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Geothermal Energy – Country Update for the Faroe Islands

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ABSTRACT

Through the last 10 years more than 300 shallow geothermal wells have been drilled in the Faroe Islands for extraction of ground source heat for private households. These wells have given valuable insight into the variations of the geothermal gradient and the groundwater resources in the Faroese subsoil.

Little research had been conducted on the subjects prior to commercialization of geothermal wells in the country, and due to lacking regulations on data gathering while drilling, only a small amount data was collected for the first few hundred wells. This data, although sparse, gave new and exciting insight into the geothermal gradient and the groundwater system on the islands. Unexpectedly, data showed a geothermal gradient ranging from around 20°C/km to as high as 40°C/km for the uppermost 300 meters in places. It also revealed a well-functioning groundwater system, with fresh water most likely residing at layer boundaries and in open fracture systems in the volcanic rocks. The several hundred drilling sites across the islands show an approximation of about 10-15% of the wells being artesian in nature, encountering large quantities of fresh water ranging in heat from 8°C to as high as 27°C. Due to very high precipitation rates in the area the recharge time of the groundwater aquifers is most likely only a few years.

In order to fully understand the overall geological and structural framework onshore the Faroe Islands, new research has been commensed that - in combination with new data from the rapidly increasing number of geothermal wells being drilled - will aid in the development of a viable model for the geothermal and groundwater resources available in the Faroe Islands.

1. INTRODUCTION

In the summer of 2014, two shallow geothermal wells were drilled in the village of Kollafjørður, on the main island of Streymoy, Faroe Islands. Several similar shallow boreholes had been drilled throughout the country during the past 5-6 years, all showing an expected geothermal gradient of around 20-40 °C/km and water temperatures around 7-13°C. The two new wells therefore unexpectedly encountered large amounts of anomalously warm artesian fresh water with initial flow rates of 20,000 liters/hour of 20°C warm water from the first well, and as high as 33,000 liters/hour of 27°C warm water from the other. The wells continued to pour water to the surface, and during the next 7 months flow rates decreased and stabilized at about 300 and 16,000 litres/hour, while maintaining stable water temperatures of 20°C and 27°C respectively. Since then, five more wells have been drilled in a 150 meters radius from the first one. All well were drilled for the purpose of heating private households, except for one well that was drilled by the municipality of Tórshavn and the Faroese Geological Survey for the possibility of further investigations. All wells encountered significant quantities of groundwater reserves (Ólavsdóttir et al. (2015), (2016) and (2018); GEUS well logging report, (2016)).

In 2015, the newly appointed Faroese government agreed upon a new energy-policy, that aims at reorganizing the country's energy usage towards greener and more environmentally friendly energy. The policy focuses on investments in greener energy solutions that will make the country self-sufficient in renewables in the near future. It prioritizes expansion, reorganization, production and use of renewable energy sources for the entire country and states that by 2025 at least half of all private houses and buildings will be heated by green energy. By 2030 the entire electrical power grid will be delivered by renewables and in order to exploit any remaining electrical power and make room for expansion on the area, all private households, industry and transportation will be encouraged to switch to greener solutions. All new public buildings will be heated by green energy and a plan for energy savings and -reorganization of older buildings created. Industrial development and education in renewable energy and green technical solutions are prioritized and the smaller island communities serve as test-sites for more environmentally friendly energy solutions (The Faroese Environment Agency).

The Faroese government is regulating the legislation on geothermal resources and has appointed the Environment Agency, a government body under the Ministry of Health and the Interior, as the controlling party on the subject. When initial interest on commercialization of geothermal energy started in the Faroe Islands some 10 years ago, little knowledge existed on geothermal- or groundwater resources and the groundwater system in general. Most freshwater reserves in the country today come from surface streams and springs and no wells have yet been drilled for the utilization of groundwater alone (Ólavsdóttir et al. 2015, 2016 and 2018). Planning has commenced for the first groundwater well to be drilled in the fall of 2019 on the island of Vágar, as part of an industrial PhD-project, that will investigate and explore for freshwater resources to be used in onshore smolt production. The project is funded by the Faroese salmon farming company Hiddenfjord, the Faroese Research Council and supervised by the Norwegian University of Science and Technology (NTNU) as well as the Faroese Geological Survey/Jarðfeingi (Ellefsen, M. Industrial PhD project, (2018-2021)).

No separate legislation for the utilization of groundwater resources exists today, but the government has appointed the Faroese Geological Survey, a government body under the Ministry of Foreign Affairs and Trade, as the controlling party on the groundwater subject. The Geological Survey together with the ministry, have just started working on an updated version of the legislation on natural resources in the Faroese subsoil, including the exploration and utilization of groundwater resources (Ministry of Foreign Affairs and Trade; The Faroese Geological Survey).

2. GEOLOGICAL BACKGROUND

The Faroese continental margin is located in the North Atlantic Ocean on the outer part of the NW European continental margin, approximately in the central part of the North Atlantic Igneous Province (NAIP) (Ólavsdóttir et al. (2017)). Lower Palaeogene extrusive igneous rocks of the Faroe Islands Basalt Group (FIBG) dominate and cover approximately 99% of the Faroese area, with flood basalts extending eastwards into the Faroe-Shetland Basin, and formed as part of the NAIP in connection with the breakup of the NE Atlantic Ocean (Ólavsdóttir et al. (2019)) (Fig. 1). The FIBG has been subdivided into seven formations (Passey and Jolley (2009)), with four of these being sedimentary (of volcaniclastic origin) in nature (Lopra, Prestfjall, Hvannhagi and Sneis formations), while the other three formations being basaltic lava flows (Beinisvørð, Malinstindur and Enni formations) (Figs. 2 and 3). The thickness of the sedimentary sections ranges from around 15 meters to less than a meter, while the lava formations are up to more than a kilometer thick. Fracture analysis onshore Faroe Islands reveal a distinct difference in the dominant trend of faults, fractures and dykes in the pre-breakup lava formations (NW/SE-NNW/SSE) compared to the syn-breakup formations (ENE/WSW, WNW-ESE). The pre-breakup formations, exposed on the west side of the Faroe Islands, are adjacent to a proposed parallel early Paleocene transient rift, while the syn-breakup formations orientation, exposed on the east and north east side of the islands, is parallel to a minimum stress direction associated with the continental breakup between Greenland and Eurasia (Geoffroy et al. (1994), Walker et al. (2011), Ziska (2012)).

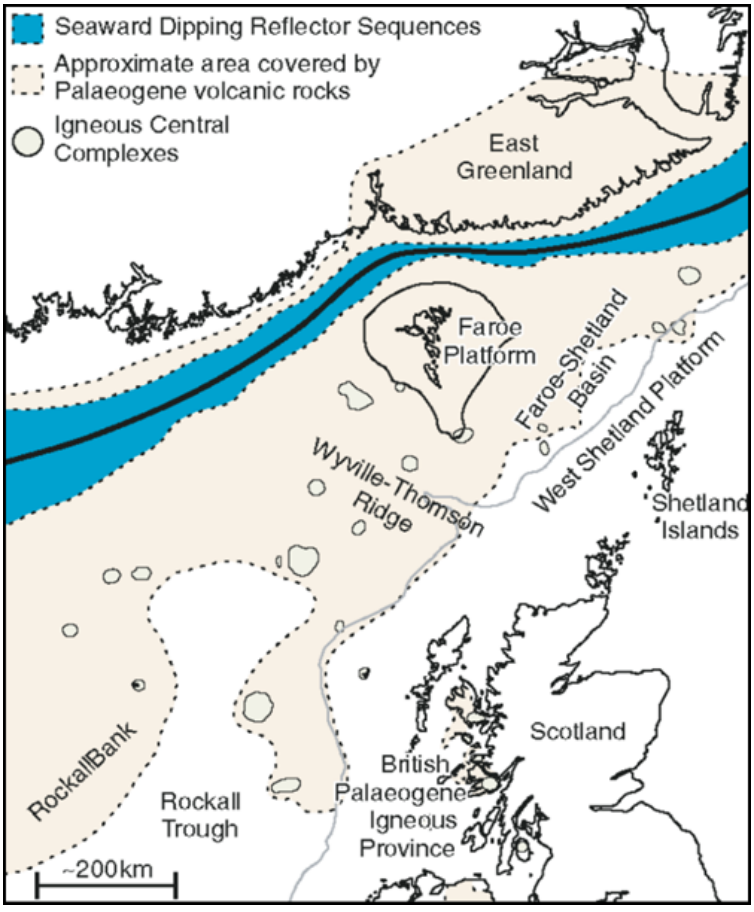

Figure 1. Position of the Faroe Islands at the opening of the NE Atlantic Ocean during late Paleocene to early Eocene (dotted light brown area shows the approximate extent of extrusive igneous rocks covering much of the area) (Passey and Bell (2007))

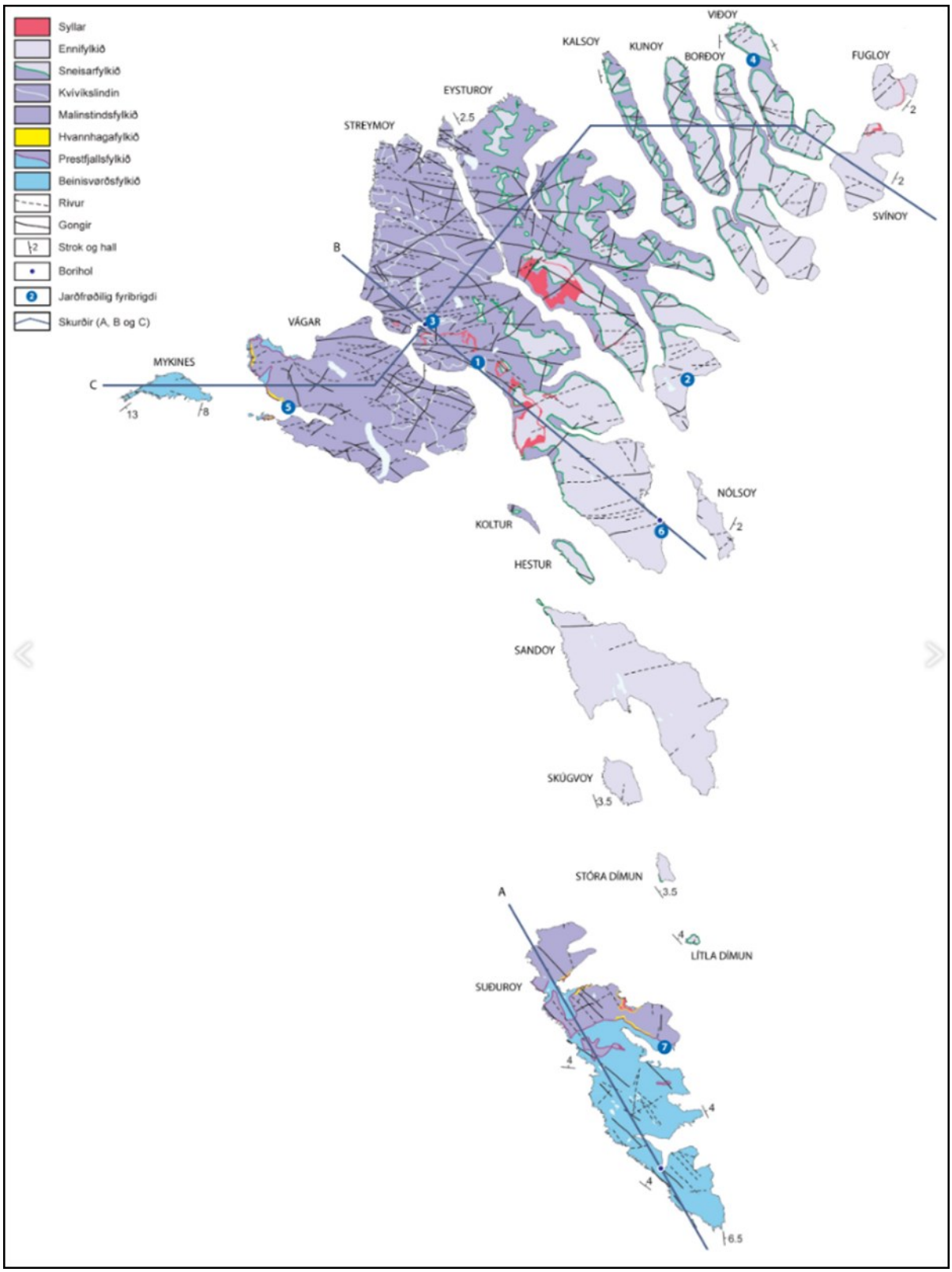

Figure 2. Geological map of the Faroe Islands (lines represent profile A, B and C in Fig. 3) (Faroese Geological Survey).

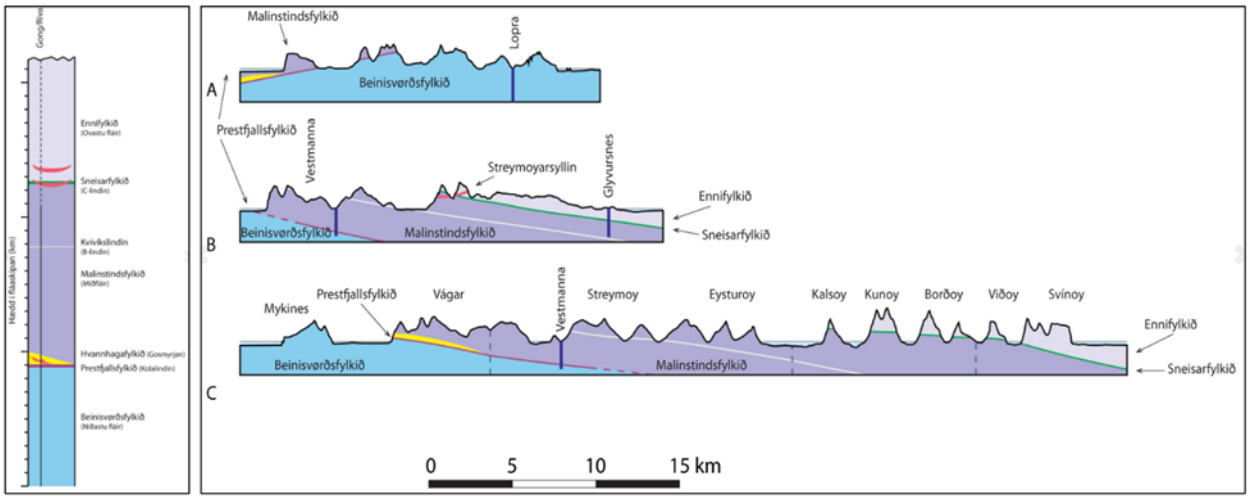

Figure 3. Right side: Geological stratigraphical column of the Faroe Islands. Left side: Profiles A, B and C (location seen on Fig. 2) illustrating the different geological formations onshore Faroe Islands (Faroese Geological Survey)

Volcanic rocks are, in themselves, relatively compact geological formations that hold little to no water. They can have a high porosity but are often low in permeability which makes them poor reservoirs for groundwater and other fluids. But the brittle nature of the volcanic basalt makes it highly susceptible to fracturing under stress, which, in combination with erosion and more sediment-prone deposits at flow-boundaries – and later induced volcanic intrusions cross-cutting their way through the lava-pile – creates an interconnected network of permeable fractures, carrier-beds and potential pathways for deep groundwater-circulation, transforming the compact basalt layers into high-potential groundwater reservoirs and source for geothermal energy (Ólavsdóttir et al. (2015)).

3. GEOTHERMAL RESOURCES AND POTENTIAL

The current hypothesis for the anomalously warm geothermal system, exposed by several shallow boreholes in the village of Kollafjørður, invokes thoughts of a possible sub-basalt shallow basement block located under northern part of Streymoy, causing an above average geothermal gradient in the area. The structural high is fault-bounded to the south (approximately at the location of Kollafjørður) against what could be interpreted as a sub-volcanic sedimentary basin. Syn- to post-volcanic strain during changing stress regimes has led to several deformation stages that again have led to the reactivation of faults bordering the basement block – allowing for deep groundwater recharge through open faults cutting through colder, more insulating and less permeable basalt layers. Heated groundwater is then returned towards the surface, where (semi) confined aquifers have the possibility to develop below non-permeable volcanoclastic claystone layers (Ólavsdóttir et al. (2018)). Preliminary investigations in regards to a deep onshore well on the Faroe Islands executed by the Faroese Geological Survey, also supports the hypothesis of a high velocity body underlaying a large part of Streymoy and the area around Kollafjørður, revealing a possible shallow basement high (Ólavsdóttir et al. (2017)) or intruded sill/dike swarms (Ólavsdóttir et al. (2018)) just a few kilometers below the surface.

Numerous springs have been located on the Faroe Islands through the years, and there is knowledge of warmer-than-average springs on several islands. Some reported only in older literature and therefore lacking exact positioning of the surface spring and others very well known. These springs seem to be part of a belt of warm springs (ranging from just below 12 up to almost 19°C) stretching from the middle part of the island of Eysturoy in a south-westerly direction across the middle and northern part of Streymoy – crossing the 660 meter deep scientific Vestmanna-1 well (with a geothermal gradient of approximately 40°C/km) drilled in the outskirts of the village of Vestmanna, all the way to the northern most part of the island of Vágar towards the west (Fig. 4) (Ólavsdóttir et al. (2015)).

In November 2018 geologists from the Faroese Geological Survey participated in an international workshop on deep geothermal energy in Strasbourg, France, to gain knowledge and explore possibilities on the subject of deep geothermal resources (www.jf.fo). Data from all the drilled wells on the islands, several government-conducted investigations and published reports – and the public and private sectors growing interest in funding future projects on the subject – indicate that both geothermal energy and groundwater utilization have potential of becoming valuable resources for the Faroese society in the future.

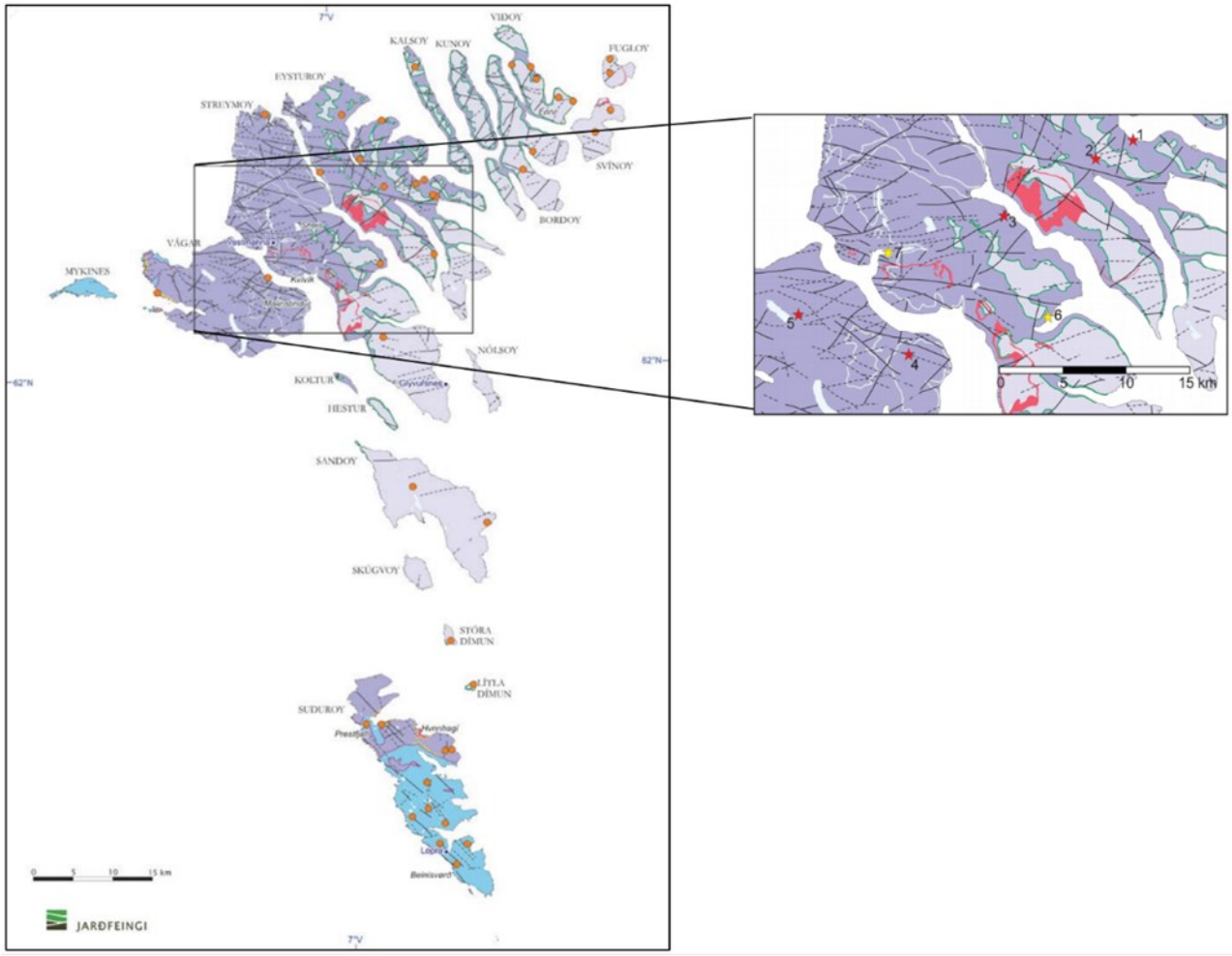

Figure 4. Geological map showing known springs on the Faroe Islands (orange dots on right figure). Inserted map on the right side of the figure show the location of reported warm springs (red stars) and warm groundwater found in wells (yellow stars – no. 6: Geothermal well, Kollafjørður, no. 7: Scientific well, Vestmanna-1) (Ólavsdóttir et al. (2015)).

4. GEOTHERMAL UTILIZATION AND DISCUSSION

Geothermal energy utilization is quite new in the Faroe Islands, with only just over 300 shallow geothermal wells drilled over a 10-year period. Data information from the wells has been very scarse due to poor regulations on the area, but from 2019 the Faroese Geological Survey is actively engaged in data-collection and well-logging in all new wells being drilled. This will help create a comprehensive database for future planning and optimization regarding geothermal energy.

Due to the relatively small amount of data available, only three of the standard tables (1-8) are applicable for the Faroe Islands at present. These are: Table 1, 4 and 7 (see below). Data for the tables has been delivered by the Faroese Environmental Agency.

Table 1 shows an estimate of present and planned production electricity for December 2019 to the end of 2020. Unfortunately, it seems there is no plan for geothermal production of electricity over the next year – and therefore no data is filled in the "Geothermal" column in table 1. Table 4 shows the number of drilled geothermal wells installed with ground-source heat pumps up until today (304 in total as of July 2019), but no estimation on numbers for the last quarter of 2019. Table 7 shows professional personnel involved in geothermal activities in the Faroe Islands and the numbers clearly indicate that there is room for much more government-owned funding going into geothermal activities in the upcoming years, in order to reach the countries energy goals of zero fossil fuels on land by 2030. For the last couple of years, two people (or full time positions) have been allocated to work on geothermal activities, although this is not much, it is a great improvement from 2016 (with zero persons allocated) and 2015 and 2017 (with only one person allocated). Hopefully the government, local municipalities, universities and private companies will see possibilities in investing in the geothermal energy sector.

It seems that the wells in Kollafjørður and Vestmanna together with older knowledge on warm springs across the country, has sparked a public and political interest in geothermal and other renewable energy solutions, that hopefully will continue to expand – also after the next elected Faroese government takes seat in fall 2019.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Wind)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	0	0	93	180	40	108	0	0	18	64	151	352
Under construction in December 2019	0	0	37	120	0		0	0	6	21	43	141
Funds committed, but not yet under construction in December 2019	0	0	0	0			0	0	36	125	36	125
Estimated total projected use by 2020	0	0	130	170	40	110	0	0	60	180	230	400

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

Locality	Ground or Water Temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used[5] (TJ/yr)	Cooling Energy[6] (TJ/yr)
Faroe Islands	12	12	300	V	3.5	2000	19	0
Faroe Islands	7	15	4	W	3.5	2000	1	0
TOTAL								

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Progra
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	0	0	0	1	0	0
2016	0	0	0	0	0	0
2017	1	0	0	0	0	0
2018	1	0	1	0	0	0
2019	1	0	1	0	0	0
Total						