2016 Iceland Country Report

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1. Introduction

Utilisation of geothermal resources has expanded rapidly in Iceland during the last decade and is expected to increase further in the future. Electricity generation is estimated to increase by 12% from 5.0 TWh in 2016 to 5.8 TWh in 2020 and geothermal heat use from 27.1 PJ in 2015 to 34 PJ in 2020. A population growth of 36% is expected by 2050, and geothermal utilization is estimated to increase by over 70% by 2050, to almost 50 PJ. Iceland's long term objective is to ensure the sustainable utilisation of its resources, and the future implementation of the Master Plan for hydro and geothermal energy resources in Iceland is a step in maintaining and sustaining this objective. Iceland has developed a great deal of know-how and experience in the harnessing of geothermal resources, both for space heating and electricity generation.

During the 20th century Iceland has emerged from being a nation dependent upon imported oil and coal, to a country where practically all stationary energy, and 83% of primary energy, is derived from domestic renewable sources, with near carbon-free electricity production in 2016. This is the result of an effective policy in making renewable energy a long-term priority in Iceland. Nowhere else does geothermal energy play a greater role in providing a nation's energy supply. In Figure 1 an overview is given of the main production wells in Iceland operated for electricity generation, and by heat utilities that have a natural monopoly license. Auto-producers are excluded, of which there are over 100 in Iceland, although they are only 14% of the final use. However for heat use, main activity producers dominate, with 80% share (23.1 PJ) of total heat use.

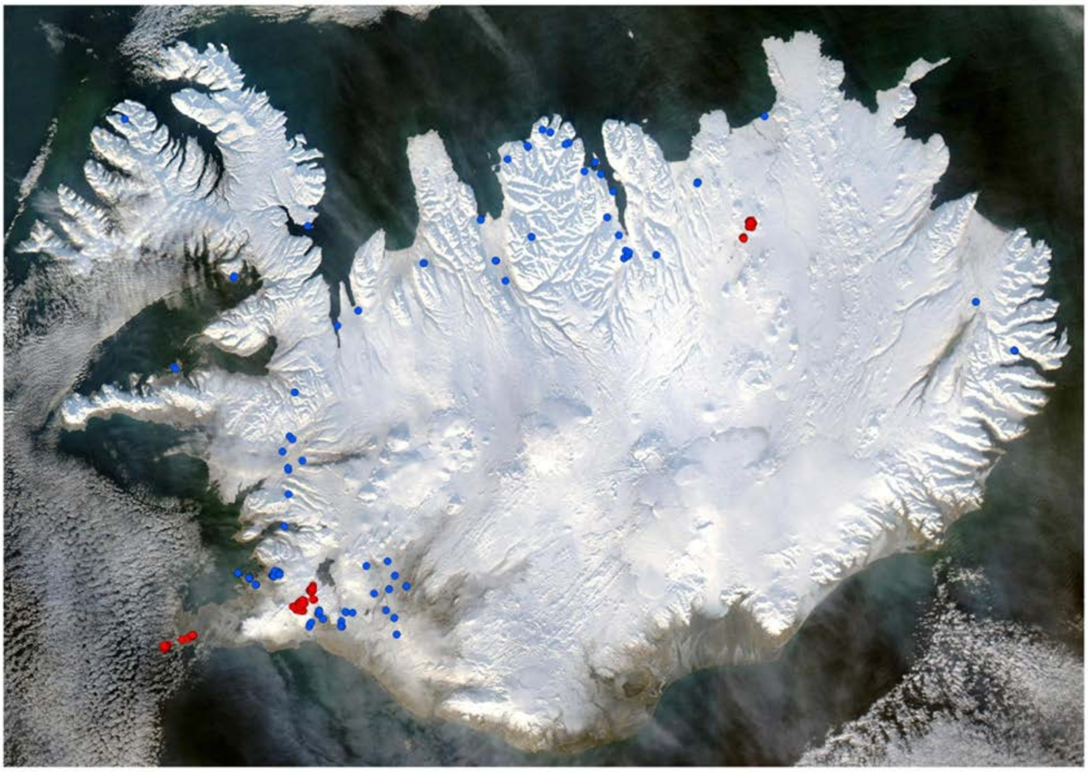

Figure 1 Satellite image of Iceland in winter showing geothermal production wells in operation. Geothermal power plants are shown in red, heat utilites in blue.

Electricity		Direct Use	
Total Installed Capacity (MW_e)	665	Total Installed Capacity (MW_{th})	2500*
New Installed Capacity (MW_e)	0	New Installed Capacity (MW_{th})	0
Total Running Capacity (MW_e)	663	Total Heat Used (PJ/yr) [GWh/yr]	33 PJ
Contribution to National Capacity (%)	24	Total Installed Capacity Heat Pumps (MW_{th})	N/A
Total Generation (GWh)	5067,3	Total Net Heat Pump Use [GWh/yr]	N/A
Contribution to National Generation (%)	27	Target (PJ/yr)	
Target (MW_e or % national generation)		Estimated Country Potential (MW_{th} or PJ/yr or GWh/yr)	N/A
Estimated Country Potential (MW_e or GWh)	4255 MW_e		

(N/A = data not available)
(* indicates estimated values)

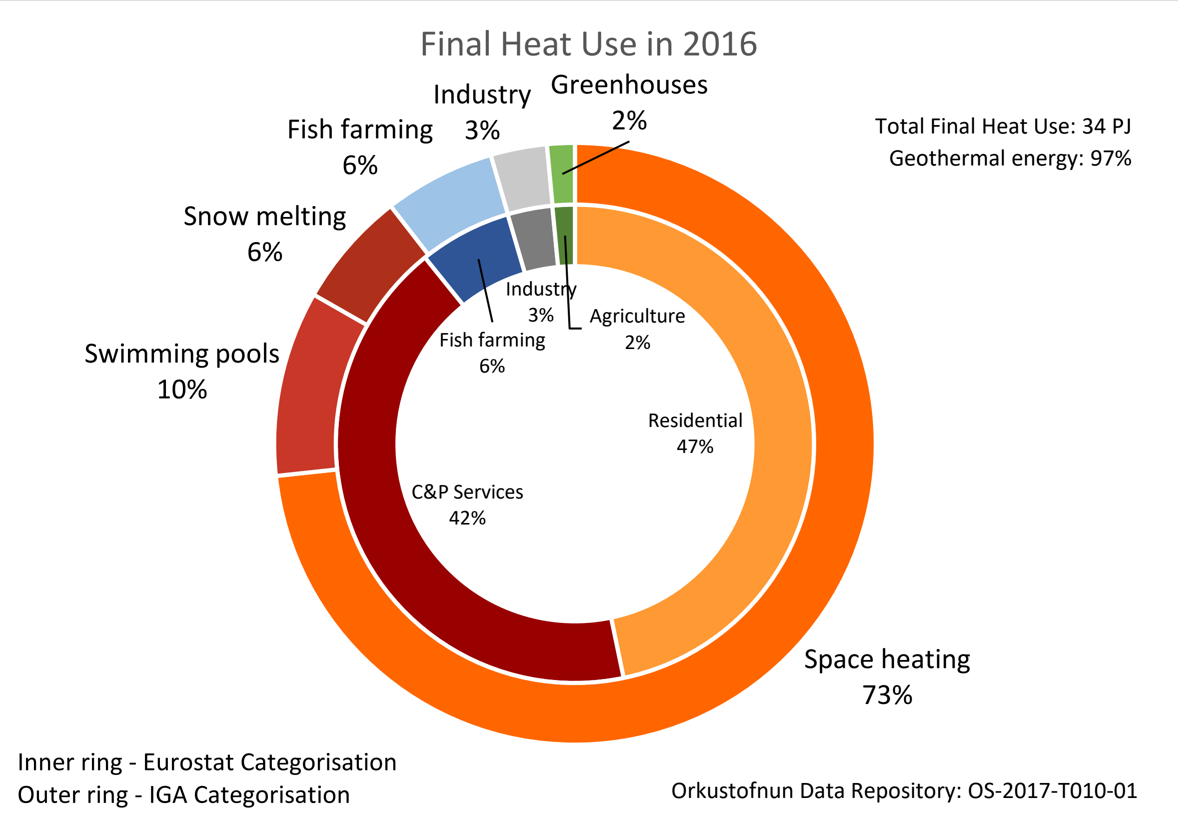

Figure 2 Final heat use in Iceland in 2016. 97% of heat use in Iceland is geothermal heat.

2. Changes to Policy Supporting Geothermal Development

Geothermal policy has not undergone significant changes in recent years in Iceland. Geothermal development is mature in Iceland, and most households, over 90%, use geothermal energy for heating. Geothermal power development is not supported by any market incentives in Iceland. The Energy fund, operated by Orkustofnun, supports geothermal development in areas where geothermal is not used for heating, often referred to as "cold" areas. In the "cold" areas heating is mainly electrical and subsidized by the government, since it is more expensive than geothermal heating. A lump sum comprised of 16 years-worth of subsidies is available to those who want to establish a geothermal heating system, or other more efficient means of heating, such as heat pumps. One such project is under development in Kjós, just north of Reykjavík. Geothermal exploration had been ongoing for years until a well producing enough water was finally drilled in 2015. The construction of the district heating system is underway and began operations in 2017.

3. Geothermal Project Development

3.1 Projects Commissioned

Kjós district heating system. Started operations in early 2017.

IDDP-2 well in Reykjanes, drilling commenced in August 2016.

Construction of Þeistareykir power plant.

4. Research Highlights

New and effective exploration techniques have been developed to discover geothermal resources. This has led to the development of geothermal heating services in regions that were not thought to enjoy suitable geothermal resources. Iceland's geothermal industry is now sufficiently developed for the government to play a more limited role than before. Successful power companies now take the lead in the exploration for geothermal resources; either geothermal fields that are already being utilized, or discovering new fields.

The Icelandic Government supports the Iceland Deep Drilling Project (IDDP) with 342 million ISK, along with the three largest energy companies in Iceland. If successful this project could start a new era in geothermal development. The main purpose is to find out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions. The first well, IDDP-1 in Krafla yielded superheated steam after drilling into magma at roughly 2 km depth. The second well IDDP-2 was drilled from August 2016 to January 2017 in Reykjanes. For this phase Norwegian company Statoil joined the original partners, and the drilling was made possible with a €20 million grant from the EU Horizon 2020 programme. The drilling was successful and hit supercritical conditions at 4,659 m. The temperature was measured to be 427°C with fluid pressure of 340 bars. Cores were retrieved for further study and the rock appears to be permeable at depth. There are exciting times ahead for this project and the third IDDP well is already being planned for the Hengill area.

Figure 3 Cores retrieved from IDDP -2 (HS-Orka, 2017).

Orkustofnun also supports a few projects coordinated by the Icelandic Geothermal Research Cluster GEORG, e.g. the Deep Roots for Geothermal Systems (DRG-project) aimed at research of the roots of magma-driven high temperature geothermal systems.

Reykjavík Energy, the University of Iceland, Columbia University and CNRS collaborated on a project called CarbFix, which aimed at injecting CO_2 emissions from Hellisheiði geothermal power plant back into the reservoir where they would mineralise. The project has been ongoing for the last 10 years or so and in June 2016 the results were published in Science. The CO_2 from Hellisheiði which was injected into the reservoir, along with waste water from the power plant, was shown to mineralise in the basaltic rock in under two years, while it is estimated that it takes CO_2 hundreds or even thousands of years to mineralise in sedimentary rock. In addition, this method is up to three times less expensive than conventional CCS methods. Another project called SulFix uses a similar technique to inject H_2S released from the power plant. Currently, around 65% of H_2S and 50% of CO_2 from the power plant is being injected.

5. Other National Activities

5.1 Geothermal Education

The United Nations University-Geothermal Training Programme (UNU-GTP) has been operating in Iceland since 1979, with the aim of assisting developing countries with significant geothermal potential to establish groups of specialists in geothermal exploration and development. A graduate programme was started in 2000 in cooperation with the University of Iceland, and several UNU-GTP students have since continued their studies to obtain MSc and PhD degrees. UNU-GTP receives its funding from the government of Iceland, 5 M US$/yr. Since 1979, 554 scientists have graduated from 53 countries. They have come from countries in Asia (40%), Africa (32%), Latin America (16%), and Central and Eastern Europe (12%). Amongst these have been 107 women (19.5%).

Iceland School of Energy was established at Reykjavik University which offers postgraduate courses in the field of renewable energy. University of Iceland also offers specialized post graduate studies in renewable energy, focusing on geothermal energy.

5.2 Conferences

The third Iceland Geothermal Conference 2016 was successfully held at the Harpa Conference Centre in Reykjavík, between April 26 and 29, 2016. Over 700 delegates from 46 countries attended the conference, which focused on direct use, how to develop new opportunities, and how to create value by maximizing the utilization of the geothermal resource. This conference is hosted by the Iceland Geothermal cluster. Other smaller meetings and conferences were also held as usual, such as the GEORG Geothermal Workshop in November 2016.

5.3 Publications

Icelandic scientists produce numerous publications on geothermal development and research every year.

Publications on projects supported by GEORG research group: http://georg.cluster.is/publications/papers/

Paper on the completion of the IDDP-2 well http://iddp.is/wp-content/uploads/2017/02/IDDP-2-Completion-websites-IDDP-DEEPEGS2.pdf

Paper published on the results of the CarbFix project: Matter et al. *Rapid carbon mineralization for permanent disposal of anthropogenic carbon dioxide emissions.* Science, vol 352, issue 6291, pp. 1312-1314.

5.4 Useful Websites

Orkustofnun Data Repository: http://www.nea.is/the-national-energy-authority/energy-data/data-repository/

United Nations University Geothermal Training Programme: http://www.unugtp.is/

GEORG Geothermal Research Cluster: http://georg.cluster.is/

Iceland Deep Drilling Project: http://iddp.is/

6. Future Activity

The Icelandic Government published a white paper on sustainability in the Icelandic society in 1997, in which the need for the development of a long term Master Plan for energy use in Iceland was once again stressed. All proposed projects should be evaluated and categorized on the basis of energy efficiency and economics, as well as on the basis of the environmental impact of the power developments. A Master Plan of this kind is comparable to the planning of land use and land protection in a strategic environmental assessment (SEA) process. It is not supposed to go into the details required for environmental impact assessment (EIA). The vision is to prepare an overview of the various potential energy projects in hydro and geothermal and to evaluate and rank these based on their energy and economic potential, feasibility, national economy and the estimated impact that each project would have on nature, environment, cultural heritage and the society, as well as the potential for other uses of the areas in question. The Master Plan should be based on the best available scientific information and conclusions should be transparent and reproducible and made available to the public. It was considered of vital importance to establish public confidence in the evaluation process. The Master Plan aims to identify power projects that rank highly from an economical point of view, have a minimum negative impact on the environment, and a positive impact on the society. Such a score card for the energy projects helps decision makers to filter out which of the proposed projects are likely to become controversial and disputed and which ones not. It also directs attention to those project areas that might have protection value and should be left untouched by human development. The third cycle of the Master Plan, which includes 33 geothermal options, was presented to the minister for Industry in September 2016, and as of May 2017 is under review in parliament.

Þeistareykjavirkjun power plant (Figure 4) is being developed by Landsvirkjun (National Power Company) in northern Iceland. The first 45 MW phase is expected to start operations at the end of 2017, while a second 45 MW phase will be added in 2018.

Direct geothermal use is expected to increase with population increases. It is estimated that heat use will reach 50 PJ in 2050 (Figure 5).

Figure 4 Þeistareykir power station under construction in September 2016 (Landsvirkjun, 2016).

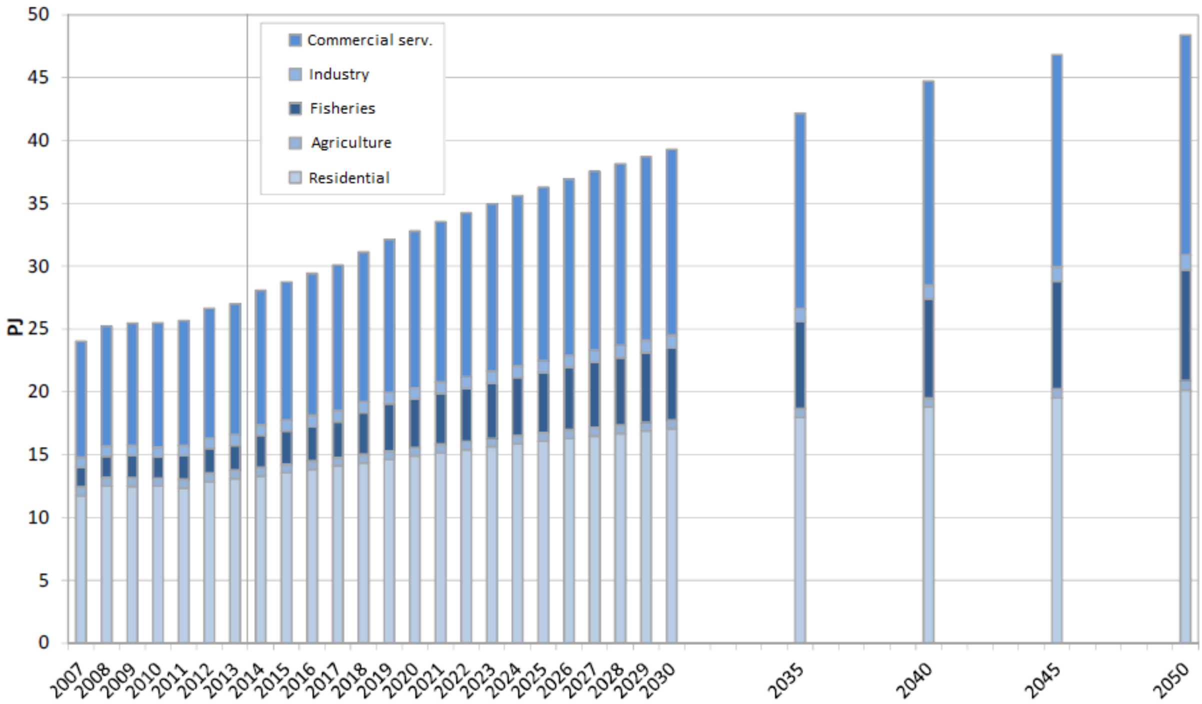

Figure 5 Geothermal utilization forecast 2007-2050 (Orkustofnun, 2015).

7. References

Orkustofnun (2017). OS-2017-T008-01: Installed Electrical Capacity and Electricity Generation of Geothermal Power Plants [data file]

Orkustofnun (2017). OS-2017-T009-01: Primary energy use in Iceland 1940-2016 [data file].

Orkustofnun (2017). OS-2017-T010-01: Final Heat Use in Iceland 2016 by District Heating Area [data file].

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