# Geothermal Sustainability Assessment Protocol

Landsvirkjun

## Theistareykir Power Project

Iceland

Project Stage: Preparation

Assessment Date: 16/01/2017 to 27/01/2017

Final

Report Date: 03/05/2017

**Assessor:** Dr Joerg Hartmann, Independent Consultant

**Project size:** 90 MW

**Cover page photo:** Theistareykir Power Station under construction in front of Bæjarfjall mountain. View from construction camp to the south. Steam rising from tests of production well on the left, and steam supply system in the centre, close to powerhouse and cooling towers.

# Acronyms

| Acronym | Full Text |
|---|---|
| ASÍ | Icelandic Confederation of Labour |
| CEO | Chief Executive Officer |
| EEA | European Economic Area |
| EFTA | European Free Trade Association |
| EMP | Environmental Management Plan |
| EU | European Union |
| EIA | Environmental Impact Assessment |
| EIB | European Investment Bank |
| FIDIC | International Federation of Consulting Engineers |
| GDP | Gross Domestic Product |
| GPS/GNSS | Global Positioning System/Global Navigation Satellite System |
| HSE | Health Safety Environment |
| IHA | International Hydropower Association |
| IMF | International Monetary Fund |
| InSAR | Interferometric synthetic aperture radar |
| ISO | International Organisation for Standardization |
| ISOR | Iceland Geosurvey |
| IST | Icelandic Standards |
| LCOE | Levelized Cost of Energy |
| masl | Meter above sea level |
| MoU | Memorandum of Understanding |
| NPV | Net present value |
| OECD | Organisation for Economic Co-operation and Development |
| OH&S | Occupational Health and Safety |
| OHSAS | Occupational Health and Safety Assessment Series |
| PPA | Power Purchase Agreement |
| SCSI | Soil Conservation Service of Iceland |
| SA | Confederation of Icelandic Employers |
| US EPA | United States Environmental Protection Agency |

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# Executive Summary

This report presents the findings of an assessment of the Theistareykir Power Project, using the Geothermal Sustainability Assessment Protocol. Theistareykir is a 90 MW geothermal power plant, with potential for future expansion, owned by Landsvirkjun and located in north-eastern Iceland. The assessment was carried out over a four-month period, with a planning visit in October 2016 and an on-site assessment in January 2017, encompassing two weeks of stakeholder interviews.

Iceland has significant geothermal potential and an installed capacity of some 700 MW. The project has benefitted from the combined experience of Landsvirkjun and two other power companies (Orkuveita Reykjavik and HS Orka), the National Energy Authority (Orkustofnun), the Environmental Agency (Umhverfisstofnun), the Planning Agency (Skipulagsstofnun), other government agencies, and specialised companies, such as consulting and drilling companies. The geothermal sector in Iceland is also supporting geothermal development abroad.

This assessment is the first test of the draft Geothermal Sustainability Assessment Protocol. The primary objective was to learn about the applicability of a sustainability protocol, modelled on the Hydropower Sustainability Assessment Protocol, to geothermal power projects. A second objective was 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 preparation stage of the project, before key decisions such as the granting of licenses and the final investment decision were taken. Experience shows that choices made in the preparation stage have the largest influence on sustainability, and therefore the assessment tool for the preparation stage was the first to be developed, and applied in this test. As Theistareykir is already under construction, the assessment was able to look backwards in history (to understand the choices made during preparation) as well as at the present status (to understand how plans have been implemented, or had to be adapted). The focus, however, is on the preparation stage, in particular the period between the founding of the project company Theistareykir ehf. in 1999, and the decision by the Landsvirkjun board to authorize tendering of the first steam turbine in 2014.

The results of the assessment show that Theistareykir has low adverse environmental and social impacts, and positive socio-economic effects for the project region, primarily by enabling industrial development and economic diversification in the sparsely populated north-east. Landsvirkjun is a strategic company for the Icelandic economy and for its owner, the Icelandic state, and has been a strong supporter of sustainability initiatives. Preparation of the project has been thorough, and there is only a limited number of issues that have to be considered as gaps, against the definitions of proven best practice in the Geothermal Protocol. There is broad stakeholder support for the project, although a transmission line is delayed because of some stakeholder opposition.

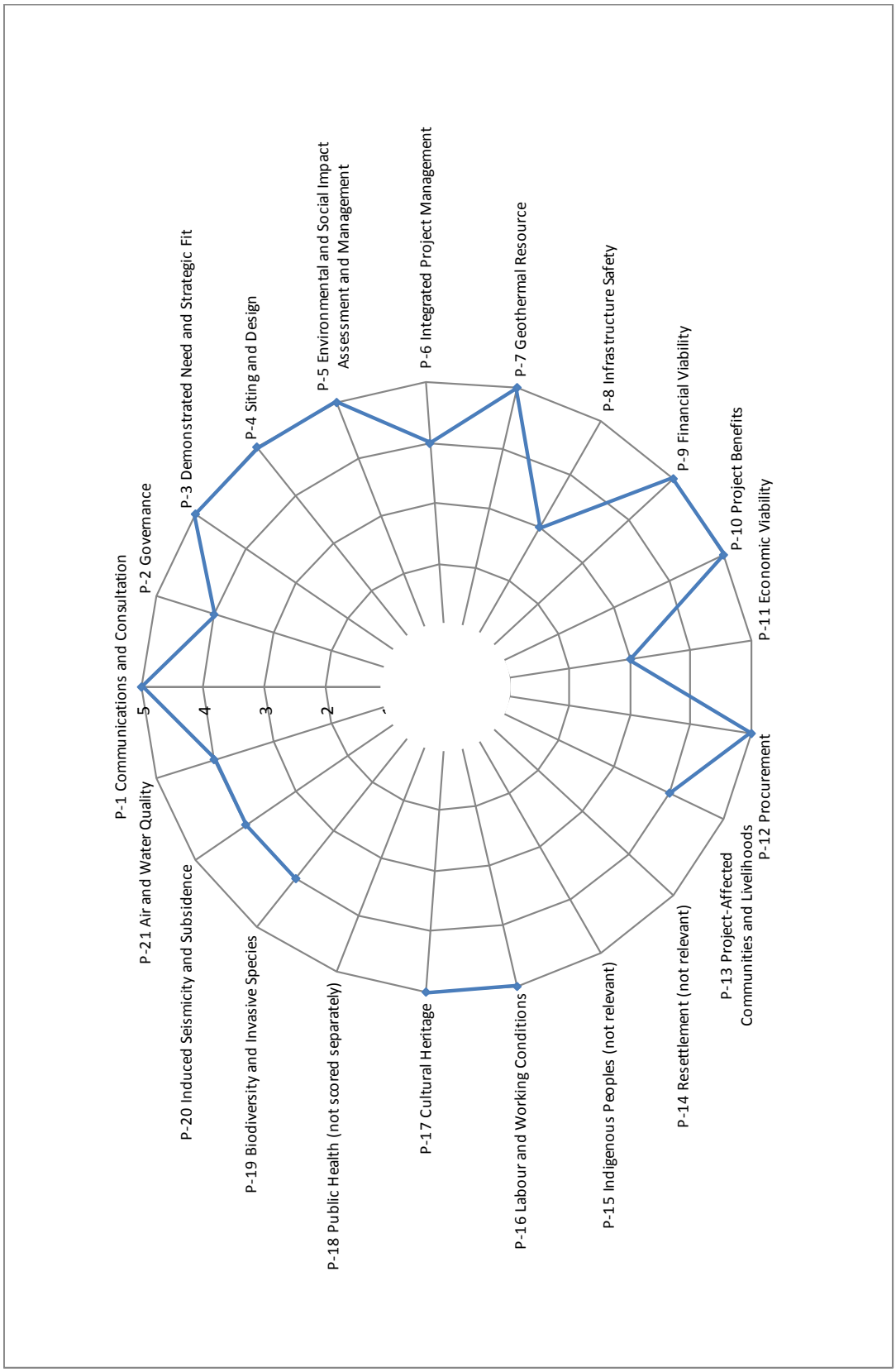
These issues are reflected in the findings of this assessment, and in a range of high scores that summarise the findings. Theistareykir meets Proven Best Practice on 10 topics: Communications and Consultation; Demonstrated Need and Strategic Fit; Siting and Design; Environmental and Social Impact Assessment and Management; Geothermal Resource; Financial Viability; Project Benefits; Procurement; Labour and Working Conditions; and Cultural Heritage.

The project exceeds Basic Good Practice on 6 topics, each of these with one significant gap against Proven Best Practice: Governance; Integrated Project Management; Project-Affected Communities and Livelihoods; Biodiversity; Induced Seismicity and Subsidence; and Air and Water Quality.

The project meets Basic Good Practice on 2 topics: Infrastructure Safety; and Economic Viability.

One topic, Public Health, was Not Scored to avoid duplication with Air and Water Quality. Two topics, Resettlement and Indigenous Peoples, are Not Relevant to Theistareykir. 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 | P-8: Potential public safety risks not systematically assessed, to inform siting and design of project components.<br>P-11: No estimates available at the project level, of the values of positive and negative externalities and of the range of potential outcome for net benefits (same gap under Outcomes).<br>P-20: No assessment of induced seismicity and subsidence risk in the EIA, or in subsequent reports.<br>P-6: Delay of transmission line, which could have been avoided by earlier action by Landsnet and/or by more timely decisions by government agencies and committees, risking the contractual power delivery date (same gap under Outcomes). |
| Management | No significant gaps | P-8: No independently reviewed public safety plans.<br>P-19: The lack of follow-up and monitoring of thermophilic biodiversity and potential impacts.<br>P-21: Diesel generators for the drilling rig instead of construction power supply. |
| Stakeholder Engagement | No significant gaps | P-11: No economic viability analysis for the project nor important elements thereof (financial costs and revenues) publicly disclosed.<br>P-13: A perception of a lack of participatory stakeholder engagement by Landsnet. |
| Stakeholder Support | No significant gaps | No significant gaps |
| Conformance/ Compliance | No significant gaps | No significant gaps |
| Outcomes | No significant gaps | P-2: The responsibility of municipalities for permitting major power projects. |

# 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 initiative 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 Theistareykir product was its first test. It should currently be considered a draft, with additional input to be requested from geothermal sector stakeholders. Only a tool for the Preparation stage is currently developed; other tools for other stages in the project cycle (early stage/project selection, implementation, and operation) may be developed over time. Ideally, the Geothermal Protocol 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 assessment, a Lead Assessor for the Hydropower Protocol was 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. Topic-by-topic scoring is an essential feature of the Protocol, providing an easily communicated and replicable assessment of the project's strengths, weaknesses and opportunities. 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 Theistareykir project, and future Landsvirkjun geothermal projects
- To facilitate a discussion within Landsvirkjun, with stakeholders, and with other working group members about sustainability in geothermal projects
- To test the draft Geothermal Sustainability Assessment Protocol

# Project Description

The high-temperature geothermal field at Theistareykir in north-east Iceland has a large power generation potential, with an estimated capacity of several hundred MW. It has been researched since the 1970s, and the first wells were drilled from 2000. At the time, the developer was a special-purpose vehicle, Theistareykir ehf. (Ltd.), with shareholders from local municipalities and utility companies. Since then, there have been extensive investigations and physical preparation.

Regional and municipal plans were developed, and environmental impact assessments undertaken for the power station, 220kV transmission lines to Bakki near Húsavík in the north and to Krafla in the south, and an industrial customer. From 2005, Landsvirkjun took over initially 32% of Theistareykir ehf., and then successively larger shares, eventually assuming full control in 2014. Investment required the identification of an industrial "anchor" customer that would take a large amount of reliable baseload power. This was initially going to be an aluminium smelter, but was then replaced by a siliconmetal factory.

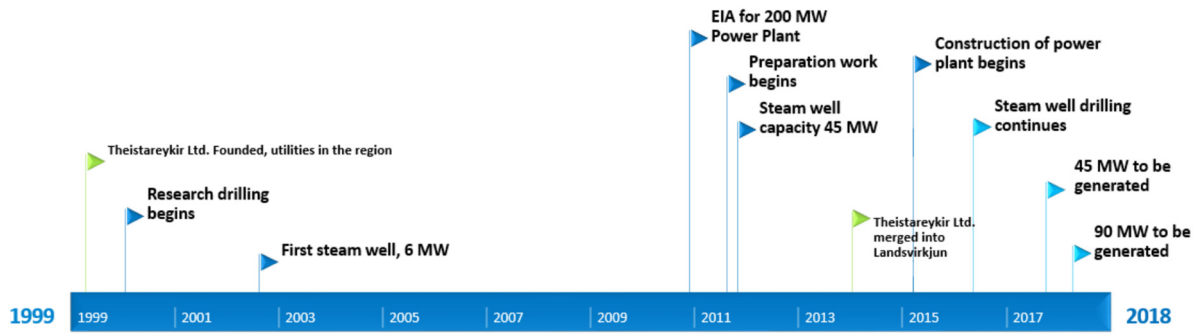
The preparation stage already included the construction of a 28km access road from Húsavik, groundworks for the power station foundation, and the installation of camps, a 9.5km long cold water supply system, electrical and telecommunications systems. Before the final investment decision was taken in 2014, enough wells had been drilled to substantiate projected power output for one 45 MW turbine.

The main investment phase started in 2015 and includes the drilling of additional production wells from several well pads, and construction of a steam supply system, powerhouse with adjacent cooling towers and service buildings, and a re-injection system. As drilling proceeded, it became clear that a second 45 MW was justified, and this was ordered in 2015. The first turbine is expected to be commissioned at the end of 2017, and the second one at the beginning of 2018. The annual output is expected to be 738 GWh, or about 4% of Iceland's total annual generation.

In parallel, transmission lines and the siliconmetal factory in Bakki, as well as an access road, tunnel and harbour expansion in Húsavík are being built. This assessment covers the transmission lines and roads required to build and operate Theistareykir, but not the infrastructure expansion and factory in the Húsavík area.

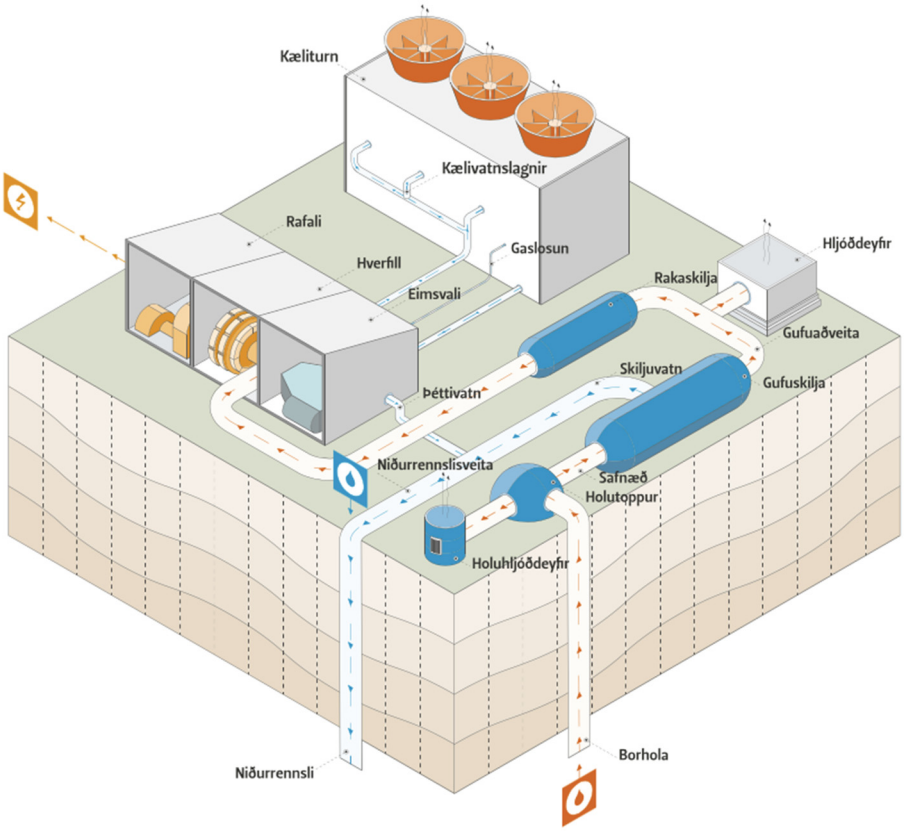
**Figure 1. Aerial view towards north over Theistareykir Project (image: Hreinn Hjartarson)**

**Figure 2. Timeline of Theistareykir Project**




The generation technology at Theistareykir involves harnessing geothermal fluids from deep wells. Superheated fluid at temperatures over 250°C comes up under its own pressure and boils as it rises to the surface. The steam/water mixture is transported from the wellheads to a separator station through a network of pipelines. The separator station and a secondary demister ensure that water ('brine') is separated from the steam. A valve station with silencers is able to shut down steam supply to the plant, if required. The dry steam then 'flashes' through the turbines (which drive the generators) into a condenser, which is cooled by a cooling system. Gases are separated from the steam in the condenser, and ejected via the cooling towers. The condensed water as well as brine from the steam separator, is pumped into re-injection wells.

**Figure 3. Schematic of Theistareykir Project**



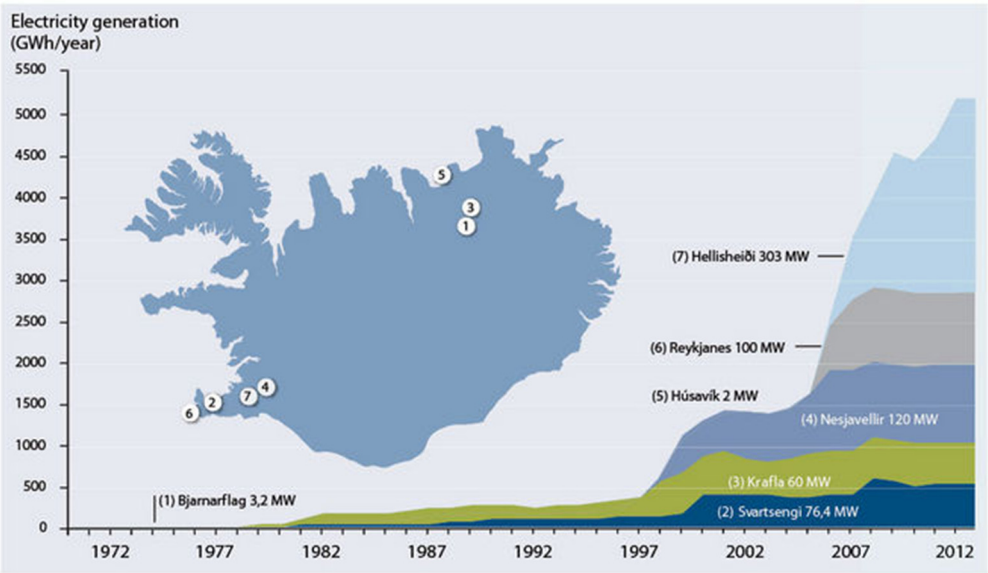
## Assessment Process

The assessment was carried out over a four-month period, starting with a planning visit in October 2016 which involved discussions with the working group of Icelandic government agencies and power companies (National Energy Authority, Environmental Agency, Landsvirkjun, Orkuveita Reykjavik, HS Orka) supporting the Protocol initiative, as well as visits to geothermal power plants. The visits to Hellisheidi, Svartsengi, Krafla and Bjarnaflag (locations shown in Figure 4 below) were selected to provide insights into projects

- in those high-temperature fields that are currently used, in the south-west and north-east of the country,
- by all three major power companies,
- with and without additional uses of the geothermal resource (district heating and chemical products), and
- developed at different times and with different technologies, since the 1970s.

It was decided to use Theistareykir for the test of the Geothermal Protocol because it is the only geothermal project currently under development, representing the cumulative experience of the Icelandic geothermal sector.

**Figure 4. Development of Geothermal Generation in Iceland Over Time**




The on-site assessment was conducted in January 2017 by a single assessor, and involved two weeks of site visits and 39 interviews with internal and external stakeholders in Reykjavik, Akureyri, Húsavík, Laugar, and at the project site in Theistareykir. Following the on-site assessment, the assessor developed a draft report, which was discussed during a follow-up visit in March 2017. After consensus was reached on the assessment results, the assessor finalized the report and provided recommendations for the revision of the draft geothermal Protocol.

## Assessment Experience

As the first test of the draft Geothermal Sustainability Assessment Protocol, with the objective of being a learning experience for all involved, this assessment was undertaken in close collaboration with a Landsvirkjun team, consisting of Elín Inga Knútsdóttir, Ragnheidur Ólafsdóttir and Jón Ingimarsson; with Sigurdur St. Arnalds of Mannvit as a consultant to the Geothermal Protocol working group; and with the working group members.

There were some implications from choosing Theistareykir for the test assessment. As Theistareykir is already under construction, the assessment was able to look backwards in history (to understand the choices made during preparation) as well as at the present status (to understand how plans have been implemented, or had to be adapted). However, in general it is advisable to use an assessment tool that is designed for the current status of a project.

The fact that the Geothermal Protocol was still in draft stage did not present major issues. The assessor was able to use the draft to cover all sustainability aspects that arose, and will recommend only minor changes to the draft. However, to ensure that the Geothermal Protocol reflects sustainability issues across the entire spectrum of geothermal power plants, it is advisable to test it on a number of other projects, which should include projects

- in developing countries,
- with combined power generation and direct use,
- with different technologies (e.g. single and double flash, binary cycles), and
- at different stages in the project cycle.

## Layout of this Report

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

For eighteen topics, 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 (P-1)

This topic addresses the identification and 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 establish a foundation for 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:

- (in the project locality) owners of land that will be used by the Theistareykir project, residents using the area, local businesses including the offtaker PCC BakkiSilicon hf. and tourism businesses, employees during construction and operation, and the municipalities of Thingeyjarsveit, Nordurthing and (to a lesser extent) Skútustadahreppur;
- (outside the project locality) Landsvirkjun, Landsnet, National Energy Authority, Environment Agency, Planning Agency, Cultural Heritage Agency, and other government agencies;
- (within the project-development group) Landsvirkjun's different departments involved in Theistareykir, consultants (Mannvit, Verkis), contractors (e.g. the drilling company) and service providers (e.g. Northeast Iceland Nature Research Centre).

There is also a range of important, but not directly-affected stakeholders, including government agencies, NGO's such as Landvernd (Icelandic Environment Association), and the Icelandic Labour Union (ASÍ).

The project manager in cooperation with Landsvirkjun's Corporate Communications department oversees internal and external communications, and is responsible for producing project newsletters, responding to stakeholders' queries, organising public consultation meetings, publishing studies and updating websites. The project manager generally handles communications with authorities.

## 1.2 Detailed Topic Evaluation

### 1.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *Stakeholder mapping has been undertaken to identify and analyse stakeholders, to establish those that are directly affected, and to establish communication requirements and priorities, with no significant gaps.*

Local stakeholders are well known to Landsvirkjun, due to its long presence in the north-eastern region with the projects at Bjarnarflag and Krafla, and the involvement in Theistareykir for over 10 years; Landsnet has a similar long term involvement in the region through building and operating the transmission system. Both companies also have a good understanding of national level stakeholders, although Landsnet has made fewer efforts at engagement.

The Theistareykir project development team maintains and updates quarterly, a detailed stakeholder register, which contains all relevant organisations and individuals, Landsvirkjun staff members who are responsible for contacts, specific interests of those stakeholders, levels of influence and relevance for the project, contact

information, emails received and responded to, and status of licenses and permits. Interactions with stakeholders are planned for the year ahead, and tracked.

The highest priority stakeholders in terms of communication and consultation are Landsvirkjun's management and board, landowners, regulators, municipalities, Landsnet and the complaints commission at the Ministry of Environment.

**Criteria met: Yes**

### Analysis against proven best practice

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

The stakeholder register is comprehensive, up to date and is actively used for communications.

**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, have been developed at an early stage applicable to project preparation, implementation and operation that outline communication and consultation needs and approaches for various stakeholder groups and topics.*

Landsvirkjun has a proactive approach to communication at the corporate level, and publishes a wide range of information that may be of interest to stakeholders.

At the project level, in the early years of preparation Theistareykir ehf. did not have specific communications plans and processes, but as a local joint venture of municipalities and utilities, these were well informed and closely involved. More formalized consultation processes were introduced during the environmental impact assessments, as described under P-5. As Theistareykir ehf. became integrated into Landsvirkjun, the approach to communications became more systematic. The 2013 Communications Plan is headlined 'No Surprises' (neither for stakeholders nor for Landsvirkjun) and outlines communication principles, pathways, and specific activities such as workshops for each quarter of 2014.

The main communication and consultation mechanisms have been:

- The Landsvirkjun website, which contains extensive project information with project descriptions, videos, news, newsletters, brochures, timelines and maps, the EIA and monitoring reports, in Icelandic and English; dissemination of reports also through the public library site www.gegnir.is
- An email list to distribute newsletters and other information, and a project email theistareykjavirkjun@landsvirkjun.is to which enquiries can be directed
- Suggestion boxes at the administration centres of the three municipalities in the project area
- Press releases and conferences at various points in the project history, often connected to major events (such as the official laying of the cornerstone by the Icelandic president in 2016) and leading to newspaper and internet articles
- Public meetings and briefings for the general public and for specific audiences (for example, with the tourist associations on tourism development potential, with professional facilitation)
- Regular calls and meetings with individual stakeholders, regulators and municipalities; meetings with landowners, in particular the municipalities, are subject to a formalized consultation mechanism between Landsvirkjun high-level management representatives (deputy CEO) and mayors
- Landsvirkjun participation in open meetings or seminars on issues related to the project
- Public information signs at the main tourist spot in the Theistareykir area; public visitor centre at Krafla to inform visitors about geothermal technology and development in the region

- Open house event at the construction site in 2016, with 300 visitors
- Landsvirkjun's Annual Reports 2014 and 2015 contain several pages of project descriptions and updates

Additionally, there is a North-East Iceland Sustainability Initiative, originally established in 2008, parallel to the environmental assessment. One of the original partners was Alcoa, who at the time was planning to build a smelter at Bakki. After Alcoa dropped out of the Bakki project, the Sustainability Initiative was dormant for a while but has been revived in 2014-2015, in cooperation with the local municipalities. The steering committee includes representatives from the University of Akureyri Research Centre, Landsnet and stakeholder groups from the tourism industry; and there are hopes to motivate the large offtaker PCC to participate. The objectives are to capture the expectations and concerns of stakeholders, develop and monitor sustainability indicators, and build up knowledge and data to improve decision making and enable adaptive management of cumulative impacts of all energy and industrial projects in the north-east. Basic sets of indicators will cover the economy (employment, properties/debts, real estate market), society (demography, income of residents, education), and environment (geothermal utilization, biota, release of air pollutants). There are some concerns about establishing clear cause-and-effect linkages, for practical decision-making. The Húsavík Academic Center has been asked to manage the project.

**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.*

Landsvirkjun staff know many regional stakeholders on a personal level and have many informal contacts. Some staff are from the area. Stakeholders confirmed that there was never a problem in reaching project representatives and discussing issues. Communication materials include non-technical and consumer-friendly materials such as videos on technical and environmental aspects on YouTube.

Key processes to identity emerging issues include the frequent direct meetings with stakeholder representatives, as well as the round-table Northern Iceland Sustainability Initiative and other joint initiatives with stakeholders.

**Criteria met: Yes**

## 1.2.3 Stakeholder Engagement

### Analysis against basic good practice

***Scoring statement:*** *The project preparation stage has involved appropriately timed communications and engagement, often two-way, with directly affected stakeholders on topics of interest and relevance to them; engagement is undertaken in good faith; ongoing processes are in place for stakeholders to raise issues and get feedback.*

At the national level, there is and has been extensive stakeholder engagement to select the next generation of power projects, through the masterplan process (see under P-3). There have been no major concerns at that level, about placing Theistareykir in the 'utilization' category.

At the regional and local level, stakeholders had many opportunities to participate in the planning processes conducted by the municipalities. The main expectations and concerns of local stakeholders are positive effects on the local economy and society, and impacts on the natural environment. Because the project was based, to a large degree, on a local initiative, these expectations and concerns had been taken into account from the beginning. There is some degree of satisfaction in seeing that Landsvirkjun is bringing a project to fruition, which the local initiative by itself could not have realized. Stakeholders have been invited to meetings or to provide comments on documents, on many different occasions. These opportunities have not always been used, indicating that there often were no pressing issues. Occasionally, stakeholders make suggestions, which are

reportedly always responded to, and sometimes realized. Engagement with stakeholders is planned in advance and is tracked, including email communication. There are relatively few instances of stakeholders raising issues through the email channel or otherwise, that require responses.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, engagement with directly affected stakeholders has been 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.*

All indications are that local stakeholders have a high degree of confidence in Landsvirkjun, based on a respectful, participatory and responsive approach. At the time of the investment decision for the Theistareykir project, discussions with local stakeholders had already moved on from concerns and mitigation options, to potential opportunities.

In the case of Landsnet, various stakeholders commented that communication and negotiations are more difficult (for example, over alignment options for transmission lines or compensation rates). These issues may have contributed to the mixed reputation of Landsnet in some project-affected communities (P-13) and to the delays on the Krafla-Theistareykir line (P-6). However, reportedly Landsnet is in the process of modernizing its approach to stakeholder engagement.

**Criteria met: Yes**

## 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 any communications related commitments have been or are on track to be met.*

Landsvirkjun's Code of Conduct provides the overriding principles for communications: "*We engage in honest communication with our co-workers and stakeholders. We promote professionalism when answering enquiries and support our answers with the relevant data when appropriate. We protect the reputation of Landsvirkjun in all outside communication*." There are no indications of any project staff not complying with these general principles, or with specific communications and information commitments towards stakeholders. The same applies to the formal consultations during the EIA and the regional and municipal planning exercises, which are described in more detail in P-4 and P-5.

**Criteria met: Yes**

### Analysis against proven best practice

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

As stated above, there are no indications for 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 are no significant gaps against proven best practice.

**0 significant gaps**

## 1.3 Scoring Summary

Landsvirkjun has engaged stakeholders of the Theistareykir project through a systematic and participatory communications and consultation process, that went beyond regulatory requirements and established productive, positive stakeholder relations. All relevant stakeholder groups have opportunities to receive appropriate information, contribute their views and engage in dialogue. There are no significant gaps, resulting in a score of 5.

**Topic Score: 5**

## 1.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 6, 9, 11-13, 17, 18, 25, 28, 29, 32, 36, 37 |
| **Document:** | 1-11, 38, 133 |
| **Photo:** | 16, 55-57 |

# 2 Governance (P-2)

This topic addresses corporate and external governance considerations for the project. The intent is that the developer 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

Landsvirkjun is a public company originally established with Act. No 59 from 1965 to produce and transmit high voltage electricity, and is now fully owned by the Icelandic state. The act, as amended sets out the corporate structure and responsibilities; the independent Board of Directors is appointed by the Minister of Finance. Landsvirkjun has a ~75% market share of Icelandic electricity generation. As a member of the European Economic Area (EEA) and European Free Trade Association (EFTA), Iceland generally applies the EU Energy Market legislation, to ensure a competitive, reliable and environmentally friendly power supply. Under a new electricity act that entered into force in 2005, Landsvirkjun's Transmission Division became Landsnet, an independent company and 65% subsidiary of Landsvirkjun, which owns and operates the transmission system and acts as the overall power system operator.

Iceland has two tiers of government, national and municipal. There are three municipalities in the Theistareykir project region. The power station and some roads and transmission lines are located within Thingeyjarsveit municipality, a rural area with 917 residents. The main linkages of the project are with the municipality of Nordurthing, with a population of 2,822 residents, 2,205 of which in Húsavík, where most of the power from Theistareykir will be used in the industrial area of Bakki just outside Húsavík. To the south is the municipality of Skútustadahreppur, which also has two other Landsvirkjun geothermal stations, which will be connected to Theistareykir by road and transmission lines.

Two main regulatory frameworks apply to a geothermal power station. The National Energy Authority authorizes geothermal research, utilization of geothermal and groundwater resources, and power plant operations. If the power plant is on land that is not owned by the state or the developer - as in Theistareykir, where it is on land owned by the Thingeyjarsveit municipality - the developer also has to come to an agreement with the owner. The municipalities authorize the construction and operation of the power plant and associated infrastructure, on the basis of an environmental impact assessment, which is subject to review and comments by various government agencies, and a public consultation process.

As a state-owned company developing, managing and operating a range of power stations and assets, Landsvirkjun has a complex system of processes and procedures that provide the framework under which the company works and reports. Its corporate governance and compliance systems are highly developed. Annual reporting is provided for key areas (general/financial, environment including carbon footprint, and social responsibility) which are available on Landsvirkjun's external website.

## 2.2 Detailed Topic Evaluation

### 2.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *Assessments have been undertaken of political and public sector governance issues, and corporate governance requirements and issues, through the project development cycle with no significant gaps.*

Iceland generally ranks highly in international assessments of public governance, although not quite as highly as other Nordic countries (for a range of indices, see http://info.worldbank.org/governance/wgi/#reports).

As a strategic public company, Landsvirkjun is often the subject of external assessments and recommendations (for example, from the OECD and IMF) and political debates, and pays close attention to relevant government initiatives, policies and reforms. In its 'Platform of the Coalition Government', the new government has pledged

- a stability fund to manage dividends from public energy resources,
- no new concessionary investment agreements for polluting heavy industry, and
- an ownership policy for Landsvirkjun, *'the aims of which will include the maximisation of the value of generated power and having the company operate in harmony with environmental considerations and public opinion'*.

Through its multiple projects, Landsvirkjun is well aware of the regulatory framework in Iceland, including those requirements arising from membership in the EEA.

**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.*

There are no indications that Landsvirkjun is overlooking any internal or external governance issues.

**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, grievance mechanisms, ethical business practices, and transparency; policies and processes are communicated internally and externally as appropriate; and independent review mechanisms are utilised to address sustainability issues in cases of project capacity shortfalls, high sensitivity of particular issues, or the need for enhanced credibility.*

Two important processes for Landsvirkjun to respond to the owner's expectations and to understand and manage political and public sector risks and opportunities, are through its board, appointed by government, and through its direct relationships with a range of government agencies.

Within their mandates, board and management formulate corporate objectives, policies and processes, and authorize individual investments and contractual commitments. Landsvirkjun sees its role as to '*maximise the potential yield and value of the natural resources it has been entrusted with in a sustainable, responsible and efficient manner'*. Key policies related to sustainability are the Corporate Social Responsibility strategy (2011), Code of Conduct (2013) and Supplier's Code of Conduct (2015), and Environmental Policy (2015). These policies are further broken down into operational guidelines and processes, which are easily available for staff and on which training is provided. Landsvirkjun's internal audit and legal units are tasked with legal and contractual compliance issues.

There are some concerns in Iceland that investors are overly optimistic, suffering from 'group think', and that especially public utilities tend to over-invest and are less risk-aware than private utilities. That risk is amplified by the nature of geothermal projects, which require such large expenditures on preparation, and may tempt a company to 'just keep trying', drilling more wells to justify past decisions. An important process for Landsvirkjun to manage that risk, is the stage-gate process that was introduced in 2015, just after the Theistareykir investment decision. This process clarifies the information that senior management and the board will require before authorizing expenditure of project preparation, and taking an investment decision. That information will now be summarized in one 'business case' document, instead of being spread out across a range of documents. Rate-of-return-on-equity comparisons for different alternatives should be included, and compared to Landsvirkjun's cost

of capital. This process will also clarify the responsibility of different business units to recommend investment decisions.

Programmes that are related to corporate social responsibility such as support for research and sponsoring are conducted under clear guidelines, to make Landsvirkjun's contributions as systematic, efficient and transparent as possible, and to ensure that the projects supported comply with Landsvirkjun's policies:

- The Energy Research Fund's objective is to support environmental and energy research relevant to Landsvirkjun through grants.
- The Community Fund's objective is to support projects with broad community relevance and the potential to positively impact Icelandic society.

Landsvirkjun proactively releases significant corporate and project-level information; its website is well-designed and useful for stakeholders and the general public.

Landsvirkjun's stakeholders can raise concerns, grievances and complaints through a number of channels. Due to close stakeholder relations, most often the project or station managers will be contacted in person, via telephone or email.

There are independent regulatory reviews in a number of sensitive areas, as well as occasional additional voluntary reviews (such as this sustainability assessment, and others that Landsvirkjun has commissioned). In the case of the Theistareykir project, for example, the geothermal reservoir modelling was reviewed by an independent expert (see P-7).

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, contractors are required to meet or have consistent policies as the developer; and processes are in place to anticipate and respond to emerging risks and opportunities.*

Landsvirkjun's Supplier Code of Conduct and Requirements Towards Contractors and Service Providers with Regard to Environmental and Health and Safety Matters lay out the expectations regarding contractor behaviour (see also P-12).

The corporate governance arrangements described above help Landsvirkjun to identify emerging risks and opportunities.

**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.*

Stakeholder engagement is at the top of the agenda for Landsvirkjun's management (see also P-1). While generally stakeholder acceptance may be easier to achieve for Landsvirkjun as a public company, than for a private investor, Landsvirkjun is highly interested in maintaining a good reputation and goodwill among stakeholders. Senior management is directly involved in stakeholder engagement, particularly at the level of central and municipal governments.

Landsvirkjun makes a range of project preparation reports, background research, and project monitoring and progress reports publicly available.

**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.*

Landsvirkjun does not undertake a materiality process to determine what is of high interest to its stakeholders; however, the range of publicly available material is so wide that very likely all stakeholder interests are satisfied.

**Criteria met: Yes**

## 2.2.4 Conformance / Compliance

### Analysis against basic good practice

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

In the pre-construction phase, Theistareykir ehf. obtained the required exploration license from the National Energy Authority.

Landsvirkjun has obtained, and is subject to the conditions in, the following permits and licenses:

2014 - Utilization license for the use of groundwater – 100 MW, National Energy Authority

2014 - Utilization license for the use of geothermal energy – 100 MW, National Energy Authority – 50 years (Resource Act)

2014 - Power development license to construct and operate – 100 MW, National Energy Authority – not time bound (Energy Act)

2014 - Development consent for the construction – 100 MW, municipality of Thingeyjarsveit

2016 - Operation license – 90 MW – municipality of Thingeyjarsveit's health inspectorate

Appeals against these licenses are possible, but none are pending.

Landsnet has similarly obtained all required licenses, with one appeal pending but permission to go ahead with construction. Additionally, Landsvirkjun and Landsnet are subject to all relevant Icelandic laws.

There are no indications for any non-compliances related to the project.

**Criteria met: Yes**

### Analysis against proven best practice

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

As stated above, there are no indications for any 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.*

There are no governance issues that will hinder the development of the Theistareykir project, although there may be small delays from appeals against the development consent of the transmission line.

**Criteria met: Yes**

### Analysis against proven best practice

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

Although the Theistareykir project will deliver power as contractually agreed, possibly with a slight delay, there are a range of lessons learnt and wider governance issues that require a discussion and possibly, consideration of reforms.

The most important one appears to be the permitting through municipalities. Even large generation and transmission projects, with regional impacts and costs of hundreds of millions of USD, are permitted through municipalities, some of which have populations of less than 60 people, and small and inexperienced administrations without technical and legal staff (although with some support from the association of Icelandic municipalities). In the case of Theistareykir, key permits were issued by the municipality of Thingeyjarsveit, with a population of 920 people. Some of these municipalities do not even want this responsibility, and are exposed to appeals and lawsuits, especially if they make formal mistakes. The Thingeyjarsveit municipality in particular, spent significant amounts of time and resources on the permitting process. Even following exactly the recommended license conditions from the Planning Agency, does not protect them from challenges. While there are good reasons to have spatial planning and zoning at the municipal level, assigning power infrastructure permitting at this level is a **significant gap** against proven best practice.

There are a number of other governance issues that are worth discussing, although they would not be considered gaps:

- Landsnet as a regulated transmission monopoly is under an obligation to develop the transmission network in an economic manner; however a narrow interpretation of this obligation may generate stakeholder conflicts and delays. It may be advisable to update Landsnet corporate responsibility approaches.
- It is unclear what the overall benefit to Landsvirkjun and the Icelandic state is, from keeping power purchase agreements, costs of individual projects, and other project-level financial information confidential.
- There may be a case for reform of ownership rights in below-ground resources, which are currently quite complex. The system would be more streamlined if all resources were owned by the state and leased to developers. This would also make it more straightforward to implement a uniform royalty system for the use of geothermal (as well as hydropower and wind) resources, increase the share of the rents that the public receives from these resources, and agree on a fair distribution of those rents between the central and municipal governments.

**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

The responsibility of municipalities for permitting of major power projects.

**1 significant gap**

## 2.3 Scoring Summary

Landsvirkjun is a strategic company for the Icelandic economy and for its owner, the Icelandic state, and is a strong supporter of good corporate governance, including sustainability initiatives. It operates within a public governance structure that has grown over time and might benefit from some additional reforms, in particular regarding the responsibilities of small municipalities in permitting large power projects. There is one significant gap against proven best practice, resulting in a score of 4.

Topic Score: 4

## 2.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 4, 5, 12, 13, 17, 18, 28, 37 |
| **Document:** | 12-30, 38, 97, 101, 133 |
| **Photo:** | -- |

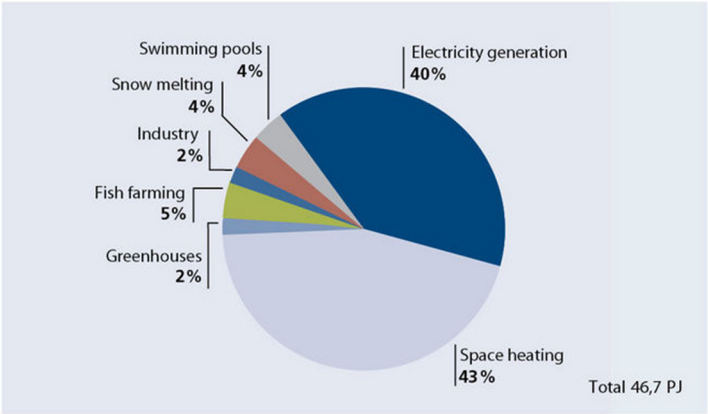
# 3 Demonstrated Need and Strategic Fit (P-3)

This topic addresses the contribution of the project in meeting demonstrated needs for electric power and, if applicable, direct use, as identified through broadly agreed local, national and regional development objectives and in national and regional policies and plans. The intent is that the project can demonstrate its strategic fit with development objectives and relevant policies and plans can be demonstrated, and that the project is a priority option to meet identified needs for electric power and, if applicable, direct use.

## 3.1 Background Information

Geothermal resources provide about 2/3 of primary energy use and 1/4 of power generation in Iceland. Most geothermal energy is used in heating, as more than 90% of Icelandic buildings are heated by warm water, delivered by district heating systems, from low-temperature geothermal fields or from dual-use power generation and heating plants in high-temperature fields.

**Figure 5. Use of Geothermal Energy in Iceland**



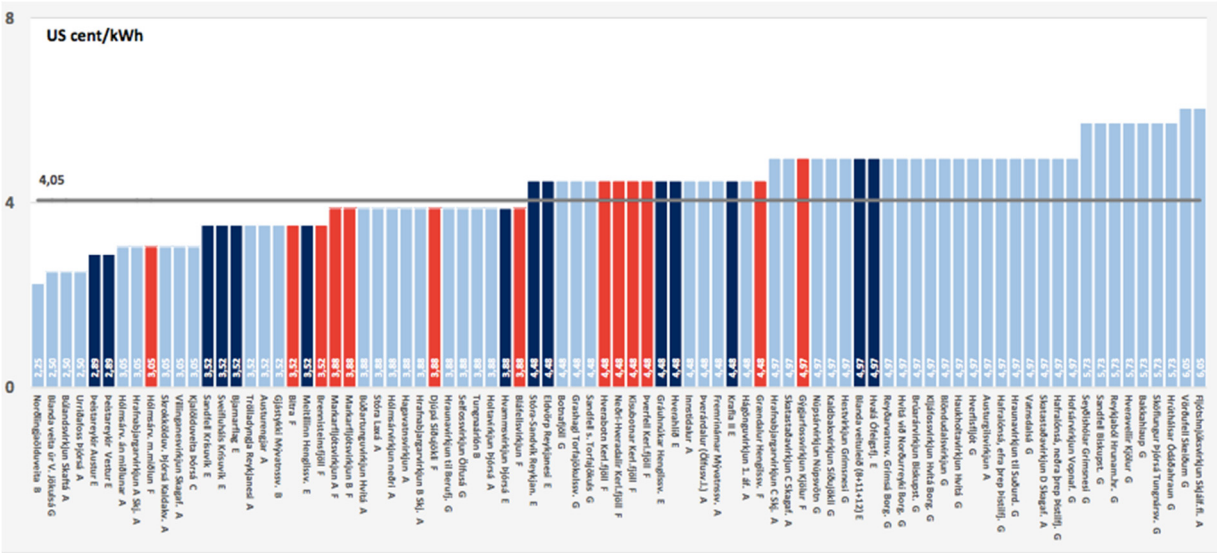

Direct use of the heat from geothermal resources is, however, restricted to users within a reasonable distance from the fields. Therefore, geothermal power plants in the south-west, close to Iceland's population centres, are generally dual-use while those in the north-east, with a low population density, are generally single-use, exclusively for power generation. This also applies to Theistareykir, which is lacking obvious outlets for heat supplies. The closest population centre is Húsavík at a distance of 27 km, which already has a geothermal district heating system, coupled with a 2 MW power plant (currently out of operation).

Iceland has the highest power generation per capita globally because of an unusually high industrial demand. About 80% of power is used by industries, largely for aluminium and ferro-silicon processing. This is the result of a deliberate strategy to attract power-intensive industries to Iceland, offering high reliability of supply, low costs, and low carbon intensity. Large power projects, including Theistareykir, have only been built once an industrial customer had been identified and a PPA negotiated.

New power projects have to be prioritized through the national hydropower and geothermal masterplan and regional/municipal plans. One of the reasons for prioritizing new projects is equitable regional development. Iceland's northern and eastern regions have experienced a long-term population loss to the capital region.

Theistareykir was accepted for development in the second phase (2013) of the masterplan. A 2016 analysis by Samorka, the association of Icelandic power companies, of all generation project in the third phase of the masterplan confirms that the current 90 MW Theistareykir project is the option with the lowest cost per kWh in the 'utilization' category (5th from the left in chart below).

**Figure 6. Projects ranked by LCOE in the three masterplan categories 'utilization' (dark blue), 'on hold' (light blue) and 'conservation' (red)**




## 3.2 Detailed Topic Evaluation

### 3.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment has been undertaken of needs for electric power and, if applicable, direct use, of options to meet these needs; and of national and regional policies and plans relevant to those needs, with no significant gaps.*

The key assessments of power needs and options have been undertaken through the following processes:

- National energy policies have emphasized renewable energies for decades. Following the EU Renewable Energy Directive 2009/28/EC, Iceland developed a National Renewable Energy Action Plan, with the most ambitious target for renewables in Europe (72% by 2020). Iceland's 2015 progress report shows that the country is on track to achieve the target. Since almost all electricity and most heating is already from renewable sources, efforts now focus on increasing the share of electricity and biofuels in road transport.
- Regional development policies have also been implemented for decades, to slow down migration to the capital region, including fiscal transfers, farm subsidies, support for public and private investments, government offices moved, and over-representation of rural areas in parliament. Power projects have the advantage of enabling industrial development and the diversification of rural economies, which often rely on farming, fishing and over the last years, increasingly on tourism.
- To select individual renewable power projects, Iceland introduced a masterplanning process in 1999 and formalized it through Act No. 48/2011 on the Plan for Nature Protection and Energy Utilisation. Every four years, the minister responsible for the environment in consultation with the minister responsible for energy presents an update of the plan to parliament. Once parliament votes on the plan, all governmental authorities (for example, municipalities licensing power projects) are bound by the categories assigned to projects.
- Regional initiatives in the north-east have aimed to develop the Theistareykir project since at least 1999, when the Theistareykir ehf. development company was created as a joint venture between local

municipalities and utilities. The commitment to the project was confirmed through regional, municipal and site plans. The main objective of regional stakeholders is economic diversification. In 2012, the Northeast Iceland Development Agency (Atvinnuthróunarfélag Thingeyinga) also prepared a Northeast Iceland Infrastructure Analysis, in preparation for energy intensive industry in the region. This was done by agreement between the Ministry of Industry, Energy and Tourism, Landsvirkjun and four municipalities, to ensure that regional infrastructure and public services could accommodate the upcoming investments.

- Landsvirkjun became a partner in Theistareykir ehf. in 2007 and included the project in its investment plans, as an expansion of its existing north-eastern geothermal complex.
- Regional power needs were identified at least since 2005, when the Icelandic Ministry of Industry, Alcoa and several municipalities in northern Iceland signed a Memorandum of Understanding (MoU) on a feasibility study for a possible aluminium smelter in northern Iceland, with a power demand of up to 400 MW. In 2006 the MoU was renewed, on the basis of a site comparison study, with a site for a smelter at Bakki north of Húsavík. Alcoa started negotiating a PPA with Landsvirkjun, made a commitment to contribute to the costs of exploration drilling, and the smelter was included in the joint regional EIA (see P-5). There were increasing doubts, however, as to the availability of 400 MW from the geothermal complex, if utilized sustainably. For a number of years, through the financial crisis, different organizations including Alcoa, Chinalco (China's largest aluminium company), HS Orka, Icelandic pension funds and banks, and even farmer's associations and drilling companies were looking at the project as potential investors or offtakers. Eventually, plans were downscaled, the local partners sold their shares to Landsvirkjun, and PCC became the first offtaker with an initial PPA signed in 2012, for an initial power demand of 52 MW.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment is based on dialogue with government planners, policy makers and key stakeholder groups; and the assessment shows a strong emphasis on social and environmental related needs, policies and plans including the need for sustainable development of the geothermal reservoir.*

Government planners and policy makers, as well as key local and national stakeholders, have been involved with the selection and definition of the project at multiple stages.

Social and environmental needs, policies and plans have been strongly emphasized in the masterplan, the joint regional EIA, the project EIA, regional and local plans, and project design. As described under P-7, there is a very high probability that the geothermal reservoir will be used sustainably by the project as currently developed. As more is learned about the Theistareykir reservoir, and as expansion projects in Krafla and Bjarnarflag are advanced, an expansion of the Bakki industrial area with increased power demand may become possible.

**Criteria met: Yes**

## 3.2.2 Stakeholder Engagement

### Analysis against basic good practice

***Scoring statement:*** *The results of the assessment of strategic fit are publicly disclosed.*

All documents mentioned above are publicly available, and discussions about strategic fit have been held with the involvement of multiple stakeholders, at different levels from the municipal councils, to the masterplan steering committee, and the parliament.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *No addition to basic good practice.*

**Criteria met: Yes**

### 3.2.3 Outcomes

### Analysis against basic good practice

***Scoring statement:*** *The strategic fit of the project with needs for electric power and, if applicable, direct use, and relevant policies and plans can be demonstrated.*

The Theistareykir project in its current form is compatible with all plans described under Assessment above, namely macro-level energy and regional development policies, a multi-criteria project selection process, regional and corporate plans, and demonstrated power needs. By hosting power-intensive industries, Iceland also makes a contribution to global climate mitigation.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the project is one of the priority options to address demonstrated needs.*

The internal Landsvirkjun prioritization process (see also P-4) and the masterplanning process, in all three stages so far, have confirmed that Theistareykir is one of the priority options to expand power generation.

**Criteria met: Yes**

### 3.2.4 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

There are no significant gaps against proven best practice.

**0 significant gaps**

## 3.3 Scoring Summary

The need for additional power generation is shown by continued interest from large industrial customers, including in the project area. Iceland has an institutionalized planning process for the expansion of generation, which has confirmed Theistareykir as a low-impact and low-cost option. There are no significant gaps against proven best practice, resulting in a score of 5.

**Topic Score: 5**

## 3.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 2, 3, 9, 12, 13, 17, 23, 28, 37, 38, 39 |
| **Document:** | 31-38, 123, 133 |
| **Photo:** | 27-31 |

# 4 Siting and Design (P-4)

This topic addresses the evaluation and determination of project siting and design options, including the power station with associated structures, wells with connecting geothermal supply system, and associated infrastructure such as access roads and transmission lines. The intent is that siting and design are optimised as a result of an iterative and consultative process that has taken into account technical, economic, financial, environmental and social considerations.

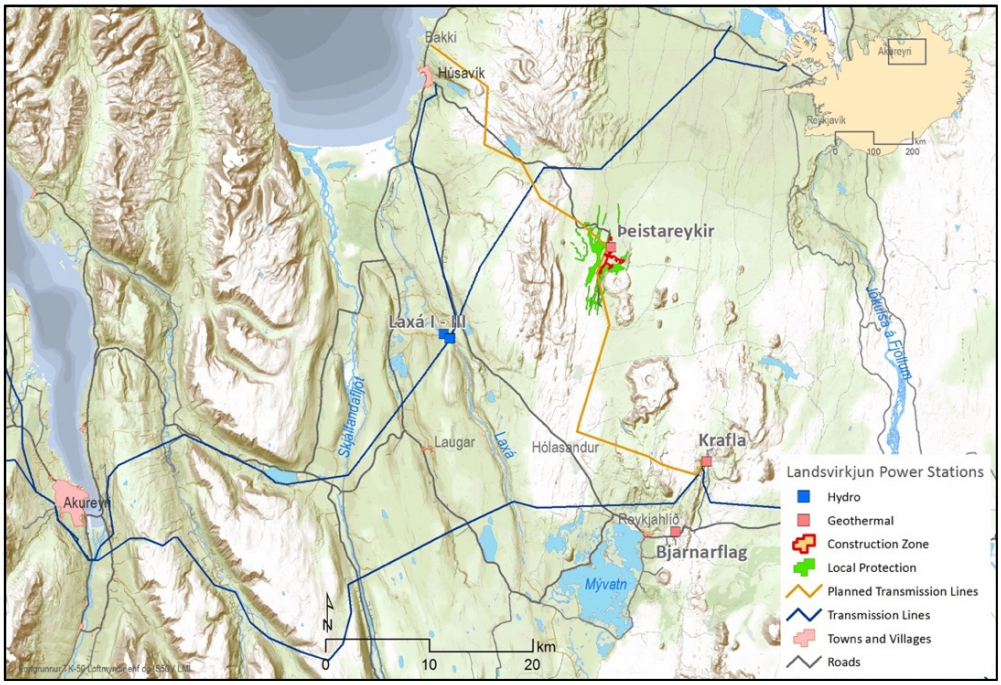
## 4.1 Background Information

The high-temperature geothermal fields in north-east Iceland have been extensively researched over the past 50 years, and the following potential sites have been identified for development (from south to north), and could have supplied the industrial customer at Bakki:

| | Capacity and Development Status | Masterplan Phase II Category |
|---|---|---|
| Fremrinámar | Potential capacity 45-90 MW | On Hold |
| Bjarnarflag | 3 MW power plant commissioned in 1969, potential expansion to 90 MW | Utilization |
| Krafla | 1st phase 30 MW commissioned in 1978, expanded to 60 MW by 1999, potential expansion by 135 MW | Utilization |
| Gjástykki | Potential capacity 45-90 MW | Protection |
| Theistareykir | Phases 1 and 2 (2x45 MW) under construction, potential expansion by 90 MW | Utilization |

Exploration drilling and other preparations have been conducted in parallel for the three sites in the utilization category. The characteristics of the resources at the different sites are relatively similar, and plant design was standardized as far as possible for cost savings and ease of operations. Decisions over which sites to develop and in what stages are complex and depend, among other things, on the confidence in the resource, costs, power demand (both for individual industrial customers, and to feed into the overall north-eastern grid), environmental impacts, public acceptance, and categorization in the national masterplan.

**Figure 7. Regional Context of Theistareykir Project**



The Bjarnarflag expansion was long seen as the most promising project, and was further advanced than the Krafla expansion or the greenfield project in Theistareykir. However, because of delays related to landowners and stakeholder concerns about impacts on Lake Myvatn, the expiry of a 2003 EIA after ten years, and because of reduced power demand compared to the original 400 MW Alcoa smelter, Landsvirkjun has postponed Bjarnarflag for now and has given priority to Theistareykir.

The local municipalities developed a joint Regional Plan for the high-temperature geothermal areas in the Thingeyjarsyslur region, for the period 2007-2025, which included the Theistareykir site and the required access infrastructure. This is the only comparable regional plan in Iceland. The municipal plans were updated accordingly in 2011, and a more detailed site plan for the power plant approved in 2012. In parallel, feasibility studies, EIAs and conceptual, detailed and tender designs have been developed.

Since a few years, Landsnet also develops country-wide transmission network expansion plans, which are subject to strategic environmental assessments and approval by the National Energy Authority; one of their functions is to create more stakeholder consensus over the siting and design of transmission projects.

## 4.2 Detailed Topic Evaluation

### 4.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *Technical information has been analysed at an early stage alongside social, environmental, economic, financial, and regulatory considerations in order to develop a preliminary project design and some options around this.*

The siting and design process at Theistareykir took almost 15 years until the final investment decision in 2014. It was an iterative process during which geological, engineering, environmental, social, financial and regulatory information from Theistareykir and from other geothermal projects was gathered, and options were developed with an increasing degree of confidence and detail.

A preliminary project design was already available at the time of the Regional Plan and the EIAs, between 2007 and 2010. Key decisions such as the generation technology (single flash turbines), the location of the powerhouse at the centre of the wellfield (to reduce length of steam supply pipes), the necessary distance to steam separators (at least 500 m), locations of quarries and cold water supplies and some of the well pads, areas of high natural or cultural heritage value that needed to be avoided, etc. had already been taken at the time.

A focus of the Regional Plan – as it affected all municipalities – was the alignment of transmission lines. Some considerations were, whether parts of the existing ring line corridor could be used; how sensitive landscape features, such as young lave fields, could be avoided; how the rift zone could be avoided (to increase reliability, especially for substations); whether two parallel lines were required for redundancy, and at what distance; whether at least parts of the line should be laid underground (especially if Gjástykki should be developed); how land disturbance from road access to the line can be minimized; etc.

Following the EIA, more specific designs could be developed for all project components. A site plan in 2011-2012, developed cooperatively with municipal council members, further reduced the degrees of freedom. Detailed and tender designs were developed for the different contracts, in the order in which they were going to be implemented, and environmental management plans developed.

Some elements of the Regional Plan are not being implemented at this time. For example, two separate transmission lines to Bakki to supply the larger 400 MW load with a high degree of redundancy (required for a smelter) became unnecessary, and for the time being a single line (the eastern line) from Krafla through Theistareykir to Bakki is sufficient.

The EIA, municipal and site plans, feasibility study (also called project planning report), Landsvirkjun's requirements and Icelandic norms (for example, regarding wind, snow and earthquake loads) became the basis for the design work, which was contracted with a consortium of Mannvit-Verkis consultants in October 2011, for approximately USD 25 million (including design for Bjarnarflag, and construction supervision).

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, options taken into consideration have been thoroughly analysed with respect to sustainability perspectives.*

There was no formal, multi-criteria analysis of alternatives in the design process. However, Landsvirkjun and its partners in the project development company, consultants, and government agencies contributed a range of sustainability criteria, perspectives and experiences to the decision-making process. During the development of the regional, municipal and site plans, which are a clearly a governmental responsibility, Landsvirkjun only supplied information, and otherwise stepped aside and let the municipalities consider the various options, with the support of planning consultants and the Planning Agency.

**Criteria met: Yes**

## 4.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *An optimisation process has been undertaken to assess the project siting and design options.*

Mannvit-Verkis developed design criteria and subsequently, technical design and tender documents on the basis of the documents mentioned above. In this process, the design group took lessons from other projects executed in Iceland during the past 10 years into account, such as Hellisheidi. Design discussions and decisions have been well documented, with minutes of design meetings for all contracts. Under some contracts, design suggestions were made by contractors. Other suggestions were made by the Planning Agency and other stakeholders. There are multiple examples for project components for which different options were assessed, and designs improved from the first draft plans:

- The locations of various well pads have been adjusted to avoid local protected areas like wetlands, following consultations with the Planning Agency. Because of directional drilling, the location of well pads can be handled fairly flexible.
- The alignment of steam supply pipes was adjusted, after consultations with the Cultural Heritage Agency over visual and physical impacts.
- The Environment Agency suggested joining the contractors' and Landsvirkjun's camp on one platform, thus reducing their footprint.
- Land rehabilitation along roads was done by transplanting turf with vegetation, instead of re-seeding, for the first time on a large scale in Iceland.
- The visual impact of buildings, steam supply pipelines and other components was reduced by choosing dark grey, non-reflective colours. A 3-D program was used to consider architectural and landscaping impacts and options, aligning components south-north with natural landscape features and wind directions, keeping pipelines close to the ground, and putting up earthen berms to reduce visibility of well pads, quarries and other components. The design was coordinated, up to the point possible, with the architect for Landsnet's components, which should have a similar, non-obtrusive design.
- Landsvirkjun's Krafla operations team commented on draft tender documents, and suggested changing specification of wiring and other electrical equipment which will be exposed to sulphides.
- Some waste heat will be used to heat buildings and for snow melting.

- Initially, surface disposal was considered for separated and condensed geothermal water. Later reinjection was agreed, and a depth was selected that is not too shallow to interfere with groundwater, nor not too deep to be overly costly. The reinjection strategy can be adapted later if necessary. The location and design of reinjection wells was also adjusted, because of visual impact.
- Landsvirkjun's board rejected the first investment proposal, and several changes to save costs without affecting the safety and reliability of the power plant were made for the final design. For example, the steam separators are now outside and not covered by a building.
- There have been arguments for laying parts of the linear project infrastructure (steam supply lines, transmission lines) underground. The 11km, 11kV line for construction power is indeed underground, along the Theistareykir-Húsavík road. The Planning Agency recommended as a permitting condition, that more visible parts of the steam pipeline system should be laid underground, but this was not taken up by the municipality. NGOs have long preferred that transmission lines should be laid underground, but this has not been taken up because of increased costs, land disturbance (the Environment Agency was against it particularly in the case of lava fields), and the low thermal conductivity of the lava soils, which can cause overheating of the underground cable. Underground installation would also make future decommissioning more difficult.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *No addition to basic good practice.*

**Criteria met: Yes**

## 4.2.3 Stakeholder Engagement

### Analysis against basic good practice

***Scoring statement:*** *The siting and design optimisation process has involved appropriately timed, and often two-way, engagement with directly affected stakeholders; ongoing processes are in place for stakeholders to raise issues and get feedback.*

Because the local municipalities have been directly involved in planning the project, there have been many opportunities for stakeholder engagement, besides the formal consultation meetings and public hearings on regional and municipal plans, and the joint and specific EIAs. The municipal councils were represented on the board of Theistareykir ehf. and the steering committee of the Regional Plan. This engagement and the ongoing consultation processes are described in more detail in P-1 and P-5. In a number of cases, stakeholder input led to minor siting and design changes. Stakeholder concerns during the regional plan consultations, for example, concerned local protected areas, sheep grazing, and employment. There were few comments from private landowners or NGOs on the transmission line, although that would later become a focus of discussion.

There has been some NGO resistance to the industrial development in the north-east, of which Theistareykir is a part. There was opposition to the aluminium smelter, which was seen as too large and polluting, and associated with the east Iceland Alcoa smelter and hydropower project at Kárahnjúkar, that had generated a lot of opposition. However, a siliconmetal plant was seen as more benign than a smelter, and geothermal was seen as more benign than hydropower. There was some opposition to the Gjástykki project, in a pristine area, and to the Bjarnarflag project, which was seen as too close to Lake Myvatn. There were also issues with overhead transmission lines to connect the plants to the national grid. However, there was general consensus regarding the Theistareykir geothermal plant itself and the road access, and limited interest of stakeholders to become engaged or propose specific siting and design improvements.

The lack of serious stakeholder concerns for the current siting and design has been ascribed to open discussion of alternatives, a pragmatic interest in regional economic development, and the distance to the capital Reykjavik, with the highest interest in protecting wilderness values.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, engagement with directly affected stakeholders has been inclusive, and participatory; and feedback on how issues raised have been taken into consideration has been thorough and timely.*

Regarding the geothermal plant, there are no indications that engagement was not inclusive and participatory. No stakeholders have come forward to suggest that their issues were not taken into account, or that feedback was not adequately provided.

There are some concerns about stakeholder engagement by Landsnet, specifically over the siting and design of transmission lines, and compensation for impacts, both monetary and through revegetation efforts. This is discussed under P-1, P-6 and P-13.

**Criteria met: Yes**

## 4.2.4 Outcomes

### Analysis against basic good practice

***Scoring statement:*** *The final project siting and design has responded to many sustainability considerations for siting and design.*

The siting of the overall project at Theistareykir, its size, and the siting and design of the project components in the area, has balanced a number of sustainability considerations. As in any project, a number of siting and design decisions are debatable, there are different interests and opinions, and disagreements may persist. For example, Landsnet wanted the 220kv transmission line from Theistareykir to Bakki to leave the road for a section, in order to avoid crossing of lines, reduce visibility and to shorten the distance. This was supported by the municipality of Nordurthing, as well as earlier, during the Regional Plan development, by the cooperation committee of all relevant municipalities. A local landowner, however, preferred the line to follow the road and avoid crossing a hill.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *The final project siting and design is optimal with respect to sustainability considerations for siting and design.*

The final project siting and design allows significant flexibility for future developments, for example for future increases or decreases in the industrial load at Bakki, as the transmission system allows feeding either into the national grid or into Bakki. Stepwise expansion of Theistareykir, Krafla and/or Bjarnarflag are all possible. Within the site, the footprint has been minimized as far as possible, and the incremental footprint of make-up wells or an expansion would be limited. Other additions, such as a potential visitor centre, could be easily added.

The project has a modern design, has benefited from lessons learned in the sector, and will generally have lower impacts than other geothermal projects in Iceland.

**Criteria met: Yes**

### 4.2.5 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**

## 4.3 Scoring Summary

Several options for the siting of new geothermal plants in the north-eastern high temperature field have been explored, initially to supply a 400 MW smelter, before the decision was made to scale down the program and develop Theistareykir first. Also several design alternatives have been compared. Siting and design decisions are based on multiple criteria, are well documented and justified, and have generally received stakeholder endorsement. There are no significant gaps against best practice, resulting in a score of 5.

**Topic Score: 5**

## 4.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 3, 4, 6, 8, 9, 11, 13, 14, 18, 19, 21, 24, 28-32, 34, 37, 39 |
| **Document:** | 12, 15, 19, 39-52, 58, 62-64, 133 |
| **Photo:** | 33-41, 46-51, 53-54, 58-59, 70-77, 85 |

# 5 Environmental and Social Impact Assessment and Management (P-5)

This topic addresses the assessment and planning processes for environmental and social impacts associated with project implementation and operation throughout the area of impact of the project. The intent is that environmental and social impacts are identified and assessed, and avoidance, minimisation, mitigation, compensation and enhancement measures designed and implemented.

## 5.1 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 (primarily for cooling); landscape, visual effects, tourism and recreation; biological resources; noise, air and water pollution; and cultural heritage.

According to the Environmental Impact Assessment (EIA) Act of 2000 (amended 2005 and 2014), the following types of projects related to geothermal power development will always be subject to EIA:

- Geothermal power stations with a heat output of 50 MW or more
- Groundwater abstraction where the volume is 300 l/s or more
- Overhead electrical power lines, with a voltage of 66 kV or more
- New roads outside of urban areas which are 10 km or longer; re-building of roads outside of urban areas where the planned new construction is at least 10 km in length; all new roads outside of urban areas in protected areas and in areas which are on the list of sites of special natural interest; rebuilding of roads outside of urban areas in protected areas.

There are also a number of project types which may have substantial effects on the environment and are assessed on a case-by-case basis, such as deep drilling of production and research wells in high-temperature geothermal regions; steam pipelines; smaller geothermal power stations; geothermal district heating stations; low-voltage and underground transmission lines; etc.

The EIA process is managed by the 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 for 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 authorities granting development permits, the municipalities.

## 5.2 Detailed Topic Evaluation

### 5.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *Assessments of project environmental and social impacts have been undertaken for project implementation and operation, including evaluation of associated facilities, scoping of cumulative impacts, role and capacity of third parties, and impacts associated with primary suppliers, using appropriate expertise and with no significant gaps; and a baseline has been established and well-documented for the pre-project condition against which post-project changes can be compared.*

Project development was initiated by Theystareykir ehf., a local company with basic environmental and social assessment and management practices. During the early years of the project, the main activity on site was exploratory drilling. No EIA was required by the authorities, but some guidance was provided on minimization of impacts.

The main EIA was initiated in 2006, when Mannvit Consultants were hired by Theistareykir ehf., now with Landsvirkjun as a partner. The EIA included the Theistareykir-Húsavík road and some primary supplies, such as quarries. It took several years, until November 2010, to finalise the EIA with the opinion of the Planning Agency, because in parallel there were EIAs ongoing for transmission lines, the expansion of the Krafla power plant, and the aluminium smelter at Bakki; government requested a joint or cumulative EIA for all of these, to be submitted at the same time as the individual ones; and the municipalities developed a joint regional plan and following that, municipal plans. These developments made the elaboration of the EIA quite unpredictable. As the EIAs came after the regional plan (accepted by the Minister of Environment in January 2008), which had already taken some decisions, not many alternatives were left to consider.

The EIA team was qualified and experienced in geothermal-specific issues. Baseline data generation for the EIA was largely subcontracted to a number of competent consultants and agencies; the baseline is well documented. There were no major surprises in the assessment results.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and both risks and opportunities; and the social impact assessment incorporates assessment of human rights.*

The EIA process went beyond scoping of cumulative impacts, which in Iceland is expected from all EIAs, and through the joint EIA evaluated a range of cumulative impacts of the various parallel projects. The requirement for a joint EIA came out the recent Kárahnjúkar/Fjardaál experience, where it was felt that separating out the assessments missed some significant issues. There were some doubts, however, (a) whether an additional joint EIA was actually necessary, given that the municipalities had just completed a regional plan covering the same projects, and a joint Sustainability Initiative of the developers was already underway; and (b) whether the joint EIA contributed additional information, beyond a summary of the impacts in the individual EIAs. Some 'lessons learnt' papers were produced by the consultants and developers, concluding that the process was costly and time-consuming and did not add significantly to the quality of the EIAs.

The regional plan, joint EIA and the individual EIA for Theistareykir tended to overestimate the impacts, as (a) the smelter was replaced by a much smaller siliconmetal facility, (b) one of two parallel transmission lines became unnecessary, (c) the Krafla expansion project was postponed, and (d) the Theistareykir project was built smaller than originally anticipated, with 90 MW instead of 200 MW. Nevertheless, they provide a useful framework, should future expansion of be considered.

Human rights were not specifically considered in the impact assessment. This is not a significant gap, given the positive human rights situation in Iceland in general, Landsvirkjun's commitment to the Global Compact, and the absence of resettlement, expropriation or other measures in this project which can typically cause human rights issues.

**Criteria met: Yes**

## 5.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *Environmental and social issues management plans and processes have been developed with appropriate expertise (internal and external) for project implementation and operation with no significant gaps; in addition to key social and environmental issues relating to the geothermal project, plans address construction*

*related waste, noise, air quality, land disturbance and rehabilitation; the environmental and social impact assessment and key associated management plans are publicly disclosed.*

The EIA assessed the impacts of an early version of the project design. In parallel and after the EIA, design work was ongoing and the EIA had considerable influence over siting and design choices (see P-4).

Iceland's regulatory framework does not require an environmental and social management plan. After the approval of the EIA and the issuing of the development permit, it is left to the developer to decide how the comments of the environmental authorities and the permit conditions will be addressed and fulfilled. The EMP was therefore produced late in the process in 2015, to summarize the project's approach to mitigation and compensation measures.

The EMP specifically addresses the project components that comments were received on (roads and tracks, drilling sites, steam pipes, and spoil area) as well as several environmental aspects (geothermal heat, flora and fauna, cultural remains, groundwater, air quality, visual impact, social impact, and other issues not raised by the authorities), and lays out the monitoring program.

There are specific plans for dealing with:

- Solid waste (of which relatively little is expected during construction, and even less during operations) and drill cuttings; covered under P-21,
- Noise (which can be substantial during construction, primarily due to well testing; but is less during operation). A 2010 study calculated the expected noise levels. Silencers are installed on wells and on other parts of the plant. A permanent noise monitor has been set up by the cabin in the area, monitoring sites have also been determined where noise levels are measured six times a year, and 2014 and 2015 noise monitoring reports are available online. The noise limit at the border of the industrial area is 70 db.
- Air and water quality (covered under P-21)
- Land disturbance, which is minimized by keeping the footprint of the project small, in fact so small that there have been some issues with construction management around the powerhouse. Some rehabilitation is done directly by contractors. The main measure to compensate for the remaining approximately 80 affected hectares is a land rehabilitation program contracted with the public Soil Conservation Service of Iceland (SCSI, Landgrædsla Ríkisins), with activities on a total of approximately 200 hectares (see also P-19). Part of the compensation has been done by planting roughly 125,000 plants in the Nordurthing area, while the rest or roughly 165 ha will be revegetated using seeds and fertiliser. SCSI also supported the experimental turf transplanting by the road contractor and other civil contractors, in order to apply it along other roads (for example, to Dettifoss). Much of the rehabilitated land will be used by sheep farmers for grazing (farmers in Thingeyjarsveit and Nordurthing jointly graze about 5,000 sheep on 25,000 hectares of municipal land), but some of it will be fenced off.

In general, all documentation on environmental and social impact assessment, management and monitoring since 2008 has been publicly disclosed.

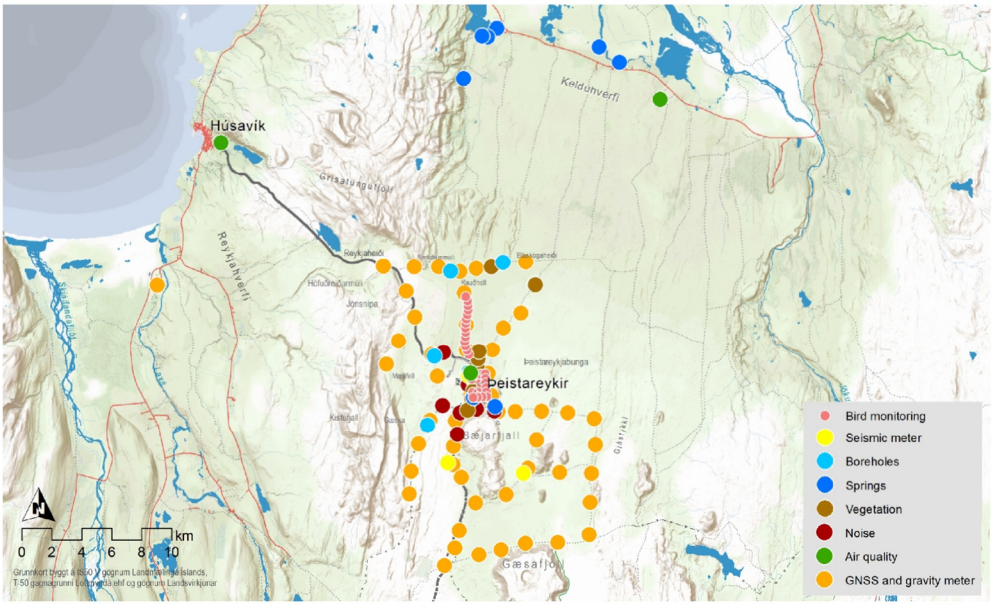
**Criteria met: Yes**

## Analysis against proven best practice

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

The map below shows the locations of the monitoring points, which contribute to the monitoring programs addressed under different topics in this report.

**Figure 8. Environmental Monitoring Locations**




Monitoring results are reported to regulators and licensing agencies (specifically, the National Energy Authority and the municipalities, especially their health directorates) and made public. Other monitoring is going on in parallel with or without involvement by Landsvirkjun. For example, SCSI monitors vegetation quality with special indicator plants and pictures taken annually at the same exact location identified by GPS.

Theistareykir's EMP is embedded within Landsvirkjun's ISO 14001 certified Environmental Management System. Landsvirkjun's annual 'Green Accounts' show quantitative data which are independently verified.

**Criteria met: Yes**

## 5.2.3 Stakeholder Engagement

### Analysis against basic good practice

***Scoring statement:*** *The environmental and social impact assessment and management planning process has involved appropriately timed, and often two-way, engagement with directly affected stakeholders; ongoing processes are in place for stakeholders to raise issues and get feedback.*

There was extensive engagement with directly affected stakeholders, particularly during scoping stage and after publication of draft EIA, with meetings locally and in Reykjavik. The Planning Agency was consulted for guidance on process, organized meetings, and provided a timetable. The draft scoping document was presented to meetings, and some stakeholders received special presentations. The draft EIA report was advertised by the Planning Agency, 4 open meetings were conducted, and the draft was shared with agencies and NGOs for comments, which are all publicly available and have all been responded to. After receiving the final draft, the Planning Agency had a month to issue her opinion, which was broadly accepted with no large debate afterwards.

Ongoing processes are in place for stakeholders to raise issues and get feedback, as described under P-1.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, engagement with directly affected stakeholders has been inclusive and participatory; and feedback on how issues raised have been taken into consideration has been thorough and timely.*

The engagement around the EIA has included all interested stakeholders as well as their representatives, such as municipal councils.

Not all comments by different authorities have been taken on board, but all have been responded to and explanations have been provided on the chosen approach to managing issues.

**Criteria met: Yes**

### 5.2.4 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Environmental and social plans avoid, minimise and mitigate negative impacts with no significant gaps.*

The Theistareykir area was not pristine before the geothermal project, as it had been used for farming, sulphur mining, and recreation over centuries. Nevertheless, it has high biological, cultural and landscape values which have been a concern of local residents, competent authorities, and NGOs. The Planning Agency, summarizing the opinions of other authorities, categorized the overall impact as significant and recommended a number of permitting conditions. These have largely been followed by the municipality, and address all identified negative impacts.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, environmental and social plans avoid, minimise, mitigate and compensate negative project impacts with no identified gaps; and plans provide for enhancements to pre-project environmental or social conditions or contribute to addressing issues beyond those impacts caused by the project.*

The main compensation program in the Theistareykir project is the land rehabilitation program. Other negative impacts (such as noise or visual impacts) are mitigated but cannot be compensated.

Icelandic EIAs and EMPs rarely identify opportunities to enhance pre-project conditions, or resolve other issues unrelated to the project, as they are strongly oriented towards the specific negative impacts of the project. The Theistareykir EIA and EMP make no exception. This issue is addressed under specific topics (for example, P-10 and P-21).

**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 environmental and social impacts of the Theistareykir project were assessed early enough and with a broad enough scope (including cumulative impacts) to have significant influence on project siting and design, thus avoiding and minimizing a number of possible impacts. Mitigation, compensation and monitoring measures have

been implemented for the remaining impacts, and are embedded into Landsvirkjun's overall environmental management system. There are no significant gaps against proven best practice, resulting in a score of 5.

**Topic Score: 5**

## 5.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 3, 8-11, 15, 18, 19, 24, 26, 28, 32, 35, 37 |
| **Document:** | 53-67, 130, 134, 190 |
| **Photo:** | 64 |

# 6 Integrated Project Management (P-6)

This topic addresses the developer's capacity to coordinate and manage all project components, taking into account project construction and future operation activities at all project-affected areas. The intent is that the project meets milestones across all components, delays in any component can be managed, and one component does not progress at the expense of another.

## 6.1 Background Information

The preparation process for geothermal power projects takes a long time (in the case of Theistareykir, 15 years), is dynamic, and places high demands on project management. Understanding of the geothermal resource grows with continued exploration and eventually, operation of the power plant. Sources of uncertainty are:

- Difficulties in projection of reservoir behaviour
- Unknown impact of earthquakes and volcanic eruptions on reservoir yield
- Unknown design and location of facilities, including number of drilling pads and wells needed and the reinjection scheme, depending on drilling results and on the nature and evolution of the reservoir
- Possible modifications of the steam/brine system and the power plant, in case of steam cap development and/or effects of earthquakes and volcanic eruptions
- Possible changes with time of the chemistry of the geothermal fluid

All activities in the preparation phase – technical designs, financial modelling, environmental impact assessment, licensing and stakeholder information – are subject to modification as that understanding grows. This calls for an iterative, stepwise and adaptive approach, with gradually increasing confidence. Even during construction, design modifications are made.

Landsvirkjun is an experienced project developer, with 17 power stations in operation (8 of which are larger than Theistareykir). One new power plant (Búdarháls, 90 MW) was commissioned in 2014, and Landsvirkjun is currently expanding Búrfell by 100 MW. As part of its corporate governance, Landsvirkjun has comprehensive processes and procedures for project management. Landsvirkjun had no direct experience in greenfield geothermal development before Theistareykir. The two other power stations in the north-eastern geothermal field, Bjarnarflag and Krafla, were purchased from the state after years of operations; Krafla was later expanded by Landsvirkjun. However, there is strong exchange of experience between power companies, consultants and authorities in Icelandic, so that Landsvirkjun can benefit from the accumulated geothermal project management experience in the sector.

## 6.2 Detailed Topic Evaluation

### 6.2.1 Management

#### Analysis against basic good practice

***Scoring statement:*** *An integrated project management plan and processes have been developed that takes into account all project components and activities with no significant gaps; and a construction management plan has been developed that identifies construction risks and describes processes that contractors and others are required to follow to manage these risks.*

During preparation and construction of Theistareykir, a project manager from the Landsvirkjun Research & Development or Construction Division has the overall responsibility. During preparation, he was supported by a small internal working group, with technical, geological, and environmental expertise, coordinating the different preparation workstreams. A steering group of senior managers is appointed, all of which have to eventually support taking the project to the board for an investment decision.

The working group has series of meetings with external advisers. During the EIA, for example, the Mannvit consultant team had 14 formal meetings with the working group to review progress. After the EIA was finalized, a design consultant was selected. The 2011 design contract with Mannvit-Verkis was originally for 36 months, but had to be extended. Landsvirkjun took significant time for decisions, owing to the high degree of complexity of project definition at the time; the ToR considered up to 7 different scenarios. During the design period, there were weekly meetings between the consultant and the Landsvirkjun project team, both on design and on procurement strategy. The consultant focused on quality, while the project team was responsible for operational reliability, cost and schedule issues. Other consultants were also working in parallel, for example on the access road and on drilling supervision. A high degree of adaptability was required, and eventually a much-downscaled project was taken forward. All project documents are named consistently NAL (for north-east region, contracts for the entire north-eastern geothermal complex), THR (contracts for Theistareykir) or BJA (contracts for Bjarnarflag) with corresponding numbers. Many equipment contracts were supposed to be exactly the same for the different geothermal sites, while other, such as civil works, differ.

The package of supporting documents assembled for the 2014 board investment decision included: cost and schedule estimates, PPA, licenses, stakeholder register, and risk register. The risk register contained seven sections, contributed by different business units, covering a broad range of potential risks from regulatory changes, stakeholder conflicts, technical and contracting, and cost and revenue risks. For each risk, probabilities, consequences, responsible staff, and mitigation actions are described. The highest risks were identified through a collaborative 'mind map' exercise.

The Research & Development Division prepares the project´s feasibility study ('verkhönnun'). The Planning & Construction Department is responsible for the detailed design as well as the tender document writing, tendering and purchasing processes. Research & Development remains responsible for all geological aspects of the drilling work, steam well design and positioning, but the project management of the drilling contract is part of the Planning & Construction responsibility. A Project Implementation Masterplan is drawn up. The formal board decision is required for investments above USD 5 million; but once formally accepted the board only needs to approve major contract awards.

Once contractors are selected, they are required to submit programs, schedules, drawings, risk registers and other documents for each contract, which are internally adapted to a master plan and approved. Risk registers for each contract are based on suggestions in tender documents, which need to be completed by the contractor. Some of the schedules – for example, for the THR-02 drilling contract – are quite complex. During implementation, Landsvirkjun is responsible for providing site services such as utilities to contractors. Every 2nd week there are project coordination meetings, to review and resolve issues. There are also regular informative meetings with Landsnet, but clear separation of roles is required. The Landsvirkjun project team tracks progress and manages the different contracts. For civil and steam supply contracts, Earned Value Analysis is applied.

**Criteria met: Yes**

## Analysis against proven best practice

***Scoring statement:*** *In addition, the integrated project management plan sets out measures to manage interface and delay issues without impinging on overall project timetables and budgets; construction management plans ensure that land disturbance and waste generation activities will be managed so that later rehabilitation activities can be undertaken efficiently and effectively; and processes are in place to anticipate and respond to emerging risks and opportunities.*

The Project Implementation Masterplan guides the Landsvirkjun project team in managing interfaces between the multiple contractors. Landsvirkjun also expects some self-management of interface issues from contractors, which all have contractual clauses to conclude cooperation agreements with each other, share time schedules, agree on joint access to sites, and on services from each other, as required. This applies, for example, to the interface between the drilling contractor and the steam supply contractor, who has to connect newly drilled

wells. The powerhouse is slightly delayed, but has now been handed over by the civil contractor to a number of other contractors for equipment installation. The first turbine and generator have arrived from Japan, and the testing of the unit is planned to start August 10. The target date for commercial power deliveries to PCC is December 1, with full capacity achieved by February 2018 and the second unit in April 2018.

There are currently delays, however, with the transmission line. Landsnet had the EIA available at the same time as Landsvirkjun, who already had all licenses (except the operation license, July 2016) available by April 2014. However, Landsnet only contracted a design consultant in September 2015, and applied for the four required transmission line permits, after contracting with the offtaker PCC. The permits were issued in 2016, just two weeks after regulatory changes, and were challenged in court by national level NGOs (Landvernd and Fjöregg) on the basis of new provisions, which require a more explicit justification. Two permits were declared invalid and needed to be reapplied for. While this challenge has now largely been resolved (one permit in Skútustadahreppur is still pending, but Landsnet may proceed), there is still no resolution of a conflict with two landowners. According to Landsnet, this conflict was difficult to foresee, as it emerged within a large joint ownership group that had previously been among the first to negotiate contracts. The Ministry of Industry has however given the permission to expropriate, the valuation committee has decided on compensation payments (USD 22,440), and a court order for enforcement is expected shortly. All groundwork except in the section of these landowners was finished before the winter 2016/2017, and once all issues are resolved, groundwork is hoped to be completed, and towers and cables erected in the summer of 2017. Other works such as switchyards, are under construction. However, there might be a risk that the target date agreed with Landsvirkjun, August 31, may not be kept. This is a **significant gap** against best practice, as it could have been avoided by earlier action by Landsnet and/or by more timely decisions by government agencies and committees.

Landsnet as the transmission system operator is legally responsible for developing the transmission system in an economic manner. Its internal rules reflect this obligation by stating that planning, permitting, procurement and construction of a line can only start after a Transmission Agreement has entered into force. Landsvirkjun was also aware of these rules and the resulting time requirements. The responsibility for the delays is thus a complex issue, and shared between different parties. Avoiding such delays may require significant changes, possibly including both internal and regulatory changes (see also the gap under P-2). For Landsnet, improved stakeholder engagement is one possibility (see P-13), although there are no guarantees that this results in less opposition from some determined stakeholders. The other possibility is starting processes earlier, recognizing the high probability of challenges, even from stakeholders who had not used previous opportunities for interventions, and the delays in resolution of such challenges, for example when rulings by government committees are required.

A number of alternative solutions have been considered by Landsvirkjun and Landsnet in case the transmission line is not available on time, in order to avoid contractual penalties and preserve reputations. It may be possible to use a dummy load for full load testing of the generation unit, and/or to deliver power to the national grid over the existing Laxá hydropower stations connection (28 MW). PCC has been informed and discussions about solutions initiated. In this case the Theistareykir power plant will be operated in 'island mode' with reduced capacity to maintain the required voltage and frequency quality.

**Criteria met: No**

### 6.2.2 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *The project is likely to meet overall budget and timing objectives and targets, and plans avoid, minimise and mitigate construction risks with no significant gaps.*

No cost overruns are currently expected, but there is a risk that commissioning of the transmission line may be delayed, and that this delay cannot be compensated to ensure on-time delivery of power to the offtaker PCC. Because the delay would probably be minor, this is not considered a significant gap at this level.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the project is highly likely to meet overall budget and timing objectives and targets; and plans avoid, minimise, mitigate and compensate construction risks with no identified gaps.*

Because of the preventable delay of the transmission line, the Theistareykir project is not highly likely to meet timing objectives. This is a **significant gap** against proven best practice, the same gap as identified under Management.

**Criteria met: No**

## 6.2.3 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

Delay of transmission line, which could have been avoided by earlier action by Landsnet and/or by more timely decisions by government agencies and committees, risking the contractual power delivery date.

**1 significant gap**

## 6.3 Scoring Summary

Through the development of multiple projects, Landsvirkjun has acquired significant project management experience and has established robust processes. The Theistareykir project shows how these processes have been managed adaptively and in close cooperation with contractors. There are delays in a Landsnet transmission line, however, which were avoidable and may require additional efforts to comply with contractual power delivery dates and/or carry a slight risk of not meeting those dates. This gap results in a score of 4.

**Topic Score: 4**

## 6.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 3, 6, 7, 9, 11, 13, 14, 18, 22, 29-31, 33, 38 |
| **Document:** | 52, 56, 69-79, 127, 128 |
| **Photo:** | -- |

# 7 Geothermal Resource (P-7)

This topic addresses the level of understanding of the geothermal resource and the assessment of the geothermal production capacity, including the predicted response to the planned production, and the planned generation efficiency based on the assessed geothermal conditions and utilization strategy. The intent is that the project's planned power generation takes 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 energy resource.

## 7.1 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 taking more heat out 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 (the National Energy Authority of Iceland 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 periodic 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. 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 over 600 hot springs (temperature over 20°C).

The experience in predicting reservoir yields and responses to utilization has been increasing over time, among specialized government agencies, power companies and consultancies. Iceland has several high-temperature geothermal fields that have been utilized and closely observed over decades. The general consensus in Iceland is that it is preferable to develop fields step-wise or in stages, to take into consideration the individual conditions and response of each geothermal system.

## 7.2 Detailed Topic Evaluation

### 7.2.1 Assessment

#### Analysis against basic good practice

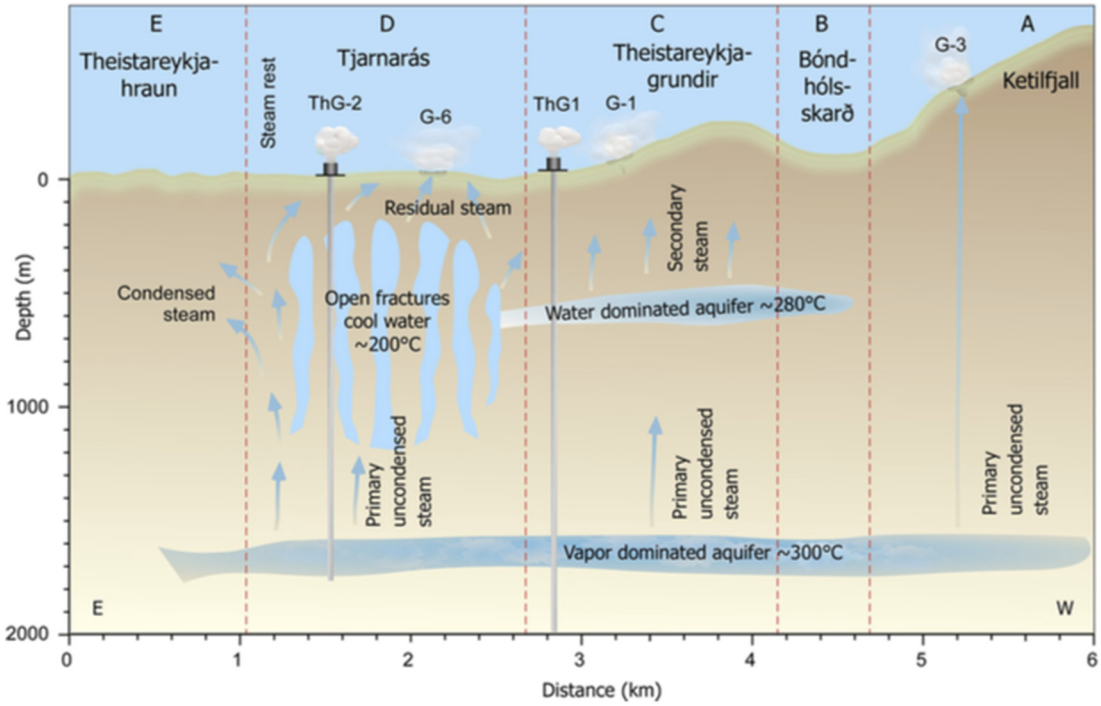
***Scoring statement:*** *An assessment of the geothermal resource production capacity has been undertaken utilising available data, field measurements, testing of wells, appropriate statistical indicators, and geothermal reservoir models; issues which may impact on geothermal availability or reliability have been identified and factored into the modelling; and scenarios, uncertainties and risks have been evaluated.*

Surface exploration and mapping of the Theistareykir high-temperature geothermal field was carried out in 1972-74 and 1981-84, and a 1984 interdisciplinary report covered temperature, resistivity, magnetism, gravity, chemistry, and geology of the field. Low-resistivity rocks are a good indicator of the presence of a geothermal reservoir. The results of electrical resistivity measurements (magnetotellurics/MT and transient electromagnetics/TEM) indicate that the geothermal area is large, up to 45 $km^2$. Most information is available from the 11 $km^2$ with surface activity (warm soil, mud-pools, fumaroles/solfataras and steam areas).

In the years 1999-2000, first shallow wells and then in 2002-2012, ten deep wells were drilled, to a maximum depth of 2,799 m, largely confirming the findings of surface exploration (although it was discovered with the drilling of well ThG-8 that the western half of the potential reservoir was in fact not productive), allowing the development of a conceptual model of the geothermal system, and increasing the confidence in estimating potential capacity. The fluids were found suitable for electricity generation, with less volcanic influence and therefore lower gas and solids content than at Krafla, and the reservoir temperatures are at least 280°C.

**Figure 9. Conceptual Model of Theistareykir Reservoir**

*(G-1, G-3, G-6 are surface fumaroles; ThG-1 and ThG-2 the first two deep exploration wells in 2002 and 2003)*




With an increasing amount of data, the conceptual model of the reservoir was used for a resource assessment study and to build a 3-dimensional numerical model of the movement of fluids in the reservoir (based on iTOUGH2 software), using continuous time series data (drawdown, production and enthalpy) as well as pressure and temperature profiles down the wells. This was done through a cooperation between ISOR, Vatnaskil and Mannvit consultants, and Landsvirkjun.

Before the investment decision, the natural heat output of the system was estimated at 350 $MW_{th}$, from measurements of groundwater and soil temperatures. The electricity generation capacity was estimated at 104 MW for 100 years, 209 MW over 50 years, or 348 MW for 30 years, in case of a more aggressive utilization. These numbers are being updated with increasing understanding of the system.

**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 uncertainties and risks including reservoir drawdown and geothermal system response have been extensively evaluated over the short- and long-term.*

In parallel, the understanding of many different aspects of the geothermal field has been growing. For example, micro-seismic monitoring data generated by ISOR, together with the regular seismic monitoring by the MetOffice, and with identification of surface fractures and structural geological analysis, helps to find fissures and assists in the siting of wells. Production wells have been logged during drilling, closed after drilling for 'warm-up' and then tested over several months, including injections to test permeability, with detailed analysis of their behaviour. The series of groundwater data has also been growing, allowing an ever better understanding of groundwater flows, temperatures, and natural variations. A sensitivity analysis of the Theistareykir reservoir models was provided by Vatnaskil Consultants in 2014. In the opinion of Landsvirkjun and their consultants, the level of confidence in the understanding of the Theistareykir reservoir is high, compared to other greenfield projects in Iceland, because of good baseline data, simulation models and sensitivity analyses.

**Criteria met: Yes**

## 7.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *A plan and processes for generation operations have been developed to ensure efficiency of geothermal energy utilization, 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.*

Sufficient steam was available for the first generation unit, before the investment decision in 2014, and there was high confidence in being able to access enough steam through the drilling program under contract THR 02, for the second generation unit. The reservoir modelling appears to confirm a very high probability that these two units can be operated sustainably over their lifetime. With their 90 MW baseload generation, they will be able to fulfil contractual obligations under the PPA with PCC, and produce excess power for increased consumption and grid stabilization in the north-east.

Depending on the reservoir response, which will be monitored constantly (flow rate at wells), and additional investigations, there may be case for further capacity additions. The EIA has already been done for a 200 MW power plant, and there are provisions in the design and in the procurement plans to expand capacity by adding an identical powerhouse. Further expansion could be done at a lower cost, and would still remain within acceptable environmental and social boundaries. For the investment decision in 2014, a simple relationship between installed capacity and net present value was calculated, with an optimum at a capacity of about 135 MW.

**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 plans exist for monitoring of the effect of operation on the resource and updating of the conceptual and numerical models to ensure that geothermal fluid 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 numerical simulation model of the geothermal reservoir is regularly updated with the support of consultants as new information becomes available, from the monitoring of vertical and horizontal surface movements, seismicity, gravity (showing recharge), surface activity, groundwater levels, temperature, pressure and chemistry

in wells, and other parameters. It provides a probability distribution of the likely sustainable yield of the reservoir (although quantification is difficult), and has been reviewed by peers in the sector, regulators, and an independent reviewer. The model will be used to locate additional wells for production and reinjection, and to guide the possible expansion of the Theistareykir project over time.

Efforts are being made in the sector to use more rigorous definitions of sustainable yield, possibly using definitions similar to the oil & gas and mining sectors, for possible, probable and proven reserves. A significant remaining uncertainty is the permeability of the reservoir.

The National Energy Authority generally requires a 95% certainty that the installed capacity can be utilized over the long term. Reductions in steam yield of 3-5% per year are acceptable as they can be compensated through make-up wells. The 2014 utilization license over 50 years for Theistareykir imposes limits on utilization (measured by reductions in pressure and in steam supply), and specific requirements for reinjection, reservoir model calibration, and other operational aspects, to ensure sustainable utilization, and requires monitoring and annual reporting. The National Energy Authority is careful not to take operational control from the developer, but to support the developer in dealing with issues, and to protect customers.

**Criteria met: Yes**

### 7.2.3 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**

## 7.3 Scoring Summary

The high-temperature geothermal reservoir at Theistareykir has been assessed over a long period of time, through surface investigations, drilling, reservoir modelling, and monitoring of a range of parameters, leading to increased confidence in understanding the resource. The step-wise development of the reservoir allows for adaptive management, and is supported by the license conditions. There are no significant gaps against proven best practice, resulting in a score of 5.

**Topic Score: 5**

## 7.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 2, 3, 6, 7, 12, 13, 14, 18, 29, 31, 34, 38 |
| **Document:** | 80-101 |
| **Photo:** | 1, 3-13, 37, 38, 41-50, 74, 86-87 |

# 8 Infrastructure Safety (P-8)

This topic addresses planning for geothermal drilling, supply system, power station and other infrastructure safety during project preparation, implementation and operation. The intent is that life, property and the environment are protected from the consequences of the geothermal energy harnessing works and other associated infrastructure safety risks.

## 8.1 Background Information

Public safety around geothermal projects requires prevention of accidents, that could result from: high pressure and high temperature installations at geothermal wells and supply system, high concentrations of hazardous gases, extreme noise during well testing and blowouts, low visibility (because of dense steam), seismic and volcanic risk, landslide, rockfall and avalanche risk, electrical hazards, road accidents, or other accidents arising from community interactions with project activities. While there may be some warning signs, natural geothermal areas and geothermal power facilities in Iceland (except the interior of buildings) are usually accessible to the public.

Public safety issues during the preparation phase are different from those during construction and operations, and mainly related to the opening of access roads and the drilling of wells. However, during project preparation, safety during future construction and operation has to be taken into account, and built into designs and contractor requirements.

Some related risks are covered under separate topics. Occupational health and safety risks to workers are covered under P-16; public health is covered under P-18/P-21; and the risks from induced seismicity and subsidence are covered under P-20.

## 8.2 Detailed Topic Evaluation

### 8.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment has been undertaken of geothermal drilling, supply system, power station and other infrastructure safety risks with appropriate expertise during project preparation, construction and operation, with no significant gaps.*

Public safety has not been assessed as a separate issue in the Theistareykir preparation phase, the joint EIA, or the feasibility study. Safety has been primarily seen as an OH&S issue, as workers are much more exposed to safety risks than the general public, and there are no known public safety incidents at geothermal power plants in Iceland. While the roads to Theistareykir are open to the public even during construction, there is no visitor centre or other encouragement, and public visitation has been low.

Traffic safety has been recognised as an issue relating to the design and alignment of the new road from Húsavík, as well as traffic safety in Húsavík, with increased traffic from several industrial projects in parallel. Regarding safety of tourism activities during the construction phase, meetings with related municipalities and tourism companies were held prior to construction start.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment includes consideration of a broad range of scenarios, and includes both risks and opportunities.*

Landsvirkjun's safety policy, a part of its Requirements Towards Contractors and Service Providers with Regard to Environmental and Health and Safety Matters, exclusively addresses workplace safety. However, many of its provisions would also help to protect the general public.

The potential public safety risks listed in the Background have not been systematically assessed, to inform siting and design of project components, which is considered a **significant gap** against proven best practice.

**Criteria met: No**

## 8.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *Geothermal drilling, supply system, power station and other infrastructure safety management plans and processes have been developed for project implementation and operation in conjunction with relevant regulatory and local authorities with no significant gaps and provide for communication of public safety measures; emergency response plans include awareness and training programs and emergency response simulations.*

Designs for a number of project components have taken safety into account. For example, the road from Húsavík is designed with the required 7 m right-of-way with no obstacles on the shoulders; wellheads are covered by domes that can be locked; steam pipes are insulated; electrical installation such as transformers and switchyard are placed indoors or fenced off; buildings are designed according to recognized safety standards. Emergency releases from wells and the steam supply system are considered in designs and operational plans and licenses. During construction, a horse riding path was re-routed to increase the distance from worksites.

Although mostly related to OH&S issues, through tender documents, contracts and guidelines Landsvirkjun sets out the requirements for contractors to comply with laws, rules and regulations relating to health and safety measures in construction projects. Safety is an issue in the supervision of contractors and in the regular meetings. Risk analyses are prepared for heavy road transports, pressure testing and other activities with potential safety implications, and these activities are discussed beforehand with public authorities, such as the police, fire brigade and hospital in Húsavík and the Administration for Occupational Health & Safety, for example in the Theistareykir Safety Committee. The Department of Civil Protection and Emergency Management has responsibility for emergency response across Iceland. These emergency response partners are listed with their contact information in the project emergency response plan.

There is some signage at Theistareykir but no access control to the worksites. This is not considered a significant gap at the basic good practice level, because the exposure of the general public is low.

**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; plans provide for public safety measures to be widely communicated in a timely and accessible manner; and emergency response plans are independently reviewed.*

One of the objectives of licensing and monitoring by municipalities and the National Energy Authority, besides reservoir sustainability and environmental protection, is to ensure the safe and responsible design and management of power plants. Other government agencies also cover aspects of public safety. Landsvirkjun, contractors and public authorities have shared safety-relevant information and contact information in case of emergencies.

There emergency response plans for the Theistareykir project are not independently reviewed, which is a **significant gap**.

**Criteria met: No**

### 8.2.3 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Plans avoid, minimise and mitigate safety risks with no significant gaps.*

The objective level of public safety risks around the Theistareykir project is low. Standard practices for road safety, electrical safety, insulation and shut-off systems for hot and pressurized parts, and other safety aspects have been followed. It would be impossible to fence off or control access to an entire geothermal power plant, including its steam supply system. Even blocking road access would let hikers and others approach individual components. However, more systematic safety management will be required if tourism and recreation in the area will be encouraged, after the commissioning of the power plant. A small step would be better signage to alert people to the inherent risks, in particular tourists who may not be familiar with geothermal installations.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, plans contribute to addressing safety issues beyond those risks caused by the project itself.*

There is a contribution to public safety from developing the Theistareykir project, in terms of access to first aid, mobile phone coverage, snow clearing and other services that would not otherwise be available in the area.

**Criteria met: Yes**

### 8.2.4 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

Potential public safety risks have not been systematically assessed, to inform siting and design of project components.

There are no independently reviewed emergency response plans for the Theistareykir project.

**2 or more significant gaps**

## 8.3 Scoring Summary

The Theistareykir project involves relatively low safety risks for the general public. Workers are much more exposed, and it was generally assumed that work safety protections would also adequately cover the general public. A number of additional public safety measures have been implemented, but these are not based on a systematic assessment, and there is no independently reviewed emergency response plan. These gaps result in a score of 3.

**Topic Score: 3**

## 8.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 6, 7, 25, 27-29, 36, 37 |
| **Document:** | 58, 62-64, 70, 155 |
| **Photo:** | 5, 48, 51, 52, 86 |

# 9 Financial Viability (P-9)

This topic addresses both access to finance, and the ability of a project to generate the required financial returns to meet project funding requirements, including funding of measures aimed at ensuring project sustainability. The intent is that projects proceed with a sound financial basis that covers all project funding requirements including social and environmental measures, financing for resettlement and livelihood enhancement, delivery of project benefits, and commitments to shareholders/investors.

## 9.1 Background Information

Geothermal power plants, like other renewables, have relatively high capital investment costs but low operational and maintenance costs. Data from the International Renewable Energy Agency (IRENA) show that

- Conventional condensing "flash" geothermal projects that utilise high-temperature resources generally have installed costs of USD 1.9-3.8 million/MW, while binary power plants to exploit lower-quality resources have installed costs of USD 2.25-5.5 million/MW.
- The two largest cost components are drilling and the power plant, which both account for between ¼ and ½ of the total investment costs. A production well that can support 5 MW of generation may cost USD 10 million, with a 20% failure rate. Investment costs depend on a number of factors, such as the availability of drilling rigs, costs of steel, and climate conditions that may restrict the ability to construct year-round.
- Geothermal offers some of the least-cost electricity of any source where good resources exist, with levelized costs of energy (LCOE) between USD 40/MWh at the most competitive projects (often the second-stage development of an existing field) and USD 140/MWh for greenfield developments.

Comparing geothermal with hydropower projects, the two main options for Iceland, on average the investment costs of geothermal are similar; the operation and maintenance costs are higher in relation to the investment costs, and less predictable; and the lifetime is shorter. However, geothermal is a baseload technology with a higher capacity factor and reliability, if sized conservatively. Stepwise development of a geothermal project, as commonly practiced in Iceland, entails a relatively low risk of failure, relatively small increments of investment, gathering of information about the resource which can be used to improve design of the next step, and growth in generation that is synchronized with demand. Most system components can be expanded in a modular manner.

At the end 2016 Landsvirkjun had assets valued at USD 4.3 billion, liabilities of USD 2.4 billion, and equity of USD 2.0 billion. Operating revenues in that year were USD 420 million, and net profits USD 67 million. Loans for the Theistareykir project were obtained from the European Investment Bank (USD 140 million), the Nordic Investment Bank (USD 50 million), and from a Japanese export credit consortium for up to USD 68 million, with no state guarantees. Initially 52 MW, later rising to 58 MW of power have been contracted under the current PPA (March 2015) with the offtaker PCC, with a take-or-pay obligation. Surplus power will be fed into the national grid and sold on the wholesale market.

Iceland is a member of the European Free Trade Association (EFTA), and the EFTA Surveillance Authority supervises state aid to companies to ensure effective competition. The Authority has reviewed the PCC investment and concluded that the terms of the power contract between Landsvirkjun and PCC, and the transmission contract between Landsnet and PCC, do not constitute state aid, and that the Theistareykir project is profitable under the conditions of the contracts.

## 9.2 Detailed Topic Evaluation

### 9.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment of corporate financial viability, including potential project costs and likely revenue streams, has been undertaken using recognised models with no significant gaps; analyses include risk assessment, especially adequate resource assessment based on physical parameters from surveys including well testing, scenario testing and sensitivity analyses including decay of yield over time.*

At the time of the investment decision, Landsvirkjun did not yet have a formal stage-gate process. Geothermal projects have unusually large preparation costs, with board pre-authorization, which at the time of the investment decision are sunk costs. Financial analysis had been ongoing in parallel with preparation of the geothermal projects in north-east. When decision was taken in 2012 to advance Theistareykir first, instead of Bjarnarflag, the financial model from Bjarnarflag was adapted. Theistareykir has slightly higher costs, due to a lack of road access.

The financial analysis is based on a cash flow model with various market assumptions, and cost estimates from the technical project development team, at the level of contracts, in different currencies. Important assumptions at the time of the investment decision were the cost of funding, the corporate income tax, and the asset life. The investment proposal included overall costs (with significant economies of scale from developing 90 MW instead of 45 MW), net present values (NPVs) and internal rates of return. Scenarios included cost overruns, schedule overruns by 1-2 quarters, increased number of make-up wells; the impact of scenarios was shown as a range of NPVs.

The investment proposal first goes to senior management, then to the board. The first proposal was rejected by the board with a request to explore cost reduction potential; a second proposal was accepted. The board generally makes investment decisions on the basis of financial data such as return on equity and cost of capital, but also takes into account locations and local concerns, customers/demand, and grid stability.

The financial model is continuously updated as more information becomes available (for example, final power price). The marketing department has the customer relationship, while the finance department provides valuations to support price negotiations. The PPA was changed in 2014 and 2015. Prices under PPAs as well as long-term wholesale prices are considered quite predictable.

Because of the growing demand in Iceland (Landsvirkjun is actually sold out in 2017) and the need for grid stabilization in north-east, there could have been an argument for the Theistareykir investment without a PPA with an industrial offtaker; however, the PPA provides increased certainty.

The assessment of financial viability by the lenders is largely focused on the corporate financials, and on environmental and social impacts.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, project costs and revenue streams are fully detailed; and financial viability of the project has been analysed and optimised including extensive scenario testing, risk assessment, confirmation of resource capacity based on drilling, testing and geothermal resource modelling, detailed cash flow modelling and sensitivity analyses.*

The financial modelling is appropriately detailed. The knowledge of geothermal reservoir and generation potential is good, as described under P-7. The energy agency also sees it as their responsibility to ensure economic use of the resource, by not issuing licenses before approximately 50% of the required steam's availability is proven; and also reviews the financial case for the project, and access to finance to ensure that only

responsible investors use the resources. Its license for Theistareykir license was actually delayed because it was seeking additional information. Additionally, there was an independent review of the profitability of the project by the EFTA Surveillance Authority.

**Criteria met: Yes**

## 9.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *Financial management plans and processes have been developed for project implementation and operation with no significant gaps, and opportunities for project financing have been evaluated and pursued.*

The finance department is responsible for overall corporate financing needs. Annual and 3-year budgets are prepared and approved by the Board and new projects are generally fully funded, even if some of the funds will not need to be drawn. While financing was difficult following the financial crisis (for example, financial closure for Búdarháls in 2010 depended on institutional credits), access to financing was considerably better for Theistareykir in 2015, and without state guarantee (which in principle, can be applied for). Despite improved access to international bond markets Landsvirkjun sought funds from institutional lenders that offered favourable terms for Theistareykir.

On the revenue side, the offtaker PCC does not have a credit rating, but was analysed by Landsvirkjun. The price in the 15-year PPA is linked to certain market prices and may therefore vary, but this ability to fluctuate also reduces the counterparty risk for Landsvirkjun. The contract price has a floor and a cap, and Landsvirkjun has conducted Monte Carlo simulations to analyse the expected power price distribution, which is generally expected to be closer to the floor.

The project manager is responsible for following the costs during implementation, and overruns have to be approved by the Board.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, financial management plans provide for well-considered contingency measures for all environmental and social mitigation plans and commitments; and processes are in place to anticipate and respond to emerging risks and opportunities.*

The direct environmental and social mitigation costs are low. Many impacts are avoided through siting and design, and some design measures lead to increased investments costs (e.g. increased length of a steam pipe to reduce visual impact); other environmental and social commitments become part of the future operating costs (e.g. environmental monitoring, lease fees to municipality).

There are no specific contingencies for environmental and social commitments, but there is no concern that commitments might not be honoured.

Costs and revenues are continuously monitored.

**Criteria met: Yes**

## 9.2.3 Outcomes

### Analysis against basic good practice

***Scoring statement:*** *The project can manage financial issues under a range of scenarios, can service its debt, can pay for all plans and commitments including social and environmental, and access to capital can be demonstrated.*

Margins in Icelandic power projects are typically relatively low. The average price for industrial customers was USD 23.9 / MWh (incl. transmission) in 2016, and the average wholesale price is ISK 4.6 / kWh which is equivalent to about USD 38 / MWh, in line with lower generation costs for high-capacity baseload customers. The LCOE for Theistareykir was estimated at USD 28.9 / MWh (see chart in P-3) based on an investment cost estimate of USD 2.65 million per installed MW. The price in the PPA has to be higher than the actual LCOE for the project to be profitable.

There are some financial risks from a delayed completion of the transmission line, as described under P-6. Transmission line delays may lead to increased costs for contractors and for technical interim solutions, contractual penalties, delayed revenues, and reputational issues which impact future contract negotiations.

However, under the scenarios analysed in Landsvirkjun's financial modelling, the project will be profitable even with delays in the order currently considered, and there are no concerns regarding debt service and the ability to pay for all plans and commitments.

The access to capital has been demonstrated.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the project can manage financial issues under a broad range of scenarios.*

Risks for Landsvirkjun as a company with financial implications may result from a range of issues such as changes in ownership policy, regulatory changes, economic downturns and reductions in aluminium and other commodity prices, overinvestment in generation capacity, operational risks and hazards, hydrological fluctuations, foreign exchange risks, counterparty risks, etc. Landsvirkjun aims to understand, mitigate and hedge such risks as far as possible. Both Moody's and Standard & Poors rate Landsvirkjun's debt as investment grade. As described above, there are no reasonable scenarios under which the project, backed by the company Landsvirkjun would not be able to pay for its contractual commitments. The ratings agencies also expect support by the Icelandic state if it should be required.

Because the initial 90 MW is part of a larger geothermal complex, there are significant economies of scale if further expansion becomes possible. There is also a possibility to add further uses of the steam and by-products; an informal objective of Landsvirkjun is to reach 10% non-power revenue from geothermal projects.

With an increasing demand for power, recent contracts with large offtakers in Iceland tend to feature higher prices, to be of shorter duration, and to have more limited exposure to commodity and other risks. There is also the longer-term possibility of undersea cable exports to markets with significantly higher prices. As a consequence, the long-term financial prospects appear positive.

**Criteria met: Yes**

## 9.2.4 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

There are no significant gaps against proven best practice.

**0 significant gaps**

## 9.3 Scoring Summary

The financial viability of the Theistareykir project and the project's implications for Landsvirkjun were adequately assessed before the investment decision, and there have also been reviews by regulators, ratings agencies, banks, and a competition surveillance authority. A significant number of measures reducing financial risks are in place, and there are no concerns that the project may not be able to manage financial issues. There are no significant gaps against proven best practice, resulting in a score of 5.

**Topic Score: 5**

## 9.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 3-5, 9, 12, 13, 16-18, 38 |
| **Document:** | 16-18, 102-114, 121 |
| **Photo:** | -- |

# 10 Project Benefits (P-10)

This topic addresses the additional benefits that can arise from a geothermal project, and the sharing of benefits beyond one-time compensation payments or resettlement support for project affected communities. The intent is that opportunities for additional benefits and benefit sharing are evaluated and implemented, in dialogue with affected communities, so that benefits are delivered to communities affected by the project.

## 10.1 Background Information

Benefits covered under this topic are additional to any benefits that affected communities receive as mitigation or compensation for negative impacts, which are addressed under P-13.

The Theistareykir project was originally planned by the municipalities and utilities in the region, which formed the Theistareykir ehf. joint venture in 1999, in order to contribute to the economic development and diversification of north-eastern Iceland. Even though they were financially unable to implement this large-scale investment and had to bring in Landsvirkjun, they have supported and continue to support the project, with the same objective. The primary pathways through which the project contributes to the regional economy are:

- Sale of shares in Theistareykir ehf. to Landsvirkjun, at a price that allowed shareholders to recover early investments; the second tranche was paid as the investment decision was taken
- Municipal revenues through leasing of land, payment per kWh, fees for water extraction (in the case of Thingeyjarsveit, approximately 10-15% of municipal revenue) and taxes
- Use of the power by industrial customers, particularly in the Bakki area near Húsavík, and the associated employment, tax, and infrastructure benefits
- Strengthening of infrastructure such as roads and the transmission network
- Income from employment and local contracts for goods and services
- Opening up of the Theistareykir area as a potential tourist destination
- Possible use of heat and other by-products from the power plant in the future

One of the issues that has held back rural areas of Iceland has been the limited capacity of the network, as most of the generation capacity and demand is concentrated in the more urbanized south-west, and the 132kV ring line around Iceland (closed in 1984) was not designed for the current demand. The transmission lines associated with the Theistareykir project (60 km long 220kV lines from Krafla to Theistareykir and Bakki), and the additional generation will contribute to a significantly stronger and more reliable network in the north-east (see also Figure 7). Under some conditions, the line from the hydropower plants at Laxá to Akureyri may no longer be needed and can be removed.

## 10.2 Detailed Topic Evaluation

### 10.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment of opportunities to increase the development contribution of the project through additional benefits and/or benefit sharing strategies or further or associated use of the resource has been undertaken; and the pre-project baseline against which delivery of benefits can be evaluated post-project is well-documented.*

The benefits listed under Background, have been the primary motivation for the Theistareykir project, and have been assessed through various studies. At the time of the first discussions about the project, north-east Iceland was in economic difficulties and urgently needed to diversify. In the meantime, the economy and demographics

have stabilized, largely thanks to tourism. The Theistareykir project and the associated industry are providing an additional boost.

An agreement on a payment per kWh to the municipality of Thingeyjarsveit was made at the very beginning of the project, before Landsvirkjun became a partner in Theistareykir ehf. At the time this was a new concept in Iceland, but there are now a number of other precedents. An update of the underlying formula is under negotiation between Landsvirkjun and Thingeyjarsveit. A 90-year lease agreement for the municipal land at the power plant was concluded in 2011. The lease fee is dedicated to grazing improvements on other municipal land. Landsvirkjun is also investing directly, in the rehabilitation of 160 hectares in Thingeyjarsveit as a compensation measure; and has a separate agreement with the municipality on a carbon sequestration project, the only such project in Northern Iceland.

The municipality of Nordurthing is benefiting primarily through the industrial development and increased employment; the road to Theistareykir, opening up its hinterland, including a small Nordic ski resort; and the rehabilitation of land along the road.

Landsvirkjun has made an effort to promote local content, through market studies and selecting local contractors.

The baseline situation is well documented.

**Criteria met: Yes**

## Analysis against proven best practice

***Scoring statement:*** *In addition, broad considerations have been taken into account in identifying opportunities.*

Farmers of Thingeyjarsveit were involved in defining new road alignment between Theistareykir and Hólasandur, to improve access to grazing land and move the road onto barren land. The road, when and if approved by Landsvirkjun´s board, will be paved and, once finished, be handed over to the Icelandic Roads Administration (Vegagerdin) together with the Theistareykir-Húsavík road. It will further increase visitor access, for all kinds of outdoor opportunities. Other power projects such as Nesjavellir and the Búrfell wind farm have resulted in good roads, and are precedents for the benefits of improved access.

Regarding associated and additional uses of the geothermal resources,

- the heating market in Iceland is considered nearly saturated, and most local municipalities already have district heating systems,
- there may be other uses of heat such as hot pools, greenhouses or fish farming, and there are local precedents for such multiple uses in Húsavík and Bjarnarflag, and
- there may also be opportunities for chemical by-products.

Discussions with potential investors about additional uses have been held at various stages. Recently a 3-year public-private partnership project called 'Eimur' has been started to systematically promote such uses across north-east Iceland. The founding members who have contributed a budget of USD 890,000 are Landsvirkjun, Nordurorka, Orkuveita Húsavíkur and Eything (Association of Municipalities in Northeast Iceland); also part of Eimur are the Iceland Geothermal Cluster and the Icelandic Tourism Cluster, along with the Regional Development Agencies.

The assessment of tourism opportunities has made little progress. While a framework policy already exists in the Regional Plan, and some traffic counts have been conducted, the municipalities were initially not sure whether they wanted to promote more access to the project area, changing its character even further, or keep it for local sheep farmers and recreation. They are also limited in the resources that they could invest in tourism facilities and promotion. Landsvirkjun on the other hand, did not want to promote tourism at least during the construction phase, due to public safety concerns. There is a sense that the combination of natural landscape, history and renewable technology at Theistareykir could be attractive to tourists, but due to the above-mentioned

uncertainties, no specific assessments have been undertaken. This is a gap, but it is not considered significant, because tourism expansion in the region has occurred very recently, and any tourist facilities that might be developed (such as a geothermal visitor centre, interpretive trails, horse stables, parking facilities etc.) could still be retrofitted into an existing site arrangement.

**Criteria met: Yes**

### 10.2.2 Management

#### Analysis against basic good practice

***Scoring statement:*** *Project benefit plans and processes have been developed for project implementation and operation that incorporate additional benefit or benefit sharing commitments; commitments to project benefits are publicly disclosed.*

Plans have been developed and agreements concluded for the benefits listed above. For example, Landsvirkjun leases 3,480 hectares from the municipality of Thingeyjarsveit, an arrangement that has been approved by the municipal council and disclosed in the community. It is expected that the exact revenues are disclosed through the municipal budgeting process, which is necessary for accountability.

Landsvirkjun is interested to hire and contract locally where possible, but has found the capacity of the local labour market and contractors limited, and has made no formal commitments.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, processes have been developed to anticipate and respond to emerging risks and opportunities.*

The general monitoring and consultation processes that Landsvirkjun, local municipalities, and the local business community have established, would also help to identify risks to existing benefits, or opportunities for additional benefits.

A specific consultation process with the tourism industry has begun, with an initial workshop in January 2015 and a site visit at Theistareykir in June 2016. There are precedents for Landsvirkjun involvement with the nature baths at Bjarnarflag, which receive 200,000 visitors a year, and on a much smaller scale, with walking trails and a visitor centre at Krafla. However, it is unclear who should take the lead in the case of Theistareykir.

**Criteria met: Yes**

### 10.2.3 Stakeholder Engagement

#### Analysis against basic good practice

***Scoring statement:*** *The assessment and planning process relating to project benefits has involved appropriately timed, and often two-way, engagement with directly affected stakeholders; ongoing processes are in place for stakeholders to raise issues and get feedback.*

As described under P-1 and P-5, there have been multiple opportunities for stakeholder engagement through general communication and consultation mechanisms. Specifically for project benefits, there are one or two high-level consultative group meetings with municipalities per year; as well as an ongoing dialogue with farmers over grazing access and with the tourism industry over opportunities.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, engagement with directly affected stakeholders has been inclusive and participatory; and feedback on how issues raised have been taken into consideration has been thorough and timely.*

There are no indications that engagement has not been inclusive and participatory. The representatives of municipalities and tourism businesses confirmed that there is a constructive dialogue on benefits. The results for tourism opportunities are inconclusive at this stage, but that is not due to a lack of engagement from Landsvirkjun's side.

**Criteria met: Yes**

## 10.2.4 Outcomes

### Analysis against basic good practice

***Scoring statement:*** *Plans deliver benefits for communities affected by the project.*

Even before commissioning, the project is already delivering benefits to local residents. For example, the municipality of Thingeyjarsveit is investing some of its additional revenues in broadband internet access, and Húsavík is seeing an increase in population.

**Criteria met: Yes**

### Analysis against proven best practice

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

The benefits are significant for both the municipalities of Thingeyjarsveit (with long-term lease and benefit sharing agreements) and of Nordurthing (with long-term economic development opportunities, primarily from power-intensive industries). Skútustadahreppur has only indirect benefits.

Municipal leaders in the area would like to see Landsvirkjun invest in further expansion of Theistareykir and the other two geothermal power plants, Krafla and Bjarnarflag. However, there is also some opposition to further expansion, particularly in the Lake Myvatn area. The assumption is that, the better Landsvirkjun's reputation becomes through its management of Theistareykir, the more goodwill it will also find at Lake Myvatn.

**Criteria met: Yes**

## 10.2.5 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**

# 10.3 Scoring Summary

There are important direct and indirect benefits from the Theistareykir project for the local communities, which is the reason why they have promoted the project over a long period of time. There is also potential for further benefits from secondary uses of the geothermal resource and from tourism, which are being explored. There are no significant gaps against proven best practice, resulting in a score of 5.

Topic Score: 5

## 10.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 6, 8, 9, 17, 18, 23, 28, 29, 32, 35-39 |
| **Document:** | 58, 62-64, 115-119 |
| **Photo:** | 16, 18-32, 39-41, 55-57 |

# 11 Economic Viability (P-11)

This topic addresses the net economic viability of the project. The intent is that there is a net benefit from the project once all economic, social and environmental costs and benefits are factored in.

## 11.1 Background Information

Iceland's economy has largely recovered from the severe crisis in 2008. Investment in the energy-related sector has remained an important component of overall investment, and revenues and dividends from the power sector are expected to become important fiscal stabilization factors. State guarantees for Landsvirkjun and financial risks have been reduced. Long-term, competitive fixed-price power purchase agreements are an important competitive advantage for Iceland.

There are some macro-economic challenges from the dependence on power generation and power-intensive industries. Their contribution to employment is limited, and spillovers to other sectors are limited due to the sector-specificity of skills, and high capital intensity. The productivity (measured in GDP per employee, at purchasing power parity) in the industry and energy sector is less than half that in other Nordic countries. There is no royalty system for the state to share in the economic rents from energy resources. There are potential trade-offs with another increasingly important economic sector, nature-based tourism. Power prices are relatively low (although increasing), because multinational companies have the option to invest elsewhere. The ability to export 'stranded' power, via an undersea cable that is being studied, would increase the value of generation along with other benefits.

At the level of individual projects, neither Landsvirkjun nor government agencies undertake comprehensive cost-benefit analysis during project preparation. The introduction of cost-benefit analysis has been recommended, for example, by the Parliamentary Committee on the Strengthening of the Green Economy (2011) and by the OECD in their reviews of the Icelandic economy and environment. However, there are a number of sources on cost and benefit values, and studies on the overall effect of Landsvirkjun's operations on the Icelandic economy. Also, the multi-criteria approach in Iceland's masterplan ensures that not just least-cost considerations are taken into account when selecting new projects such as Theistareykir.

## 11.2 Detailed Topic Evaluation

### 11.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment of economic viability has been undertaken with no significant gaps; the assessment has involved identification of costs and benefits of the project and either valuation in monetary terms or documentation in qualitative or quantitative dimensions.*

The closest to a project-level economic viability analysis is the masterplan, which provides a comparative analysis between potential projects, including

- the costs of investment per MW and the cost of generation per MWh (LCOE),
- the impacts of projects on other values including landscape, cultural heritage, and biodiversity, which can be interpreted as negative externalities, and which are ranked according to quantitative scores.

The masterplan has a number of limitations as a source for, or replacement of a cost-benefit analysis:

- the latest (3rd) stage of the masterplan does not appear to have updated the project costs, and has generally paid less attention to economics,
- there is no analysis of potential revenues,

- there is no analysis of positive externalities,
- the scoring of negative externalities would be difficult to translate into actual quantitative, or even monetary values.

Nevertheless, the masterplan does show that the Theistareykir project has relatively low costs and relatively low externalities.

**Criteria met: Yes**

## Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and includes sensitivity analyses.*

At the national level, there are estimates available for the three positive externalities which are likely to be the largest, namely

- the economic stimulus effect of power projects,
- the replacement of fossil fuel imports, and
- the displacement of carbon emissions.

Landsvirkjun's contribution to the national economy has been estimated through a 2011 study by GAM Management, taking into account effects from investments (depending on whether the Icelandic economy is at full capacity at the time of the investment), from the operation of energy plants and new industrial activity, and from the improved financial situation of Landsvirkjun, i.e. dividends and taxes paid to the Icelandic state. At the time, Landsvirkjun's investment plan included all geothermal capacity in the north-east at Theistareykir, Krafla and Bjarnarflag; Búdarháls and the Búrfell expansion which are underway; plus six additional hydropower plants. If it were fully implemented, investment would peak in 2017 and the stimulus effect would peak in 2026, adding 14% to state revenues and 6% to GDP.

In order to account for the economic value of geothermal heating, the National Energy Authority annually calculates the utility revenues for heat (as a measure of cost of providing the service) and the oil bill that would have been required for heating in the absence of geothermal heat; the difference is the avoided cost. Over the past 20 years, this avoided cost has fluctuated between 1.5% and 7.5% of GDP. In 2014, it was USD 811 million, or 4.5% of GDP. Some of these benefits can be attributed to dual-use power geothermal plants. The same calculations could be applied to power generation (although not to capacity additions, as it is doubtful whether additional power generation capacity would be built if it depended on importing fossil fuels).

An additional value of the displacement of fossil fuels in the power and heating industries can be calculated by multiplying the social cost of carbon (USD/ton of greenhouse gas emitted) by the avoided emissions. This depends on multiple assumptions, on the exact cost of carbon (for example, USD 36/ton $CO_2$ as estimated by the US EPA for 2015 at a 3% discount rate), the fossil fuel mix that Iceland would have in the absence of renewable sources (or the fuel mix that other countries would use, if power-intensive industries would be located elsewhere), and the current greenhouse gas emissions from power generation in Iceland (which are publicly available). The National Energy Authority annually calculates the avoided $CO_2$ emissions by using geothermal energy for heat and power, instead of oil. In 2014, this amounted to 7.5 million tons of $CO_2$; at a value of USD 36/ton, this would result in a total value of USD 270 million/year. Because of Iceland's carbon tax from fossil fuels, part of that value would be captured by the government.

There are no estimates available at the project level, of these positive externalities or for that matter, for the value of the negative externalities, nor are there sensitivity analyses. This is a **significant gap** against proven best practice.

**Criteria met: No**

### 11.2.2 Stakeholder Engagement

#### Analysis against basic good practice

***Scoring statement:*** *The results of the economic viability analysis are publicly disclosed.*

Elements of an economic viability analysis, as described above, are publicly available.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *The economic viability analysis is publicly disclosed.*

There is no specific economic viability analysis for Theistareykir to be disclosed, and some of the required inputs for a cost-benefit analysis, such as project costs and revenues, are not publicly available. This is a **significant gap** against proven best practice.

**Criteria met: No**

### 11.2.3 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *From an economic perspective, a net benefit can be demonstrated.*

Given what is known about the financial costs and the financial revenues of the Theistareykir project, and plausible values of positive and negative externalities, it is likely that a net benefit can be demonstrated. However, this analysis has not been done yet.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, the project benefits outweigh project costs under a wide range of circumstances.*

There is not sufficient information available to confirm that the project has a net benefit under a wide range of circumstances; this is essentially the same gap as above under Assessment.

**Criteria met: No**

### 11.2.4 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

No estimates available at the project level, of the values of positive and negative externalities and of the range of potential outcome for net benefits.

No economic viability analysis for the project nor important elements thereof (financial costs and revenues) publicly disclosed.

**2 or more significant gaps**

## 11.3 Scoring Summary

The Theistareykir project has significant financial costs and revenues, as well as broader economic costs and benefits, also called negative and positive externalities. Despite the importance of the energy sector to the

Icelandic economy and society, and the fact that it is likely that an economic net benefit could be shown, there are no comprehensive analyses of the economic viability of individual power projects. There are two gaps against proven best practice for this topic, resulting in score of 3.

**Topic Score: 3**

## 11.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 4, 12, 13, 17 |
| **Document:** | 37, 58, 62-64, 120-125 |
| **Photo:** | -- |

# 12 Procurement (P-12)

This topic addresses all project-related procurement including works, goods and services. The intent is that procurement processes are equitable, transparent and accountable; support achievement of project timeline, quality and budgetary milestones; support developer and contractor environmental, social and ethical performance; and promote opportunities for local industries.

## 12.1 Background Information

Procurement during the preparation stage of the Theistareykir project was focused on consulting services, drilling, and other preparatory works, as well as preparing for procurement during the implementation stage. The end of the preparation period is here interpreted as the decision by the Landsvirkjun board to authorize tendering of the first generation unit, in 2014.

Procurement was initially done under the internal rules of Theistareykir ehf., and then increasingly, as Landsvirkjun acquired shares and management control of Theistareykir ehf., under Landsvirkjun's own rules, which also evolved over time. Landsnet is subject to public procurement rules, and has broken down the transmission lines into approximately ten contracts for supplies, groundworks, connections, and tower and cable erection.

Landsvirkjun also decided to break down preparation and construction into a relatively large number of individual works, supply and services contracts. The following list shows most significant contracts and the location of the contractors, roughly in the order in which they are performed:

- EIAs (both for Theistareykir and the joint EIA) and feasibility study: Mannvit (Kópavogur)
- Design of the power station and preparation of tender document: consortium of Mannvit (Kópavogur) and Verkís (Reykjavik)
- Service contracts with a number of public institutions such as ISOR (Iceland Geosurvey, Reykjavik), Northeast Iceland Nature Research Centre (Húsavík), Landgrædsla ríkisins (SCSI, Húsavík branch)
- Upgrade of the Reykjahlídarvegur road's first section: Ístrukkur (Kópasker) and Jón Ingi Hinriksson
- Works for the Reykjahlídarvegur road's second section: Höfðavélar (Húsavík)
- Water utilities: Þ.S Contractors (Egilsstadir)
- Powerhouse foundation, groundworks on transmission line: G. Hjálmarsson hf. (Akureyri)
- Smaller wells at the project site (2014): Ræktunarsamband Flóa & Skeida (Selfossi)
- THR 02 Geothermal drilling: Jardboranir hf. (Kópavogur)
- THR 15-1 Civil works (construction of the powerhouse) and THR 10-2 Steam supply system: LNS Saga (now Munck Íslandi, subsidiary of Danish Munck Group)
- NAL 30 Supply contract for two power-generating turbine and generator units and cold-end equipment including steam surface condenser, cooling tower, gas extraction system and pump, spare parts: consortium of Fuji Electric (Japan) and Balcke Dürr (Germany)
- NAL 31 Power Transformers: Tamini (Italy)
- THR 10-1 Steam separators: Vélsmidjan Hédinn hf. (Hafnarfjordur)
- NAL 35 Control system: ABB (Denmark)
- NAL 37 Station auxiliaries: Rafeyri ehf. (Akureyri)

## 12.2 Detailed Topic Evaluation

### 12.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment of major supply needs, supply sources, relevant legislation and guidelines, supply chain risks and corruption risks has been undertaken with no significant gaps.*

Landsvirkjun is subject to the Directive 2014/25/EU on 'Procurement by entities operating in the water, energy, transport and postal services sectors', which modified an earlier 2004 directive. While many European power companies operating in competitive markets are exempt, Landsvirkjun is not because of its large market share. Procurement practices have to be clear, fair and traceable. Procurement complaints can be directed to a committee under the Ministry of Finance, which may also be asked for guidance.

A procurement strategy is developed for each contract, involving market research to ensure sufficient competition, usually between the project development team and the legal and procurement departments. At the time of launching the Theistareykir tenders, the market was still recovering from the financial crisis; more recently the number of bidders has gone down, indicating that contractors are busy.

More recently, after the main Theistareykir procurement processes, Landsvirkjun has started using the Achilles Sellihca database. Sellihca is a supplier register and pre-qualification system used by the Nordic utilities to manage supplier information and risk within the supply chain as well as to procure efficiently in accordance with EU regulations, with over 4,400 qualified suppliers.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment includes opportunities for local suppliers and local capacity development.*

Market surveys always include an evaluation of local suppliers, and opportunities are broadly announced. However, equipment is usually imported, and many civil works contracts in Iceland could not be performed by the local workforce or local contractors alone. By breaking procurement down into multiple contracts and allowing subcontracting, many of these become accessible to small local companies. Engineering and environmental services are typically performed by Icelandic consulting companies. There are no local content requirements.

**Criteria met: Yes**

### 12.2.2 Management

#### Analysis against basic good practice

***Scoring statement:*** *Procurement plans and processes have been developed for project implementation and operation with no significant gaps.*

Landsvirkjun has comprehensive internal processes and procedures for procurement which are available to all staff via Landsvirkjun's intranet, including easy-to-read flowcharts. Landsvirkjun has three tiers of procurement, dependent upon the size and service type required, with the most complex being a formal tender process. The project manager has some authority for smaller procurement decisions.

For the Theistareykir project, almost all procurement (~95% by value) was done through open tenders, with the rest through closed tenders and direct negotiations. The project development team is responsible for drawing up tender documents, which generally follow Icelandic standards (such as IST 30) or FIDIC. In the case of Theistareykir, these designs were done collectively for the three projects in the north-east, to achieve economies

of scale and ease of operations; some contracts have options to also supply the upcoming expansion projects. Once the tender has been launched, communication with tenderers is handled exclusively by the procurement department. Evaluation of tenders is a joint effort between relevant departments, sometimes with the support of consultants, and is typically based on lowest price or most economical bid. Some results of tenders (including bidding prices), for example for the generating units and cold end equipment, have been publicly disclosed, although that is not a requirement of the EU Directive.

An example for innovative procurement processes is the drilling contract THR 02. This was the first FIDIC-based, English language open tender for geothermal drilling in Iceland (7+3 wells). Unlike most drilling contracts with hourly rates, this one is based on meter rates, and more like a turnkey contract to deliver production wells. There are provisions for a maximum number of meters per hour, to encourage prudence. If the company encounters a geological problem that cannot be resolved within 6 hours, it will consult with the client's geologist and switch to day rates. Landsvirkjun also launched separate tenders for equipment, such as steel casings, pipes, fittings and valves, to reduce the risk of delays and make foreign bidders more competitive. The outcome of this tender was approximately 40% below the cost estimate and significantly below international benchmarks; it was won by the main Icelandic drilling company. Valid, non-winning bids were reimbursed USD 50,000 each, to encourage participation.

The civil works and steam supply contracts THR 15-1 and THR 10-2 (based on a modified Icelandic standard IST 30 contract) were won by the Icelandic subsidiary of a European contractor, 8% over the cost estimate. Management experience is key because of the high degree of subcontracting in the Icelandic construction industry, mainly with local and Polish companies.

**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; sustainability and anti-corruption criteria are specified in the pre-qualification screening; and anti-corruption measures are strongly emphasised in procurement planning processes.*

If suppliers are not already prequalified by registration in the Sellihca database (which contains information on sustainability issues, for example commitments to the Global Compact), there may be a prequalification step in the procurement process, or documentation has to be submitted with the main tender. Because of regulatory requirements, Landsvirkjun cannot easily impose its own prequalification requirements. For example, certifications comparable to ISO 14001 and ISO 9001 have to be accepted.

However, post-procurement Landsvirkjun imposes contractual requirements on its business partners that are summarized in its 'Supplier's Code of Conduct' and the detailed 'Requirements Towards Contractors and Service Providers with Regard to Environmental and Health and Safety Matters'.

These processes and requirements are being regularly reviewed and updated, for example in 2016 with respect to the responsibility of contractors for the actions of their sub-contractors and suppliers, along the value chain. Efforts are also made to include these requirements retroactively in existing contracts. Landsvirkjun also became a founding member of the Green Public Procurement program in 2014, which is a forum for collaboration on green procurement, led by the Ministry for the Environment and Natural Resources; amendments were made to Landsvirkjun's procurement processes in 2015. Practices pioneered by Landsvirkjun and a few other organizations like the Municipality of Reykjavik (for example, the principle of responsibility along the value chain) are often later adopted by other organizations.

**Criteria met: Yes**

### 12.2.3 Conformance / Compliance

#### Analysis against basic good practice

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

Internal stakeholders as well as contractors confirm that Landsvirkjun has followed procurement processes and has treated them fairly. Tender documents were seen as well prepared, and there has been room for clarification questions during tenders; responses become part of the contracts. Tenderers have to describe their HSE track record and submit an HSE plan with their tenders. There have been disagreements during contract implementation (for example, with the drilling company over responsibility for one well that had to closed), but these have been resolved bilaterally (in the case of the drilling company, with an independent engineer's opinion).

**Criteria met: Yes**

#### Analysis against proven best practice

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

There are no indications that procurement has not followed legal and internal requirements, and no complaints have been registered.

**Criteria met: Yes**

### 12.2.4 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Procurement of works, goods and services across major project components is equitable, efficient, transparent, accountable, ethical and timely, and contracts are progressing or have been concluded within budget or that changes on contracts are clearly justifiable.*

There are no indications that procurement has not been equitable, efficient, transparent, accountable, ethical and timely. Minor delays and cost overruns are described under P-6.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, opportunities for local suppliers including initiatives for local capacity development have been delivered or are on track to be delivered.*

Although most capital goods and major equipment in Iceland are imported, the project has contracted with a significant number of Icelandic companies and organizations. This has further contributed to the development of capacities in the Icelandic geothermal sector, which make it more competitive globally. There have also been learning effects that are applicable to other sectors (for example, vegetation transplanting in road construction) or that apply more generally across the Icelandic economy (for example, the HSE requirements – including small changes like backing up into a parking spot -, and the principle of responsibility for labour issues in the supply chain).

**Criteria met: Yes**

### 12.2.5 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**

## 12.3 Scoring Summary

Procurement has been well prepared, and procurement results have remained within budget for the Theistareykir project. Landsvirkjun is continuously upgrading its procurement processes, and is making significant efforts to have positive impacts on its business partners through the supply chain. There are no gaps against proven best practice, resulting in a score of 5.

**Topic Score: 5**

## 12.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 5, 7, 14, 17, 18, 22, 23, 33 |
| **Document:** | 39, 42, 46-49, 126-131 |
| **Photo:** | -- |

# 13 Project-Affected Communities and Livelihoods (P-13)

This topic addresses impacts of the project on project affected communities, including economic displacement, impacts on livelihoods and living standards, and impacts to rights, risks and opportunities of those affected by the project. The intent is that livelihoods and living standards impacted by the project are 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 are fully delivered over an appropriate period of time.

Topics P-14 'Resettlement' and P-15 'Indigenous Peoples' that follow specifically address two subsets of project affected communities.

## 13.1 Background Information

Communities affected by the project include residents in the municipalities of

- Thingeyjarsveit: population 917, population density 0.15/km$^2$, seat of administration Laugar, affected by power plant, transmission lines and roads (an existing dirt road of 21 km from Theistareykir to Hólasandur road junction, with some modifications)
- Nordurthing: population 2,822, population density 0.76/km$^2$, seat of administration Húsavík, affected by transmission line Theistareykir-Bakki, the parallel main access road (26 km of substantial upgrades), and a quarry
- Skútustadahreppur: population 399, population density 0.07/km$^2$, seat of administration Reykjahlíd, affected by transmission line Krafla-Theistareykir and parallel road upgrading

Residents can be affected in different ways, depending on whether they are owners of land; users of land for hunting, recreation or other purposes; local business owners and employees; or exposed to emissions from the project and other changes in environmental quality. The area around the power plant itself was not easily accessible, before the project built the access road, and even today is not frequently visited. A farm was abandoned in 1883, after which there was summer sheep grazing and some ptarmigan hunting, horse riding and snowmobiling; there is a cabin for occasional visitors.

This topic focuses on potential negative impacts, and the efforts of the project to avoid, minimize, mitigate and compensate them. Topic P-10 focuses on potential positive impacts.

A number of other topics also relate to P-13, and potential negative impacts on specific groups or of a specific nature. If people need to be physically relocated because of a project, and if indigenous people are affected, topics P-14 and P-15 become relevant. However, this is not the case in the Theistareykir project. Community safety impacts are covered under P-8, and community health impacts under P-18. Impacts on local workers are covered under P-16, and impacts on cultural heritage under P-17.

## 13.2 Detailed Topic Evaluation

### 13.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment of issues relating to project affected communities has been undertaken with no significant gaps, utilising local knowledge.*

The Theistareykir EIA predicts a number of negative social impacts that are not covered under other topics, namely

- significantly negative temporary impact on transport, tourism and recreation due to traffic, nuisance and noise from wells
- significantly negative landscape and visual impact of the geothermal plant; considerable/somewhat negative impact of the access road
- temporary negative impact on highland pasture within the geothermal utilisation area

Since the EIA, a number of additional concerns have appeared in Húsavík. The Theistareykir project contributes, although in a minor way compared to other developments, to a housing shortage. (While the camps at the project site are housing all workers required for the power plant construction itself, the secondary economic effects – such as increased employment with local contractors and shops - are attracting more residents). Reportedly, there can be 70-80 applications for rentals coming on the market. This development was not assessed in the EIAs (except in a background analysis for the Alcoa smelter), nor in the 2012 Northeast Iceland Infrastructure Analysis. However, the housing market in Húsavík was depressed until a while ago, and homeowners and local contractors will benefit from the shortage. Also in Húsavík, there is some concern over increased shipping and its impact on whale watching and local boat traffic. Again, the Theistareykir projects contributes to shipping, but in a very minor way.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and both risks and opportunities.*

The impact predictions are backed up by some data, but are not based on quantitative models (for example, of the reduced carrying capacity of the highland pasture; or of the reduced experience value and predicted visitor numbers, as a function of noise and visual impacts).

This is not considered a significant gap, as several of the impacts are temporary, affect a small number of people, and/or are overcompensated by improved road access and improved highland pasture over time.

**Criteria met: Yes**

## 13.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *Management plans and processes for issues that affect project affected communities have been developed with no significant gaps including monitoring procedures, utilising local expertise when available; and if there are formal agreements with project affected communities these are publicly disclosed.*

Regarding the three impacts identified in the EIA, the project has adopted the following approaches:

- *Traffic, nuisance and noise*: silencers on wells and other project components, including a new more effective model; standard speed limits; noise monitoring with mobile stations and stationary/continuous stations (at the Theistareykir cabin, Krafla and Reykjahlid school); staying within 70db noise limits except temporarily near wells and machinery; horse riding tours redirected to a new riding path around the construction site
- *Landscape and visual impact*: unobtrusive design and colours of project components; landscaping and earthen berms; revegetation
- *Highland pasture*: Avoidance of land acquisition; impact on small share of grazing lands; Landsvirkjun (ongoing) and Landsnet (starting in 2017) contribute to a compensation program managed by SCSI which overcompensates land impact; vegetation quality and vegetation impacts are monitored

**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 environmental quality around the geothermal power plant is being monitored, including geothermal surface activity, vegetation, birds, noise, and air quality. Traffic is counted automatically.

**Criteria met: Yes**

## 13.2.3 Stakeholder Engagement

### Analysis against basic good practice

***Scoring statement:*** *Engagement with project affected communities has been appropriately timed and often two-way; ongoing processes are in place for project affected communities to raise issues and receive feedback.*

The engagement during project preparation and implementation, and specifically during the EIA has been covered under P-1 and P-5. Communities have had, and still have, opportunities to raise concerns and grievances. Typical concerns that community members have been raising are related to traffic noise and speed, gas emissions and health impacts, and the impact on a traditional cultural landscape associated with sheep grazing.

Communication has been both about larger design alternatives, and about short term issues. For example, the road from Húsavík starts close to downtown and goes through a small suburb on the way to Theistareykir. Landsvirkjun offered to look at alternative routes that would have avoided construction traffic through town, but the municipality preferred this route that is more convenient for people from Húsavík. In the short term, there have been meetings with sheep farmers to inform them of construction progress, for example to make them aware of the excavation of the powerhouse foundation and the danger that may pose to sheep.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, engagement with project affected communities has been inclusive and participatory; and feedback on how issues raised have been taken into consideration has been thorough and timely.*

Landsvirkjun has focused its engagement on municipal leaders. Direct communication between Landsvirkjun project staff and management through email has worked well. Consultation approaches are discussed in the high-level consultative group meetings, once or twice a year. Municipal leaders will generally have the best sense of how to engage the broader community, and what the best ways are to receive information (for example, in the case of Nordurthing, on the arrival of major equipment shipments that will require traffic closures).

Communication has been kept up even during complex situations and interruptions in project preparation (particularly, the withdrawal of Alcoa). At the time, there were difficult meetings with up to 500 people, with concerns about demographic change and the lack of opportunities for young people.

Landsvirkjun has offered different media formats such as newsletters and videos on groundwater impacts, air emissions and noise, geothermal reservoir monitoring and other topics to keep people engaged and informed.

Although Landsnet has participated in stakeholder meetings and joint initiatives, it has been criticized for insufficient dialogue with the broader community, including opponents of the transmission lines. One reason for this is that Landsnet does not have the same permanent presence in the area as Landsvirkjun, and often has to deal with many more landowners – both individual and municipal ones - than Landsvirkjun in its projects. At the level of individual impacted landowners, Landsnet reportedly insisted on its preferred alignment of the line. It is unclear whether landowners properly understand that alignments had been defined years earlier during the planning and EIA processes, and cannot easily be changed, and what the degree of flexibility is during final design. Landsnet also ran into a number of disagreements over compensation rates. After initially offering compensation

rates differentiated by land value, in separate negotiations with different landowners, later uniform and higher compensation payments were agreed. (Landsnet paid for the landowners' lawyers in these negotiations.) Agreements were reached with landowners representing more than 99% of affected land. As described under P-6, two landowners are being expropriated. Overall, a perception of a lack of participatory stakeholder engagement remains and is recognized as an issue by Landsnet, and is a **significant gap** against proven best practice. More participatory stakeholder engagement might have contributed to a reduction in delays (see P-6).

**Criteria met: No**

### 13.2.4 Stakeholder Support

#### Analysis against basic good practice

***Scoring statement:*** *Affected communities generally support or have no major ongoing opposition to the plans for the issues that specifically affect their community.*

While community leaders such as municipal council members have consistently supported the project, and a large majority of community members also support it, the farming community (between 10 and 20% of the population) has been sceptical; reportedly many farmers are against the project. They express regrets over the loss of a beautiful and peaceful area, and increased noise and road traffic that causes disturbance of sheep and possibly, accidents. Only a small group of farmers, perhaps 10-15 families, have actively used the Theistareykir area for summer pasture, but a larger group has used it for recreation, and at least one wedding was held there. However, most farmers also accept that land disturbance will recover over time, and that the project has many practical advantages, including a much easier access to summer grazing areas. As an example, only because the road to Theistareykir had been largely built, several thousand sheep could be rescued in a snowstorm on September 10 and 11, 2012.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, formal agreements with nearly all the directly affected communities have been reached for the mitigation, management and compensation measures relating to their communities.*

Mitigation, management and compensation measures have been primarily negotiated with landowners and municipalities. Except for one group of landowners affected by a section of transmission line, formal agreements have been reached.

**Criteria met: Yes**

### 13.2.5 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Plans provide for livelihoods and living standards impacted by the project to be improved, and economic displacement fairly compensated, preferably through provision of comparable goods, property or services.*

Livelihoods and material living standards in the surrounding communities will improve notably through the construction and operation of the geothermal, transmission and industrial projects.

Economic displacement effects are not expected by the tourism industry, which believes that the projects and tourism are compatible and that in fact, tourism is more likely to benefit from improved roads and access to additional attractions. Economic displacement of sheep farming is temporary and will be overcompensated by a larger vegetated area than before, and easier access to pasture.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, plans provide for livelihoods and living standards that are impacted by the project to be improved with the aim of self-sufficiency in the long-term; and the project contributes to addressing issues for project affected communities beyond impacts caused by the project itself.*

With a more diversified economy, there is little doubt that even a remote region like north-east Iceland can be self-sufficient. The project contributes significantly to the long-term prospects of the north-east, and equitable regional development in Iceland.

**Criteria met: Yes**

## 13.2.6 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

A perception of a lack of participatory stakeholder engagement by Landsnet.

**1 significant gap**

## 13.3 Scoring Summary

The impacts on the livelihoods and living standards of communities in the project area are relatively minor after mitigation, and in many cases temporary and/or compensated. Individual households and the overall communities can be expected to experience improvements in livelihoods and living standards. Stakeholder engagement on the transmission lines could have been better handled, which is a significant gap against proven best practice, resulting in a score of 4.

**Topic Score: 4**

## 13.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 6, 8, 11, 17, 20, 27, 28, 32, 35, 36, 37 |
| **Document:** | 31, 58, 60, 62-64, 132-131 |
| **Photo:** | 16, 18-32, 39-41, 55-57 |

# 14 Resettlement (P-14)

This topic addresses physical displacement arising from the geothermal project development. The intent is that the dignity and human rights of those physically displaced are respected; that these matters are dealt with in a fair and equitable manner; and that livelihoods and standards of living for resettlees and host communities are improved.

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

# 15 Indigenous Peoples (P-15)

This topic addresses the rights, risks and opportunities of indigenous peoples with respect to the project, 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 project 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 Theistareykir project, because the native Icelandic population is considered homogenous, with no ethnic minorities.

# 16 Labour and Working Conditions (P-16)

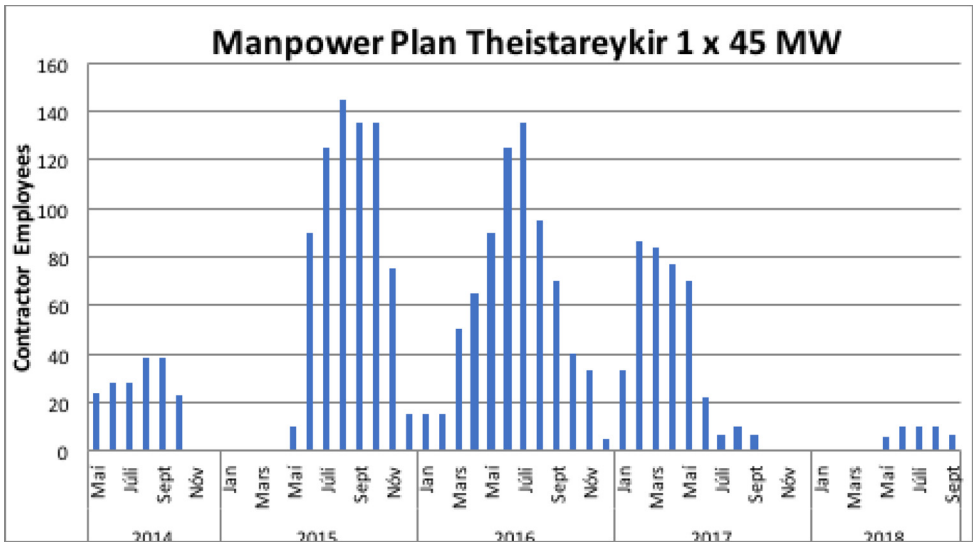
This topic addresses labour and working conditions, including employee and contractor opportunity, equity, diversity, health and safety. The intent is that workers are treated fairly and protected.

## 16.1 Background Information

Iceland's labour market is characterized by a high participation rate and high demand for labour. From more than 8% in the economic crisis, the unemployment rate has gradually come down to less than 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. In 2008, these two parties concluded an Agreement on Major Projects, which specifies labour and working conditions in major hydropower and geothermal as well as road and tunnelling projects, and which is updated periodically. Many workers on construction projects are foreign nationals.

The chart below shows the manpower planning at the beginning of the implementation stage, indicating the strong seasonality of the works. In the first winter 2014-2015, when the permanent camp was not yet erected, works stopped completely. The chart sums up the employees of a number of major contractors, but does not yet show the additional manpower required for the second unit and associated works, as this was decided later in the year. It also does not show Landsvirkjun's own employees, as well as consultants and smaller contractors associated with the project. Landsvirkjun had 249 full-time employees at the end of 2015.

**Figure 10. Manpower Plan, Feb. 2015**




Some of the 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 drilling, high pressure and high temperatures.

## 16.2 Detailed Topic Evaluation

### 16.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment has been undertaken of human resource and labour management requirements for the project, including project occupational health and safety (OH&S) issues, risks, and management measures, with no significant gaps.*

Landsvirkjun regularly evaluates its internal human resources situation through various mechanisms, for example, with regards to accidents (annual statistical report, with one lost-time accident in both 2014 and 2015, publicly available), workplace satisfaction (annual survey, 4.29 out of five possible points in 2014 and 4.36 in 2015, publicly available), and gender equality (external review by PwC, 0.1% gender gap in fixed, non-shift pay).

Through its multiple previous projects, Landsvirkjun is well aware of labour issues in large, remote construction projects in Iceland, and specifically the conditions in the north-east highlands. Minimum requirements have been agreed with labour unions. The outcomes of collective bargaining agreements apply to all workers, including temporary foreign guest workers. Manpower requirements for the construction of Theistareykir have been estimated, and the camp planned accordingly. The Administration on Occupational Health & Safety also reviewed plans for the camp.

Landsvirkjun has increased the workforce in its regional team based out of Krafla and is training a small number of staff to take over operations of Theistareykir after commissioning. The plan is to have a minimum of two employees present at all times, but have additional accommodation available during maintenance projects, for example the drilling of make-up wells.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and both risks and opportunities.*

Accidents lead to work stoppages and are followed up by investigations and where possible, changes in equipment or processes.

**Criteria met: Yes**

### 16.2.2 Management

#### Analysis against basic good practice

***Scoring statement:*** *Human resource and labour management policies, plans and processes have been developed for project implementation and operation that cover all labour management planning components, including those of contractors, subcontractors, and intermediaries, with no significant gaps.*

Landsvirkjun has a range of relevant policies, plans and processes, including a commitment to and reporting against the Global Compact, a Human Resources Policy (updated 2014), Gender Equality Policy and action plan (2015), a safety manager (since 2014), an occupational health and safety management system certified to OHSAS 18001, an electrical safety management system reviewed annually by a certified inspector, and supplier codes of conduct and requirements. A risk assessment is conducted for all Landsvirkjun jobs and projects, a safety committee is mandatory for larger worksites, a risk register is developed for larger projects that includes HSE risks, and an HSE plan is prepared for all contracts. Each worksite and power station has a person responsible for HSE.

Landsvirkjun has implemented a so-called zero-tolerance policy at Theistareykir. The policy aims to create an accident-free workplace via an active safety system, supervision and training. All new employees at the Theistareykir site, regardless their contractual situation, need to attend a course on HSE matters. A total of 283 employees attended the course in 2015 (117 foreign employees and 166 local employees). In 2015, Theistareykir achieved a total of 150,000 work hours without any lost-time injuries, and the current total rate is 9 lost time injuries per 1 million work hours. Worksites are equipped with stationary and portable $H_2S$ gas monitoring equipment; workers wear personal protection equipment; there are signs, barriers, first aid stations, ventilation and firefighting equipment, and emergency showers. There are rules that there should always be at least two workers present in dangerous situations. The nearest hospital in Húsavík can be reached by ambulance in 30 minutes.

The safety processes are supported by the Administration of Occupational Health & Safety, through comments on plans (for example, design drawings for the power house) and inspections (30 inspections since 2008). Heavy equipment has to be inspected once a year, workers have to be certified and the papers of foreign workers checked, and practical skills tested. The Húsavík receives weekly safety reports and conducts monthly meetings. It has some experience with OH&S issues in geothermal deep well drilling, from a study at Krafla; work procedures were changed there after a well blow-out.

The preparation and construction stage activity with some of the highest safety risks is drilling. The drilling contractor has international experience, including from New Zealand with particularly strict safety regulations. He brought a permit-to-work system to the Theistareykir contract, and has established its own HSE system with a site-specific HSE plan and supervisor, and communication requirements. After incidents, within 3 hours a flash report and within 24 hours a full report have to be issued. The HSE systems have been integrated in and made consistent with, Landsvirkjun's systems. Most accidents actually occur not during drilling (which is largely automated on modern rigs) but during moving materials, or trip-and-fall. After a week with three incidents, management of the drilling company intervened and assessed workers for safety awareness and attitudes; some workers had to be dismissed.

Other contractors, such as LNS Saga, do not practice a permit-to-work system but have daily safety management meetings. If safety breaches occur, the escalation steps are that the worker is warned, the group is warned, and the worker is dismissed; Landsvirkjun tries to avoid work stoppages to remain within schedule.

**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.*

In spite of the zero-tolerance policy, there have been some work accidents, some also with time lost, but no major injuries or fatalities, and appropriate follow-up. The safety committee, site inspections, and analyses of safety statistics all contribute to identifying safety issues. Workers complaints also help to identify risks (see below).

**Criteria met: Yes**

## 16.2.3 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.*

All workers at Theistareykir (except a few minor and temporary service providers) are subject to collective agreements, covering pay, benefits, accommodation and a range of other working conditions. Landsvirkjun has internal process for suggestions and complaints. Landsvirkjun employees and those of contractors may also raise

issues with safety committee members, trade union representatives, or those of government agencies such as the Administration of Occupational Health & Safety. Trade union representatives often maintain offices inside workplaces. In the Theistareykir region, Framsyn is the largest trade union with approximately 3,000 members across a range of professions but mainly lower-skilled workers. They expect, for example, to have about 100 of the 125 permanent positions at PCC as their members. Landsvirkjun supports the union, has made an office at the camp available, and contributes to the costs of inspections that check whether the requirements of the collective agreements are met. The Framsyn representative is also a member of the Theistareykir and PCC safety committees, and is informed of any accidents.

**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.*

The only major labour issue encountered during the Theistareykir project construction concerned the largest subcontractor under the civil works contractor. The Polish company G&M, which employed about 60 workers at Theistareykir, disregarded rules limiting temporary foreign workers to 183 days without a residence permit and income tax requirements; paid their employees late; and failed to pay the minimum wage, overtime and taxes on its operation in Iceland. After increasing complaints and investigations by unions, Landsvirkjun, the main contractor LNS Saga, the police, the Directorate of Labour, and the Administration of Occupational Health& Safety over several months (made more difficult because of insufficient documentation and language barriers), Landsvirkjun and LNS SAGA decided to terminate the contract. LNS SAGA compensated workers for losses, even though exact amounts where difficult to establish. A short time afterwards, Landsvirkjun updated its policy on value chain responsibility (see also P-12).

**Criteria met: Yes**

## 16.2.4 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 Theistareykir 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, which extend to guest workers. Landsvirkjun and Landsvirkjun's projects achieve high marks on labour satisfaction, work safety, gender equality, and have received a number of external awards and recognitions.

**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

Labour and working conditions at Landsvirkjun and in Landsvirkjun's projects are covered by comprehensive collective agreements, OH&S policies, and other rules which equally apply to foreign workers. Issues that arise (such as accidents, or problems with labour relations at a subcontractor) are dealt with promptly and effectively. Objective measures such as work satisfaction, pay equality, accident rates and others are positive. There are no significant gaps against proven best practice, resulting in a score of 5.

**Topic Score: 5**

## 16.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 5, 6, 7, 18, 20, 22, 25, 27, 28, 31, 33, 37 |
| **Document:** | 21, 22, 26, 70, 134-143 |
| **Photo:** | 31, 43, 60-62, 66-69, 71-73, 75-79, 81-84 |

# 17 Cultural Heritage (P-17)

This topic addresses cultural heritage, with specific reference to physical cultural resources, at risk of damage or loss by the geothermal project and associated infrastructure impacts (e.g. new roads, transmission lines). 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.

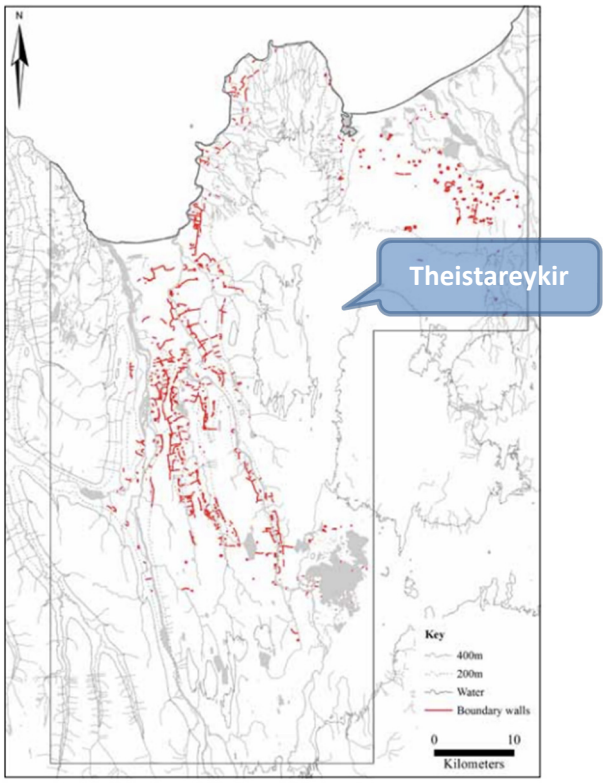
## 17.1 Background Information

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.

North-east Iceland has a rich cultural heritage, extending over more than 1,000 years since the settlement. There are traditional farming practices and festivals, and places with cultural significance such as farms mentioned in the sagas, birthplaces of historical persons, museums and archaeological sites.

Recent regional surveys using a combination of remote sensing and ground investigations have shown that medieval turf walls are the most prominent archaeological features in the region, indicating the presence of human settlements and farms. At a total length of approximately 400 km, they are the most extensive archaeological phenomenon in Iceland. As can be seen in the map below, the Theistareykir project and its associated infrastructure have only minor overlap with these features. However, the work identified ten areas with outstanding archaeological value in the region, two of which are just north and south of Húsavík and thus could be indirectly affected, and one of which is close to the project, namely the sulphur mining area and farm site of Theistareykir.

**Figure 11. Turf walls as indicators of human settlement in the project region (Einarsson and Aldred 2011)**



## 17.2 Detailed Topic Evaluation

### 17.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *A cultural heritage assessment has been undertaken with no significant gaps; the assessment includes identification and recording of physical cultural resources, evaluation of the relative levels of importance, and identification of any risks arising from the project.*

There were a series of studies on cultural heritage in the area, starting in 2001 with a summary study on the history and known resources, followed by several reports and detailed surveys between 2006 and 2008. These showed 58 remains within the power plant area, and 36 close to the road to Húsavík. The transmission lines and roads have minor impacts through proximity to sites like historic cairns.

Theistareykir has been settled intermittently at least since the Middle Ages, and was first mentioned in historic texts in 1318. The entire Theistareykir area constitutes a significant cultural landscape. It had the main sulphur mine in Iceland over centuries, where sulphur was produced and shipped to Europe (mainly for use by the Danish military). There are structures associated with an isolated farm, relatively far inland, that would have depended on warm springs.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and both risks and opportunities.*

Cultural heritage surveys during the project preparation period were thorough and identified a large number of resources, including stone cairns and others that might be considered minor.

Significant early exploration works were going on before the detailed surveys, in particular associated with drilling (which also involves cold water supply, access roads and borrow pits). The Planning Agency ruled in 2001 that the impacts of exploration drilling were not significant enough to require an EIA. At the same time, Theistareykir ehf. commissioned a study by the Icelandic Institute of Archaeology, based on secondary sources, aerial pictures and brief field surveys. No excavations had been conducted by that time, but a significant number of sites were already known and listed. The study warns that roads would be the biggest threats to sites in the upcoming exploration program. The authorization from the National Energy Authority for exploratory drilling, which generally takes preliminary investigations and expert opinions into account, includes precautions to avoid damages.

The EIA did not identify cultural heritage opportunities, but this is not considered a gap here, as the only relevant opportunity is associated with increased access for visitors, discussed under P-10.

**Criteria met: Yes**

### 17.2.2 Management

#### Analysis against basic good practice

***Scoring statement:*** *Plans and processes to address physical cultural resources have been developed for project implementation and operation with no significant gaps; plans include arrangements for chance finds, and ensure that cultural heritage expertise will be on site and regularly liaised with by the project management team during construction.*

The emphasis in cultural resource management is on avoiding impact. Through appropriate siting of project components, direct impacts have been avoided (with one exception, see below under Outcomes). This is in line with typical approaches in Iceland, where only a small percentage of sites are actually excavated.

Chance find procedures in Iceland are simple and well-known; in case of a find, the Cultural Heritage Agency must be called and may order a stop to works (for example, to enable excavation).

**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 are supported by public, formal and legally enforceable commitments.*

The last monitoring visit by the Cultural Heritage Agency was in 2015, with no issues raised.

**Criteria met: Yes**

## 17.2.3 Stakeholder Engagement

### Analysis against basic good practice

***Scoring statement:*** *The assessment and planning for cultural heritage issues has involved appropriately timed, and often two-way, engagement with directly affected stakeholders; ongoing processes are in place for stakeholders to raise issues and get feedback.*

Cultural heritage has been an issue in all regional, municipal, and site planning; as well as in the individual and joint EIAs. As described under P-1, P-4 and P-5, stakeholder engagement in those processes has worked well, and there are ongoing mechanisms for communications with stakeholders.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, engagement with directly affected stakeholders has been inclusive and participatory; and feedback on how issues raised have been taken into consideration has been thorough and timely.*

See above.

**Criteria met: Yes**

## 17.2.4 Stakeholder Support

### Analysis against basic good practice

***Scoring statement:*** *There is general support or no major ongoing opposition amongst directly affected stakeholder groups for the cultural heritage assessment, planning or implementation measures.*

There are no indications for any opposition to the handling of cultural heritage issues. As described under P-13, there are regrets among some people who knew Theistareykir before the project, for the alteration of the traditional cultural landscape, but this is more associated with changes to sheep farming and recreation traditions, than with impacts on physical cultural resources.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, formal agreements with the directly affected stakeholder groups have been reached for cultural heritage management measures.*

Since 2012, cultural heritage regulations are significantly stronger than during the first years of project preparation. If the project were permitted today, 50m or 100m distances of project components to identified heritage resources might be required. However, the current site arrangements are accepted by the Cultural Heritage Agency.

**Criteria met: Yes**

### 17.2.5 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Plans avoid, minimise, mitigate, and compensate negative impacts on cultural heritage arising from project activities with no significant gaps.*

No significant gaps have been identified by any stakeholders.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, plans avoid, minimise, mitigate and compensate negative cultural heritage impacts with no identified gaps; and contribute to addressing cultural heritage issues beyond those impacts caused by the project.*

Even before detailed surveys, the drilling company and other contractors used existing tracks as far as possible, to minimize risks. There has been partial damage to a ruin by the access road, which was difficult to avoid and cleared with the Cultural Heritage Agency beforehand, as the ruin was not considered particularly relevant. This is not considered a gap. There are other examples of project infrastructure moved to avoid impacts.

The much-improved road access to Theistareykir now enables appreciation of its cultural heritage value by a much larger population. However, except for one sign near the abandoned farm structure, there are currently no plans for interpretation of the area's heritage, for example through self-guided tours with the help of brochures or maps, or a visitor centre.

The EIA has increased the understanding of the cultural heritage of the Theistareykir area.

**Criteria met: No**

### 17.2.6 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**

## 17.3 Scoring Summary

North-east Iceland in general and the Theistareykir area in particular have a long history and significant cultural heritage. The emphasis in project siting, design and construction was on identifying cultural resources and avoiding damages. There are no significant gaps against proven best practice, resulting in a score of 5.

**Topic Score: 5**

## 17.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 9, 18, 19, 21, 28 |
| **Document:** | 52, 58, 62-64, 144-150 |
| **Photo:** | 23, 41 |

# 18 Public Health (P-18)

This topic addresses public health issues associated with the geothermal project. The intent is that the project does not create or exacerbate any public health issues, and that improvements in public health can be achieved through the project in project-affected areas where there are significant pre-existing public health issues.

## 18.1 Background Information

Iceland has a well-developed public health-care system that covers all residents. The health status and life expectancy of the population are above the European average.

General public health problems around large construction projects can be related to interactions between the workforce and the local population, pressure on public health facilities with limited capacities, and the effects of reduced environmental quality (e.g. noise). In the particular case of Theistareykir, none of these effects are likely to be significant:

- The camp at Theistareykir is at a significant distance from Húsavík, the number of workers and interaction is limited, and contagious and sexually transmitted diseases are not a major health threat in Iceland.
- The public health system in the region can absorb the potential additional workload. A Northeast Iceland Infrastructure Analysis in 2012 analysed, among other sectors, the health services particularly in Húsavík and Akureyri, and the cumulative requirements of the Theistareykir, PCC and other industrial projects. It concluded that local health services, while well equipped, might need additional staff to cope with emergencies, but that the Akureyri hospital with emergency helicopter services was fully prepared. The Theistareykir project has a contract with the Húsavík hospital.
- Noise from the power plant cannot be heard by any permanent residents or workers outside the project. Noise from construction traffic is limited, as there are no large-scale civil works and few commuters from Húsavík to the project.

Natural geothermal and volcanic areas can present some health hazards due to emissions of gases such as CO, $CO_2$, $SO_2$, HCl, HF, $H_2S$, $H_2$, $N_2$, $CH_4$, $NH_3$ and radon. Emissions are typically increased by geothermal exploration and generation. There has been some research in Iceland exploring links between low-level exposure to hydrogen sulphide and radon, and asthma and cancer. Exposure to gases depends on emissions, distances and dispersal; in the case of Theistareykir, the closest permanent settlements are at a distance of about 15 km.

Groundwater contamination by drilling, disposal of geothermal water and other activities may also cause health issues.

Since both these potentially relevant public health issues are linked to air and water quality, to avoid duplication they are covered under P-21, and P-18 is not scored separately.

# 19 Biodiversity and Invasive Species (P-19)

This topic addresses ecosystem values, habitats, and species in the project areas, as well as potential impacts arising from pest and invasive species associated with the planned project. The intent is that there are healthy, functional and viable terrestrial and aquatic ecosystems in the project-affected area that are sustainable over the long-term, and that biodiversity impacts arising from project activities are managed responsibly.

## 19.1 Background Information

Iceland has relatively few species (for example, 1 native mammal, 6 fish, 75 breeding birds, 1400 insects), related to its geographic isolation, northern location and geologically young age. It has diverse but relatively simple ecosystems, in terms of communities and food-webs. Since human settlement, biodiversity has been affected by deforestation, overgrazing and large-scale erosion. There is some biodiversity specifically associated with geothermal surface manifestations, including vegetation, invertebrates, and microorganisms (which are poorly researched).

While about 16% of Iceland's land area is covered by strictly protected areas, there are no such areas in the Theistareykir region. In the course of the development of the project, municipal and site plans defined parts of the project area which should not be affected because of their natural or visual value, such as wetlands, young lava fields, and geothermal surface manifestations.

South of Theistareykir is the Lake Myvatn and Laxá River conservation area, protected since 1974, a Ramsar site since 1977, and considered for nomination as a World Heritage Site since 2011, as a unique freshwater ecosystem in the northern hemisphere.

## 19.2 Detailed Topic Evaluation

### 19.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *An assessment of terrestrial and aquatic biodiversity including loss of connectivity to significant habitat; and risks of invasive species has been undertaken with no significant gaps.*

Key biodiversity information in the EIA was provided by the Icelandic Institute of Natural History (Náttúrufrædistofnun Íslands) and by the Northeast Iceland Nature Research Centre (Náttúrustofa Nordausturlands), one of seven regional institutes of natural research, based in Húsavík. The main taxonomic groups assessed were plants, birds, and invertebrates. There are no fish, amphibians, reptiles, or mammals at risk in the area.

In general, land impacted by construction activities in Iceland can take long to recover. However, the vegetation in the project area denser than usual for this elevation (350 masl), with a good micro-climate, snow cover, warm summers, and good precipitation.

The non-native Nootka lupine (*Lupinus nootkatensis*) is used in revegetation programs in Iceland. There are different opinions on its use, as it can take over native vegetation, but is by far the most cost-effective method (1/10$^{th}$ of cost of native plant seeds and fertilizer, per hectare).

In 2003, there was an assessment of three geothermal areas, commissioned by the National Energy Authority. It found 51 vascular plant species, 25 moss species, 18 lichen species, and 146 invertebrate species such as beetles, close to geothermal surface manifestations at Theistareykir.

In 2008-2009, there was a 1:15,000 mapping and demarcation of areas with geothermal vegetation. One of the species identified was *Ophioglossum azoricum,* which is on the Icelandic red list of threatened species.

Three key bird species are ptarmigan, gyrfalcon and raven. Ptarmigan are an important game species in Iceland, but are experiencing a long-term downward trend. They are one of the main food sources for gyrfalcon, the largest falcon species, found around the Arctic but rare, with around 150 breeding pairs in Iceland. Two pairs have nested in the Theistareykir area, but have not been seen for several years. There are around 2,500 breeding pairs of raven in Iceland. For all three species, north-east Iceland provides significant habitat. They can be affected by disturbances and habitat alteration, including fences and power lines. Increased human access may lead to increased hunting for ptarmigan, indirectly affecting gyrfalcon.

In 2011, aquatic invertebrates in ponds at Theistareykir were assessed, and this assessment was repeated in 2016. A study on terrestrial invertebrates was suggested by the Northeast Iceland Nature Research Centre, but not pursued by Landsvirkjun.

A small snail (*Vallonia excentrica*) has been found in the geothermal area at Theistareykir. While widespread in Europe and North America, in Iceland it is only known from Theistareykir and possibly, from Krafla and Bjarnarflag. It appears to depend on warm soil temperatures. It may have been accidentally introduced, possibly with the medieval sulphur trade.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and both risks and opportunities.*

Geothermal surface manifestations show steep gradients and rapid changes in water and soil temperature, humidity, acidity, and unusual concentrations of minerals and elements; as such they are extreme and specialised habitats for thermophilic (heat loving) biodiversity. Due to the distances between geothermal areas, different species can evolve. There has been some research on the geothermal-specific biodiversity in Iceland, such as thermophilic microorganisms, and the Theistareykir EIA found a large number of new species in samples from 2008 (described in EIA Annex A12).

**Criteria met: Yes**

## 19.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *Plans and processes to address identified biodiversity issues have been developed for project implementation and operation with no significant gaps.*

The main approach to biodiversity management has been the avoidance of wetlands, geothermal surface manifestations and other zones with particular conservation values. For example, well pads were moved during the project siting and design process.

A soil reclamation/revegetation program has been conducted with SCSI, as discussed under P-5. Landsvirkjun's 5-year program for 1.6 $km^2$ is well underway; its compensation ratio was 2x for unvegetated and 3x for vegetated land. Additional areas are planned to be revegetated as part of Landsnet's compensation efforts and as part of Landsvirkjun's carbon neutral program; these last ones will be fenced off and not be open for sheep grazing.

The landscaping for example on roadsides and well pads, also contributes to revegetation. A special construction method was used along the roadsides, transplanting turf to speed up vegetation recovery.

**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 commitments in plans are public, formal and legally enforceable.*

Under contract with Landsvirkjun, the Northeast Iceland Nature Research Centre has been monitoring vegetation and birdlife in the Theistareykir area since the summer of 2012. The annual monitoring includes vegetation density and chemistry, the nesting density of heathland birds, and the occupation of nests and breeding success of the gyrfalcon. Vegetation plots are located along a south-north line from the power plant, to be able to detect influence (through air pollution) with varying distances. Monitoring points are shown in Figure 8 in P-5. No obvious trends have been detected yet, but there are natural fluctuations.

The Institute of Natural History is complementing this work by researching heavy metals in moss, and gyrfalcon.

The National Energy Authority has monitored geothermal surface activity at Theistareykir since 1982, and there have been significant natural changes to the surface temperature. Landsvirkjun monitors surface temperature in the area using infrared photographic evidence and sampling. This detailed information on the development of surface temperature aids in the assessment of how and if geothermal utilisation is affecting the area, and may also be useful to predict any impacts on biodiversity associated with surface activity. If surface activity is affected, however, mitigation (through changes in reservoir exploitation) may take years to have an effect. Also, the initial research during the EIA, which discovered previously unknown microorganisms and snail species, has not been followed up. There has been no research on the habitat requirements of these species, and the possible impacts of construction and operations of the power plant, or monitoring of their populations. This is a **significant gap** against proven best practice.

While the natural ponds at Theistareykir do not have a particular conservation value, their biology has been assessed two times. The 2016 study shows a recovery from the effect of earlier inflows of drilling effluents.

**Criteria met: No**

### 19.2.3 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Plans avoid, minimise, mitigate, and compensate negative biodiversity impacts arising from project activities with no significant gaps.*

The negative biodiversity impacts of the project are limited, and some of them are temporary during the construction period. The biodiversity-related management plans are adequate. Areas with higher conservation values are protected through the municipal land use plans.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, plans avoid, minimise, mitigate and compensate negative biodiversity impacts due to project activities with no identified gaps; and plans provide for enhancements to pre-project biodiversity conditions or contribute to addressing biodiversity issues beyond those impacts caused by the project.*

While the project aims to avoid impacts on hot springs, fumaroles and other geothermal surface activities, and the residual impacts may be minor, there has been relatively little effort to assess and follow up on thermophilic biodiversity. For example, there has been no further research into the distribution and monitoring of the snail *Vallonia excentrica*, and into the new species of microorganisms. This is the same **significant gap** as mentioned above, under Assessment.

A small enhancement of the biodiversity value of the area is that the main pond at Theistareykir, which used to dry out in the summers, is now permanent due to the inflow of clean water from the cooling cycle, and may become a wetland with some value for aquatic birds and other species. The revegetation efforts supported by Landsvirkjun and Landsnet will lead to a net increase in vegetation cover, which over time will support increasing populations of native plants and animals. There is also a possibility that utilization will enhance geothermal surface activity, as it has done at other geothermal projects, and increase habitat for thermophilic species.

The EIA and ongoing monitoring are increasing the understanding of the natural history of the north-eastern highlands.

**Criteria met: No**

### 19.2.4 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

The lack of follow-up and monitoring of thermophilic biodiversity and potential impacts.

**1 significant gap**

## 19.3 Scoring Summary

The Theistareykir project has minor and in some cases, positive impacts on biodiversity. There is monitoring of birds, vegetation, aquatic invertebrates, and geothermal surface manifestations which provide habitat for some specialized biodiversity. However, there has been no direct follow-up on that specialized biodiversity, which is considered a significant gap against proven best practice, resulting in a score of 4.

**Topic Score: 4**

## 19.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 1, 8, 10, 15, 24, 26, 35, |
| **Document:** | 52, 58, 62-64, 157-169, 190 |
| **Photo:** | 2, 3, 22, 34, 37, 38, 56 |

# 20 Induced Seismicity and Subsidence (P-20)

This topic addresses the management of induced seismicity and subsidence issues associated with the project. The intent is that physical impacts such as induced seismicity and subsidence caused by the project are recognised and managed responsibly and do not present problems with respect to other social, environmental and economic objectives.

## 20.1 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 causes more stress than extraction. Reinjection of almost all used water into the geothermal reservoir is usually required by license in Iceland, to (a) protect the surrounding environment from surface disposal of geothermal water, (b) avoid contaminating groundwater reserves, (c) maintaining pressure in the reservoir, and (d) reduce public safety risks from hot water on surface. There have been a number of notable incidences of induced seismicity, especially two magnitude 3.8 earthquakes near the Hellisheidi geothermal plant in 2011. While these caused no 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 and caused some concerns.

The central north coast of Iceland, including the Theistareykir project region, is part of the North Iceland Seismic Zone with some of the highest earthquake probabilities in Iceland.

Rising and sinking land surfaces 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). Iceland has some experience with subsidence that has been linked to geothermal production, particularly in the Svartsengi field in the south-west, where the surface has subsided by about 10 mm/year on average, over a large area. However, not all geothermal fields in Iceland have reacted with subsidence, and no damages from subsidence are known.

## 20.2 Detailed Topic Evaluation

### 20.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *Assessments of induced seismicity and subsidence issues have been undertaken with no significant gaps; the assessments identify impacts that may be caused by the project, issues that may impact on the project, and establish an understanding of the expected seismic behaviour and surface subsidence as relevant.*

Induced seismicity and subsidence are not addressed in the EIA. However, extensive geological research and baseline assessments have been conducted in the Theistareykir area. The last volcanic eruption occurred about 2,400 years ago. The last major earthquake occurred in 1940, with a magnitude of 5.2 just west of Theistareykir.

The tectonic history is complex, spanning several million years. The geothermal field has been created by intense tectonic fracturing; fractures have been mapped with aerial imagery and ground studies. Seismic activity and crustal movements have been monitored across the north-eastern geothermal complex. Between 1993 and

2011, 600 earthquakes with magnitudes of 0,6≤M≤3,2 were registered at Theistareykir. A continuous GPS station has been installed at Theistareykir since September 2011. Horizontal and vertical velocities of several mm/year have been observed at the different GPS stations. Horizontal movements are related to the spreading of plate boundaries; vertical movements are less predictable, with significant differences of subsidence or uplift between years and monitoring stations.

In 2007, a geohazards analysis was conducted to consider the risks for geothermal power plants in the north-east region and mitigation options, such as structural design criteria. The major vertical movements at Krafla during the 1970s and 1980s (more than 1 m) did not have structural or operational impacts on the power plant (but caused changes to the geothermal system). Compared to those movements, subsidence induced by geothermal exploitation is small.

Power plants and transmission lines in Iceland have suffered only minor damage from earthquakes. Because earthquakes induced by geothermal exploitation are likely to be smaller than the Maximum Design Earthquake which is used in structural design, the geohazards analysis did not address induced seismicity.

By implication, risks from induced seismicity and subsidence outside the geothermal power plants are considered negligible; especially at Theistareykir with a large distance to the nearest permanent settlements and any other infrastructure.

**Criteria met: Yes**

### Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and both risks and opportunities.*

The recent incidences in the south-west of Iceland (see above under Background) have increased public awareness of induced seismicity and subsidence. Because these factors were not directly addressed in the Theistareykir EIA, or through other dedicated studies at a later time, there is a risk of misunderstandings and opposition. Should earthquakes or subsidence occur in the area, these might be wrongly attributed to the effects of geothermal exploitation. This risk is considered a **significant gap** against proven best practice. More recently, assessment of induced seismicity has become mandatory for new geothermal project EIAs.

**Criteria met: No**

## 20.2.2 Management

### Analysis against basic good practice

***Scoring statement:*** *Plans and processes to address identified induced seismicity and subsidence issues have been developed for project implementation and operation with no significant gaps.*

Because induced seismicity and subsidence are not expected to be relevant risks for the project, there are no plans and processes beyond (1) the structural design criteria (which are oriented towards natural earthquakes and subsidence processes, expected to be larger than induced ones) and (2) monitoring, as described below. Reinjection is expected to increase induced seismicity risks, but reduce induced subsidence risks.

**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.*

A micro seismic monitoring network has been set up to collect data and assess whether and how utilisation affects seismic activity. GPS/GNSS, gravity and InSAR data will provide information on any changes to the land, both horizontal and vertical. The measurements will also be used for ongoing research on the geothermal

reservoir, specifically to assess the effects of utilisation. There are some technical options, for example related to reinjection processes, that may reduce induced seismicity and subsidence if they should occur.

**Criteria met: Yes**

### 20.2.3 Stakeholder Engagement

#### Analysis against basic good practice

***Scoring statement:*** *The induced seismicity and subsidence issues, as relevant, have been explained and discussed with directly affected stakeholders; ongoing processes are in place for stakeholders to raise issues and get feedback.*

While there were no explanations and discussions with directly affected stakeholders during the regional planning and EIA processes, because induced seismicity and subsidence was not yet considered a relevant risk, this has changed over the last years.

The same processes as described under P-1 are in place for stakeholders to raise questions or grievances. Monitoring results are generally publicly available, although not easy to interpret for stakeholders.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, engagement with directly affected stakeholders has been inclusive and participatory; and feedback on how issues raised have been taken into consideration has been thorough and timely.*

The geothermal sector in Iceland is realizing that induced seismicity and subsidence may affect people's opinion more than previously thought. Stakeholder risk perceptions may be a risk to stakeholder relations, and to projects themselves, and therefore even nuisance and trivial damage should be addressed with care. After induced seismicity and subsidence became issues in public discussions, Landsvirkjun made an effort to engage stakeholders in the Theistareykir project and explain the issues, with support from scientists, in stakeholder meetings.

**Criteria met: Yes**

### 20.2.4 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Plans avoid, minimise and mitigate induced seismicity and subsidence issues arising from project activities and induced seismicity and subsidence issues that may impact on the project with no significant gaps.*

Both the hazards from induced seismicity and subsidence, and the exposure of local stakeholders and the project itself are limited; therefore, the plans are considered adequate.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, plans avoid, minimise, mitigate and compensate induced seismicity and subsidence issues due to project activities with no identified gaps; and plans provide for enhancements to pre-project induced seismicity and subsidence conditions or contribute to addressing induced seismicity and subsidence issues beyond those impacts caused by the project.*

The plans are considered adequate. The geological research associated with the project will enhance understanding of seismicity and subsidence issues in the north-eastern geothermal complex.

Criteria met: Yes

### 20.2.5 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

No assessment of induced seismicity and subsidence risk in the EIA or in subsequent reports.

1 significant gap

## 20.3 Scoring Summary

There have been instances of seismicity and subsidence induced by geothermal utilization in Iceland. While these have not caused significant damages, and are even less likely to do so at Theistareykir because of large distances to the nearest settlements, the risk perception and awareness by stakeholders has increased. The fact that there was no systematic and documented risk assessment is a significant gap against proven best practice, resulting in a score of 4.

Topic Score: 4

## 20.4 Relevant Evidence

| | |
|---|---|
| **Interview:** | 2, 3, 6, 7, 12, 18, 28, 31, 34, 37 |
| **Document:** | 31, 58, 62-64, 99, 100, 170-181 |
| **Photo:** | -- |

# 21 Air and Water Quality (P-21)

This topic addresses the management of air and water quality issues associated with the project. The intent is that air and water quality in the vicinity of the project is not adversely impacted by project activities.

## 21.1 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 electrical projects, related to disposal of solid and liquid waste, project-related transport, 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 $CO_2$, $H_2S$, $CH_4$, $NH_3$ and radon. Hot geothermal water can hold in solution trace amounts of toxic chemicals, such as mercury, arsenic, boron, antimony, and salt. These pollutants can contribute to global warming, acid rain, radiation, noxious smells, health risks, and soil and water pollution if released. Binary geothermal technologies in lower-temperature fields, that keep geothermal fluids in a closed cycle and use heat exchangers, avoid this problem, but 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 are typically 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. Total annual emissions from existing geothermal plants were 163,000 tons/year of $CO_2$ and 23,000 tons/year of $H_2S$ in 2015. Stricter air quality standards for $H_2S$ took effect in Iceland in 2014. Even at lower levels, $H_2S$ can be smelled and be a nuisance. Iceland is also interested in further contributing to climate mitigation by reducing $CO_2$ emissions.

The capture and use or reinjection of gases is at this stage, practiced only on an experimental basis. At the Hellisheidi power plant a successful research project is capturing, dissolving, reinjecting and mineralizing gases. $CO_2$ and $H_2S$ react with calcium, iron and magnesium in the basalt bedrock to form calcite and pyrite. The estimated cost of full scale gas abatement at Hellisheidi would be USD 26/ton. Other technologies are being tested, for example the cultivation of microalgae that absorb $CO_2$, and the production of methanol from $CO_2$ at Svartsengi power plant. In other countries, scrubbers are used to remove $H_2S$.

Air and water quality issues have a variety of consequences, among them public health impacts. A background on public health impacts is provided under P-18. Because all relevant public health impacts of the Theistareykir project are related to air and water quality issues, they are described here under P-21.

## 21.2 Detailed Topic Evaluation

### 21.2.1 Assessment

#### Analysis against basic good practice

***Scoring statement:*** *Air and water quality issues assessment have been undertaken with no significant gaps.*

Landsvirkjun and the Icelandic geothermal sector in general have long-term experience with air and water quality issues, and have been monitoring emissions and improving modelling approaches over time. The EIA for Theistareykir applied that experience to a new geothermal field, and additional studies and monitoring have been ongoing since the EIA.

Two air and water quality issues and their potential public health effects were highlighted in the EIA and the subsequent discussion with the authorities:

- *Gas emissions*. The content of non-condensable gases in the geothermal steam at Theistareykir (by mass) is 0.3%. The main gases are carbon dioxide ($CO_2$) with approximately 77%, hydrogen sulphide ($H_2S$) 19%, nitrogen ($N_2$) 3%, hydrogen ($H_2$) and methane ($CH_4$). Radon concentration is low, and not mentioned in the EIA. Total release of gases from a 200 MW plant is estimated at 28,960 tons/year, 5,470 tons of which are $H_2S$, the main health concern. (A 90 MW plant as currently built, will emit proportionately less.) A total of 5,000 tons/year is also emitted from Krafla and Bjarnarflag.
- *Groundwater pollution*. Geothermal drilling and exploitation may change groundwater chemistry, and the access road from Húsavík crosses the drinking water source protection area of Húsavík. Expected quantities for a 200 MW plant are 100 l/s of cooling water from shallow wells, which will be disposed of at the surface, and 320 l/s of separated water at 180°C, which will be reinjected at depths of 200-400 m, below cold groundwater layers.

Regarding $H_2S$ emissions, for baseline information Landsvirkjun has set up a network of monitoring stations, two of which are south of Theistareykir, near the Krafla and Bjarnarflag fields in Reykjahlíd, one is north-west of Theistareykir in Húsavík, and one is north-east of Theistareykir at Eyvindarstödum in Kelduhverfi. Some of these data are available online, close to real time.

Under Icelandic Regulation no. 514/2010, on the Concentration of Hydrogen Sulphide in the Atmosphere, the limits outside industrial areas are set to 50 µg/m$^3$, for the running 24-hour average. The concentrations may exceed those limits no more than three times every year. The annual average shall be below 5 µg/m$^3$. This is significantly stricter than WHO guidelines. Over the last years, the monitoring stations around the north-east geothermal complex have not exceeded the annual average or the 24-hour limits; there are variations related to weather conditions.

Dispersion modelling was performed for Theistareykir and also for the larger north-east geothermal complex for $CO_2$ and $H_2S$, showing that the added emissions from Theistareykir would not breach the Icelandic limits in the nearest settled areas.

The $CO_2$ emissions from a 200 MW plant at Theistareykir would be equivalent to about 0.5% of all $CO_2$ emissions in Iceland.

Regarding potential groundwater pollution, Landsvirkjun has been working with the University of Akureyri, ISOR and Vatnaskil Consultants to understand the groundwater flows, establish baseline data and predict impacts. Groundwater generally flows in a northerly direction, from the Vatnajökull glacier to the sea. As part of the EIA, monitoring wells north of Theistareykir were analysed between 2007 and 2009. Groundwater models have been developed and refined in the area over decades, originally due to concerns related to water quality in Lake Myvatn. Changes in the chemical composition of geothermal fluids and shallow groundwater have been tracked over time, to inform the models. Arsenic and aluminium are found in geothermal water from Theistareykir, and would make surface disposal difficult. The chemical composition of water, quantities, and disposal pathways at Theistareykir have been analysed to come to the conclusion that it is highly unlikely that there would be measurable impacts beyond a radius of 2 km.

A groundwater model was also used to determine that the quarries and access road are outside the relevant catchment for Húsavík's drinking water. The risk of oil spills on the road was assessed.

**Criteria met: Yes**

## Analysis against proven best practice

***Scoring statement:*** *In addition, the assessment takes broad considerations into account, and both risks and opportunities.*

The assessment takes a broad view of possible impacts. Opportunities for re-injection or utilization of gases were not considered in detail during project preparation. However, at the time these options were still at an early research & development stage, with Landsvirkjun participating in discussions and contributing to the costs; hence this is not considered a gap.

**Criteria met: Yes**

### 21.2.2 Management

#### Analysis against basic good practice

***Scoring statement:*** *Plans and processes to address identified air and water quality issues have been developed for project implementation and operation with no significant gaps.*

The most relevant plans and processes are the following:

- non-condensing gases will be dispersed by release through cooling towers
- separated water will be reinjected
- minimization of water used in drilling
- compliance with general rules on protection from oil spills, equipment to contain spills, dedicated storage area for hazardous materials etc.
- drill cuttings (100-200 $m^3$ per well) are cleaned and used to backfill borrow areas, as defined in the operational license
- the project will comply with current rules on construction of access road and quarries in water protection zones, in consultation with the municipal health inspectorate

**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.*

There is ongoing air quality and ground/spring water quality monitoring, both continuous and periodic, building on the baseline monitoring established during the project preparation. Monitoring points are shown in P-5, and monitoring results are publicly available. Natural gas emissions from the surrounding geothermal areas will be monitored for comparison. Possible impacts on vegetation are monitored (see P-19). Additionally, the chemical composition of geothermal fluids will be monitored in the power plant. Gas analyses taken after the EIA suggest that the $H_2S$ content is higher (30% by mass) and the $CO_2$ content lower (60% by mass) than measured during the EIA.

There are inspections of heavy machinery such as trucks and excavators by the Administration on Occupational Health & Safety, to reduce the risk of spills, and equipment to respond to spills. Oil separators and septic tanks are monitored.

If unexpected impacts should arise, there are regulatory requirements and commitments from Landsvirkjun to respond, and there are technical options to reduce emissions. For example, the necessary flanges and pipes are already built into the design to permit easy connection of gas re-injection and utilization equipment, should this become necessary or should investors be identified.

One opportunity that was missed is the ability to run the large drilling rig on electricity from the construction power supply, instead of by diesel generators. While this would have required some technical changes (frequency adjustments) with significant costs, it would also have saved significant amounts of diesel and reduced air pollution, greenhouse gases, noise, and the risks of spills. The option was considered during preparation of the drilling tender, but no alternative offers were requested, to be able to compare costs and benefits. This is a **significant gap** against proven best practice.

**Criteria met: No**

### 21.2.3 Outcomes

#### Analysis against basic good practice

***Scoring statement:*** *Plans avoid, minimise and mitigate negative air and water quality impacts arising from project activities with no significant gaps.*

No significant air and water quality impacts are expected. A minor oil spill has occurred, but was contained. Even without mitigation of $CO_2$ emissions, these are a small fraction of alternative power generation options.

**Criteria met: Yes**

#### Analysis against proven best practice

***Scoring statement:*** *In addition, plans avoid, minimise, mitigate and compensate negative air and water quality impacts with no identified gaps; and plans provide for enhancements to pre-project air and water quality conditions or contribute to addressing air and water quality issues beyond those impacts caused by the project.*

Gas emissions could be further reduced by re-injection or utilization at the site, thus contributing to climate change mitigation, elimination of public health risks, and nuisance from $H_2S$. Landsvirkjun has been conducting research on technical options (for example, through a prefeasibility study of combined $H_2S$ removal and $CO_2$ production at Krafla and Theistareykir), there is a joint regional initiative called 'Eimur' to promote additional uses of geothermal steam (see P-10), there are pilot applications in Iceland (as described in the Background section), and there are technical preparations already built into the Theistareykir design.

**Criteria met: Yes**

### 21.2.4 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

Diesel generators for the drilling rig could have been replaced by construction power supply.

**1 significant gap**

## 21.3 Scoring Summary

Geothermal fluids at Theistareykir carry gases and minerals that can lead to air and water pollution, and these risks are adequately understood and managed through dispersion modelling, re-injection of geothermal water, monitoring, and preparation of adaptive measures should they become necessary. There are other air and water quality risks related to construction activities. The fact that diesel generators to power the main drilling rig have not been avoided in the procurement process, is a significant gap against proven best practice, resulting in a score of 4.

**Topic Score: 4**

## 21.4 Relevant Evidence

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|---|---|
| **Interview:** | 1, 3, 6, 8, 14, 18, 24, 27, 28, 29, 37, 39 |
| **Document:** | 58, 62-64, 82, 94, 117, 151-156, 182-189 |

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|---|---|
| **Photo:** | 10, 11, 29, 38, 44, 69 |

# Appendix A: Verbal Evidence

| Ref | Interviewee/s, Position | Organization | Department | Date | Location |
|---|---|---|---|---|---|
| 1 | Jóna Bjarnadóttir, *Project Manager* | Landsvirkjun | Environment, Research & Development Division | 16.1.2017 | Landsvirkjun Head Office |
| 2 | Guðni Axelsson, *Director of Geothermal Training*<br>Magnús Ólafsson, *Head of Geoscience* | Isor | - | 16.1.2017 | Landsvirkjun Head Office |
| 3 | Ásgrímur Guðmundsson, *Project Manager*<br>Bjarni Pálsson, *Manager of Geothermal Department*<br>Egill Júlíusson, *Project Manager*<br>Ólafur Sverrisson, *Expert* | Landsvirkjun | Geothermal, Research & Development Division | 16.1.2017 | Landsvirkjun Head Office |
| 4 | Jóhann Þór Jóhannsson, *Assistant Treasurer*<br>Kristján Gunnarsson, *Manager of Treasury and Financial Analysis* | Landsvirkjun | Treasury, Finance Division | 17.1.2017 | Landsvirkjun Head Office |
| 5 | Sigurður Björnsson, Manager of Procurement | Landsvirkjun | Procurement, Finance Division | 17.1.2017 | Landsvirkjun Head Office |
| 6 | Steinn Ágúst Steinsson, *Krafla Power Plant Manager* | Landsvirkjun | Energy Division | 17.1.2017 | Telephone Conference |
| 7 | Gunnar Freyr Guðmundsson, COO | Iceland Drilling | - | 17.1.2017 | Landsvirkjun Head Office |
| 8 | Auður Andrésdóttir, *Resource Manager*<br>Rúnar Bjarnason, *Environmental Consultant* | Mannvit Consulting Engineers | Environmental and Safety Division | 17.1.2017 | Landsvirkjun Head Office |
| 9 | Árni Gunnarsson, *Senior Project Manager* | Landsvirkjun Power | - | 18.1.2017 | Landsvirkjun Head Office |
| 10 | Albert Guðmundsson, *Project Manager* | Landsvirkjun | Water and Wind, Research & Development Division | 18.1.2017 | Landsvirkjun Head Office |
| 11 | Árni Jón Elíasson, *Expert* | Landsnet | Development and Technology Department | 19.1.2017 | Landsvirkjun Head Office |
| 12 | Jónas Ketilsson, *Senior Manager* | National Energy Authority (Orkustofnun) | - | 19.1.2017 | Landsvirkjun Head Office |

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| 13 | Óli Grétar Blöndal Sveinsson, *Executive Vice President* | Landsvirkjun | Research & Development Division | 19.1.2017 | Landsvirkjun Head Office |
| 14 | Claus Ballzus, *Senior Project Manager* | Mannvit Consulting Engineers | - | 19.1.2017 | Landsvirkjun Head Office |
| 15 | Sveinn Kári Valdimarsson, *Project Manager* | Landsvirkjun | Environment, Research & Development Division | 20.1.2017 | Landsvirkjun Head Office |
| 16 | Rebekka Valsdóttir, *Expert* | Landsvirkjun | Operation Development, Finance Division | 20.1.2017 | Landsvirkjun Head Office |
| 17 | Ragna Árnadóttir, *Deputy CEO* Jóhanna Harpa Árnadóttir, *Manager of social responsibility* | Landsvirkjun | Corporate Office | 20.1.2017 | Landsvirkjun Head Office |
| 18 | Valur Knútsson, *Senior Project Manager* | Landsvirkjun | Project Planning and Construction Division | 23.1.2017 | Landsvirkjun Office in Akureyri |
| 19 | Árni Ólafsson, *Architect and managing director* | Teiknistofa Arkitekta | - | 23.1.2017 | Landsvirkjun Office in Akureyri |
| 20 | María Markúsdóttir, *Health Inspector* | Public Health Authority in Northeast Iceland | - | 23.1.2017 | Landsvirkjun Office in Akureyri |
| 21 | Rúnar Leifsson, Cultural heritage manager for North East Iceland | The Cultural Heritage Agency of Iceland (Minjastofnun) | - | 23.1.2017 | Landsvirkjun Office in Akureyri |
| 22 | Hjálmar Guðmundsson, *Contractor* | G.Hjálmarsson hf | - | 23.1.2017 | Landsvirkjun Office in Akureyri |
| 23 | Franz Árnason, *former CEO* | Norðurorka Ltd. | - | 23.1.2017 | Landsvirkjun Office in Akureyri |
| 24 | Björn Stefánsson, *Specialist* | Environmental Agency (Umhverfis-stofnun) | Department for Integration | 24.1.2017 | Telephone Conference |
| 25 | Aðalsteinn Á. Baldursson, *Chairman* Aðalsteinn J. Halldórsson, *Supervision and Service* | Framsýn, labour organization in Northeast Iceland | - | 24.1.2017 | Húsavík Academic Center |

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| 26 | Þorkell Lindberg Þórarinsson, *Director* | Northeast Iceland Nature Research Center | - | 24.1.2017 | Húsavík Academic Center |
| 27 | Sigurgeir Stefánsson, *Corporate Supervisor* | Occupational Safety and Health Authority | - | 24.1.2017 | Húsavík Academic Center |
| 28 | Arnór Benónýsson, *Chairman* | Þingeyjarsveit Municipality | - | 24.1.2017 | Thingeyjarsveit Office in Laugar |
| 29 | Hreinn Hjartarson, *Project Manager* | Landsvirkjun | Project Planning and Construction Division | 25.1.2017 | Landsvirkjun Office in Theistareykir |
| 30 | Einar Erlingsson, *Resident Engineer* | Landsvirkjun | Project Planning and Construction Division | 25.1.2017 | Landsvirkjun Office in Theistareykir |
| 31 | Björn Halldórsson, *Project Manager*<br>Einar Erlingsson, *Resident Engineer*<br>Ólafur Sverrisson, *Expert* | Landsvirkjun | - | 25.1.2017 | Theistareykir Construction Site |
| 32 | Sigurður Á. Þórarinsson, *Farmer and landowner* | - | - | 25.1.2017 | Landsvirkjun Office in Theistareykir |
| 33 | Guðmundur Þórðarson, *Project Manager* | Munck Íslandi | - | 25.1.2017 | Landsvirkjun Office in Theistareykir |
| 34 | Sigurgeir Björn Geirsson, *Project Manager* | Landsvirkjun | Project Planning and Construction Division | 25.1.2017 | Landsvirkjun Office in Theistareykir |
| 35 | Daði Lange Friðriksson, *District Representative* | SCSI, Soil Conservation Service of Iceland (Landgræðsla ríkisins) | - | 26.1.2017 | Húsavík Academic Center |
| 36 | Haraldur Bóasson, *Chairman of Tourism Association in Thineyjarsveit*<br>Hörður Sigurbjarnason, *CEO of North Sailing* | - | - | 26.1.2017 | Húsavík Academic Center |
| 37 | Kristján Þ. Magnússon, *Mayor* | Norðurþing Municipality | - | 26.1.2017 | Norðurþing Office in Húsavík |
| 38 | Bjarni Pálsson, *Manager of Geothermal Department* | Landsvirkjun | Geothermal, Research & | 27.1.2017 | Landsvirkjun Head Office |

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| | | | Development Division | | |
| 39 | Jakob Gunnarsson, *Expert* | National Planning Agency (Skipulag-stofnun) | Environmental Assessment Division | 27.1.2017 | Landsvirkjun Head Office |

# Appendix B: Documentary Evidence

| Ref | Author / Organisation | Title | Year | Original language | Description / Weblink |
|---|---|---|---|---|---|
| 1 | Einar Erlingsson, Jóna Bjarnadóttir and Valur Knútsson/ Landsvirkjun | Theistareykjavirkjun, Geothermal Project - Northern Iceland (Presentation) | 2016 | English | Internal |
| 2 | Eygló Svala Arnarsdóttir/ Iceland Review | Geothermal Power Plant Underway in North Iceland | 2015 | English | Weblink |
| 3 | Jóna Bjarnadóttir/ Landsvirkjun | Theistareykir - a new power plant, stakeholder consultation and monitoring impacts (Presentation) | 2016 | English | Internal |
| 4 | Landsvirkjun | A geothermal power station by Þeistareykir, Annual report 2014 | 2015 | Icelandic/ English | Weblink |
| 5 | Landsvirkjun | Geothermal Power Station at Theistareykir, Energy Utilisation in Northeast Iceland (Pamphlet) | 2016 | Icelandic/ English | Internal |
| 6 | Landsvirkjun | Increasing energy supply, Annual report 2015 | 2016 | English | Weblink |
| 7 | Landsvirkjun | Orkunýting við Þeistareyki/ *Energy Utilisation in Theistareykir* | 2016 | Icelandic | Weblink |
| 8 | Magnús Orri Schram and Ása Karin Hólm Bjarnadóttir/ Capacent | LV-2015-028. Samráðsfundur með ferðaþjónustuaðilum vegna framkvæmda við Þeistareyki, samantekt/ *Consultation meeting with tourism operators due to constructions in Theistareykir* | 2015 | Icelandic | Internal |
| 9 | Landsvirkjun | Samskiptaáætlun Landsvirkjunar vegna fyrirhugaðra virkjana í Bjarnaflagi og á Þeistareykjum (NAL)/ *Landsvirkjun's Communication plan for proposed power plants in Bjarnarflag and Theistareykir* | 2014 | Icelandic | Internal |
| 10 | Landsvirkjun | Samskiptaáætlun vegna framkvæmda á Þeistareykjum/ Communication Plan due to construction in Theistareykir | 2015 | Icelandic | Internal |
| 11 | Landsvirkjun | Þeistareykjavirkjun, Geothermal Power Plant (Presentation) | 2015 | English | Internal |
| 12 | Alta | Aðalskipulag Norðurþings 2010-2030, Húsavík/ *Municipal plan of Norðurþing for years 2010-2030, town of Húsavík* | 2010 | Icelandic | Weblink |
| 13 | Alþingi | Act no.57 on the survey and utilisation of ground resource | 1998 | English | Weblink |
| 14 | Alþingi | Act no.65 on electricity | 2003 | English | Weblink |

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| 15 | Alþingi | Act no.73/1997, no.135/1997 and no.58/1999 on planning and building | - | English | Weblink |
| 16 | EFTA Surveillance Authority | Case No 74081. EFTA Surveillance Authority Decision on the PCC Silicon Metal Plant at Bakki (Iceland) | 2014 | English | Weblink |
| 17 | EFTA Surveillance Authority | Case No 77190. EFTA Surveillance Authority Decision on the transmission of electricity to the PCC Silicon Metal Plant at Bakki | 2015 | English | Weblink |
| 18 | EFTA Surveillance Authority | Case No 77201: EFTA Surveillance Authority Decision on the sale of electricity to the PCC Silicon Metal Plant at Bakki under the 2015 Power Contract | 2015 | English | Weblink |
| 19 | Hornsteinar Architects and Mannvit Consulting Engineering | Aðalskipulag Þingeyjarsveitar 2010-2022/ *Municipal plan of Þingeyjarsveit for years 2010-2022* | 2011 | Icelandic | Weblink |
| 20 | Landsvirkjun | About Landsvirkjun's certifications | - | | |
| 21 | Landsvirkjun | For Modern Quality of Life, A Report on Social Responsibility | 2009 | English | Weblink |
| 22 | Landsvirkjun | Landsvirkjun's Code of Conduct, This is how we work | 2013 | English | Weblink |
| 23 | Landsvirkjun | Landsvirkjun's Environmental Policy | - | Icelandic/ English | Weblink |
| 24 | Landsvirkjun | Landsvirkjun's Environmental Reports | - | Icelandic/ English | Weblink |
| 25 | Landsvirkjun | Meginferli Landsvirkjunar/ *Landsvirkjun's Stage Gate Process* | 2013 | Icelandic | Internal |
| 26 | Landsvirkjun | UN Global Compact, Communication on Progress | 2016 | Icelandic/ English | Weblink |
| 27 | Landsvirkjun | STE-023, no. 15. Stefna Landsvirkjunar/ *Landsvirkjun's Strategic Plan* | 2016 | Icelandic | Internal |
| 28 | National Energy Authority (Orkustofnun) | Legal and Regulatory Framework, Geothermal | - | English | |
| 29 | Ragna Sara Jónsdóttir/ Landsvirkjun | Landsvirkjun's new Strategy on Corporate Social Responsibility | 2011 | Icelandic | Weblink |
| 30 | Steinar Kaldal | The Landscape is changing. Icelandic state owned enterprises and corporate social responsibility (CSR): Assessing Landsvirkjun's CRS strategy | 2014 | English | Weblink |
| 31 | Ari Páll Pálson et al./ Notheast Iceland Development Agency | Northeast Iceland Infrastructure Analysis | 2012 | Icelandic/ English | Weblink |
| 32 | Hreinn Hjartason, Runólfur Maack and Sigþór Jóhannesson | Húsavík Energy, Multiple use of Geothermal Energy | 2005 | English | Weblink |

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| 33 | Húsavík Energy | Húsavík Geothermal Power Plant | 2000 | English | Weblink |
| 34 | Iceland Review | Chinese Aluminium Giant Looks towards Iceland | 2014 | English | Weblink |
| 35 | Martin Sattler/ Sonderdruck aus dem Magazin CHANCEN der KfW Bankengruppe | Isländische Traumfabrik / *The Icelandic Dream Factory* | 2016 | German | Weblink |
| 36 | Ministry of Industries and Innovation | The Icelandic National Renewable Energy Action Plan (NREAP) | 2010 | English | Weblink |
| 37 | National Energy Authority (Orkustofnun) | Carbon Dioxide savings using geothermal instead of oil | 2015 | Icelandic/ English | Weblink |
| 38 | Steering Committee for The Master Plan for Nature Protection and Energy Utilization | The Current Master Plan, Parliamentary resolution on the Plan for Nature Protection and Energy Utilisation | - | English | Weblink |
| 39 | Ásgeir Jónsson, Gísli Gíslason, Stefán Skaptason et al./ Steinsholt sf. | LV-2014-048. Reykjaheiði, Þeistareykjavegur nyrðri - Frágangur og Umbætur á svipmót/ Access road to Þeistareykir, improvements and finish of appearance (Tender Documents) | 2014 | Icelandic | Internal |
| 40 | Bjarni Pálsson et al./ Landsvirkjun Power | Development of the 400 MW Northeast Iceland Geothermal Project, Proceeding World Geothermal Congress 2010 | 2010 | English | Weblink |
| 41 | Landsvirkjun | Diagram of Geothermal Process Flow system | - | Icelandic | Weblink |
| 42 | Landsvirkjun | LV-2015-069. Geothermal Drilling Works (Tender Documents) | 2015 | English | Internal |
| 43 | Landsvirkjun | Rýnifundir með hönnuðum á árunum 2011-2013/ *Minutes of meeting, meetings with project managers from Landsvirkjun and design consultants from Mannvit-Verkis from 2011-2013* | - | Icelandic | Internal |
| 44 | Mannvit Consulting Engineerings | Þeistareykjavirkjun, Verkhönnun/ *Þeistareykir Geothermal Power Plant, Preliminary design documents* | 2011 | Icelandic | Internal |
| 45 | Mannvit - Verkis | Basis of Design | - | English | Internal |
| 46 | Mannvit - Verkis | LV-2014-033. Þeistareykir Geothermal Power Plant, Turbines, Generators and Cold End Equipment (Tender Documents) | 2014 | English | Internal |
| 47 | Mannvit - Verkis | LV-2014-095. Þeistareykjavirkjun, Byggingar/ *Þeistareykir Geothermal Power Plant, Civil Work (Tender Documents)* | 2014 | Icelandic | Internal |
| 48 | Mannvit - Verkis | LV-2015-023. Þeistareykir Geothermal Power Plant, Control System (Tender Documents) | 2015 | English | Internal |

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| 49 | Mannvit - Verkis | LV-2015-085. Þeistareykir Geothermal Power Plant, Power Transformers (Tender Documents) | 2015 | English | Internal |
| 50 | Mannvit - Verkis | Preliminary Process flow diagram, Overview Production 45 MW | 2012 | English | Internal |
| 51 | Sverrir Thorallson | Common Problems faced in Geothermal Generation and how to deal with them | 2006 | English | Weblink |
| 52 | Teiknistofa Arkitekta | Deiliskipulag Þeistareykjavirkjunar, Þingeyjarsveit/ *Site Plan for Þeistareykir Power Project* | 2012 | Icelandic | Weblink |
| 53 | Albert Albertson et al. | Environmental Impact Assessment of Geothermal Projects in Iceland, Proceeding World Geothermal Congress 2010 | 2010 | English | Weblink |
| 54 | Alþingi | Act no.106 on Environmental Impact Assessment | 2000 | English | Weblink |
| 55 | Efla Consulting Engineers | Silicon Metal Plant at Bakki in Húsavík with production capacity of up to 66,000 tons, Environmental Impact Assessment | 2013 | Icelandic/ English | Weblink |
| 56 | Jón Ingimarsson/ Landsvirkjun | Challenges for Geothermal Energy - Experience from Iceland | 2012 | English | |
| 57 | Landsvirkjun | Vöktunaráætlun fyrir framkvæmdir á Þeistareykjum/ *Environmental Monitoring Plan for constructions in Þeistareykir* | 2016 | Icelandic | Internal |
| 58 | Mannvit Consulting Engineering | Álver á Bakka við Húsavík Þeistareykjavirkjun, Kröfluvirkjun II og háspennulínu frá Körflu og Þeistareykjum að Bakka við Húsavík, Sameiginlegt mat á umhverfisáhrifum/ *Aluminum smelter at Bakki near Húsavík, Þeistareykir Geothermal Power Plant, Krafla Geothermal Power Plant and transmission lines from Krafla through Þeistareykir to Bakki near Húsavík, Joint Environmental Impact Assessment* | 2009 | Icelandic | Weblink |
| 59 | Mannvit Consulting Engineering | Greining á landslagi á fyrirhuguðum framkvæmdasvæðum í Þingeyjarsýslum, Greinargeð/ *Landscape analysis in the proposed project area in Þingeyjarsýslur* | 2010 | Icelandic | Weblink |
| 60 | Mannvit Consulting Engineering | LV-2015-050. Vöktun hljóðstigs við jarðvarmavirkjanir, Greinargerð um hljóðmælingar árið 2014/ *Noise monitoring in the surroundings of Geothermal Power Plants* | 2014 | Icelandic | Weblink |

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| 61 | Mannvit Consulting Engineering | Sameiginlegt mat á umhverfisáhrifum, yfirlit í lok verks og úttekt á matsferli/ *Joint Environmental Impact Assessment, Lesson learned report* | 2011 | Icelandic | |
| 62 | Mannvit Consulting Engineering | Theistareykir up to 200 MW Geothermal Power Plant, EIA Summary and National Planning Agency opinion | 2015 | English | Internal |
| 63 | Mannvit Consulting Engineering | Þeistareykjavirkjun, Allt að 200 MW jarðhitavirkjun í Þingeyjarsveit og Norðurþingi, mat á umhverfisáhrifum/ *Þeistareykjavirkjun, Up to 200 MW Geothermal Power Plant in Þingeyjarsveit and Norðurþing, Environmental Impact Assessment* | 2010 | Icelandic | Weblink |
| 64 | Mannvit - Verkis | Theistareykir Geothermal Power Plant, Environmental Management Plan | 2015 | English | Weblink |
| 65 | Ministry for the Environment | Regulations on Environmental Impact Assessment | 2005 | English | Weblink |
| 66 | National Planning Agency | Sameiginlegt mat á umhverfisáhrifum fyrir verkefni á norðausturlandi, álit Skipulagsstofnunnar/ *Joint Environmental Impact Assessment for Project in Northeast Iceland, National Planning Agency Opinion* | 2010 | Icelandic | Weblink |
| 67 | Rúnar D. Bjarnason/ Mannvit Consulting Engineering | Nokkrir Punktar um sameiginlegt mat á umhverfisáhrifum/ *Few notes on the joint Environmental Impact Assessment* | - | Icelandic | |
| 69 | Boudewijn Neijens and Unnur M. Þorvaldsdóttir/ HRW-Hydro Review Worldwide | Asset Management is Key to Operation for Landsvirkjun, National Power Company of Iceland | 2015 | Icelandic | Weblink |
| 70 | Landsvirkjun | Áhættuskrá NAL vegna framkvæmda á Þeistareykjum/ *Risk Register Document for construction in Þeistareykir* | - | Icelandic | Internal |
| 71 | Landsvirkjun | Drilling Contract Schedule, THR-02 Schedule | - | English | Inernal |
| 72 | Landsvirkjun | Framkvæmdaáætlun verksamninga, Þeistareykjavirkjun/ *Construction schedule, Þeistareykir Geothermal Power Plant* | 2014 | Icelandic | Internal |
| 73 | Landsvirkjun | LV-2014-120. Handbók um verkefnastjórnun, VIN-208/ *Landsvirkjun's Guidelines for Project Managers* | 2014 | Icelandic | Internal |
| 74 | Landsvirkjun | Risk Management and Assessment Guidelines | 2012 | English | Internal |

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| 75 | Landsvirkjun | Skipurit verkefnisstjórnar Þeistareykjavirkjunar á undirbúningsstigi/ *Project Organization Chart during preparation stage* | 2015 | Icelandic | Internal |
| 76 | Landsvirkjun | Stýrihópur, hlutverk og ábyrgðarskipting/ *Steering Group, Tasks and responsibility* | 2016 | Icelandic | Internal |
| 77 | Landsvirkjun | Þeistareykjavirkjun GPP Employer's Organisation Chart | 2016 | English | Internal |
| 78 | Vala Hafstað/ Iceland Review | Environmental Concerns Halt Power Line Project | 2016 | English | Weblink |
| 79 | Vala Hafstað/ Iceland Review | Power Line Project Gets Permit to Resume | 2016 | English | Weblink |
| 80 | Andri Arnaldsson et al./ Isor and Vatnaskil | Reiknilíkan af jarðhitakerfinu á Þeistareykjum og frummat á afkastagetu/ *Numerical Model of the Geothermal System in Þeistareykir and a Performance Assessment* | 2011 | Icelandic | Weblink |
| 81 | Basil Alexander Ira Jefferies | Optimal Well Placement in the Theistareykir Geothermal Field for the Next Well in Succession, (M.Sc. Thesis, University of Reykjavik) | 2016 | English | Weblink |
| 82 | Egill Axelsson/ Landsvirkjun | LV-2014-057. Grunnvatns- og hitamælingar Landsvirkjunar á Norðausturlandi árin 2006-2013/ *Groundwater and temperature measurements in Northeast of Iceland in years 2006-2013* | 2014 | Icelandic | Weblink |
| 83 | Egill Júlíusson/ Landsvirkjun | Case Study 1, Krafla Geothermal Field - Current Power Station | 2016 | English | Internal |
| 84 | Egill Júlíusson/ Landsvirkjun | Case Study 2, Krafla Geothermal Field - 50 MW Power Expansion | 2016 | English | Inernal |
| 85 | Finnbogi Óskarsson/ ISOR | Exploration and Development of a Conceptual Model for the Theistareykir Geothermal Field, NE-Iceland (The United Nations University, Geothermal Training Programme) | 2015 | English | Weblink |
| 86 | Geothermal Working Gropu/ United Nations | Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to Geothermal Energy Resources | 2016 | English | Weblink |
| 87 | Guðni Axelsson | Sustainable geothermal utilization, Case histories, definitions, research issues and modelling (Geothermics, 39) | 2010 | English | Weblink |

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| 88 | Guðni Axelsson, Snorri Páll Kjaran et al./ Isor, Mannvit and Vatnaskil | Hugmyndalíkan jarðhitakerfisins á Þeistareykjum og jarðvarmamat með rúmmálsaðferð/ *Conceptual Model of the Þeistareykir Geothermal System and a Volumetric Assessment of Production Capacity* | 2008 | Icelandic | Weblink |
| 89 | Halldór Ármannsson/ ISOR | The Theistareykir Geothermal System, North east Iceland - Case History (The United Nations University, Geothermal Training Programme) | 2014 | English | Weblink |
| 90 | Iceland Review | Iceland Geothermal Power Plant Unsustainable | 2013 | English | Weblink |
| 91 | IGA Service GmbH | Best Practices Guide for Geothermal Exploration | 2014 | English | Weblink |
| 92 | ISOR | LV-2013-072. Þeistareykir, Afkastamat 2010-2012/ *Performance Assessment in years 2010-2012* | 2013 | Icelandic | Weblink |
| 93 | ISOR | LV-2015-039. Tectonic Control of Alteration, Gases, Resistivity, Magnetics and Gravity in Þeistareykir Area | 2015 | English | Weblink |
| 94 | Jorge Issac Cisne Altamirano | Sampling and Analyses of Geothermal Steam and Geothermometer Applications in Krafla, Theistareykir, Reykjanes and Svartsengi, Iceland (The United Nations University, Geothermal Training Programme) | 2006 | English | Weblink |
| 95 | Jónas Ketilsson et al./ The National Energy Authority | Eðli Jarðhitans og sjálfbær nýting hans, Álitsgerð faghóps um sjálfbæra nýtingu jarðhitans/ *Geothermal Characteristics and Sustainable Geothermal Utilisation, Report by Committee of Professionals* | 2011 | Icelandic | Weblink |
| 96 | Kayad Moussa Ahmed | Injection Test and Early Production History of Well THG-1 at Theistareykir Geothermal Field, N-Iceland (The United Nations University, Geothermal Training Programme) | 2009 | English | Weblink |
| 97 | The National Energy Authority | Nýtingarleyfi á jarðhita á Þeistareykjum í Þingeyjarsveit/ *Utilisation license for Geothermal Resource in Þeistareykir in Þingeyjarsveit* | 2014 | Icelandic | Internal |
| 98 | Vatnaskil Consulting Engineers | A Sensitivity Analysis of the Þeistareykir Reservoir Model, Application with Itough2 | 2014 | English | Weblink |
| 99 | Axel Björnsson et al. | LV-20017/075. Geothermal Projects in NE Iceland at Krafla, Bjarnaflag, Gjástykki and Theistareykir. Assessment of Geo-Hazards Affecting Energy Production and Transmission System Emphasizing Structural Design Criteria and Mitigation of Risk | 2007 | English | Weblink |

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| 100 | Gréta Bergrún Jóhannesdóttir et al. | Earthquakes in North Iceland - Proceedings of a workshop in Húsavík, North Iceland 6-8 June 2013 | 2014 | English | Weblink |
| 101 | Jónas Ketilsson et al./ The National Energy Authority | Legal Framework and National Policy for Geothermal Development in Iceland, (Proceedings World Geothermal Congress 2015) | 2015 | English | Weblink |
| 102 | Askja Energy Partners | The Wish-List of the Icelandic Energy Industry | 2016 | English | Weblink |
| 103 | Hörður Árnason and Rafn Lárusson/ Landsvirkjun | Landsvirkjun Financial Statements 2015, (Presentation) | 2016 | English | Weblink |
| 104 | Landsvirkjun | Base Prospectus, U.S.$1,000,000,000 Euro Medium Term Note Programme | 2014 | English | Weblink |
| 105 | Landsvirkjun | Condensed Interim Financial Statements - January 1 to June 30, 2016 | 2016 | English | Weblink |
| 106 | Landsvirkjun | Consolidated Financial Statement 2015 | 2016 | English | Weblink |
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# Appendix C: Visual Evidence

Photo 1: Steam pipes at Bjarnarflag

Photo 2: Vegetation at Bjarnarflag

Photo 3: Vegetation and fumarole at Bjarnarflag

Photo 4: Vintage 3 MW turbine at Bjarnarflag


Photo 5: Safety signage at Bjarnarflag

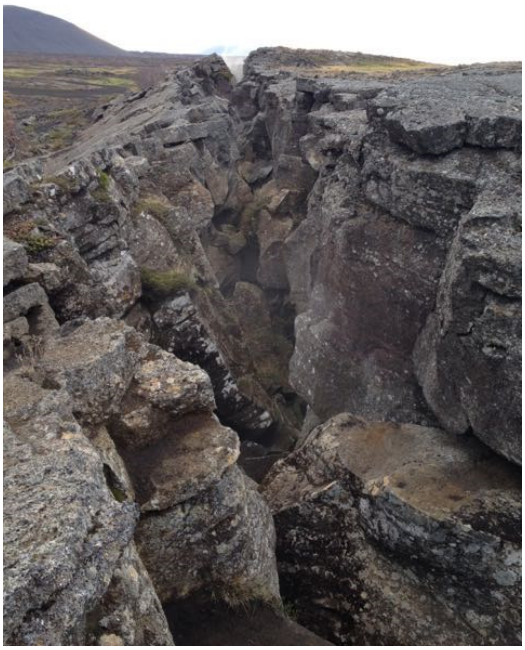

Photo 6: Rift at Bjarnarflag

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| Photo 7: Planned Bjarnarflag 2 power station site | Photo 8: Bjarnarflag area with power station in background |
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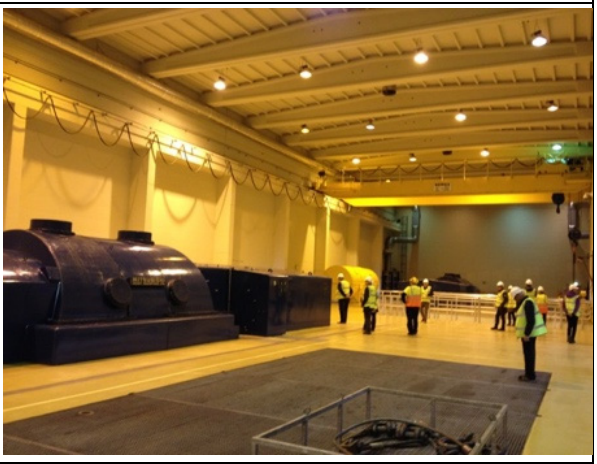
| Photo 9: Krafla power station | Photo 10: Geothermal effluent from Krafla |
|  |  |
| Photo 11: Krafla cooling towers | Photo 12: Krafla powerhouse interior |

Photo 13: Wellhead domes at Krafla

Photo 14: Landscape at Krafla

Photo 15: Landscape at Krafla

Photo 16: Krafla visitor centre on TripAdvisor

Photo 17: Krafla switchyard, with connection to Theistareykir under construction


Photo 18: Administration building of Thingeyjarsveit municipality in Laugar

Photo 19: Húsavík harbour in front of Húsavik mountain


Photo 20: Húsavík harbour and Skjálfandi bay

Photo 21: Húsavík harbour extension


Photo 22: Tourism in Húsavík


Photo 23: Tourism in Húsavík II

Photo 24: Húsavík hospital


Photo 25: Building for Northeast Iceland Nature Research Centre and other institutions on Húsavík waterfront

Photo 26: Tourist and fishing boats in Húsavík harbour

Photo 27: Industrial area Bakki north of Húsavík

Photo 28: Construction of PCC silicon metal factory at Bakki


Photo 29: Sign for PCC factory


Photo 30: PCC factory under construction


Photo 31: Work camp at PCC factory


Photo 32: Road junction in Húsavík to Theistareykir (28km)

Photo 33: Aerial view over lava fields and access road towards power plant (Hreinn Hjartarson)

Photo 34: Aerial view of quarry and revegetation (Hreinn Hjartarson)

Photo 35: Quarry (Hreinn Hjartarson)

Photo 36: Natural pond and fumaroles

Photo 37: Surface geothermal features

Photo 38: Natural pond and fumaroles (Hreinn Hjartarson)

Photo 39: Cabin

Photo 40: Cabin with power station in background

Photo 41: Abandoned farm with drill rig in background


Photo 42: Drill rig assembly


Photo 43: Drill rig operations containers

Photo 44: Diesel generator container for drill rig

Photo 45: Modern silencer on wellpad

Photo 46: Well test with steam rising through silencer

Photo 47: Wellhead protection dome under assembly

Photo 48: Wellhead valves

Photo 49: Steam supply line along pond

Photo 50: Steam supply line with powerhouse in background

Photo 51: Steam supply line crossing road


Photo 52: Safety signage

Photo 53: Landscaped warm water tank, with wellhead dome and powerhouse

Photo 54: Landsnet switchyard building under construction


Photo 55: Public information sign on geothermal area


Photo 56: Public information sign on environmental and social issues


Photo 57: Public information sign on power station

Photo 58: Powerhouse

Photo 59: Cooling towers, demister and powerhouse

Photo 60: Containers with materials and equipment at powerhouse

Photo 61: Lifting containers

Photo 62: Lifting of heavy concrete slabs

Photo 63: Powerhouse construction (Hreinn Hjartarson)

Photo 64: Wood recycling outside powerhouse

Photo 65: Works ongoing between cooling towers and power house

Photo 66: Landsvirkjun staff in Theistareykir camp

Photo 67: Canteen in camp

Photo 68: Defibrillator in camp


Photo 69: Portable hydrogen sulphide detector


Photo 70: First turbine and generator awaiting installation

Photo 71: Fuji Electric engineers during installation works

Photo 72: Workers with safety barriers

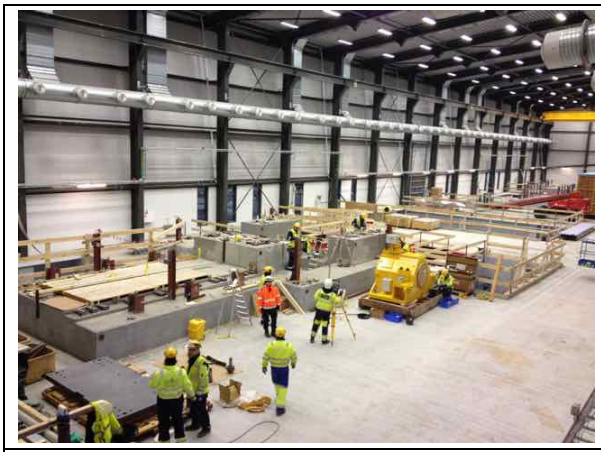


Photo 73: Turbine and generator platforms under preparation

Photo 74: Steam supply pipe coming into powerhouse, with insulation

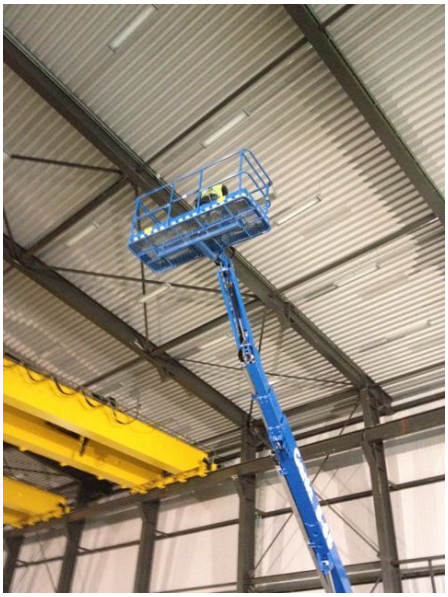


Photo 75: Working at height inside powerhouse

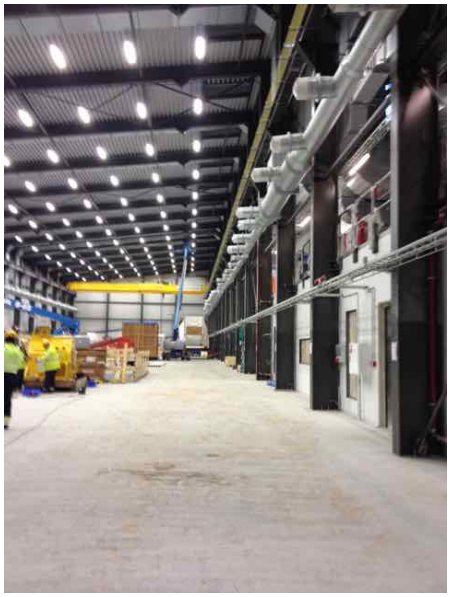


Photo 76: Ventilation system in powerhouse

Photo 77: Hazardous materials room in powerhouse

Photo 78: Multilingual access control sign

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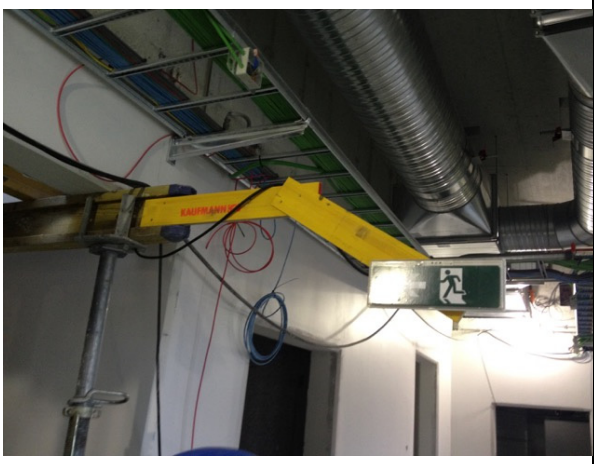
| Photo 79: Emergency shower | Photo 80: Supports in basement for heavy turbine transport above |
|  |  |
| Photo 81: Temporary escape route signage | Photo 82: Temporary protection of stairwell |
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| Photo 83: Future control room | Photo 84: Visitors with full PPE in future control room |

Photo 85: Electric control panels

Photo 86: Closed wellhead from deep drilling project at Krafla

Photo 87: Northern lights over well undergoing testing, with steam rising from silencer (Hreinn Hjartarson)