Impact of energy exchange in Iceland

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Introduction

It is quite possible to exchange fossil fuels for green electricity in Iceland due to the small size of the population and abundance of renewable energy sources. Energy exchange in Iceland would lead to increased need for electricity which in turn would call for strengthening of the electric transmission grid. It would also reduce the emissions of greenhouse gases (GHG) such as carbon dioxide (hereafter referred to as CO_2) as electricity is generated from renewable resources which cause minimal CO_2 emissions (Magnusdottir, Gudmundsson, Sveinsdottir, & Jonsdottir, 2016).

This paper discusses an impact assessment (IA) of scenarios for a developmental plan of the electricity transmission grid in Iceland. The scenarios include different ratios of energy exchange in the year 2030 and the aim of the IA was to extrapolate how much energy demand and CO_2 emissions reduction that would lead to. By energy exchange we refer to the act/scenario where electricity will replace fossil fuels as an energizer.

This project was a part of a strategic environmental assessment (SEA) of a 10-year plan regarding the development of the electricity transmission grid in Iceland, operated by the state-owned company *Landsnet*. The paper covers the background of the project, it touches on the energy environment in Iceland, the approach of the IA and discusses the project's main conclusions.

Landsnet and the 10-year plan

Landsnet's role is to operate Iceland's electricity transmission grid (figure 1) and administer its system operations. The company is obliged to present each year a 10-year plan for the development of the transmission grid and that plan is subjected to SEA. The plan is based on scenarios which describe different energy demand and supply in 2030. Different grid alternatives are then suggested which vary in route and technological implementation (figure 2).

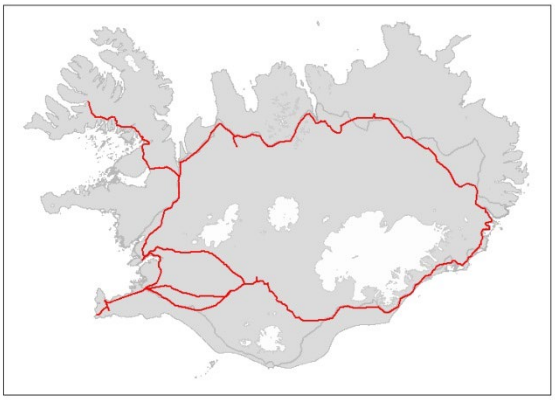

Figure 1. The current main electricity transmission grid in Iceland (red lines). Gray area is land, white areas represent glaciers.

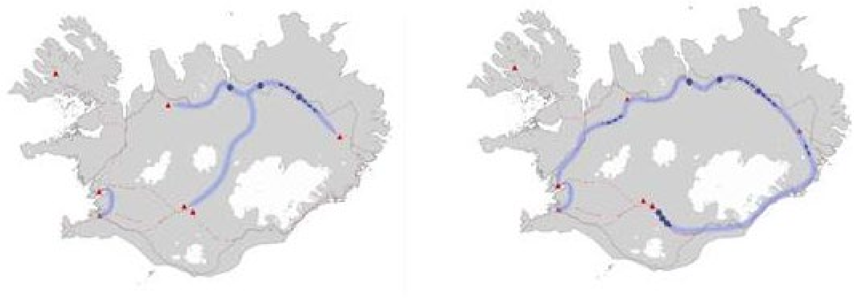

Figure 2. Two main alternatives in the future development of the main transmission grid (blue line).

This is the third time that the plan has gone through SEA but it is the first time the impact on climate change is addressed which was a pioneering effort of Landsnet. The interest and emphasis of regulators, NGOs and the public is more in nature preservation, principally the preservation of the uninhabited central highlands, the opposition of visual impacts and concerns of negative impacts on the tourism sector. Discussion on climate change in IA has been minimal to date. Thus, Landsnet received no comments or objections to the decision last year to refrain from addressing climate change matters due to insufficient data. The main objections and comments that year from regulators, NGOs and the public nearly uniformly regarded the opposition to the idea of taking a high voltage transmission line through the wilderness of the central highlands and concerns that overhead lines could harm the tourism sector by negatively affecting the experience of the tourists.

The approach to assessing the impact of energy exchange

It was not straightforward where to draw the line when deciding what to include in the IA of the transmission grid on climate change. Should we focus on the emissions due to the building and operation of the grid or should we regard the existence of the grid as enabling emissions from power plants on one end and users such as heavy industries on the other end?

We decided to do a bit of both. We calculated the carbon footprint of the grid and presented the results in the environmental statement and will not discuss that here. But we decided to place more emphasis on exploring what the future could possibly bring us with more environmental awareness and efforts to reduce impacts on climate change. What would it mean if so called green or electrified scenarios would come to realization? Would we have enough electricity to meet the demands of energy exchange and would the current and proposed grid on the 10-year plan be able to transmit that energy without many problems?

Scenarios looking to the year 2030 were put forward where different ratios of energy exchange were defined (table 1). Our main concern was to estimate possible energy demand should the energy exchange materialize. That said, it is not for us to say if energy exchange is likely to happen or if it is always feasible regarding technology and cost. The following are categories which we found likely to be able to undergo the exchange, based on available information:

a) Passenger cars, delivery trucks, buses and heavy trucks. The calculations were based on a prediction that expects increased number of cars and average travel distance per vehicle as today. As an example, it is estimated that number of passenger cars in Iceland will be approx. 304,000 in the year 2030 (Brynjarsson, 2013) and that the average travelled distance per car will be 13,000 km/year (Samgongustofa, 2016).

b) Rental cars and buses in the tourism sector. The growth of the tourism sector in Iceland is phenomenal and the latest predictions anticipate 3.5 million tourists in Iceland in 2030 (ISAVIA, 2016). Extrapolated number of rental cars in 2030 is approximately 48,600 and buses 10,500 (SAF, 2016).

c) Conclude the electrification of fish meal factories. Fish meal factories operate by the sea side around the country. Many of them run on electricity today but four of them still run on fuel oil but many parties are interested in electrifying them and thus finish the energy exchange in the fish meal factories sector (Althingi, 2016). In this case, we assume that commitment towards reducing the emission of GHG will override the fact that today it is less expensive to run those factories on fuel oil than electricity.

d) Various machineries in industries. A few aluminum smelters and other heavy industries operate in Iceland. Information on their consumption of fossil fuels for machineries and equipment is readily available and in the project, we assume that it is possible to exchange fossil fuels for electricity. Information on smaller industries is somehow limited and not included in this project. It can therefore be assumed that opportunities in energy exchange in this sector may be larger than shown here.

e) Ships in harbor will be able to connect to the electricity grid. Iceland is an island and ship traffic is considerable. While berthing at docks, the ships need to burn fossil fuels to keep necessary machines and equipment running. It is quite plausible, given an installation of the necessary infrastructure, to offer the ships a connection to the electricity grid and hence reduce the reduction of GHG emissions (Eythorsson, 2016).

Table 1. Proportion of energy exchange for different scenarios.

	Proportion of energy exchange: Scenarios			
Categories	**Business as usual**	**Increased demand**	**Electrified future**	**Further energy exchange**
Passenger cars	25%	25%	27%	100%
Buses	4%	4%	12%	100%
Delivery trucks	17%	17%	20%	100%
Heavy trucks	1%	1%	12%	100%
Rental cars for tourism	0%	0%	45%	100%
Buses for tourism	0%	0%	15%	100%
Fish meal factories	0%	0%	100%	100%
Machineries in industries	0%	0%	100%*	100%
Ships in harbors	0%	0%	100%	100%
Vegetables and flowers	0%	0%	100%	100%

*Limited information available for this category, thus 100% only stands for energy exchange for the fossil fuel we had information on.

The scenarios *Business as usual* and *Increased demand* both include the same ratio of electrification (table 1). The energy exchange in those scenarios only includes transportation on land, excluding the tourism sector vehicles. The scenario *Electrified future* includes partial energy exchange for vehicles on land but full exchange for fish meal factories, machineries in industry and docked ships. The last scenario shows full energy exchange in the categories in question (table 1).

As can be seen in table 1 the ratio of energy exchange varies between types of vehicles. That is due to the fact that technical solutions have not reached as far for larger vehicles as for passenger cars.

In addition, we envisaged a future were Iceland would be self-sufficient in growing tomatoes, cucumbers, salad, peppers and flowers. That would mean increased domestic cultivation and no import of those products which would lead to lesser GHG emissions. Increasing the cultivation of vegetables in Iceland is however not part of the energy exchange as today these products are cultivated in greenhouses heated with geothermal energy and lit by electricity. Nonetheless, when we started this project we tried to foresee how increased environmental awareness could lead to increased electricity demand. The importance of buying locally grown products is recognized today, partly because shorter transportation distances lead to reduced GHG emissions and cultivation of vegetables and flowers requires little supplies for the process. Therefore, we decided to include the calculation of energy demand and GHG reduction from that cultivation in the project.

Iceland could reduce the emission of CO_2 by 32%

Iceland could reduce its emissions by just less than 1.5 million tons of CO_2/year if the energy exchange as described in table 1 would be fully implemented without any new power plants being built. That equals 32% of Iceland's total CO_2 emissions (Umhverfisstofnun, 2016). In order to realize that reduction, we would need to put 660 to 880 MW of electricity from renewable resources into use instead of burning fossil fuels. If it is assumed that the increased energy demand will be met with new power plants, then the estimated emissions from those facilities will be less than 100,000 t CO_2 per year, and thus, the total reduction due to the energy exchange will be equivalent of 31% of Iceland's total emission per year.

Observing individual categories, the largest energy demand comes from energy exchange in the transportation sector (not counting the tourism sector vehicles), followed by the fish meal factories and industry, ships in harbors, rental cars and buses for the tourism sector and finally the self-sufficient cultivation of certain vegetables and flowers. The largest reduction in CO_2 emissions derives from the transportation sector, followed by the rental cars and buses for the tourism sector, ships in harbors, industries, fish meal factories and finally the increased cultivation of vegetables and flowers.

Table 2. Energy demand and reduction of CO_2 emissions for the scenario *Further energy exchange*

	Energy demand at min [MW]	**Energy demand at max [MW]**	**Reduction in emission [CO_2 t/year]**	**Proportion of Iceland's total emissions**
Land transportation	354	483	948,600	21%
Land transportation for the tourism sector	190	260	455,100	10%
Fish meal factories	65	68	12,100	0,3%
Machineries in industry	10	12	12,800	0,3%
Vegetables and flowers	30	38	5,000	0,1%
Ships in harbor	11	16	33,000	1%
Total	**661**	**877**	**1,466,600**	**32%**

Table 3. Energy demand and reduction of CO_2 emissions for different scenarios.

Scenario	**Energy demand at max [MW]**	**Net reduction of emissions [CO_2 t/year]***	**Proportion of Iceland's total emissions**
Business as usual	69	139,100	3%
Increased demand	69	128,500	3%
Electrified future	346	339,600	7%
Further energy exchange	880	1,411,700	31%

*Having allowed for emission from power plants.

The total population of Iceland is only 340,000 (Statistics Iceland, 2017), the country is rich of renewable resources and therefore ambitious energy exchange is viable. It is however clear that it calls for strengthened transmission grid and generation of electricity to meet the energy demand since the current grid is getting old and already poses problems in securing the delivery of electricity to different parts of the country. The proposed alternatives in the 10-year plan would though be capable of meeting the demand (Landsnet, 2017).

It is our belief that by analyzing possible energy exchange in Iceland we have contributed to and initiated further discussion on how to reduce GHG emissions. Also, importantly, we have handed the government a useful tool in decision making for a better future.

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