Geothermal Energy Fueling the Energy Transition of the Transport Sector

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Keywords: Energy transition, transport sector, decarbonization, electric vehicles, hydrogen.

ABSTRACT

Less than 20% of the primary energy consumption in Iceland is sourced by fossil fuels, as demand for heat and electricity is met by utilizing renewable resources, predominantly hydro and geothermal (OS, 2019a). However, fossil fuels are still the primary source of energy in the transport sector (OS, 2019b). One of the key aspects of Iceland's recently published Climate Action Plan is the decarbonization of the transport sector. Environmentally friendly mobility has been a large focus at ON Power and Veitur Utilities, subsidiaries of Reykjavík Energy (OR), the largest geothermal energy producer in Iceland.

A network of fast charging points for EVs and PHEVs throughout the country has been rolled out by ON Power, and mid-charging points have been installed at the company's headquarters, its power plants and other offices. Changes in the distribution network and customer services further support the ongoing rapid uptake of electric vehicles and buses in Iceland.

Additionally, an electrolyzer producing hydrogen has been installed near the Hellisheidi power plant, where hydrogen is being produced during low-load hours. The initial market for hydrogen cars and buses has been arranged as a part of the EU funded project; Hydrogen Mobility Europe (H2ME).

In the near term, controlling the peak load on the electrical grid for a national e-mobility fleet remains an ambitious task. The ownership of EVs and PHEVs cars has increased exponentially in recent years with only Norway exceeding Iceland on a per-capita scale (Phillips, 2019). Moving the battery charging time to off-peak hours is beneficial for all relevant entities; the transmission system, distribution system and production. As households in Iceland's capital have generally been reducing their consumption of electricity in recent years, a typical household might double its electricity use with the addition of an EV, whilst visits to petrol stations will no longer be needed.

1. INTRODUCTION

Reykjavík Energy and subsidiaries (OR) have set and reached various ambitious climate change targets and continuously aim to improve. (OR, 2019a) Furthermore, OR's Owners' Policy (OR, 2019b) is to utilize natural resources with responsibility and consideration to enhance the quality of life of present and future generations. Energy transition of the transport sector, eco-friendly energy transformation in Iceland and innovation in the utilization of natural resources is our main environmental focus. OR plays a leading role in building up and providing green transition solutions for the transport sector in Iceland.

Figure 1: A natural resource borehole at Hellisheiði Geothermal Power Plant

2. THE ENERGY TRANSITION OF THE ICELANDIC CAR FLEET

OR's goal is to pioneer the energy shift in transportation (Power, 2019). In the last 5 years, the subsidiary ON Power has set up dozens of fast-charging points around Iceland and now provides a sales system for every charger available in the network. ON Power and Veitur Utilities are also consulting homeowners and companies for charging solutions at their sites. The goal is to find favorable and environmentally friendly uses for our energy, to improve energy efficiency and be able to provide better rates. Figure 2 shows the current distribution of the fast charging network and the planned expansion for 2019.

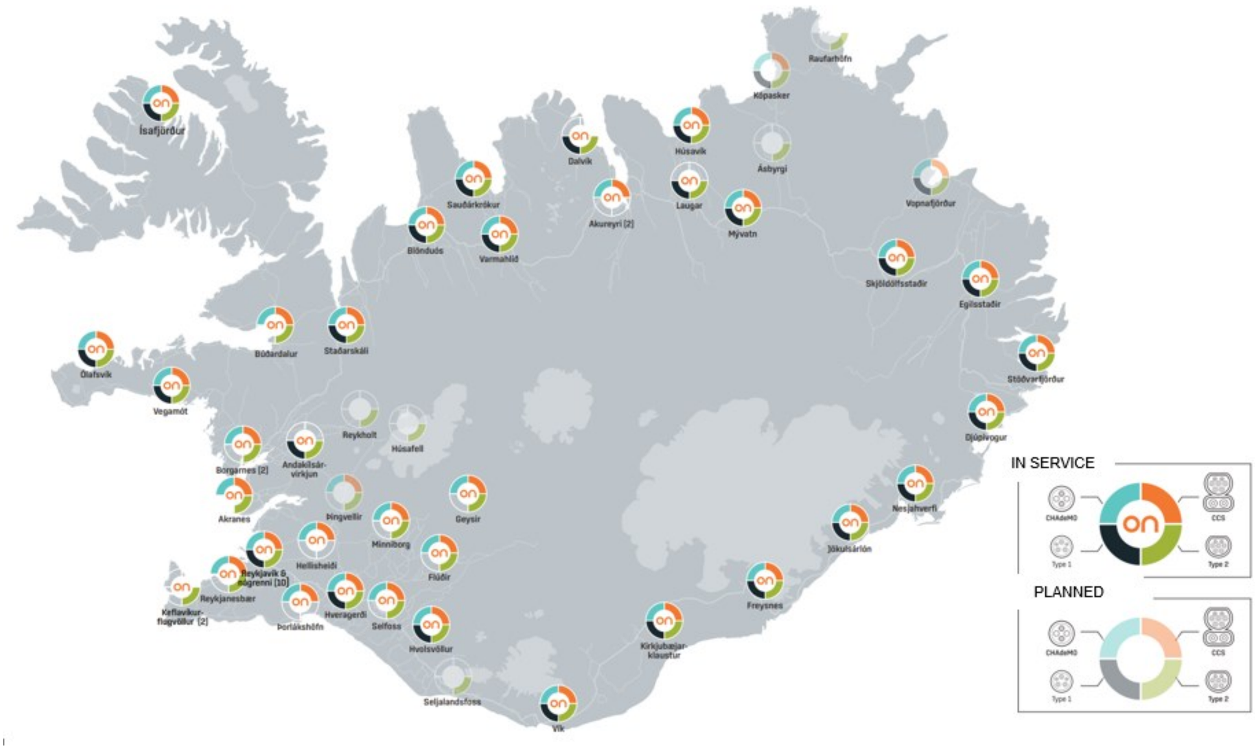

Figure 2: ON Power's fast charging network all around Iceland, both chargers in service and planned locations in 2019.

Iceland is ideal for electric vehicles (EVs) for several reasons:

- Virtually all electricity produced is renewable
- Travelling distances are relatively short
- Favorable climate
- Public acceptance

The highway around Iceland's perimeter is 1,352 km which is ideal for electric cars as the EV range has been increasingly improving with many varieties of EVs on the market able reach up to 500 km on only one charge. Furthermore, about 80% of the Icelandic population lives within a one-hour-drive from the capital. (SI, 2019). The climate in Iceland is also very favorable for EV's, around 3-12 degrees all year around, which is not too cold nor too warm for charging the EV lithium batteries. In Iceland, the EV energy transition can be colloquially described as a "just do it" project. Exchanging all of the 240.000 cars in the country for EV's will enhance energy security for the country as well as decrease emissions. According to a recent Gallup survey (Gallup, 2018), 78% of Icelanders already say that they would choose an EV or PHEV were they to buy a new car today.

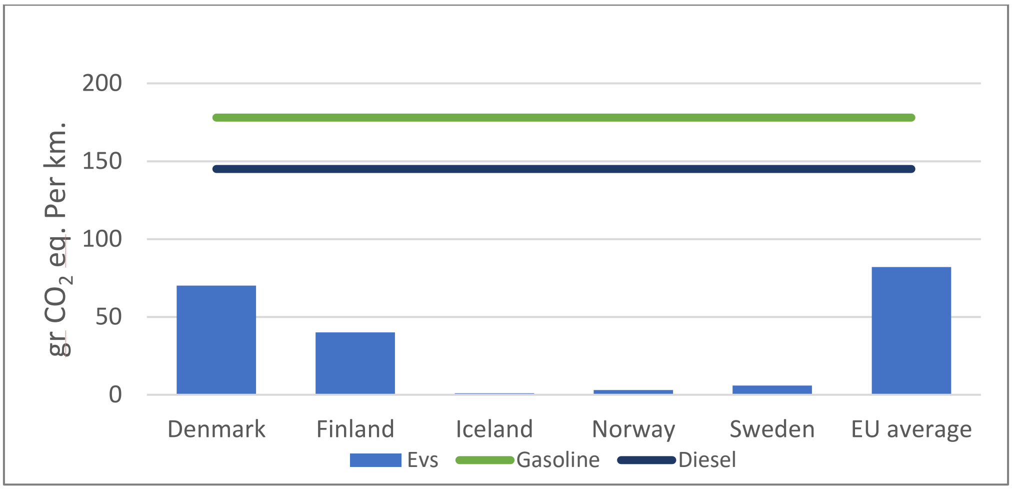

Figure 3: EV emission footprint is proportionally lower in Iceland owing to the source renewable energy

2.1 A Life Cycle Assessment Review Analyzing the Global Warming Potential of EV's with an Icelandic Perspective

The Icelandic government announced its new Climate Action Plan in September 2018, declaring official support for both the EV market and the infrastructure needed to support it. This came just months after ON Power completed the installation of the first countrywide EV charging network throughout Iceland. Such industry support is not confined to Iceland. Worldwide, automakers are increasingly adding electric vehicles to their production. A KPMG study on over 900 automotive industry executives has shown that EVs and emission free vehicles will be a top trend and a priority in the coming years. However, as the push towards EVs continues there is a growing public concern towards EV, particularly questions regarding how environmentally friendly these vehicles are. These are typically focused on the greenhouse gas (GHG) emissions associated with EV battery production and the emissions from the electricity source that will eventually power an EV (KPMG, 2018).

ON Power prepared a detailed Life Cycle Assessment (LCA) report to address these concerns and to put them into an Iceland-specific context (Dillman & Hauksdottir, 2019). This was done by performing a literature review of LCAs with respect to GHG emissions associated with the lifecycle of EVs..The lifecycle of an EV or conventional vehicle includes the extraction of raw material, manufacturing/production of the parts and vehicle, the use phase, and the End of Life (EOL). In the report prepared by ON Power, EOL was considered outside of the system boundary of the study, following ISO LCA standards, primarily due to discrepancies in the research in how to treat EOL (recycling versus waste emissions). This was considered acceptable since the key concerns the LCA sought to address were focused on the battery production and the use phase of the vehicle.

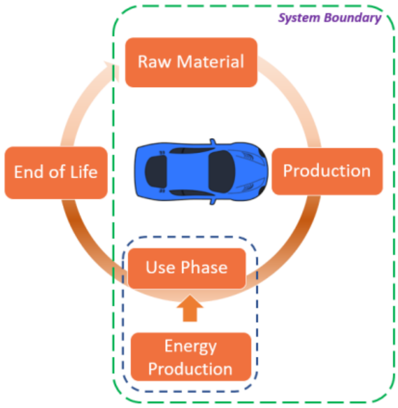

Figure 4: System boundary used within analysis for the LCA report (Dillman & Hauksdottir, 2019).

In the report, it was determined that Internal Combustion Engine Vehicles (ICEV) emit 4 to 4.5 times more GHGs than a comparable EV when driven in Iceland. While concerns about battery production are valid, at a battery capacity of 24-30 kWh, where the production impacts are slightly less than double that of an ICEV, an environmental payoff is quickly met, in around 1.5 years, when driving in Iceland. Even at the largest battery size (85 kWh), when driving in Iceland, the environmental payoff can be found in as little as 4-5 years. If the EVs were to be used either in the European Union (EU) or in the United States, it would be important to think about the additional impacts associated with their greater use of fossil fuels within each region's electricity mix (Dillman & Hauksdottir, 2019).

Within an Icelandic context, the environmental benefits of driving an EV quickly outweigh the higher environmental impacts associated with producing an EV in terms of GHG emissions. This provides an answer to the question of whether the cleaner use phase of EVs outweighs the more emission heavy production phase as compared to ICEVs. The results are that within an Icelandic context this overall GHG emission breakeven is quickly met, less than 1.5 years, when using an EV due to Iceland's low use phase emissions associated with the country's renewably sourced electricity (Dillman & Hauksdottir, 2019).

According to the Icelandic Automobile Association, the average Icelander drives an estimated 15,000 km per year (Icelandic Automobile Association, 2018). At this rate, driving should take a little over a year (~18,000 km) for an EV to become superior to diesel or gasoline vehicles in terms of GHG emissions. The longer an EV is driven, the greater this benefit becomes. Therefore, assuming 200,000 kilometers as the lifetime for EVs and ICEVs (200,000 km was approximately the average of the estimated lifetime of an EV between the studies considered), it was determined that the use of an EV in Iceland could result in as much as a 75-80% reduction of GHG emissions as compared to an ICEV over the lifetime of a vehicle. These results are displayed in Figure 5 for the life cycle phases considered within the analysis conducted by Dillman & Hauksdottir 2019.

Figure 5 depicts the emissions associated with different vehicle types, with the y-intercept depicting the emissions from production phase and the slope representing the emissions associated with the use phase over time. The emissions related to the production of an EV are almost twice as high compared to emissions in the same phase for an ICEV. However, during the use phase of the vehicles EVs emit significantly less when powered by clean electricity, resulting an increasingly greater amount of emissions avoided when using an EV over time.

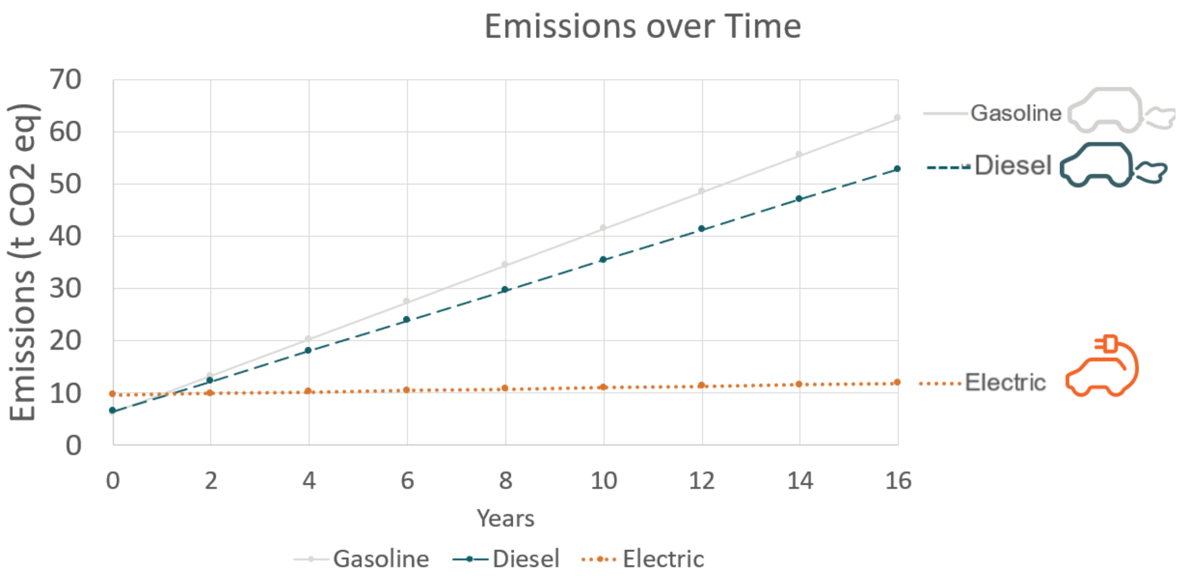

Figure 5: Emissions over time by vehicle type with EV powered by Icelandic electricity (Dillman & Hauksdottir, 2019).Figure 6 depicts these emissions summed over the lifetime of the vehicle, assumed to be 200.000 km. As seen in the previous chart the emissions associated with production of an EV are almost twice as high compared to emissions in the same phase for an ICEV. However, because of the significantly cleaner use phase, the use of EVs results in a decrease of 4-4.5x the amount of emissions associated with ICEV use over a 200.000 km lifetime when using Icelandic electricity.

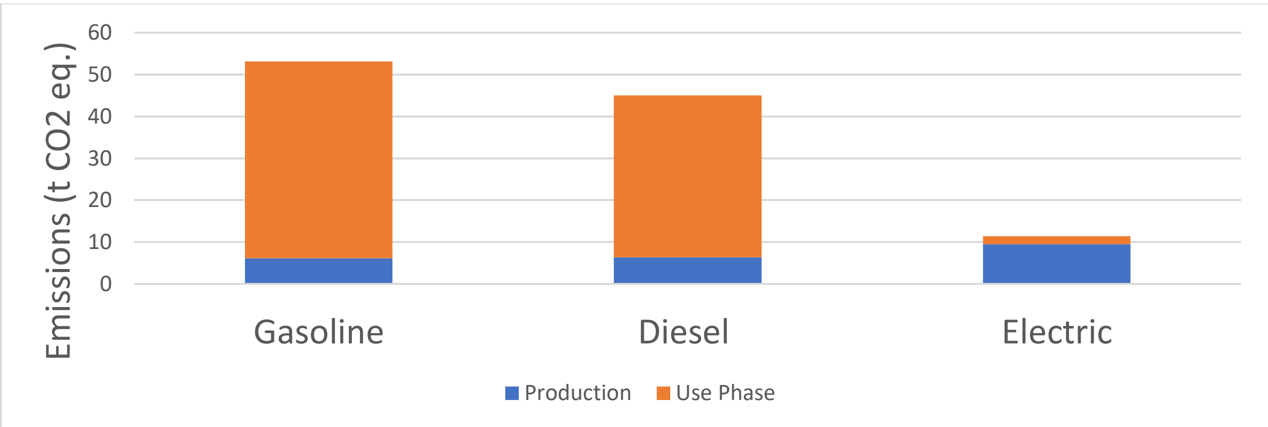

Figure 6: Total Life Cycle Emissions from Production and Use Phase (Dillman & Hauksdottir, 2019).

Figure 7 illustrates that EVs powered by different sources of electricity display a similar relationship with emissions from ICEV as other EVs, having a higher production footprint which then breaks even after a period of less than 50,000 km – except for the scenario in which an EV is sourced entirely by coal. However, according to the overall environmental impact the source of the electricity has a significant effect, where at 200,000 km, an EV powered by the EU electricity mix would emit roughly double the amount of GHG emissions as an EV powered by the Icelandic electricity mix (Dillman & Hauksdottir, 2019).

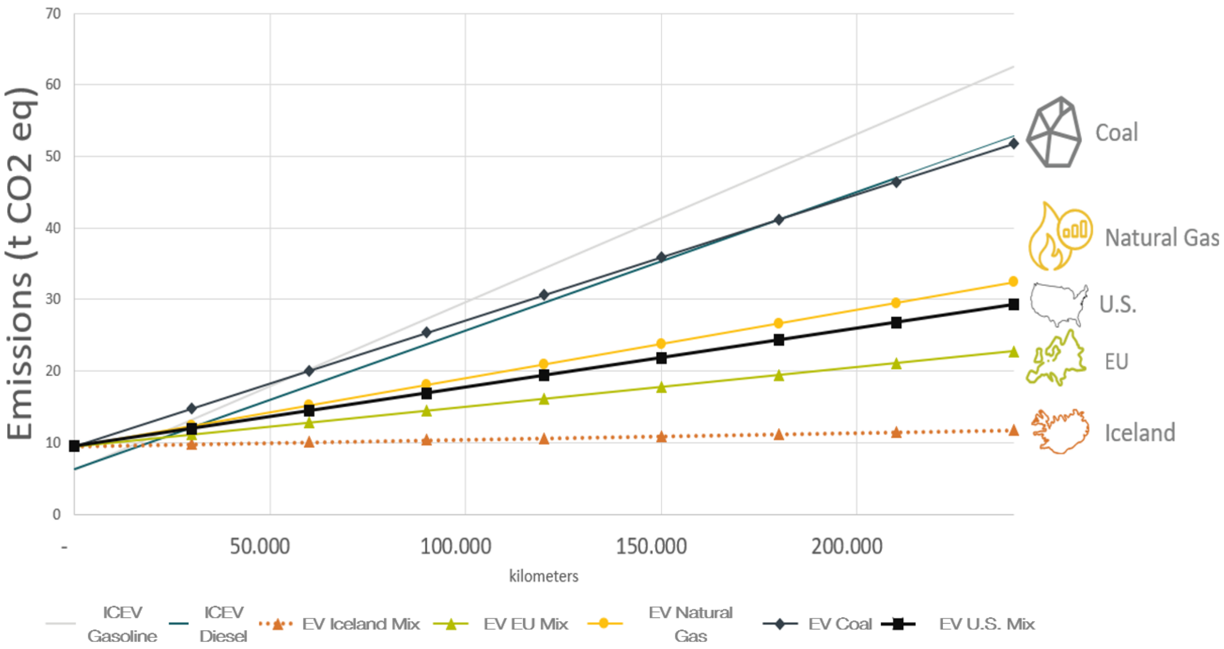

Figure 7: Emissions over use phase of EV by electricity source (Dillman & Hauksdottir, 2019).

Figure 7 displays the importance of understanding the carbon intensity of the electrical grid in which the EV exists and helps illustrate consumer concerns about the impact of this electricity within the life cycle of a vehicle. These concerns are with good reason, the where at a 200.000 km lifetime an EV may only be ~2x better in the US and ~2.5x better in Europe. The final results of this research found with Figures 5, 6, and 7 however show that though consumer concerns about battery production and the source of electricity powering an EV are valid, within an Icelandic context, when using virtually 100% renewable energy, EVs will help decrease GHG emissions within the transportation sector over the lifetime of a vehicle.

2.2 Veitur Utilities – a Distribution Company with a Clear Vision for the Future of the Transport Sector

Veitur Utilities, a subsidiary of Reykjavík Energy, has taken steps to support the energy transition in Iceland by ensuring that the distribution system will be ready for full integration of EVs into the car fleet, a total of 240.000 cars. Veitur Utilities has in that respect already changed the design criteria for electricity connections to be able to support the increased need for power for EVs. Rebates are available for apartment buildings who are in the need for a bigger connection and or a second connection (Veitur, 2019). The change from one-phase electricity to three-phase electricity is also without extra cost for users.

Veitur Utilities additionally goes the extra mile to give better consultancy to professionals, companies and the general public concerning information and specialty knowledge regarding connections, for example the power needed to charge EVs and advice concerning the need for a larger connection in the most economical way possible.

The City of Reykjavík and Veitur Utilities have decided to work together on a project concerning setups of a total of 90 chargers around the city in the next three years for people without parking at home.

Veitur Utilities has, furthermore, decided to install smart meters in all homes in the next 5 years, which will offer the possibility of a variety of rates depending on demand, e.g. during off peak hours, which will help the distribution system to offer load balancing solutions in the future. This upgrade of Veitur Utilities' grid was not initiated as a climate or transportation project, but certainly supports initiatives in those fields and

2.3 Hydrogen Production at Hellisheiði Power Plant

ON Power is participating in a European Union supported project, Hydrogen Mobility Europe (H2ME), alongside Skeljungur, Íslensk Nýorka and Íslenska Vetnisfélagið. The H2ME project aims to distribute hundreds of fuel cell hydrogen cars, vans, trucks and refuelling infrastructure across eight countries in Europe. In the case of ON Power, the company's policy of cleaner transportation is not limited to electricity. By producing hydrogen at the Hellisheidi Geothermal Power Plant, the company takes a fuel-type neutral position.

The hydrogen plant is placed near Hellisheidi power station which is the largest geothermal power plant in Iceland. The hydrogen is being produced via an electrolyser where electricity from Hellisheidi is used in the process. The result of using an electrolyser where the electricity is produced by a renewable energy source is that the hydrogen will also be considered renewable. Figure 9 shows the hydrogen plant at Hellisheidi.

Figure 8: Hydrogen plant, Hellisheidi power plant is in the background

The electrolyser is supplied by Nel hydrogen, a Norwegian company. Figure 10 shows a container similar to the one at Hellisheidi. In the electrolyzer, a direct electric current is led through water. The product of this process is hydrogen and oxygen. After the electrolyzer the hydrogen goes through a dryer unit that is used to purify the hydrogen gas before it goes through a compression unit and thereafter to a storage unit.

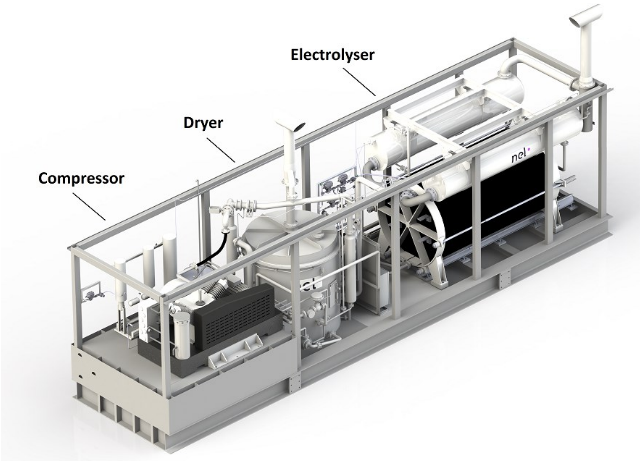

Figure 9: An overview of the electrolyzer container (Nel Hydrogen, 2019)

The electrolyzer can operate from 20% up to 100% of its design capacity, 30 – 150 Nm^3/h (2,7 – 13,5 kg/h). At Hellisheidi, the hydrogen gas is compressed into hydrogen pressure vessels at 200 bar. The vessels are transported in containers, around 200 kg of hydrogen in each container, to three refilling stations where hydrogen is available for end-customers. At the stations, hydrogen is pressurized from 200 bar to 800 bar for refill purposes. The refilling stations are all a part of the flex-fuel stations under the brand Orkan. Two of the stations are located in Reykjavík and one in Reykjanesbær, near Keflavík airport.

Another reason why ON Power is interested in hydrogen production, besides cleaner transportation, is the possibility of combining hydrogen production to the geothermal power production at Hellisheidi power plant at times when it is suitable. The role of geothermal power plants in the electrical system is mainly to produce base-load electricity, while hydropower deals with flexible loads. Currently, ON Power has limited access to hydropower so flexible loads are mainly met via purchases from other producers. By producing hydrogen during low load hours and turning off the hydrogen production during higher load hours, the efficiency of Hellisheidi's power production is improved.

3. FUTURE THOUGHTS AND GOALS FOR THE ENERGY TRANSITION IN ICELAND

The government of Iceland have set their goal to do even better than promised in the Paris agreement by aiming for a carbon neutral Iceland in 2040. They have also set their goal on a 40% reduction in carbon emissions in 2030, with respect to the emissions from 1990. The carbon emission fee will soon be set 50% higher than today and will in the future get even higher with respect to Iceland's plan for climate change (mbl.is, 2017).

Reykjavík Energy has set their own goals to promote the energy transition, including projects of various kinds in both subsidiaries; ON Power and Veitur Utilities. OR has for example set a goal to promote EV's in Iceland up to 40thousand in 2023 and up to 100thousand in 2030. OR envisions its role and responsibility in the energy transition as very important enabler by providing infrastructure that is a prerequisite for making such transition a reality.

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