies. This is an adequate approach to identify issues. The well-staffed Environmental Affairs unit of OR together with plant staff in ON's Power Plant Operations group are fully qualified to use the monitoring results for anticipation of emerging risks and opportunities, and devise suitable responses.

The land reclamation efforts are carried out with only indigenous species and will strengthen the indigenous flora by revegetation of considerable areas previously devoid of vegetation due to past land disturbance and erosion.

Criteria met: Yes

14.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives in place to manage biodiversity issues have been and are on track to be met with no significant non-compliances or non-conformances, and biodiversity related commitments have been or are on track to be met.*

The regulators report no non-compliances, nor non-conformances and all biodiversity-related commitments, i.e. monitoring programmes, have been and are on track.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

There are no non-compliances, nor any non-conformances.

Criteria met: Yes

14.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *Negative biodiversity impacts arising from activities of the operating facility are avoided, minimised, mitigated, and compensated with no significant gaps.*

The outcomes in terms of land reclamation are described above under O-3.

There have been no unpredicted biodiversity impacts that have emerged over the time of operation, thus far.

The evaluation of the monitoring of the mosses' response to air emissions, mainly H_2S, will be considerably strengthened during 2018 through the second monitoring report by the Icelandic Institute of Natural History. Thus far the early impressions of the scientists are mixed with no clear pattern.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are healthy, functional and viable aquatic and terrestrial ecosystems in the area affected by the geothermal facility that are sustained over the long-term; or the facility has contributed or is on track to contribute to addressing biodiversity issues beyond those impacts caused by the operating geothermal facility.*

It is still too early to say whether the H_2S impacts on vegetation are significant over more than very localised patches of vegetation in close vicinity to emission sources. Given the result and recommendations from the EIA process, it is likely that negative impacts, if any, are very limited. This opinion is shared by key relevant interviewees.

The tourist-trail system in the Hengill area contributes to improved knowledge about local plants and animals through signage along the trails and the Geothermal Exhibition also includes some information on biodiversity aspects of the area.

Criteria met: Yes

14.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There are no significant gaps against proven best practice.

0 significant gaps

14.3 Scoring Summary

The Hellisheidi area is not rich in biodiversity and the project has been assessed as having minor impacts. There is monitoring of vegetation, especially mosses as these are considered potentially sensitive to increased H_2S concentrations in the air and studies of thermophilic biodiversity in hot-water habitats in order to improve the understanding of these highly specialised communities.

The revegetation efforts implemented as part of the projects land-reclamation responsibilities are both extensive and successful. This work has employed innovative methods and has been awarded a prize. The ecosystems in the project's area of operation should generally be able to remain healthy, functional and viable.

There are no significant gaps, resulting in a score of 5.

Topic Score: 5

14.4 Relevant Evidence

Interview:	6, 9, 11, 28, 29
Document:	206, 418-465
Photo:	32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42

15 Induced Seismicity and Subsidence (O-15)

This topic addresses the management of induced seismicity and subsidence issues associated with the operating geothermal facility.

The intent is that physical impacts such as induced seismicity and subsidence caused by the operating geothermal facility are recognised and managed responsibly, and do not present problems with respect to other social, environmental and economic objectives; and that commitments to implement measures to address these impacts are fulfilled.

15.1 Background Information

Geothermal production can increase seismic activity, against the background seismicity that is usually present in geologically dynamic regions, where geothermal fields are located. Pressurized injection of fluid during drilling, and reinjection of water that has cooled down, in a different location from where it was extracted, can cause earthquakes. Injection generally causes more stress than extraction. Reinjection of almost all separated water (geothermal brine) into the geothermal reservoir is required by license in Hellisheidi, to 1) protect the surrounding environment from surface disposal of geothermal water, 2) avoid contaminating groundwater reserves, 3) maintain pressure in the reservoir, and 4) reduce public safety risks from hot water on surface.

Deformation of the land surface (rising and sinking) can have natural geological causes, particularly in geologically dynamic regions where geothermal fields are located. However, sinking or subsidence of land may also be due to human activities (underground mining, oil and gas exploitation, and withdrawal of groundwater and geothermal fluids), and reinjection may cause local rising of the surface. These can cause surface damages, and could trigger increases seismicity. Iceland has some experience with subsidence caused by geothermal production, but not all geothermal fields in Iceland have reacted with subsidence, and no damages from subsidence are known.

15.2 Detailed Topic Evaluation

15.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Ongoing or emerging induced seismicity and subsidence issues have been identified, and if management measures are required then monitoring is being undertaken to assess if management measures are effective.*

The project area has been seismically active before the project, and earthquakes unrelated to the project continue to occur. There was a swarm of earthquakes in the Hengill area from 1993-1998, peaking at magnitude 5.4. The most recent large earthquakes in the South Iceland Seismic Zone occurred in 2000 (2 x magnitude 6.5) and 2008 (magnitude 6.3). The epicentre of the 2000 earthquakes were further to the east, but the 2008 earthquake occurred approximately 15 km east of the power plant, with its epicentre between the towns of Selfoss and Hveragerdi. No loss of life occurred, but 50% of all buildings in the area as well as public infrastructure such as water pipes suffered damage; this loss was covered by the Icelandic Catastrophe Insurance.

Natural surface deformation due to plate boundary movements is significant in the volcanically active zones in Iceland.

Extraction of geothermal fluid at Hellisheidi began in 2006 and resulted in a drop in reservoir pressure and local subsidence, in the range of 15-30mm/year. This is of a similar order of magnitude as natural surface movements.

Reinjection of water at the Gráuhnúkar field began in 2007 and caused very little microseismicity. During well drilling at the second reinjection field Húsmúli from 2002, there were first signs of induced seismicity with magnitude 2 earthquakes. Reinjection at the field began in 2011, and multiple small earthquakes occurred, culminating about 6 weeks later in the two largest induced earthquakes with magnitude 4. Earthquakes above magnitude 2.5 can be felt in Hveragerdi, and the largest earthquakes were also felt widely in the Reykjavík area. The Húsmúli field stabilized after these events, but smaller earthquakes have continued to this day, as reinjection has continued. Notable swarms occurred when the volume of reinjection water increased and its temperature dropped, in 2012 and 2014, in connection with the CarbFix and SulFix projects (see O-16). Increased seismicity at Húsmúli has been accompanied by surface uplift, also of a similar order of magnitude as natural surface movements.

According to a group of researchers from the University of Iceland and Reykjavík University (Halldorsson et al, 2012), "the largest horizontal [pseudo-spectral acceleration] values in Hveragerdi were 22% g and 17% g in the two largest events, respectively. This earthquake action is equal to, and in some cases higher than, the codified design demand applied for the majority of the building stock. Thus, the induced earthquakes may have caused some progressive damage, especially to older buildings and to those that suffered the intense near-fault motion during the May 2008 M6.3 earthquake."

Following these events, monitoring of seismicity and surface deformation has been intensified, as described below, to inform the ongoing management measures.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging induced seismicity and subsidence issues takes into account both risks and opportunities.*

It is now understood that induced seismicity is important because it can create risks for public and employee safety, project infrastructure and project acceptance.

The initial induced seismicity during drilling at Húsmúli was not recognized as a warning sign and not taken sufficiently into account when planning large-scale reinjection. There was insufficient monitoring equipment and no risk mitigation plan. After the 2011 magnitude 4 earthquakes triggered a strong public reaction (following closely after the natural earthquake in 2008), a panel with experts from ÍSOR, the MetOffice, the University of Iceland, OR and the town of Hveragerdi was established to evaluate the situation. Among other things, the panel recommended to

- Make all production data from the beginning of reinjection into the Húsmúli area available to scientists in as close to real time as possible
- Temporarily increase seismic network coverage in the area
- Increase continuous GPS monitoring in the area
- Install a strong motion seismometer at the Hellisheidi power plant to measure ground acceleration
- Put in place a formal communication route to nearby communities that can alert the public to sudden changes in reinjection that could increase seismic risk

These recommendations were implemented quickly except the last one, which was put in place in 2014, after discussions with local stakeholders (see below under Management). In parallel, since 2014 a dedicated seismic monitoring system in all geothermal production areas in Iceland is being set up by ÍSOR, under contract with the power companies. This network has about 20 stations in the Hengill area and allows a much closer monitoring compared to the MetOffice's countrywide seismic monitoring network, which is focused on natural hazards. It also supports improved understanding of the geothermal fields for generation purposes (see O-4).

A number of reports have been issued that aim to increase the understanding of the underlying geological processes. The seismicity is not caused by direct fracturing of the rock, as the pressure of the reinjection water

is not sufficient, but rock strength may be lowered. Thermal expansion is also thought to be an unlikely cause of seismicity. However, injection always increases pore pressure in the reservoir, and earthquakes may only occur where pressure is added to systems which are already under pressure, with fractures that are ready to slip. Surface uplift may indicate increases in stress.

The processes appear to be very site-specific. No linkages between geothermal fluid extraction, subsidence and seismicity have been established in Reykjanes, for example, where the geological situation is different from Hengill.

Some of the scientific work has been undertaken through international cooperation, for example with partners from Switzerland and Germany in the EU-supported 'Geyser' program. Further research grants are being pursued between ÍSOR and OR, for example on hazard analysis software. The University of Iceland also has their own seismic monitoring stations and participates in the research.

Except for the Hellisheidi plant itself, there are no buildings or other infrastructure in the area that has experienced subsidence or uplift. No damages to the plant are known, and thus research into surface deformation has not been a priority.

Criteria met: Yes

15.2.2 Management

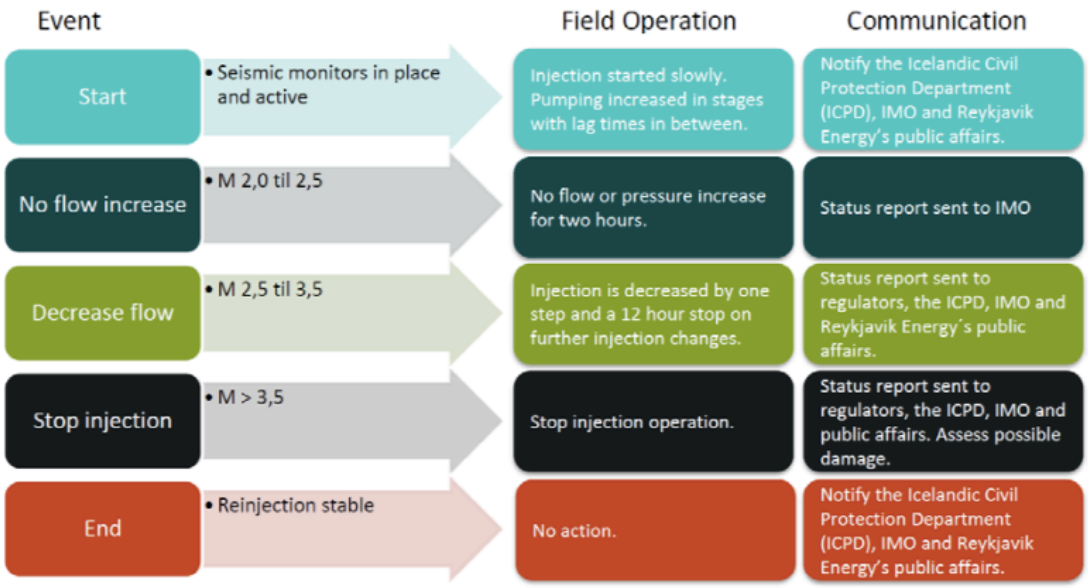
Analysis against basic good practice

Scoring statement: *Measures are in place to manage identified induced seismicity and subsidence issues.*

ON's current work procedures for reinjection pursue the objective of causing 'minimal inconvenience and no damage'. Prior to significant changes to reinjection processes, ON typically obtains third-party hazard assessments. The MetOffice has, for example, evaluated the hazards of injecting into wells HE-23, HE-25 and HE-38, and ÍSOR has been asked to provide an assessment of the planned conversion of some production to reinjection wells.

During reinjection operations operators are required to follow a 'traffic light' procedure which includes monitoring of seismic activity and information to stakeholders, as shown below. The communication procedure follows the protocol that was agreed with stakeholders in 2014.

Figure 7. ON Work Procedure for Injection-Induced Seismicity



Notifications to the Civil Protection Department are published on their website and regularly reported by the media.

A number of minor adjustments to procedures have been made since the protocol was introduced. Review meetings have been held with the MetOffice and the Civil Protection Department to discuss potential improvements. ON has asked stakeholders, for example, whether the frequency of warnings could be reduced, with warnings issued only for major changes in reinjection operations, as there have been no significant events for a number of years. However stakeholders for the time being prefer to keep the current arrangements.

If damages occur despite this management approach, and can be attributed to induced seismicity, ON will be liable. After the 2011 earthquakes, the company cooperated with Iceland Catastrophic Insurance who have experience in processing damage claims.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities.*

The monitoring and research program described above under Assessment provides an improved understanding of the geothermal reservoir and helps to anticipate operational risks. Starting in 2018, ON will have an in-house seismologist to further work on this issue. ON has also explored several options to change or reduce reinjection, for example by reinjecting into fields with higher permeability, at deeper depths, or reducing reinjection by taking some of the separated water to a sea outfall (most likely a pipeline to Thorlákshöfn, at a distance of about 21 km). All of these options carry costs and additional risks. The National Energy Authority is sceptical about the sea outfall option as it would reduce pressure in the reservoir; in any case this option would not be covered under the current license.

Some of the risks are related to the public perception of risks, which may be higher than justified by current scientific understanding. OR/ON have organised increased communications efforts around the issue of induced seismicity, including at the annual Science Days held since 2015, and have included information in the Geothermal Exhibition. The emergency services and municipalities also organise town meetings and other events to communicate earthquake hazards and emergency responses, whether natural or induced (see O-6). The National Energy Authority and ÍSOR have made efforts to explain induced seismicity to the general public and made monitoring data and research available. While the seismicity risks have been significantly reduced since 2011, there may be an ongoing need to better understand and respond to public perceptions specifically in Hveragerdi. This is addressed under O-9.

Criteria met: Yes

15.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives in place to manage induced seismicity and subsidence issues have been and are on track to be met with no significant non-compliances or non-conformances, and induced seismicity and subsidence related commitments have been or are on track to be met.*

When the utilization licence was updated in 2015, after consultation with ON a new Annex 5 with rules for reinjection was inserted, partly to address induced seismicity. These rules are consistent with the protocol agreed with local stakeholders. Management of surface deformation is not a license issue.

There are no indications that the license rules or the protocol have not been followed. After earthquakes in 2016 questions arose about attribution to reinjection, but ON requested expert opinions from the MetOffice and ÍSOR,

which showed no relationship. These were published through various channels, including ON's and the municipality of Hveragerdi's websites.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

There are no indications for any non-compliances or non-conformances.

Criteria met: Yes

15.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *Induced seismicity and subsidence issues are avoided, minimised and mitigated with no significant gaps.*

There have been no notable earthquakes which could be attributed to induced seismicity, since the adoption of the new reinjection procedures, and no impacts from surface subsidence or uplift.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, induced seismicity and subsidence associated with operating facility do not present ongoing problems for environmental, social and economic objectives of the facility or the project affected areas.*

There is broad agreement that the current reinjection procedures have successfully mitigated the induced seismicity risks, although understanding of earthquakes will always be limited and there can be no absolute assurance.

The main remaining issue is public acceptance. Induced seismicity is a complex technical issue, and residents need to trust that the authorities, experts and the operator will handle it prudently. Such trust can be enhanced by personal and regular interaction with the community, and by involving them in decision-making. As discussed under O-1 and O-9, this is a significant gap across various issues; it will not be double-counted here.

If earthquakes should occur again, there may be disagreements over attribution and liability which could affect stakeholder relations.

Criteria met: No

15.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There are no significant gaps against proven best practice.

0 significant gaps

15.3 Scoring Summary

The most notable incidences of induced seismicity in Iceland were two magnitude 3.8 earthquakes near the Hellisheidi geothermal plant in 2011. While these caused few damages and were much smaller than the natural magnitude 6.3 earthquake that hit the same area in 2008, they were felt in a large area of south-west Iceland. The understanding of induced seismicity has since improved substantially, and ON has followed new reinjection procedures and successfully mitigated seismicity risks. In spite of these measures and substantial communication efforts, there are still some concerns in the community.

There are no significant gaps, resulting in a score of 5.

Topic Score: 5

15.4 Relevant Evidence

Interview:	6, 8, 11, 15, 20, 25, 34, 35, 37, 38
Document:	190, 267, 270, 466-475
Photo:	--

16 Air and Water Quality (O-16)

This topic addresses the management of air and water quality issues associated with the operating geothermal facility.

The intent is that air and water quality in the vicinity of the operating geothermal facility is not adversely impacted by activities of the operator; that ongoing or emerging air and water quality issues are identified and addressed as required; and commitments to implement measures to address air and water quality are fulfilled.

16.1 Background Information

Geothermal power plants and associated infrastructure can have air- and water-quality impacts from:

- emissions common to all large-scale infrastructure construction and electricity-generation projects, related to disposal of solid and liquid waste, project-related transports, accidents with or leakage of hazardous liquids or gases, windblown dust and increased turbidity of waterbodies, etc., and
- emissions specific for geothermal projects, related to gases, acids, trace elements and other pollutants carried by or dissolved in the geothermal fluids.

Geothermal fluids carry a mixture of gases, notably carbon dioxide, hydrogen sulphide, methane, ammonia and radon. Hot geothermal water can hold trace amounts of toxic chemicals, such as mercury, arsenic, boron, and antimony in solution. If released to the environment, these pollutants can contribute to global warming, acid rain, radiation, noxious smells, soil and water pollution. Binary geothermal technologies in lower-temperature fields, that keep geothermal fluids in a closed cycle and use heat exchangers, avoid this problem, but these are not used in Iceland.

Reinjection of water is widely practiced in Iceland, partially to avoid pollution of surface waters and of shallow groundwater. Non-condensing gases (which do not condense like water vapour in the condenser, and have a negative effect on generation efficiency) need to be ejected from the condensers. In Iceland, they have typically been released into the atmosphere, with the updraft from the cooling towers to aid dispersal. The gas content of steam in Iceland is relatively low compared to other countries.

The WHO public-health standard for safe H_2S emissions was published in the year 2000 and includes a safety factor of 100. The level is 150 µg/m^3 with an averaging time of 24 hours. The limit in order to "avoid substantial complaints about odour", is recommended as 7 µg/m^3 with an averaging time of 30 minutes. Even at lower levels, H_2S can be smelled and be a nuisance. In Iceland, however, H_2S odour is a daily occurrence for most people, from natural geothermal emissions as well as from hot drinking water.

Air and water-quality issues have a variety of consequences, among them public-health impacts. Air and water emissions, and their monitoring, are covered under this topic while health impacts of these emissions are covered under O-6 and the odour/inconvenience under O-9. The impacts on the non-human living environment is dealt with under O-14. H_2S also has corrosive effects, which are covered under O-5.

16.2 Detailed Topic Evaluation

16.2.1 Assessment

Analysis against basic good practice

Scoring statement: *Ongoing or emerging air and water quality issues have been identified, and if management measures are required then monitoring is being undertaken to assess if management measures are effective.*

Relevant air- and water-quality aspects for the operations phase identified as part of the EIA and licencing processes, and associated mitigation/monitoring requirements, were:

- The estimated 1,100 l/s of separated geothermal water could negatively affect water supplies, flora and fauna because of its content of e.g. aluminium and arsenic and must, therefore, be reinjected back into the geothermal reservoir through deep wells;
- The plant was estimated to cause annual emissions of carbon dioxide and methane of 57,000 tonnes and 48 tonnes respectively. These emissions were, however, debated in the EIA as to whether they constitute additional emissions or not, compared with the baseline conditions. No mitigation was suggested;
- H_2S emissions were estimated to amount to 11,000 tonnes per year. No mitigation suggested as air pollution in general was not considered a significant issue in the EIAs;
- During test drilling, discharge fluid can affect water quality near the bore holes. Hence, when drilling in water-protection zones, the discharge must be piped out of these zones and injected into deep boreholes.

Of those impacts, the various groundwater-related issues were assessed as by far the most significant, and a comprehensive monitoring programme was devised. Aspects monitored include:

- Groundwater levels in wells (over 40 wells for groundwater level and 17 for water quality);
- Temperature;
- Twice-annual samples for analyses of "main chemical components" of the water from the monitoring wells and four times annually in the effluent water from the project;
- Analyses of trace elements every five years;
- Sampling of the cold groundwater system, i.e. the so called Ellidaár groundwater flow towards the capital region.

Potential impacts to the groundwater system could affect the capital region (home to around two thirds of all of Iceland's inhabitants) as well as the town of Thorlákshöfn, the municipal centre of Ölfus where Hellisheidi is located and, considerably less likely given groundwater flow patterns, also Hveragerdi, the nearest population centre to the plant at a distance of approximately 11 km. Hveragerdi is its own municipality and is surrounded by Ölfus, see also O-9.

Comprehensive investigations on the groundwater resource was carried out in 2001 and 2002, utilising 23 boreholes distributed in all directions form the Hellisheidi project site. The number of bore holes being monitored increased to over 30 in the following years. The consulting company Vatnaskil has mapped the groundwater aquifers and flow patterns in detail, and a groundwater model was developed which was joined with an existing model for the Nesjavellir area (north of Hellisheidi) into one groundwater model. Initially the plan was to reinject geothermal water at depths around 400 metres and the potential impact, mainly from chemical pollution, of this was investigated in the 2000s. As a result of this the decision was made to reinject the separated geothermal water into even greater depths of around 800 metres. The geothermal water that is released into the superficial groundwater aquifer has a travel time from Hellisheidi to the capital region of around 3-5 years, but pollution plumes can travel up to four times as fast as that.

Air quality was not considered a serious issue by the EIAs, and the Planning Agency did not include any specific actions in relation to air quality in the licencing decision. In spite of this, and as a result of the almost immediate realisation in 2006 (when the plant went into operation) that there was indeed an issue, a number of fixed monitoring stations were established, supported by some mobile units. As of early 2018, five project-related monitoring stations are operated by the consulting company Vista for ON, including:

- One less than 1 km west-south-west of the Hellisheidi plant itself;
- One located just over 1 km north-east of Nesjavellir geothermal power plant, approximately 10 km north-east of Hellisheidi and just south-west of Thingvallavatn, Iceland's largest lake;
- One located in Hveragerdi, the nearest significant settlement to Hellisheidi, approximately 11 km south-east of the plant;

- One located at Laekjarbotnar, approximately 14 km north-west of Hellisheidi and approximately 16 km south-east of downtown Reykjavík;
- One located at Nordlingaholti, 10 km south-east of downtown Reykjavík and 20 km north-west of Hellisheidi.

The Environment Agency operates several more stations around the country, with around a dozen located within a 30-km radius of the capital area. Monitoring data from most of these stations (including those operated by Vista for ON described above) are accessible to the public online in close to real time on the agency's web site, and Vista file reports to the Environmental and Public Health Authority of South Iceland and the Environment Agency on a quarterly basis, and an annual summary report to the National Energy Authority.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, identification of ongoing or emerging air and water quality issues takes into account both risks and opportunities.*

Consideration and identification of risks and opportunities related to emissions is ongoing, both within ON/OR and in Icelandic society at large. The project and the authorities responded quickly to the realisation that H_2S emissions were indeed an issue for the public, by implementing the comprehensive monitoring programme described above.

ON has identified the potential for emissions reduction through reinjection, see below under Management and Outcomes, and completed cost calculations for 100% reinjection.

ON is investigating the impacts on groundwater quality from surface releases as well as alternative solutions to geothermal wastewater disposal, e.g. by piping some of the water to Thorlákshöfn, see also O-8 and O-9.

The Environmental and Public Health Authority of South Iceland carries out irregular inspections which are announced with very short notice, and major inspections are implemented once or twice annually.

Criteria met: Yes

16.2.2 Management

Analysis against basic good practice

Scoring statement: *Measures are in place to manage identified air and water quality issues.*

Management of air- and water-quality issues is an integral part of OR's overall EMS described under O-3 with the specifics handled by staff from both OR and ON, mainly from OR's Research and Development department and from ON's Natural Resources and Technical Development departments. Comprehensive measures are in place to manage licence requirements and methodology development, and the company meets with the regulators on a monthly basis.

As per the licence conditions, geothermal wastewater is injected into wells of 800+ metres' depth, in order to not interfere with the groundwater used for the domestic water supplies to Thorlákshöfn and the capital region. Vatnaskil continue to monitor the groundwater aquifer and continuously develop the model for groundwater flow in the area of importance for the supply of domestic water to the capital area. The groundwater model is used to assess potential impacts on the aquifer from which the capital region draws its domestic water supply.

Vista manage ON's air-quality monitoring stations and ON procure special-purpose weather forecasts for critical air emissions conditions (typically cold-weather inversion situations during mid-winter); in such conditions ON is required to alert the Environmental and Public Health Authority of South Iceland.

An ambitious drilling program is ongoing with the aim of increasing the number of production wells and the flexibility for wastewater reinjection, which would also reduce the number of extreme situations during which wastewater has to be released at the surface.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, processes are in place to anticipate and respond to emerging risks and opportunities.*

The Hellisheidi project is the focus of a successful project to capture, dissolve, reinject and mineralize gases. These efforts go by the names of CarbFix and SulFix and are globally ground-breaking advances in technology which have been frequently publicised in high-impact scientific journals such as Science, and on international TV. The project, which has evolved over approximately a decade, has involved researchers from e.g. Iceland, the USA and France and received funding from the EU. A pilot phase was started in 2011-2012 and the project reached industrial scale in 2014. The general idea is that CO_2 and H_2S react with calcium, iron and magnesium in the basalt bedrock to form calcite and pyrite. Through this process the amount of CO_2 injected into the bedrock has developed from 0 in 2013, via 10% in 2014; 15% in 2015; 25% in 2016 and 34% in 2017. The same figures for H_2S are: 0; 22%; 35%; 53% and 68% in 2017. The goal is to get to around 80%.

H_2S from geothermal sources is a natural part of much of the Icelandic landscape, making it important to determine what the additional impact of a development such as Hellisheidi is. The lack of baseline studies on this issue created a risk to the project, and the opportunity to resolve this is now being realized as a decision to investigate the issue has recently been taken by ON.

The opportunity of going to 100% reinjection of H_2S has been planned for and costed. The estimated cost of full-scale gas abatement for both H_2S and CO_2 at Hellisheidi is estimated at below USD 25/tonne.

Criteria met: Yes

16.2.3 Conformance / Compliance

Analysis against basic good practice

Scoring statement: *Processes and objectives in place to manage air and water quality issues have been and are on track to be met with no significant non-compliances or non-conformances, and air and water quality related commitments have been or are on track to be met.*

An earlier Icelandic H_2S regulation (number 514/2010) stipulated that a maximum running average concentration of 50 µg/m^3 on a 24-hour basis could be exceeded up to five times per year, for each individual monitoring station. Those regulations were amended as number 715/2014, with the limit to be exceeded reduced to a maximum of three times per year. Furthermore, the annual average concentration may not exceed 5 µg/m^3. Also, when concentrations have exceeded 150 µg/m^3 for 3 hours, the appropriate authorities must be notified.

The 50 µg/m^3 24-hour running-average compliance requirement has never been exceeded at any monitoring station.

In 2017, the stations at Hellisheidi and Nesjavellir exceeded the annual average with results of 7.0 and 12.1 µg/m^3 respectively. This is not regarded as a gap as there are no people resident near these stations and exposure limits to workers are considerably higher, see O-12. The more important stations at Hveragerdi, Nordlingaholti and Laekjarbotnar showed average annual results of 4.2, 3.1 and 2.6 µg/m^3 respectively, all under the permissible level.

The 3-hour limitation for 150 µg/m^3 has not been broken during 2017 at any of the monitoring stations relevant to the public. At Nordlingaholti only one hourly value was over 150 µg/m^3 in 2017. At Hveragerdi, on the 27th of

November, seven hourly measurements were above 70 µg/m^3 and two (in succession) above 150 µg/m^3, but the 3-hour stipulation was not exceeded. At Laekjarbotnar the highest measured value during 2017 was 93 µg/m^3.

Release of geothermal water to the surface is, in principle, not allowed. However, in emergencies due to 'major failures', some surface spilling has been tolerated but is subject to immediate reporting, explanation and discussion, to both the National Energy Authority and the Environmental and Public Health Authority of South Iceland. The National Energy Authority is advocating strongly for fewer surface releases, with the aim of reaching zero as soon as possible.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, there are no non-compliances or non-conformances.*

The repeated non-compliances in relation to the current utilization licence conditions on surface disposal are considered a significant gap under O-4, but not under this topic O-16. Hellisheidi is considered to be compliant under the operating licence from Environmental and Public Health Authority of South Iceland, and there are no detected environmental impacts as a result of the surface releases.

The CEO has publicly stated that the aim of the OR group is zero net emissions. The path toward that goal is described below under Outcomes.

Criteria met: Yes

16.2.4 Outcomes

Analysis against basic good practice

Scoring statement: *Negative air and water quality impacts arising from activities of the operating geothermal facility are avoided, minimised and mitigated with no significant gaps.*

The prediction in the EIA that the H_2S emissions (which were approximately correct in terms of annual totals) were not going to cause any significant impacts has proven wrong. Approximately two thirds of Iceland's population live in the capital area and another 2,500 in the town of Hveragerdi just east of Hellisheidi. In both places impacts have been substantial, but are dealt with under O-6 and O-9.

The H_2S emissions have had negative impacts on both ON's and other actors' assets through corrosion effects. In terms of ON's assets there is a general impact on all metal infrastructure at and around the plant, and external impacts can be exemplified by Landsnet whose transmission towers are affected, reducing their life span, and potential impacts on the emerging data-centre industry in Iceland, as all electronics are negatively affected by H_2S. Sensitive electronics can be effectively shielded from H_2S, albeit at a cost. This is an impact that could potentially be entirely avoided in the future if the company chooses to go to 100% reinjection.

GHG emissions were not expected to change, as the scientific understanding argued in the EIAs is that emissions from the power plant are off-setting natural emissions from the geothermal area. As such, emissions from geothermal power plants are not included in Iceland's national GHG accounts. With the CarbFix project, this is now turned into a net positive impact from the plant (or significantly reduced negative impact, if the original zero-sum hypothesis is not accepted). The specific emissions from the plant electricity amount to around 9 gCO_2eq/kWh of generated electricity. This is a very low number, lower than e.g. wind power, and only slightly higher than typical cold-temperate and sub-arctic hydropower plants in the Nordic region.

Geothermal wastewater generated by the operations amounts to around 20 million tonnes/year in 2016, around 25% of this being clean condensate water. Around 1 million tonnes were disposed on the surface in 2016. No impacts on the groundwater aquifer have been detected.

Criteria met: Yes

Analysis against proven best practice

Scoring statement: *In addition, air and water quality in the area affected by the operating geothermal facility is of a high quality; or the facility has contributed or is on track to contribute to addressing air and water quality issues beyond those impacts caused by the operating geothermal facility.*

Given the significant issues experienced by stakeholders in Hveragerdi and the capital region, it is not possible to call the air quality in the project-affected areas high. As mentioned above, in 2017 the injection of CO_2 and H_2S accounted for 34% and 68% respectively, of total gas extracted from the condensers. The total CO_2 extracted was 35,602 tonnes, out of which 12,047 tonnes were injected. For H_2S, the same numbers were 8,867 and 6,002 tonnes respectively. However, the quality is improving along with increasing share of reinjected geothermal water, and the developments of the CarbFix and SulFix technologies both represent world-leading methods, well beyond the impacts of the Hellisheidi facility. There is a potential for the CarbFix to go beyond 100% reinjection by extracting non-project-related CO_2 from the atmosphere.

ON has spearheaded the move away from diesel-operated drill rigs and the electric-powered rig now used at the Hverahlíd field means a saving of approximately 600 tonnes of CO_2eq per well drilled.

Unrelated to the Hellisheidi project, ON are investing in the electrification of Iceland's car fleet, which contribute to a reduction in vehicle emissions, and the company utilises its own fleet of electric vehicles for much of its transportation needs, and is pioneering fast-charging stations for the general public. Unlike in most other countries, the benefits of running cars on electricity are very clear in Iceland as the specific emissions from the electricity-generation system are very low by international standards.

Criteria met: Yes

16.2.5 Evaluation of Significant Gaps

Analysis of significant gaps against basic good practice

There are no significant gaps against basic good practice.

0 significant gaps

Analysis of significant gaps against proven best practice

There are no significant gaps against proven best practice.

0 significant gaps

16.3 Scoring Summary

Air and water emissions from the Hellisheidi plant are potentially large, but have been mitigated by capturing and reinjecting most of the non-condensable gases together with most of the effluent, in particular the separated geothermal water. Some of the mitigation technology is world-leading, and the publicly stated goal is zero net emissions. There are no significant gaps, resulting in a score of 5.

Topic Score: 5

16.4 Relevant Evidence

Interview:	2, 8, 9, 11, 14, 15, 16, 20, 31, 32, 34, 36, 39
Document:	135-137, 155-158, 177, 417, 476-500
Photo:	11, 16, 17, 20, 26, 52, 56, 92, 94, 100, 101, 102, 103, 104

Appendix A: Verbal Evidence

Ref	Interviewee/s, Position	Organization	Department	Date	Location
1	Bjarni Bjarnason, CEO of OR and Chairman of ON Board Bjarni Már Júlíusson, CEO of ON	OR, ON	CEO´s office at OR CEO´s office at ON	1/26/18	ON Head Office
2	Magnea Magnúsdóttir, Manager of Environmental and Land Restoration at ON Hólmfríður Sigurðardóttir, Environmental Director of OR Group Reynir Guðjónsson, Safety Manager of OR Group	ON, OR	Power plant operations, CEO´s office at OR	1/26/18	ON Head Office
3	Kristinn Rafnsson, operational specialist in Hellisheiði Power plant	ON	Power plant operations	1/26/18	ON Head Office
4	Kristín Birna Fossdal, Technical Manager of Electrical Equipment	ON	Power plant operations	1/26/18	ON Head Office
5	Magnea Magnúsdóttir, Manager of Environmental and Land Restoration at ON Eiríkur Hjálmarsson, Head of Communications of OR Group Hafrún Þorvaldsdóttir, Customer Service Manager at ON	ON, OR	Power plant operations, CEO´s office at OR Department of Consumer Markets at ON	1/26/18	ON Head Office
6	Belinda Eir Engilbertsdóttir, Specialist in Asset, Land and Territory Management at OR Einar Gunnlaugsson, Resource Manager at OR	OR	Department of Asset Management, Department of Research and Development at OR	1/26/18	ON Head Office
7	Björn Stefánsson, Specialist in Sustainability	Umhverfisstofnun (Environment Agency)	Field of Sustainability	1/26/18	ON Head Office
8	Þorsteinn Jóhannsson, Specialist in Geology	Umhverfisstofnun (Environment Agency)	Field of Nature	1/26/18	ON Head Office
9	Magnea Magnúsdóttir, Manager of Environmental and Land Restoration at ON Hólmfríður Sigurðardóttir, Environmental Director of OR Group Bergur Sigfússon, Specialist in Geothermal Research	ON, OR	Power plant operations, CEO´s office at OR Department of Research and Development at OR	1/26/18	ON Head Office

10	Sigurður Rúnar Rúnarsson, Operating Specialist at the Hellisheiði power plant	ON	Power plant operation	1/27/18	Hellisheiði power plant
11	Sigrún Guðmundsdóttir, CEO Stella Hrönn Jóhannsdóttir, Health Officer	Environmental and Public Health Authority of South Iceland	CEO, Department of Environmental and Pollution Protection	1/29/18	Hellisheiði power plant
12	Fida Abu Libdeh, CEO	GeoSilica Iceland	CEO	1/29/18	Hellisheiði power plant
13	Jóhann Jónasson, Chairman of the Board of Deilir	Deilir Technical Services		1/29/18	Hellisheiði power plant
14	Hróðmar Bjarnason, Owner of Eldhestar	Eldhestar, former member of planning committee of Ölfus		1/29/18	Hellisheiði power plant
15	Gunnsteinn R. Ómarsson, Mayor of Ölfus Sigurður Ósmann Jónsson Planning Officer of Ölfus	Ölfus Municipality	Ölfus Municipality office	1/29/18	Hellisheiði power plant
16	Eyþór H. Ólafsson, Chairman of the Board of Hveragerði and Chairman of Planning Committee of Hveragerði	Hveragerði Municipality	Hveragerði Municipality office	1/29/18	Hellisheiði power plant
17	Berglind Rán Ólafsdóttir, Managing Director of Business Market, ON	ON	Business market, ON	1/29/18	ON Head Office
18	Áslaug Telma Einarsdóttir, Managing Director of Consumer Market, ON	ON	Consumer market, ON	1/30/18	ON Head Office
19	Einar Ólafsson, Finance Specialist, OR Brynja Kolbrún Pétursdóttir Managing Director of Finance and Analysis, OR Ásgeir Westergren, Managing Director of Risk Management, OR	OR	OR Finance	1/30/18	ON Head Office
20	Edda Sif Aradóttir, Chemist and Reservoir Engineer OR Bergur Sigfússon, Geochemist, OR Bjarni Reyr Kristjánsson, Geologist, OR Marta Rós Karlsdóttir, Managing Director of Natural Resources, ON	OR, ON	Department of Research and Development, OR. Department of Natural Resources, ON	1/30/18	ON Head Office
21	Þrándur S. Ólafsson, Project Manager in Energy Trading	ON	Business Market, ON	1/30/18	ON Head Office
22	Ingvi Már Pálsson, Business administrator	Ministry of Industries and innovation		1/30/18	ON Head Office

23	Ágúst Þorbjörnsson, Independent financial expert	Framsækni		1/30/18	ON Head Office
24	Tómas Hansson, Manager of Technical Development Guðmundur Óli Gunnarsson, Technical Manager of Hot Water	Veitur - utilities	Technical development	1/30/18	ON Head Office
25	Marta Rós Karlsdóttir, Managing Director of Natural Resources, ON Edda Sif Aradóttir, Chemist and Reservoir Engineer OR Gunnar Gunnarsson, Reservoir Engineer OR Ingvi Gunnarsson, Geochemist OR Einar Gunnlaugsson, Senior Geoscientist OR	ON, OR	Department of Natural resources, ON. Department of Research and development, OR.	1/30/18	ON Head Office
26	Þórður Ásmundsson, Managing Director of Technical Development, ON	ON	Department of Technical Development, ON	1/30/18	ON Head Office
27	Ásdís Eir Símonardóttir, HR consultant, OR	OR	Department of Human Resources	1/30/18	ON Head Office
28	Trausti Baldursson, Managing Director of Ecology and Advísory Department, Ása L. Aradóttir, Professor of Restoration Ecology	Icelandic Institute of Natural History, Agricultural University of Iceland	Ecology and Advisory Department, Department of Research	1/30/18	ON Head Office
29	Auður Andrésdóttir, geologist	Mannvit Consulting	Civil Department	1/30/18	ON Head Office
30	Brynhildur Davíðsdóttir, Professor in Environmental and Natural Resources, and Chairwoman of OR Board	University of Iceland	Field of Engineering and Natural Sciences	1/30/18	ON Head Office
31	Jónas Ketilsson, Senior Manager - Deputy Director General María Guðmundsdóttir, Specialist - Geothermal Utilization	National Energy Authority		1/31/18	ON Head Office
32	Árni Finnsson, Chair of Board at Iceland Nature Conservation Association	Icelandic Nature Conservation Association		1/31/18	ON Head Office
33	Uggi Ævarsson, Archaeologist, Antiquarian of South Iceland	Cultural Heritage Agency of Iceland		1/31/18	ON Head Office

34	Sveinn Óli Pálmarsson Managing director, Magnús Ólafsson Geochemist	Vatnaskil Consulting, ÍSOR (Iceland Geosurvey)	Geothermal engineering department (ÍSOR)	1/31/18	ON Head Office
35	Kristín Jónsdóttir, Earthquake Hazards Coordinator, Björn Oddsson, Geophysicist	Icelandic Met Office, Department of Civil Protection and Emergency Management	Warning and Forecasting	1/31/18	ON Head Office
36	Pétur Halldórsson, Biologist	Icelandic Environment Association (Landvernd)	Member of the Board	1/31/18	ON Head Office
37	Jakob Gunnarsson, Environmental Specialist	National Planning Agency	Department of EIA	1/31/18	ON Head Office
38	Kristján Ágústson, Geophysicist	ÍSOR (Iceland Geosurvey)		1/31/18	ON Head Office
39	Kristín Lóa Ólafsdóttir, Public Health Officer Andrés Þórarinsson, Project Manager	Reykjavík Public Health Authority, Vista Consulting	Environmental monitoring	1/31/18	ON Head Office
40	Ásgeir Westergren, Managing Director of Risk Management, OR Hrönn Ingólfsdóttir, Specialist in Risk Management, OR Gísli Björn Björnsson, Specialist in risk management, OR.	OR	Risk Management, OR	2/1/18	ON Head Office
41	Íris Lind Sæmundsdóttir, Lawyer, Legal Affairs and Secretary of Board ON Elín Smáradóttir, Lawyer, Head of Legal Affairs of OR Group	OR	Legal Affairs	2/1/18	ON Head Office
42	Olgeir Helgason, Specialist in Quality Systems, OR Guðrún Erla Jónsdóttir Strategy officer, OR	OR	Quality Systems, CEO´s office at OR	2/1/18	ON Head Office
43	Sæmundur Guðlaugsson, Maintenance Manager	ON	Power plant operations.	2/1/18	ON Head Office
44	Hrönn Ingólfsdóttir, Specialist in Risk Management Gísli Sveinsson, Assistant of CEO	OR and ON	Risk Management CEO´s office, ON	2/1/18	ON Head Office

45	Ásdís Eir Símonardóttir HR consultant	OR	Department of Human Resources	2/1/18	ON Head Office
46	Magnea Magnúsdóttir, ON, Manager of Environmental and Land Restoration at ON Trausti Björgvinsson, Managing Director of ON Power Plant Operations Reynir Guðjónsson, Safety Manager of OR Group	ON and OR	Power plant operations, ON CEO´s office, OR	2/1/18	ON Head Office
47	Trausti Björgvinsson, Managing Director of ON Power Plant Operations	ON	Power plant operations	2/1/18	ON Head Office
48	Sigurlaug Jensey Skúladóttir, Project Manager	Árbæjarskóli (School of Árbær)		2/5/18	E-mail based interview

Appendix B: Documentary Evidence

No.	Author / Organisation	Title in English	Year	Language
1	ON	Environmental issues of ON - meeting notes and presentations list	2017	Icelandic
2	ON	Environmental issues of ON - meeting notes	2017	Icelandic
3	ON	Environmental issues of ON - meeting presentation	2017	Icelandic
4	OR	OR Project stakeholder mapping/communication plan	2017	Icelandic
5	OR	Annual report 2016	2016	English
6	ON	Facebook proactive information	2018	English/ Icelandic
7	ON	ON Articles of Association	2016	Icelandic
8	ON	ON Board Programme for 2018	2017	Icelandic
9	ON	ONS-001 Board Rules of Procedure (ROP)	2017	Icelandic
10	ON	ONS-005 ON Board ROP Meeting invitations	2017	Icelandic
11	ON	ONS-010 ON Board ROP Board Meetings	2017	Icelandic
12	ON	ONS-015 ON Board ROP Minutes	2017	Icelandic
13	ON	ONS-020 ON Board ROP Board Membership start/end	2017	Icelandic
14	ON	ONS-025 ON Board ROP Decisions dependent on GM approval	2017	Icelandic
15	ON	ONS-030 ON Board ROP Handling of Board Information Requests	2017	Icelandic
16	ON	ONS-035 ON Board ROP Information Sharing	2017	Icelandic
17	ON	ONS-050 ON Board ROP Secretary to the Board	2017	Icelandic
18	ON	ONS-055 ON Board ROP Sub-Committees	2017	Icelandic
19	ON	ONS-100 ON Board ROP Checklist for Decision Making	2017	Icelandic
20	ON	ONS-200 Board Evaluation of Work	2017	Icelandic
21	Icelandic laws	OR Act no. 136-2013	2014	Icelandic
22	OR	OR Owners policy	2014	Icelandic/ English
23	Owners of OR group	OR Partnership agreement	2014	English
24	ON	SKI-020 Organizational chart for ON	2017	Icelandic
25	ON	SKI-306 ON Risk Committee	2017	Icelandic
26	OR	SKI-510 Organizational Chart for OR group	2017	English
27	ON	STE-200 Overall Policy for ON	2017	Icelandic
28	ON	STE-215 Quality Policy for ON	2017	Icelandic
29	ON	STE-220 The Human Resources Policy for ON	2017	Icelandic
30	ON	STE-225 ON Code of Ethics	2017	Icelandic
31	ON	STE-230 Environmental and Resources Policy for ON	2017	Icelandic
32	ON	STE-235 Procurement Policy for ON	2017	Icelandic
33	ON	STE-237 Risk Policy for ON	2017	Icelandic
34	ON	STE-240 ON Policy for Safety, Health Care and Working Environment	2017	Icelandic
35	ON	STE-242 Competition Law Policy for ON	2017	Icelandic
36	ON	STE-250 Information Security Policy for ON	2017	Icelandic
37	ON	STE-260 Terms of Employment Policy for ON	2017	Icelandic

38	ON	STE-265 Gender Equality Policy for ON	2017	Icelandic
39	ON	STE-270 Service Policy for ON	2017	Icelandic
40	ON	STE-285 - Information Technology Policy for ON	2017	Icelandic
41	Internal audit OR	SFON 51 09 IE Status to ON Board of internal audits - figures	2017	Icelandic
42	Internal audit OR	SFON 51 09 IE Status to ON Board of internal audits - summary	2017	Icelandic
43	Internal audit OR	SK-2017-102 Geothermal resource management ON - summary	2017	Icelandic
44	Internal audit OR	Geothermal resource management ON - excel	2017	Icelandic
45	Internal audit OR	SK-2014-101 Energy trading - summary	2016	Icelandic
46	Internal audit OR	Final audit - Energy sales - excel	2017	Icelandic
47	Internal audit OR	SK-2016-101 Energy consumers and energy buyers - summary	2016	Icelandic
48	Internal audit OR	Energy consumers and energy buyers - excel	2016	Icelandic
48	ON	Workplace - internal website for the staff of OR group	2018	Icelandic
49	ON	Internal website - systems and processes	2018	Icelandic
50	ON	External website	2018	Icelandic/ English
51	ON	ONV-M-100 Generation procedure - main diagram	2018	Icelandic
52	ON	ONS-M-200 Sales and energy trading - main diagram	2018	Icelandic
53	ON	ON 2014 - Annual report (web version)	2018	Icelandic
54	ON	ON 2015 - Annual report (web version)	2018	Icelandic
55	ON	ON 2016 - Annual report (web version)	2018	Icelandic
56	ON	VLT-001 Risk management process - handbook	2018	Icelandic
57	ON	Overview general governance matters for ON	2018	English
58	Internal audit OR	Information security for ON - report in Excel	2018	Icelandic
59	OR	Compliance with owners' policy: Summary	2018	English
60	OR	A report on compliance with owners' policy	2017	Icelandic
61	OR	Minutes of meeting: Owners' meeting in November 2017	2017	Icelandic
62	OR	Minutes of meeting: OR's board meeting	2017	Icelandic
63	ON	ON Management system	2018	English
64	ON	Certificate for Control systems_ISO 9001_13.04.2016	2016	Icelandic
65	ON	Certificate for Control systems_ISO 14001_13.04.2016	2016	Icelandic
66	ON	Certificate for Control systems_OHSAS 18001_13.04.2016	2016	Icelandic
67	ON	BSI Certificate and Registration_ISO 27001 2013 IS 534496_Gildir until 09.06.2020	2017	English
68	ON	Internal security management for ON - Certificate	2015	Icelandic
69	OR	SKI-200 Organisational context and scope of management system		Icelandic
70	OR	STJ-010 Planning of issues		Icelandic
71	OR	STJ-011 Policy and objective process		Icelandic
72	OR	STJ-015 Financial resources process		Icelandic
73	OR	STJ-016 HR resources process		Icelandic
74	ON	INS-001 Purchasing and contracts		Icelandic
75	ON	FJM-001 Financial management		Icelandic

76	OR	PFM-001 HR processes		Icelandic
77	OR	Risk report - to Board of ON and to managers of ON	2018	Icelandic
78	OR	STJ-200 Risk management (operational risk)		Icelandic
79	OR	STJ-210 Environmental issues		Icelandic
80	OR	STJ-220 HSE controls		Icelandic
81	OR	STJ-230 Information security controls		English
82	OR	STJ-300 Management review		Icelandic
83	OR	STJ-310 Internal audits and revaluation		Icelandic
84	OR	STJ-410 Nonconformity and corrective action		Icelandic
85	OR	STJ-415 Improvements		Icelandic
86	OR	LBC-025 Interested parties		Icelandic
87	OR	SKI-100 Responsibility according to issues		Icelandic
88	OR	SkI-105 Meetings in OR group		Icelandic
89	OR	SKI-302 Management		Icelandic
90	ON	Tender documents for contractors		Icelandic
91	ON	Tender documents for contractors		Icelandic
92	ON	Tender documents for contractors		Icelandic
93	OR	LBG-020-06 The OR-Group handbook	2017	Icelandic
94	ON	Regular managers meeting in ON - minutes from a typical meeting	2018	Icelandic
95	ON	Regular managers meeting in ON - schedule and compliance/follow up on tasks	2018	Icelandic
96	ON	ONT-L-040 Risk assessment for design phase	2017	Icelandic
97	ON	Detailed Org. chart for Power Plant Operations		Icelandic
98	ON	From Natural Resource to Customer – MoM, presentations on Operations, Resources, Sales		Icelandic
99	OR	Report to Board of OR of progress for policy projects in the OR Group	2018	Icelandic
100	Iceland Chamber of Commerce, SA Business Iceland and Nasdaq Iceland	Guidelines on Corporate Governance	2015	English
101	Orkustofnun	Legal and Regulatory Framework -Geothermal (website)	2018	English
102	Einar Gunnlaugsson	The Environmental Permit Process for the Hellisheidi Power Plant in Iceland	2007	English
103	Municipality of Ölfus	Zoning Map 2010-2022	2010	Icelandic
104	OR	Complaint and Resolution - Hiking Trail at Hengill	2017	Icelandic
105	OR	Consultation with ICEBike on MTB Trails at Hengill	2017	Icelandic
106	OR	Contract with the Icelandic Scout Association Search and Rescue Team on the maintenance of marked paths at the Hengill Area	2016	Icelandic
107	ON	Geothermal Exhibition Guided Tour - Script		English
108	Hjálparsveit Skáta and OR	Report on the execution of Icelandic Scout Assocciation SAR and OR Contract on the maintenance of marked paths at the Hengill Area	2016	
109	OR	Welcome to Hengill Area	2012	English
110	OR	CarbFix		English
111	OR	CarbFix - Publications		English

112	OR	CarbFix - SulFix - From Gas to Rock	2017	Icelandic
113	OR	CarbFix and SulFix Recapitulation	2015	Icelandic
114	OR	Brochure from Educational Hikes Organised by OR		Icelandic
115	Jakob K. Kristjánsson et. al.	Comprehensive Enquiry into Hot Springs Biosphere at Hengill Area	1996	Icelandic
116	Sólveig K. Pétursdóttir et. al	EIA Geothermal Power Plant at Hellisheiði. Hot Spring Ecosystem Survey	2002	Icelandic
117	Sólveig K. Pétursdóttir et.al.	EIA Geothermal Power Plant at Hverahlíð and Ölkelduháls. Hot Spring Ecosystem survey	2006	Icelandic
118	VGK	Enlargement of Hellisheiði Geothermal Power Plant. EIA	2005	Icelandic
119	Kristján Sæmundsoon	Geological features at Hellisheiði Geothermal Power Plant impact zone	2003	Icelandic
120	VGK	Geothermal Power Plant at Hellisheiði. Environmental Impact Assessment	2003	Icelandic
121	Landslag ehf	Hellisheiðarvirkjun Site Plan	2016	Icelandic
122	Rannsóknir and ráðgjöf ferðaþjónustunnar	Hellisheiði geothermal power plant; effects on travel and tourism	2003	Icelandic
123	VSÓ Consulting	Hverahlíð 90 MWe Power Plant - EIA (See also Hverahlíð Piping)	2008	Icelandic
124	Mannvit	Landscape at Hengill Area	2009	Icelandic
125	Þóra Ellen Þórhallsdóttir	Landscape Value at Hengill area (impact zone for energy generation)	2002	Icelandic
126	Orkustofnun (National Energy Authority)	Utilisation License - Hellisheiði	2015	Icelandic
127	Guðmundur Guðjónsson et al	Vegetation and Birdlife at Gráuhnúkar and Meitlar	2009	
128	Guðmundur Guðjónsson et al	Vegetation and Birdlife at Hengill Area and Hellisheiði	2005	Icelandic
129	Jón Einar Jónsson	Wildfowl research at Ölkelduháls and Hverahlíð, summer 2006	2006	Icelandic
130	VGK	Ölkelduháls and Hverahlíð. Outdoor Recreation and Tourism	2006	Icelandic
131	OR	Comments and Complaints 2017 - Environment		Icelandic
132	OR	Contract on grant for using sustainable transport to and from work		Icelandic
133	OR	Electric and Methane Cars at ON		Icelandic
134	OR	Environmental management system ISO 14001	2018	Icelandic
135	OR	Environmental report 2016	2016	English
136	OR	Environmental Report 2016 - Presentation for licensors 3-2-2017		Icelandic
137	OR	Environmental Report 2016 - Presentation for licensors 3-2-2017 Meeting Notes		Icelandic
138	OR	ISO 14001		Icelandic
139	OR	Monthly Memo on Environmental Issues for OR board	2017	Icelandic
140	OR	Monthly Memo on Environmental Issues for OR board - list	2018	Icelandic
141	OR	Oil Tank and Oil Collector Monitoring		Icelandic

142	OR et al.	Project Plan SulFix on Disposal on H2S from Geothermal Power Plants		Icelandic
143	OR	Recycling - Coffee Corner		Icelandic
144	OR	Recycling - Open Areas		Icelandic
145	OR	Recycling - Print Room		Icelandic
146	OR	Recycling - Repair Shop and Engine Room		Icelandic
147	OR	Refuse		Icelandic
148	OR	Refuse and Hazardous Waste		Icelandic
149	OR	Risk Assessment - Risks in Operation		Icelandic
150	OR	Special- and Hazardous Waste		Icelandic
151	OR	The Protection of Drinking Water Resources		Icelandic
152	OR	Water Protection in Hellisheiði Power Plant Vicinity - Screenshot		Icelandic
153	OR	Workplace Project on Food Waste - Competition - screenshot		Icelandic
154	OR	Workplace Project on Food Waste - screenshot		Icelandic
155	Vista	35 H2S report Jan-Sep 2017 NLH-HVE 16.10.2017	2017	Icelandic
156	Vista	36 H2S report Jan-Sep 2017 Hellish-Nesjav 23.10.2017	2017	Icelandic
157	Vista	37 H2S Report Jan-Sep 2017 Lækjarbotnar 16.10.2017	2017	Icelandic
158	Umhverfisstofnun	Air quality monitoring in Iceland	2017	Icelandic/ English
159	ON	Application for License to clean and store scales with TENORM technically enhanced natural occurring radioactivity	2016	Icelandic
160	OR	Approach to revegetation and surface finish at Hellisheiði 2007-2010		Icelandic
161	ON	Calm winter weather forecast increases likelihood of higher concentration of H2S	2017	Icelandic/ English
162	Magnea Magnúsdóttir	Ecological Restoration at Hellisheiði		English
163	Elí Björk Jónasdóttir	Email - Meteorologist's Forecast on H2S distribution until new year 2017	2017	Icelandic
164	ON	Emails on sulfix air discharge station	2017	Icelandic
165	ON	Emergency brine disposal in Hellisheiði - finished	2017	Icelandic
166	ON	Emergency brine disposal posts- list	2017	Icelandic
167	ON	Environmental and resource policy of ON	2018	Icelandic
168	ON	Environmental issues of ON meeting notes	2017	Icelandic
169	ON	Environmental issues of ON meeting notes and presentations list		Icelandic
170	ON	Environmental issues of ON meeting presentation	2017	Icelandic
171	ON	Environmental Supervision Schedule for ON plants in Hengill area	2018	Icelandic
172	ON	Environmental Improvement and Restoration plan	2012	Icelandic
173	ON	Evidence of Maintenance of Horse Pen - From DMM	2016	Icelandic
174	ON	Gas Emission from Hellisheidi Geothermal Power Plant - Annual Statement 2002-2016	2017	Icelandic
175	OR	Guidelines on Restoration on Vegetated Areas	2016	Icelandic
176	OR	Guidelines on Visual Impacts and Restoration	2016	Icelandic

177	ON	H_2S monitoring reports - list	2017	Icelandic
178	OR	Health and Safety Database - Announcements of Environmental Issues	2017	Icelandic
179	Geislavarnir ríkisins	License to clean and store scales with TENORM technically enhanced natural occurring radioactivity	2017	Icelandic
180	Morgunblaðið	Magnea gets Ölfus's Municipality Environmental Award	2017	Icelandic
181	ON	Map of ON Charging Points for EC	2017	Icelandic
182	Einar Sveinbjörnsson	Meteorologist's Forecast on H2S distribution - list screenshot	2017	Icelandic
183	Ágústa Helgadóttir et. al.	Monitoring of vegetation in the vicinity of the geothermal power plants at Hellisheiði and Nesjavellir	2013	Icelandic
184	Snjólaug Ólafsdóttir	ON Hydrogen Sulphide Monitoring - 2014	2014	Icelandic
185	ON	ON Communication Plan for Environmental Issues	2017	Icelandic
186	ON	ON hosts a Public Meeting on Hverahlíð Piping	2014	Icelandic
187	Heilbrigðiseftirlit suðurlands	Operation License - Hellisheiði Geothermal Power Plant	2016-2028	Icelandic
188	Orkustofnun	Power Plant Licence - Annex		Icelandic
189	Orkustofnun	Power Plant Licence - Licence for Power Plant Enlargement	2008	Icelandic
190	ON	Procedure for Unusual or Major Fluxes in Reinjection to Wells	2017	Icelandic
191	ON	Q8 in additional questions	2018	English
192	ON	QS_10 EIA	2018	English
193	Efla	Research on Moss at Hellisheiði Geothermal Power Plant	2009	Icelandic
194	David Ostman	A New Approach for Assessing Landscape Impacts of Geothermal Power Plants: A Case Study of Hellisheiði	2015	English
195	Garðar Þorfinnsson	Restoration West of Hengill		Icelandic
196	ON	Risk Analysis - Environmental and Stakeholder Issues	2017	Icelandic
197	Heilbrigðiseftirlit Suðurlands	Scheduled Inspection from Environmental and Public Health Authority of South Iceland	2017	Icelandic
199	Heilbrigðiseftirlit suðurlands	Scheduled Inspection from Environmental and Public Health Authority of South Iceland - List		Icelandic
200	ON	Tender Documents for Hellisheiði Power Plant - Phase 6. Hverahlíð Piping	2014	Icelandic
201	Mannvit	Main pipes from Hverahlíð to HH power plant - Inquire about the obligation of assessment	2014	Icelandic
202	ON	A 3-D video clip for public and stakeholders to show the "Hverahlíðar pipe line" project and "visual impact"	2015	Icelandic
203	Mannvirkjastofnun	Certification of inner safety management according to law no. 146/1996	2015	Icelandic
204	Deloitte	Certification of EQA by Deloitte 4.4.2012	2012	English
205	OR	Press release on EQA certification	2012	English
206	Ása L. Aradóttir et. al.	Restoration of Natural Vegetation in disturbed highland areas (Hellisheiði as case study)	2011	Icelandic/ English
207	Saving Iceland	Hellisheiði_A Geothermal Embarrassment	2012	English
208	OR/ON	Resource monitoring process	2017	Icelandic

209	OR/ON	Geothermal fluid disposal and ground water monitoring process	2017	Icelandic
210	ON	Compliance with EIA and licencing: Overview and scheduling	2018	Icelandic
211	OR/ON	Resource management process	2017	Icelandic
212	OR	5-year plan for production, monitoring and research for Hengill 2017-2022	2017	Icelandic
213	OR/ON	Geothermal resource management goals	2017	Icelandic
214	OR	Production report for Hellisheiði 2016	2017	Icelandic
215	OR	Geothermal reservoir model update report from 2010	2010	Icelandic
216	OR	Dealing with intense production density: Challenges in understanding and operating the Hellisheiði Geothermal Field, SW-Iceland	2016	English
217	ON	Production plan 2017		Icelandic
218	ON	Power purchase agreements in MW and duration		Icelandic
219	Orkustofnun	Utilization licence for Geothermal Resource at Hellisheiði	2015	Icelandic
220	ÍSOR	Design of new well HE-61 to be drilled in Jan/Feb 2018	2017	Icelandic
221	OR	Well monitoring - possible effects of reinjection to a nearby production well	2017	Icelandic
222	OR	Steam supply decline - modelling results for 2017-2018: Predictions of geothermal reservoir response to production in 2018	2017	Icelandic
223	OR	Measurements of pressure drawdown in Hverahlíð and possible outcomes	2017	Icelandic
224	OR	Steam supply forecast 2017-2018: Well production data - Hellisheiði measurements 2017	2017	Icelandic
225	OR	Status of geothermal fluid reinjection at Hellisheiði 2016	2016	Icelandic
226	OR	Comprehensive tracer testing in the Hellisheiði geothermal field in SW-Iceland	2016	English
227	ON	Strategic assignment 2016: Improved energy efficiency at Hellisheiði	2017	Icelandic
228	OR	Varied production - test report	2017	Icelandic
229	ON	E-mail: Answer to additional questions from Joerg and Bernt	2018	English
230	ON/OR	2018-0004 Hverahlíð líkanreikningar 5 Feb 2018	2018	Icelandic
231	Hjalti Franzson et.al.	The Hengill-Hellisheiði Geothermal Field. Development of a Conceptual Geothermal Model	2005	English
232	María Gudmundsdottir et.al.	Best Practices and Success in Iceland on Drilling and Exploitation	2017	English
233	Iceland Review	Iceland Geothermal Power Plant Unsustainable	2013	English
234	Askja Energy	Serious geothermal troubles for Reykjavík Energy (website, February 24)	2017	English
235	Elín Hallgrímsdóttir et.al.	The Geothermal Power Plant at Hellisheiði, Iceland	2012	English
236	ON	Rotor Workshop and maintenance schedule 2018	2018	English
237	ON	Projects on schedule in DMM	2018	Icelandic
238	ON	Assessment Guidance	2018	Icelandic

239	ON	Pressure in boreholes at the top	2018	Icelandic
240	ON	steam quality measurements	2018	Icelandic
241	ON	Hellisheiði - unavailability of machines 2014 - 2018	2018	Icelandic
242	ON	Updated maintenance scheme 1998-2030 - 5-year interval of rotors	2018	Icelandic
243	ON	Maintenance scheme 2018	2018	Icelandic
244	ON	Report for machine 1 in Nesjavellir 2015	2018	Icelandic
245	ON	Generator Inspection in Nesjavellir in 2008 - a report	2018	Icelandic
246	ON	Report for individual machines Hellisheiði	2010-2018	Icelandic
247	ON	Hellisheiði- PCA - Risk engineering report	2014	English
248	ON	Nesjavellir-PCA - Risk engineering report	2014	English
249	ON	Hellisheidi Reykjavik PG Risk Survey Report Aug 2017 R1	2017	English
250	ON	Nesjavellir-Draft PG Risk Survey Report	2017	English
251	ON	KPI´s for the operation - report to Board of ON	2018	Icelandic
252	ON	Technical Report 2016_GEOTUR.pdf	2016	English
253	ON	Transformer Hellisheiði	2018	English
254	ON	DMM -Transformer analysis	2018	English
255	ON	Overhaul 11kV switchgear	2018	English
256	ON	switchgear	2018	English
257	ON	HEL - Switchgear	2018	English
258	Ari Elisson	Performance Indicators for Maintenance in Geothermal Power Plants	2013	English
259	ON	Access Permission to ON Infrastructure		Icelandic
260	ON	Communication Channel in the case of breakdown or accident at the power plant area		Icelandic
261	ON	Hydrogen Sulphide - response plan (ONV-L-105)	2016	Icelandic/ English
262	Snjólaug Ólafsdóttir	ON Hydrogen Sulphide Monitoring by ON - Status at End of Year 2014	2014	Icelandic
263	ON	Reboot of Reinjection Utility at Húsmúli		Icelandic
264	Veitur	LAV-407 Response to pollution hazards in water conservation areas	2016	Icelandic
265	ON	All Risks Insurance Survey Report	2017	English
266	ON	Hellisheiði Power Plant Evacuation Plan		Icelandic
267	OR	Earthquakes due to reinjection	2017	Icelandic
268	ON	Quality Document on Announcement to licensors on H2S	2017	Icelandic
269	OR	Water Protection in Hellisheiði Power Plant Vicinity - Screenshot		Icelandic
270	Bjarni Bessason, Eyþór H. Ólafsson, Gunnar Gunnarsson, Ólafur G. Flóvenz, Steinunn S. Jakobsdóttir, Sveinbjörn Björnsson and Þóra Árnadóttir	Report on induced seismicity due to 2011 seismic event	2012	Icelandic
271	OR	The Protection of Drinking Water Resources	2018	Icelandic
272	ON	Hellisheiði Power Plant Contingency Plan		Icelandic

273	ON	News	2017	Icelandic/ English
274	Verkís	Power generators burning and explosion risk assessment	2017	Icelandic
275	Efla	Hellisheiði area safety plan - map	2014	Icelandic
276	Einar Gunnlaugsson	The Hellisheidi Geothermal Project – Financial Aspects of Geothermal Development	2012	English
277	ON	ON budget 2018 and 5 year forecast 2019-2023	2017	Icelandic
278	ON	Risk report	2017	Icelandic
279	ON	STE-237 Risk Policy for ON	2017	Icelandic
280	ON	OR finance report 2016		English
281	ON	Fitch presentation - November 2017	2017	English
282	Moody's	Moody's changes outlook to positive on Orkuveita Reykjavikur's Ba2 rating	2017	English
283	Fitch	FITCH UPGRADES ORKUVEITA REYKJAVIKUR TO 'BB'; OUTLOOK STABLE	2017	English
284	Reitun	Positive Outlook for Reykjavík Energy	2017	Icelandic
285	ON	Memorandum - OR board counterparty risk Norðurál	2015	Icelandic
286	ON	Aluminum business cost curve	2017	Icelandic
287	ON	OR consolidated forecast 2017-2023	2017	Icelandic
288	National Energy Authority	Energy forecast 2017- 2050	2017	Icelandic
289	ON	12-month change 2018 01 02	2018	Icelandic
290	ON	2017-2023 5-year forecast	2017	Icelandic
291	ON	ON Measurements - 2017 9 m. statement	2017	Icelandic
292	ON	operating report 2017 ON		Icelandic
293	ON	Tableau Dashboard		Icelandic
294	ON	The mountain presentation 12.01.2017	2017	Icelandic
295	OR	OR financial statement 2016		Icelandic
296	Norðurál	NÁG - 2016 (Nordural Financial statement)	2017	Icelandic
297	Norðurál	Norðurál Grundartangi financial statements, progress	2017	Icelandic
298	ON	2016 Icelandic Survey - customer satisfaction	2016	Icelandic
299	ON	ON Survey on awareness and opinion of customers _Gallup	2017	Icelandic
300	ON	ON Survey - Geothermal Exhibition	2017	English
301	ON	Service survey for ON - within OR Group	2014	Icelandic
302	ON	A survey among companies in business with ON - category A	2014	Icelandic
303	ON	A survey among companies in business with ON - category B	2014	Icelandic
304	ON	Price Benchmarking in Scandinavia - Samorka 2016	2016	Icelandic
305	ON	Market research for electric cars - 2016	2016	Icelandic
306	ON	Marketing research. Analysis of Gallup's outcome in regards to effects on marketing actions.	2017	Icelandic
307	ON	Introduction of the Marketing department at ON 2016	2017	Icelandic
308	ON	Overview of surveys for ON_Zenter	2017	Icelandic
309	ON	A list in English over all surveys for ON done by Gallup	2018	English

310	ON	A general introduction on ON and the Geothermal park	2017	English
311	ON	A draft report (not approved as final) on microalgae and state of knowledge regarding environmental affairs	2017	English
312	ON	A list of streams at the Geothermal park and a list of industrial processes that may be able to utilize these resources	2017	Icelandic
313	ON	A framework for an agreement with Algaennovation	2018	English
314	ON	Internal processes for business development (energy intensive industry): ONS-D-230	2017	Icelandic
315	ON	Internal processes for review of contracts (energy intensive industry): ONS-D-231	2017	Icelandic
316	ON	Awards and recognition for ON through the years 2015-2017 - ppt slides	2017	Icelandic
317	ON	Agreement with N1 - regarding charging stations for electric cars	2017	Icelandic
318	ON	ON Charging stations 2017 - Iceland is about to open - Live streaming video	2018	Icelandic
320	ON	Contracts regarding arm floats for various swimming pools in Iceland (kútar)	2017	Icelandic
321	ON	Contracts regarding maintenance of street lighting	2017	Icelandic
322	ON	Sample of a presentation for ON managers	2017	Icelandic
323	ON	VON - system to handle investment project and their budget	2018	Icelandic
324	ON-NEW	Meeting minutes from the Board of ON - 19th of April 2017	2017	Icelandic
325	ON-NEW	Drilling a hole - a memo to the Board of ON	2017	Icelandic
326	ON-NEW	Drilling a hole - a introduction to the project to the Board of ON	2017	Icelandic
327	ON-NEW	Gas into rock, text in Icelandic and English for Finance department	2017	Icelandic/ English
328	ON-NEW	SF 189 5. Summary of status and options for Hellisheiði energy source renewal	2013	Icelandic
329	ON	ONS-D-231 Rýni samninganefndar ON á samningum (Contract review committee)	2018	Icelandic
330	ON	SKI-380 Hlutverk samninganefndar ON (Contract review committee)	2018	Icelandic
331	Property tax paid to Ölfus	Taxes paid from ON to neighboring communities in 2017	2017	Icelandic/ English
332	ON/OR	Hellisheiði Power Plant Map	2018	English
333	Ölfus	Ölfus 2004 - Agreement between OR and Ölfus on Geothermal Power Plant at Hellisheiði	2004	Icelandic
334	Ölfus	Agreement between OR and Ölfus on diverse matters related to Hellisheiði Power Plant	2006	Icelandic
335	Ölfus	Contract on the completion on agreement between OR and Ölfus on Hellisheiði Power Plant	2014	Icelandic
336	OR	Contract with a sport club - ÍR - when planning to build the power plant	2005	Icelandic
337	ON	Accident Analysis - ON Employee Case	2017	Icelandic

338	ON	Accident Solution - ON Employee Case - Part of solution document 1	2017	Icelandic
339	ON	Accidents are OFF - Checklist		Icelandic
340	ON	Accidents are OFF - Project overview - screenshot		Icelandic
341	ON	Accidents are OFF - Tableau Screenshot		Icelandic
342	OR	Application for grant for physical training		Icelandic
343	OR	Bimonthly OHS run-through on management team meeting 25-10-2017 - Presentation	2017	Icelandic
344	ON	Bimonthly OHS run-through on management team meeting 25-10-2017 - Meeting notes	2017	Icelandic
345	ON	Checklist for a job where there is a danger of H2S in hazardous amount		Icelandic
346	ON	Contingency Plan for Work on Overflow Site		Icelandic
347	ON	Contract between ON and Árnessýsla Fire Protection	2013	Icelandic
348	ON	Contract between ON and The Weather Watch	2017	Icelandic
349	OR	Contract on grant for using sustainable transport to and from work		Icelandic
350	ON	Contractors - Security Appraisal and Feedback		Icelandic
351	ON	DMM - Overview over Work Orders after Management Patrol - Screenshot		Icelandic
352	OR	Educational video about equality (1 of 4)		Icelandic
353	ON	Emergency Exits - Engine 1 Hellisheiði		Icelandic
354	OR	Employee Conversation - Applied Course for Managers	2017	Icelandic
355	OR	Employee Conversation - Guidelines for Managers		Icelandic
356	ON	Example of job advertisement	2017	Icelandic
357	Securitas	Fire Alarm System Appraisal	2017	Icelandic
358	ON	Fire Brigade Access		Icelandic
359	ON	Fire Brigade Access - Overview - Screenshot		Icelandic
360	ON	Fire Hydrants at Hellisheiði - screenshot		Icelandic
361	Vinnuvernd	Health Inspection at Orkuveitan - Summary	2017	Icelandic
362	OR	List of union representatives - screenshot		Icelandic
363	ON	Lock - Label - Test		Icelandic
364	ON	Management Safety Appraisal - Biweekly meeting invitation		Icelandic
365	ON	Management Safety Appraisal - Hellisheiði Repair Shop - Report	2017	Icelandic
366	ON	Meeting Invitation - Daily - With Contractors		Icelandic
367	ON	Meeting Invitation - Weekly - Safe Friday - Management Team		Icelandic
368	ON	Meeting Invitation - Weekly - Safe Monday		Icelandic
369	ON	OHS Appraisal for Contractors Rafmiðlun Documents 1-5		Icelandic
370	OR	OHS Database - Screenshot		Icelandic
371	ON	ON Equality Committee Annual Report 2016.pdf	2016	Icelandic
372	OR	ON OHS Control Panel - Screenshot 1		Icelandic
373	OR	ON OHS Control Panel - Screenshot 2		Icelandic
374	ON	ON Policy - Equal Rights		Icelandic
375	OR	ON Policy - OHS		Icelandic

376	ON	ON Policy - Terms of Employment		Icelandic
377	ON	ON Risk Analysis		Icelandic
378	ON	ON Safety Committee - Meeting Notes	2017	Icelandic
379	OR	OR Corporate Mgmt Meeting #1 2018 - OHS Issues	2018	Icelandic
380	OR	OR Corporate Mgmt Meeting #28 2017 - OHS Issues	2017	Icelandic
381	OR	OR Policy - Committee of Equal Rights Action Plan 2017-2018		Icelandic
382	OR	OR Policy - Equal Rights		Icelandic
383	OR	OR Policy - HRM		Icelandic
384	OR	OR Policy - Key Result Accident Frequency		Icelandic
385	OR	OR Policy - Key Result Job Satisfaction		Icelandic
386	OR	OR Policy - OHS		Icelandic
387	OR	OR Policy - Procedure for Committee of Equal Rights		Icelandic
389	OR	OR Policy - Risk Management		Icelandic
390	OR	OR Policy - Sustainable Transport		Icelandic
391	OR	OR Policy - Terms of Employment		Icelandic
392	OR	OR Policy Workplace harassment policy		Icelandic
393	OR	Pay analysis process		Icelandic
394	ON	Precaution when working on site where H2S pollution is a danger		Icelandic
395	Vottun ehf.	Report on OR Maintenance Appraisal VÚ 2017-1	2017	Icelandic
396	ON	Safety Appraisal and Feedback		Icelandic
397	ON	Safety Index ON 2017 - Management Safety Appraisal is calculated into the safety index - screenshot	2017	Icelandic
398	ON	Safety Index ON 2017 - Screenshot	2017	Icelandic
399	Efla	Security Analysis - Confidential Report - Screenshot		Icelandic
400	OR	Summer jobs 2017 - Screenshot overview		Icelandic
401	ON	Weekly OHS meeting at Hellisheiði Plant	2017	Icelandic
402	Icelandic government	390/2009 Regulation document	2012	Icelandic
403	Municipality of Ölfus	Hellisheidi Power Plant Site Plan. From Municipal Zoning Plan 2010-2022	2010	Icelandic
404	Dora Ellen Dorhallsdottir	Landscape Value at Hengill area (impact zone for energy generation)	2002	Icelandic
405	ISOR	Geological features at Hellisheidi Geothermal Power Plant impact zone	2003	Icelandic
406	Birna Lárusdóttir and Saedís Gunnarsdóttir	Archeological survey at Hellisheidi Geothermal Plant site	2003	Icelandic
407	Birna Lárusdóttir	Report on archeological relics at Hellisheidi	2007	Icelandic
408	Birna Lárusdóttir	Supplementary survey of archeological relics at Hverahlíd	2007	Icelandic
409	Mannvit	Landscape at Hengill Area	2009	Icelandic
410	Birna Lárusdóttir	Archeological survey for planned research drilling at Litla-Meitil and Gráuhnúka	2008	Icelandic
411		Report on archeological research at Hellisheidi Geothermal Power Plant		Icelandic
412		Explanation of archaeological remains in the Hellisheiði power plant area Stóra-Skarðsmýrarfjall, Ölkelduháls, Hverahlíð		Icelandic

413	OR	Strategy for Recreation and Cultural Heritage at Hengill (Not Passed)	2010	Icelandic
414	OR	Brochure from Educational Hikes Organised by OR		Icelandic
415	OR	Kolviðarhóll interactive media from geothermal exhibition – stories, recreation, flora, fauna, historical use of geothermal heat, cultural relics	2018	Icelandic
416	ON	Resource Park Site Plan	2018	Icelandic
417	OR	1.5 billion grant for climate project - News from OR	2017	Icelandic
418	OR	Approach to revegetation and surface finish at Hellisheiði 2007-2010	2010	Icelandic
419	Jakob K. Kristjánsson et. al.	Comprehensive Enquiry into Hot Springs Biosphere at Hengill Area	1996	Icelandic
420	Perkins et al.	Consistent temperature dependence	2011	English
421	Landbúnaðarháskólinn	Course in ecological restoration at construction sites	2017	Icelandic
422	Landgræðsla Ríkisins & ON	Course on how to repair moss damages	2017	Icelandic
423	Gudmundsdottir et al.	Diatoms as Indicators	2016	English
424	ON	DMM - Restoration Project Description - Screenshot	2017	Icelandic
425	ON	DMM- Restoration Project Overview - Screenshot	2017	Icelandic
426	Magnea Magnúsdóttir	Ecological restoration in Hellisheiði	2017	English
427	Guðrún Óskarsdóttir	Ecological solutions to restore roadsides	2015	Icelandic
428	Sólveig K. Pétursdóttir et. al	EIA Geothermal Power Plant at Hellisheiði. Hot Spring Ecosystem Survey	2002	Icelandic
429	Sólveig K. Pétursdóttir et. al	EIA Geothermal Power Plant at Hverahlíð and Ölkelduháls. Hot Spring Ecosystem survey	2006	Icelandic
430	VGK	Enlargement of Hellisheiði Geothermal Power Plant. EIA	2005	Icelandic
431	ON	Environmental Improvement and Restoration plan	2012	Icelandic
432	ON	Experimental plots in 2012	2012	Icelandic
433	VGK	Geothermal Power Plant at Hellisheiði. Environmental Impact Assessment	2003	Icelandic
434	OR	Guidelines on restoration on vegetated areas	2016	Icelandic
435	OR	Guidelines on visual impacts and restoration	2016	Icelandic
436	Morgunblaðið	How to repair damaged moss - news report	2017	Icelandic
437	VSÓ Consulting	Hverahlíð 90 MWe Power Plant - EIA (Not Passed - See Hverahlíð Piping instead)	2007	Icelandic
438	ON	Hverahlíð Piping - Restoration of disturbed land		Icelandic
439	O'Gorman et al.	Impacts of Warming on the Structure and Functioning of Aquatic Communities	2012	English
440	Hannesdottir et al.	Increased Stream Productivity with Warming Supports Higher Trophic Levels	2013	English
441	Jeppesen et al.	Interaction of Climate Change and Eutrophication	2010	English
442	Ágústa Helgadóttir, Ásta Eyþórsdóttir & Sigurður H. Magnússon	Monitoring of vegetation in the vicinity of the geothermal power plants at Hellisheiði and Nesjavellir	2013	Icelandic
443	Magnea Magnúsdóttir	Moss heaths; damages and methods to restore	2013	Icelandic with English abstract
444	Morgunblaðið	Moss is of special interest to me - part 1	2015	Icelandic

445	Morgunblaðið	Moss is of special interest to me - part 2	2015	Icelandic
446	Friberg et al.	Relationship between structure and function in streams contrasting in temperature	2009	English
447	Efla	Research on Moss at Hellisheiði Geothermal Power Plant	2009	Icelandic
448	ON	Restoration Videos on Youtube		Icelandic
449	Garðar Þorfinnsson	Restoration west of Hengill		Icelandic
450	Landgræðsla Ríkisins & ON	Restore the land TV - programme on ÍNN	2017	Icelandic
451	Járngerður Grétarsdóttir	Seed containing hey transfer - Screenshot	2015	Icelandic
452	Woodward et al.	Sentinel systems on the razor's edge	2009	English
453	Rasmussen et al.	Steam ecosystem properties and processes along a temperature gradient	2010	English
454	Demars et al.	Stream Hydraulics and temperature determine the metabolism of geothermal Icelandic streams	2011	English
455	ON	Tender Documents for Hellisheiði Power Plant - Phase 6. Hverahlíð Piping	2014	Icelandic
456	Ása L. Aradóttir & Guðrún Óskarsdóttir	The use of native turf transplants for roadside revegetation in subarctic areas	2013	English
457	UNU-LTR	UNU-LTR training programme visit at Hellisheiði	2012	English
458	Jóhanna Pétursdóttir	Using turf transplants for restoration	2015	Icelandic
459	Guðmundur Guðjónsson et al	Vegetation and Birdlife at Hengill Area and Hellisheiði	2005	Icelandic
460	Jón Einar Jónsson	Wildfowl research at Ölkelduháls and Hverahlíð, summer 2006	2006	Icelandic
461	ON	Willow cuttings at Gígahnjúkur	2014	Icelandic
462	ON	Restoration 2015	2015	Icelandic
463	ON	Restoration 2016	2016	Icelandic
464	ON	Restoration 2007-2014 and 2017 - GIS map	2007-2017	Icelandic
465	ON	Lupin cutting 2012-2014	2014	Icelandic
466	B. Halldorsson et.al.	On the Effects of Induced Earthquakes due to Fluid Injection at Hellisheidi Geothermal Power Plant, Iceland	2012	English
467	Hildigunnur Thorsteinsson and Gunnar Gunnarsson	Induced Seismicity—Stakeholder Engagement in Iceland	2014	English
468	Iceland Review	Sunday's Seismic Activity (website 19 Sept)	2016	English
469	D. Juncu et.al.	Injection-induced surface deformation and seismicity at the Hellisheidi geothermal field, Iceland (unpublished draft)	2018	English
470	Einar Gunnlaugsson	Environmental Management and Monitoring in Iceland: Reinjection and Sequestration at the Hellisheidi Power Plant	2016	English
471	ÍSOR	Pre-assessment report for induced seismicity due to reinjection changes in Grauhnukar and Husmuli	2017	Icelandic
472	Veðurstofa Íslands	Pre-assessment report for induced seismicity due to new reinjection site at Skarðsmýrarfjall	2016	Icelandic

473	ON/OR	email with construction permit from Ölfus municipality for new reinjection site	2016	Icelandic
474	ON/OR	Protocol for startup of reinjection to Húsmúli field	2018	Icelandic
475	Ingvar Þór Magnússon	GNSS- and gravity measurements at Hengill 2016	2016	Icelandic
476	ON	Calibrating reports - list	2017	Icelandic
477	Vista	2017-07-17 Calibrating report Lækjarbotnum july 2017	2017	Icelandic
478	ON	H2S monitoring reports - list	2017	Icelandic
479	ON	Emails on sulfix station	2017	Icelandic
480	ON	Report to licence givers on H2S	2017	Icelandic
481	ON	Gas flow - annual overview 2002-2016 from Hellisheidi power plant	2017	Icelandic
482	ON	Memo paper - Gas flow from Hellisheidi power plant	2017	Icelandic
483	Einar Sveinbjörnsson	H2S distribution estimation from weather reporter - list	2017	Icelandic
484	Elí Björk Jónasdóttir	H2S distribution estimation until new-year	2017	Icelandic
485	ON	Emergency brine disposal posts- list	2017	Icelandic
486	ON	Emergency brine disposal in Hellisheiði - finished	2017	Icelandic
487	ON	H2S monitoring management reports	2017	Icelandic
488	Vista	ON monitoring management report Vista 2017	2017	Icelandic
489	Veitur	Response to pollution hazards in water conservation areas	2016	Icelandic
490	Veitur/GR/ON	Water protection around ON´s power plants in Hengill - GIS map - 12.1.2018	2018	Icelandic
491	OR	Water resource protection (TAX-013)	2018	Icelandic
492	ON	Sulfix - development of injection - PPT slide	2018	Icelandic
493	OR	Analysis on the effect of partial surface discharge of geothermal fluid at Hellisheiði (under revision)	2017	Icelandic
494	ÍSOR	Chemical composition of ground water at Hellisheiði	2005	Icelandic
495	OR	Water level and chemical composition monitoring of ground water	2008	Icelandic
496	OR	Review of water level measurements at Hellisheiði 2001-2014	2012	Icelandic
497	OR	Production report for Hellisheiði 2016	2017	Icelandic
498	OR/ON	Geothermal fluid disposal and ground water monitoring process	2017	Icelandic
499	OR	Effects on groundwater of surface discharge of geothermal fluid at Hellisheiði	2018	Icelandic
500	Vatnaskil	Ground water flow model 2016	2017	Icelandic
501	ON, OR	Hiking Trails in the Hengill area	2012	Icelandic/ English
502	Krage Carlsen	Health effects of air pollution in Iceland	2014	English
503	University of Iceland, web site	Geothermal areas and cancer	2012	English
504	Layton, Anspaugh and O´Banion	Health and Environmental Effects Document on Geothermal Energy - 1981	1981	English
505	WHO, Regional Office for Europe	Hydrogen sulfide, Chapter 6.6 from larger publication, available on the Internet at www.euro.who.int	2000	English

Appendix C: Visual Evidence

Photo 1: Main power plant building

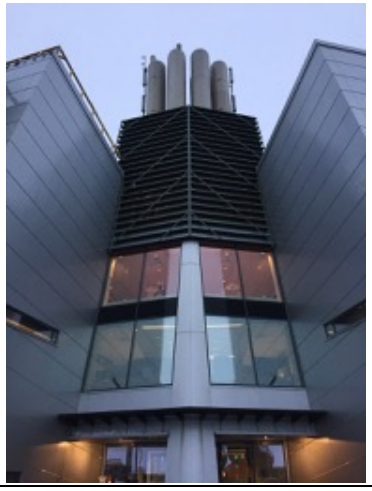
Photo 2: Cooling towers

Photo 3: Entrance to power plant by day

Photo 4: Entrance to power plant by night

Photo 5: Staff house for overnight shifts

Photo 6: Demisters to produce dry steam

	
Photo 7: Charging station for electric vehicles	Photo 8: Ventilation system and disused gas exhausts
	
Photo 9: Waste disposal containers	Photo 10: Containers for experimental-scale use of by-products

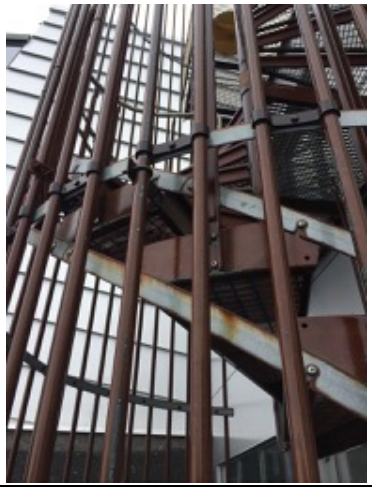



Photo 11: Corrosion of metals accelerated by H_2S	Photo 12: Storage container for tracers

Photo 13: Visitors walking through gate into restricted area

Photo 14: GeoSilica workshops behind power plant

Photo 15: Fire damage and scaffolding for repairs

Photo 16: Wellfields above power plant (Sept 2017)

Photo 17: Sleggja power plant for units 5 & 6

Photo 18: Wellfield and power plant units 5 & 6

Photo 19: Safety signage on public road to wellfield

Photo 20: Reinjection wells

Photo 21: Landsnet substation building and connection to transmission lines

Photo 22: Transmission lines near power plant

Photo 23: Local search & rescue team practicing, with steam pipelines in background

Photo 24: Drill rig at Hverahlíd

Photo 25: Drill rig at Hverahlíd 2

Photo 26: Clean up after drilling, with cement containers

Photo 27: New wellhead at Hverahlíd in foreground, without protective dome

Photo 28: Wellheads at Hverahlíd

Photo 29: Wellheads at Hverahlíd 2

Photo 30: Steam separators and pumping station at Hverahlíd

Photo 31: Well-insulated pipeline

Photo 32: Willow cuttings - two years old (ON)

Photo 33: Turf transplantation - before intervention (ON)

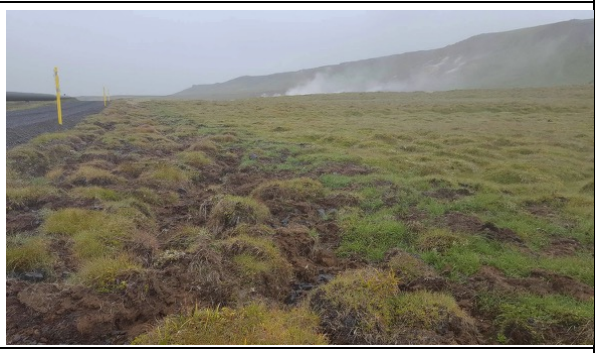


Photo 34: Turf transplantation - after intervention (ON)

Photo 35: Turf transplantation - before intervention 2 (ON)

Photo 36: Turf transplantation - after intervention 2 (ON)

Photo 37: Moss distribution by pipeline - before intervention (ON)

Photo 38: Moss distribution by pipeline - after intervention (ON)

Photo 39: Seeding with hay transfer - before intervention (ON)

Photo 40: Seeding with hay transfer - after intervention (ON)

Photo 41: Seeding with hay transfer - before intervention 2 (ON)

Photo 42: Seeding with hay transfer - after intervention 2 (ON)

Photo 43: Generator

Photo 44: Condenser

Photo 45: Cold end equipment

Photo 46: Gas vacuum pumps

Photo 47: Sump next to generator, with oil pumps and fire control system

Photo 48: Assessors in front of turbine

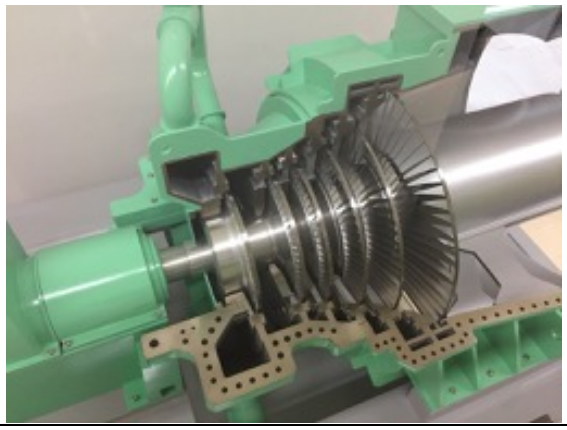


Photo 49: Turbine model

Photo 50: Machine hall roof and crane

Photo 51: PPE required in machine hall

Photo 52: Electric controls in overpressurized room (protected from H_2S)

Photo 53: Transformer in separate room

Photo 54: De-aerator in hot water plant

Photo 55: Heat exchangers

Photo 56: Hot water lab, testing for pH

Photo 57: Panels in control centre

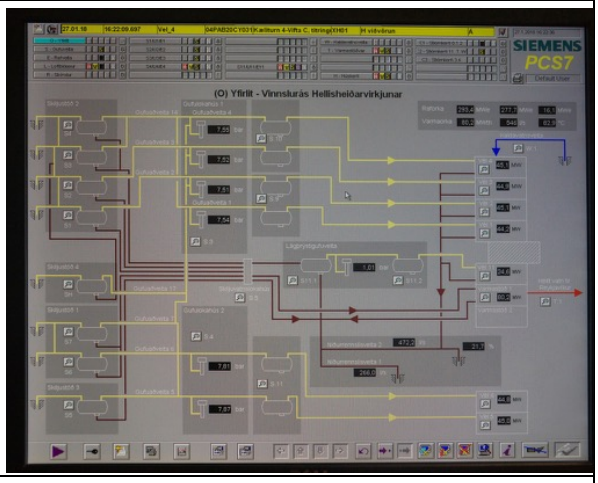


Photo 58: Overall view of plant control system

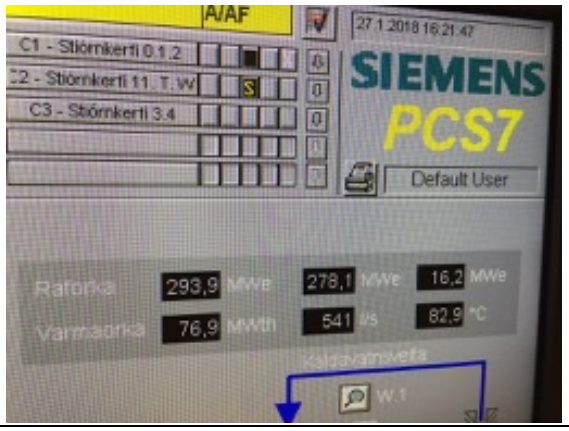


Photo 59: Current power generation, station power consumption, and hot water production

Photo 60: Newly installed camera surveillance system, with error messages

Photo 61: Staff room

Photo 62: Canteen

Photo 63: Kitchen

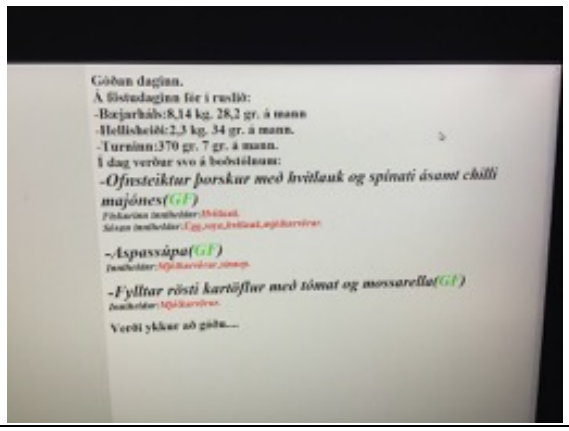


Photo 64: Information on meals, including message to encourage minimizing food waste

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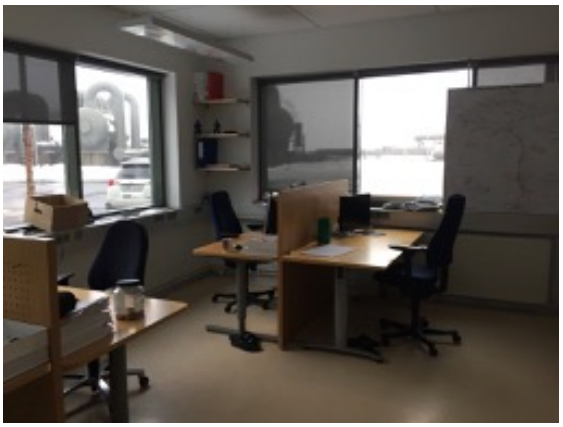
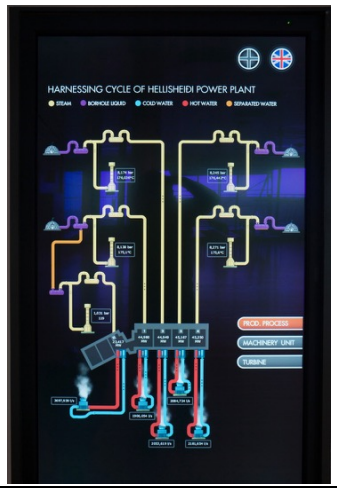
<tr><td>  </td><td>  </td></tr>
<tr><td>Photo 65: New projects office</td><td>Photo 66: Site map for Hverahlíd expansion in new projects office</td></tr>
<tr><td>  </td><td> 
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<tr><td>Photo 67: Growth experiments at Algaennovation lab</td><td>Photo 68: Display in visitor centre</td></tr>
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<tr><td>Photo 69: GeoSilica products in visitor centre store</td><td>Photo 70: Snow removal equipment</td></tr>
</table>

Photo 71: Spare parts storage

Photo 72: Work safety messages

Photo 73: Limited storage space for spare components

Photo 74: Safety cones in rotor workshop

Photo 75: Rotor workshop

Photo 76: Rotor undergoing major maintenance

Photo 77: Rotor undergoing major maintenance 2

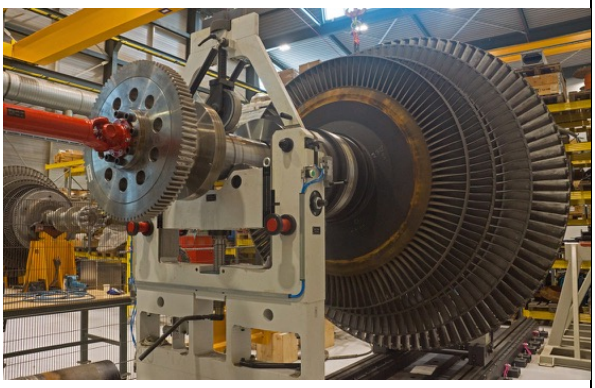


Photo 78: Rotor undergoing major maintenance 3

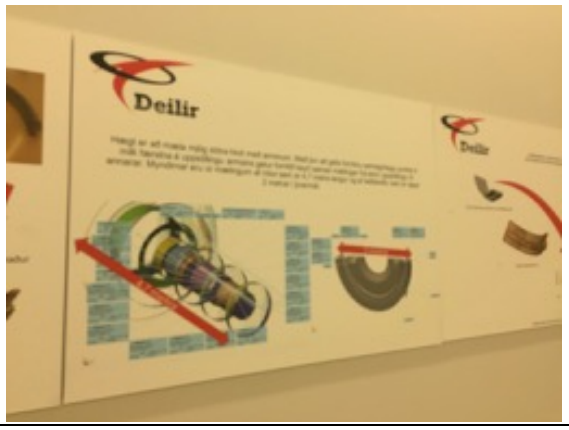


Photo 79: Charts in office of Deilir technical service contractor

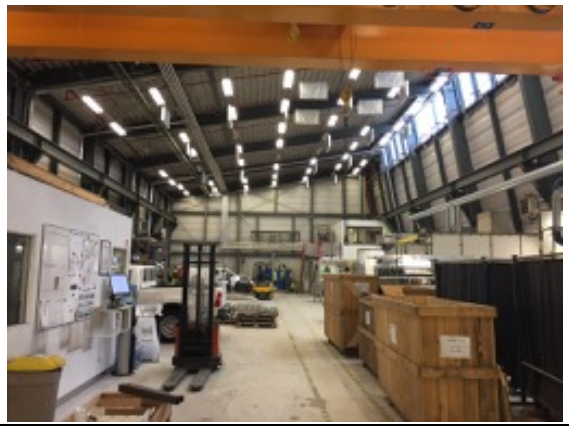


Photo 80: General workshop

Photo 81: Turbine parts welding

Photo 82: Turbine diaphragm, with Bjarni Már Júlíusson (ON CEO)

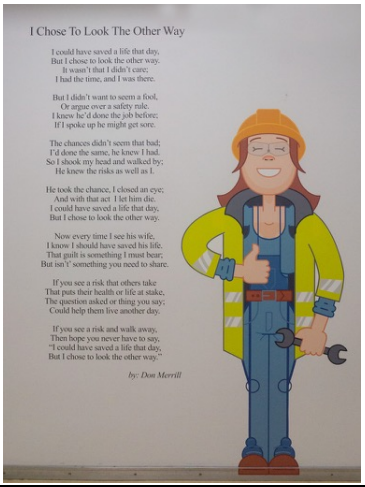
Photo 83: Welding work station message board

Photo 84: Turbine diaphragm rebuild work station message board

Photo 85: Charging station for personal H_2S meter

Photo 86: Personal H_2S meter self-calibration

Photo 87: Safety equipment and OH&S risk chart


I Chose To Look The Other Way

I could have saved a life that day,
But I chose to look the other way.
It wasn't that I didn't care;
I had the time, and I was there.

But I didn't want to seem a fool,
Or argue over a safety rule.
I knew he'd done the job before;
If I spoke up he might get sore.

The chances didn't seem that bad;
I'd done the same, he knew I had.
So I shook my head and walked by;
He knew the risks as well as I.

He took the chance, I closed an eye;
And with that act I let him die.
I could have saved a life that day,
But I chose to look the other way.

Now every time I see his wife,
I know I should have saved his life.
That guilt is something I must bear;
But isn't' something you need to share.

If you see a risk that others take
That puts their health or life at stake,
The question asked or thing you say;
Could help them live another day.

If you see a risk and walk away,
Then hope you never have to say,
"I could have saved a life that day,
But I chose to look the other way."

by: Don Merrill

Photo 88: Safety poem

Photo 89: First aid station, with Gísli Sveinsson (ON Assistant to CEO)

Photo 90: Breathing apparatus in case of gas accumulation

Photo 91: OH&S indicators displayed in power plant

Photo 92: Gas reinjection pumps

Photo 93: O&S indicators displayed in power plant 2

Photo 94: Scrubber for H_2S and CO_2 reinjection

Photo 95: Former oil-fired water heating plant in Reykjavík

Photo 96: GeoSilica brochure

Photo 97: Map for hiking trails supported by ON/OR

Photo 98: Visitor centre brochure

Photo 99: Hveragerdi town (Andrés Thorarinsson)

Photo 100: Hveragerdi geothermal emissions (Andrés Thorarinsson)

Photo 101: Hveragerdi air quality station (interior) (Andrés Thorarinsson)

Photo 102: Hveragerdi air quality station (exterior) (Andrés Thorarinsson)

Photo 103: Geothermal emissions at Hveragerdi 2 (Andrés Thorarinsson)

Photo 104: Hellisheidi Power Plant (Andrés Thorarinsson)