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The Present and Future Role of Geothermal in the Energy-Mix in Rural Iceland: A Case Study from NE-Iceland.

Gunnlaug H. Ásgeirsdóttir[1)], Guðmundur H. Sigurðarson[2)], Sigurður I. Friðleifsson[3)], Sunna Guðmundsdóttir[2)] and Bjarni Gautason[4)]

1) Eimur, Hús 8, Rangárvellir, 603 Akureyri, Iceland
2) Vistorka, Hús 8, Rangárvellir, 603 Akureyri, Iceland
3) Orkusetur, Hús 8, Rangárvellir, 603 Akureyri, Iceland
4) Íslenskar orkurannsóknir, Hús 8, Rangárvellir, 603 Akureyri, Iceland

gunnlaughelga@gmail.com

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ABSTRACT

An overview of the role of geothermal in the energy mix of the North-East region of Iceland is presented. Geothermal energy outweighs the other renewable energy source (hydro-power) in the region. The main utilization sectors for geothermal energy in Northeast of Iceland is reviewed. Space heating is by far the most important one, accounting for 80% of the direct thermal-water usage. Other sectors of usage are briefly described such as: electricity production, food production, snow melting, and leisure activities. The transportation sector is the main user of fossil fuels in the region. However, the energy transition to renewables in transportation is underway. The Northeast region of Iceland has enough energy to accept the challenge of this energy transition, with geothermal energy as a driving force.

1. INTRODUCTION

This paper presents an analysis of the current role of geothermal energy in rural NE-Iceland from the standpoint of that basic building block of modern society, the home. The home (a physical structure and its inhabitants) requires energy for sustaining non-biological functions (heat, light, screen-time etc.) and food for sustaining biological functions. In addition, energy is needed for the transport of inhabitants, both for work and leisure activities.

2. NORTHEASTERN REGION OF ICELAND

The Northeastern region of Iceland (NE-Iceland) covers 22,735 km^2 which is approximately 22% of the total area of Iceland. The western boundary follows approximately the divide along the Tröllaskagi peninsula towards the central highlands. In the east the boundary between the Northeast and Eastern region of Iceland follows the approximately the divide between Bakkafjörður and Vopnafjörður southwards and is marked by the river Jökulsá á Fjöllum further inland. Most communities are located along the (North-Atlantic) coast (Figure 1).

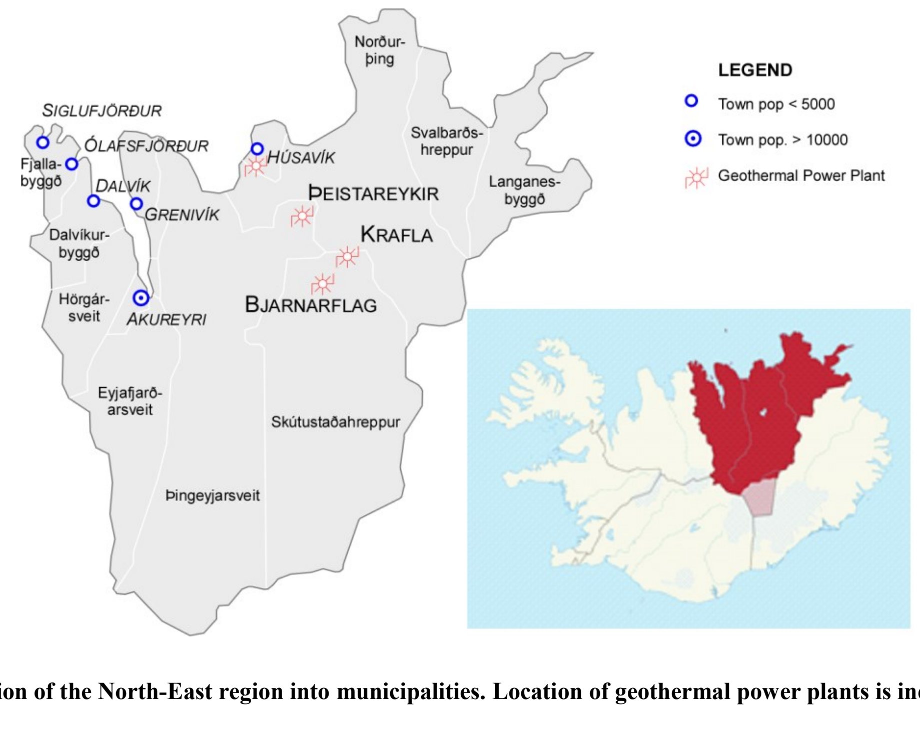

Figure 1: Division of the North-East region into municipalities. Location of geothermal power plants is indicated.

Iceland is a sparsely populated country with an average density of approximately 3 inhabitants per kilometer squared. With a total population of roughly 30 thousand inhabitants the population density in the Northeast region is only half the national average. A steady trend of urbanization has resulted in a population decline in the rural areas. Driven in part by this decline, municipalities have been amalgamated into larger units better capable of providing services for the inhabitants.

There are thirteen communities of the North-East region. According to population statistics published by Statistics Iceland (2019) Akureyri is by far the largest town in the region with a population exceeding 18,000 as of January 1st, 2019 (Figure 1). Of the remaining communities four have populations between 1000 and 4000. Six communities are below 1000 inhabitants and two have fewer than 100 inhabitants.

Energy production and usage in the North-East region, mirror what is observed in the rest of the country although there are some notable differences. Almost all electricity is produced by renewable sources (hydro and geothermal). However, the share of geothermal in in electricity production far outweighs the contribution from hydro, but for the whole country, the reverse is true. Space heating is almost entirely from direct use of geothermal energy. Transportation and fisheries are almost entirely reliant on fossil fuels. However, the transition to renewables in transportation is underway.

3. DIRECT USE OF GEOTHERMAL ENERGY

The sectorial share of direct use of geothermal energy in the Northeast of Iceland in 2017 is shown in Figure 2. The most significant usage is for space heating, 593 GWh (2,135 TJ) with about 80% of the total. The second largest sector is energy used for swimming pools with 112 GWh (403 TJ). Snow melting 26.1 GWh (94 TJ), industrial usage 6.11 GWh (22 TJ), fish farming 3.89 GWh (14 TJ) and the least significant usage are the greenhouses with 1.11 GWh (4 TJ). As Figure 2 shows, 80% of the geothermal energy is used for space heating (Orkustofnun, 2018).

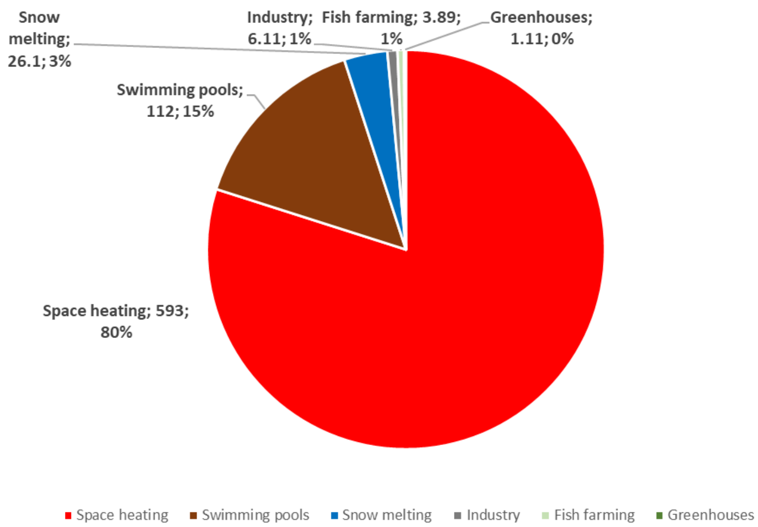

Figure 2: Sectorial share of direct use of geothermal energy utilization in the North-East region of Iceland in 2017.

3.1 Geothermal usage per community

The utilization of geothermal energy for space heating has increased as people have been moving from rural areas to the capital region as geothermal energy became more accessible and cost-effective compared to the consumer cost of oil (Bjornsson, 2006). The hot-water usage per capita for communities in NE- of Iceland is shown in Figure 3. The greatest per capita water use is in Dalvíkurbyggð, 628 m^3 per capita annually which correspond to ~1,700 Liters per day. The lowest per capita water use was in Skútustaðahreppur, 114 m^3 per capita annually year or ~300 Liters per day. The data for hot-water usage for the smaller communities was not available (Orkustofnun, 2017). In Skútustaðahreppur, hot-water is only used for space heating. Other communities in the region also use geothermal energy for other purposes, which explains the large variation in usage.

3.2 Food production

Geothermal energy is used for greenhouses and the production of vegetables. The production of vegetables in the NE- Iceland takes place in Brúnalaug and Hveravellir. Tomatoes, cucumbers and peppers are the most commonly produced vegetables (Table 1). The usage of geothermal energy in greenhouses has the main benefit of early thawing of the soil and advanced harvest. Geothermal is also used for food production outside the traditional green-houses. An example is the Reykir farmstead in Fnjóskadalur which uses geothermal water to warm up outdoor carrot fields. Furthermore, some minor food production, typically potatoes, has traditionally been associated with warm grounds in geothermal areas that allow for a longer growing season and higher growth rates. Hot-grounds have also been used for bread-baking although the production is miniscule.

Table 1: Food production based on geothermal energy in 2017.

Food	Production [tons]
Tomatoes	327
Cucumbers	158
Peppers	46
Artic char	2,200
Total	**2.731**

Besides greenhouse production, geothermal energy is also used for fish production (Table 1). There are four fish factories in the area that utilize geothermal energy for drying fish. In 2017, about 3.760 tons of dried products were exported, equivalent to about 17.000 tons of raw material or about 20% of the export value of dried seafood that year (Kristmann Pálmason, personal communication, August 2, 2018).

Geothermal water, commonly 20-50°C, is used to heat fresh water from 5-12°C. It is mainly used in the hatchery state of fish production (Bjornsson, 2006).

Production of Arctic char (Salvelinus alpinus) is the most common in the region. Land-based fish farm in Öxarfjörður uses 650 l/s of geothermal water for hatchery and production (Umhverfisstofnun, 2018). In Haukamýri, a land-based fish farm with production of arctic char uses 32,109 m^3 per year of geothermal water (Umhverfisstofnun, 2018).

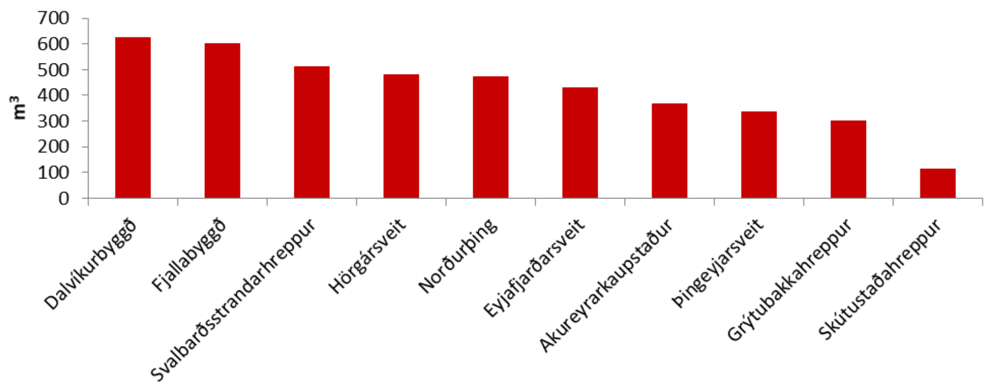

Figure 3: Geothermal water usage per capita in the communities of the North-East region in 2017.

3.3 Industry

The use of geothermal energy for industrial purposes began on a large scale in 1967 with the establishment of a diatomic plant at Mývatn near the Námafjall, high-temperature geothermal field. Today, industrial users of geothermal energy in the region are PCC BakkiSilicon's near Húsavík and TDK Foil Iceland, in Akureyri. TDK Foil Iceland produces aluminium foil for electrolytic capacitors and PCC BakkiSilicon produces silicon metal. These are two, out ten in total for the country, large electricity users that are connected to the transmission network. Previous use of geothermal energy for industrial purposes included drying of imported hardwood and production of cinder blocks at Mývatn.

3.4 Snow-melting

Snow-melting has become increasingly common to heat pavement and melt snow during winter. It is utilized by using return water from the houses, that is about 35°C (Ragnarsson, 2003). In addition, small football areas have been built in most communities and they are typically warmed with return water. There are also examples of football fields being kept snow and frost-free by direct use of geothermal water.

4 ELECTRICITY GENERATION

The electricity demand has increased considerably in Iceland in the last years due to a massive expansion in the energy-intensive industry (Bjornsson, 2006). This has been met partly by increased geothermally produced electricity. Of the total electricity generation of 1,140 GWh in 2018 in the Northeast region, 87% came from geothermal energy, 13% from hydro and less than 0.1% from fuels. Table 2 shows the geothermal power plants in the NE- Iceland and their Electricity production. The total installed capacity of geothermal power plants in the area is now 153,200 kW (Orkustofnun, 2018b).

In addition to the plants listed in Table 2 a small binary-fluid plant utilizing the Kalina-cycle technology was in operation at Húsavík from 2000 to 2008 (Ragnarson, et al. 2018). The plant was operated by Orkuveita Húsavíkur the district heating company for Húsavík. An overview of installed capacity and electricity production in the North-East region is given in Figure 4.

Table 2: Electricity production in geothermal power plants in the North-East region in 2018.

Producer	Power plant	Operation [year]	Installed capacity [kW]	Electricity generation [GWh]
Landsvirkjun	Krafla	1978	60,000	461,4
Landsvirkjun	Þeistareykjavirkjun	2017	90,000	678,3
Landsvirkjun	Bjarnarflag	1969	3,200	0.2
Total			153,200	1,140

In 2017, 77% of all produced electricity in the region came from geothermal energy, 23% came from hydroelectric power and less than 1% came from fossil fuel. In 2018 a new geothermal power plant at Þeistareykir came in with full performance and produced 678.3 GWh of electricity witch lead to around 10% increase in electricity production with geothermal energy. That is, 87% of electricity was produced with geothermal energy, 13% with hydro and less than 1% with fuel (Orkustofnun, 2018b; Orkustofnun, 2019). Figure 5 shows the electricity production by source in 2018.

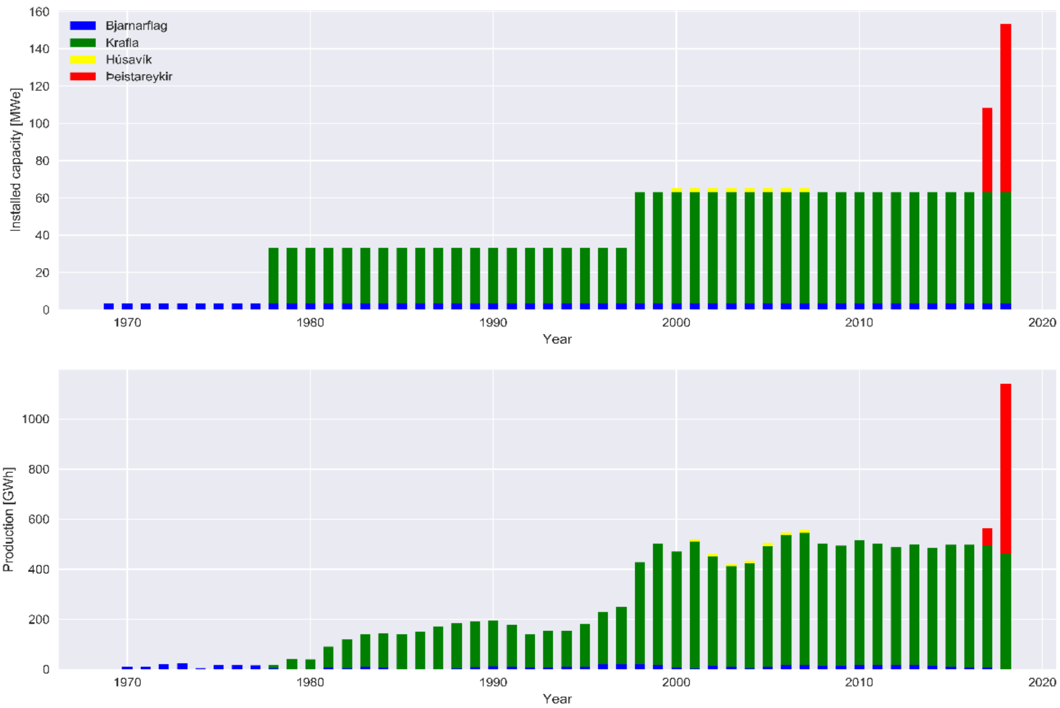

Figure 4: Installed capacity and electricity production from geothermal energy in North-East Iceland

5. TRANSPORT AND ENERGY

The Government of Iceland has put forward an action plan for on-land transport energy transition. The objective is to increase the share of renewable energy to 10% by 2020 and 40% by 2030 (Orkustofnun, National Energy Authority, https://nea.is/fuels/energy-transition/).

According the Icelandic Transport Authority there were 227.847 vehicles registered (active) in Iceland by the end of September 2019. The number for the area address in this paper is 20.506. At the beginning of year 2018 already 2% of the fleet registered in this part of Iceland was running on alternative fuel. By mid year 2019 the number had reach 4% of the total fleet.

A car that is running 100% on electricity has around 4 times the energy efficiency of a fossil fuel car. Going from fossil fuel driven transport to an electrified transport would therefore reduce the GWh demand for transport in the area by around 75%.

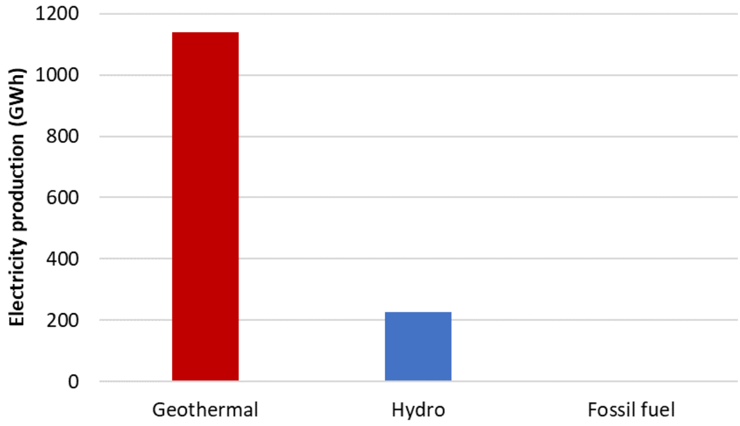

Figure 5: Electricity production in the North-East region of Iceland in 2018.

6. DISCUSSION AND CONCLUSIONS

Geothermal plays a vital role in the energy mix of North-East region of Iceland. Geothermal provided 87% of the total energy consumption in 2018. The greatest contribution by far is in space heating but electricity production is a big contributor as well. As for the rest of Iceland fossil fuels are mostly used in transportation, fishing and industry.

We expect that in the coming years the use of geothermal for space heating will increase at a slow but steady space reflecting a modest increase in population. However, industrial use e.g. drying of fish may result in a significant increase of geothermal water usage in the region. It is also considered likely that balneological use of thermal waters will increase in the coming years. Particularly if the recently established spas turn out to be successful. Such establishments provide spin-offs, in that they attract tourists who otherwise may overlook the surrounding areas as an interesting destination and in that they prolong the tourist season.

The next energy transition is underway. Currently (2019) we estimate that approximately 100 new electricity vehicles (EV) are being imported to the region annually. This number is not exact, and it includes all vehicles (privately owned, service vehicles, rent-a-cars etc.). Each vehicle uses approximately energy equivalent to that of a household. Plug-in-hybrids have also been popular choices in the last couple of years, however it is difficult to estimate to what extent electricity replaces fossil fuels in such vehicles.

The replacement of fossil fuels by renewables (geothermal and hydro in the case of the North-East region) is the biggest change in the energy mix on the horizon in in NE- Iceland. Larger harbors are currently working on electrification of their services. This is a small first step in bringing the fishing and transportation fleet to replace fossil fuels with renewables. However, the harbors will not be able to service the very large cruise ships that frequent harbors in Iceland. The current situation in North-East Iceland allows for the almost complete removal of fossil fuels from the energy mix. Geothermal energy alone can supply the inhabitants with all the energy they need for their daily activities and developing NGOs in the area are constantly working towards further utilization of the resource.

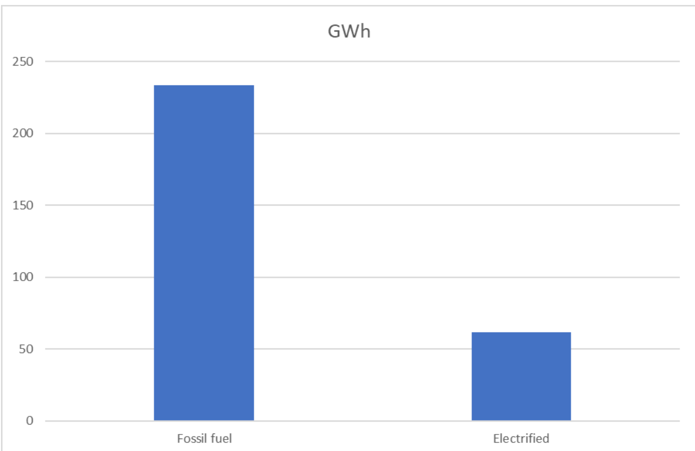

Figure 6: Anticipated reduction in energy demand resulting from the transition of on-land tranportation away from fossil - fuels to re.

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