ENERGY SYSTEM DECARBONISATION

(EE 535)

Assignment 3: NATIONAL ENERGY SYSTEM DECARBONISATION CASE-STUDY

CASE STUDY COUNTRY – ICELAND.

DONE BY: RAFAELA GRACIA NONGRUM

STUDENT NUMBER: 20210341

DATE OF SUBMISSION: 06/12/2021

The energy mix and consumption habits of a country are, in general, a complicated calculation. Cost, resource availability, production efficiency and politics are all major considerations. Even before assessing any estimates for Iceland's Carbon emissions, we already know that Iceland is well ahead of the rest of the world in its race to achieve zero emissions. This is due to the fact that it has the advantage of being able to harness the enormous amount of wind, geothermal, and hydro-energy resources which are freely available in the country. These resources are easily available here due to the country's geology and northerly location, which allows it to have vast access to renewable energy[1]. In 2016, geothermal energy produced roughly 65 percent of primary energy, hydropower provided 20%, and fossil fuels (mostly oil products for the transportation and a few other sector) provided 15%. Iceland became a wind energy producer in 2013.

The country's **geothermal** energy, which is primarily used for space heating, brings several benefits to society. This source of heat is used to heat about 90% of all homes. Swimming pools, snow melting, the aluminium industry, greenhouses, and fish farming are some of the other direct uses. In recent years, there has been a fast increase in electricity demand in the country due to the expansion of energy-intensive industries. This has boosted the development of geothermal power generation, resulting in the construction of new plants as well as the expansion of existing ones [2]. **Hydropower**, which mainly comprises of waterfalls and steams, generates the great bulk of the country's electricity (73.8% to be precise). It uses water instead of consuming it, produces no direct waste, and produces very low amounts of greenhouse emissions when compared to fossil-fuel-powered energy plants [3]. Iceland is without a doubt, the highest utilizer of renewable energy for its electricity generation [4]. Figure 1 shows this generation per capita in 2014 for several countries, where Iceland occupies the position to the top left.[4]

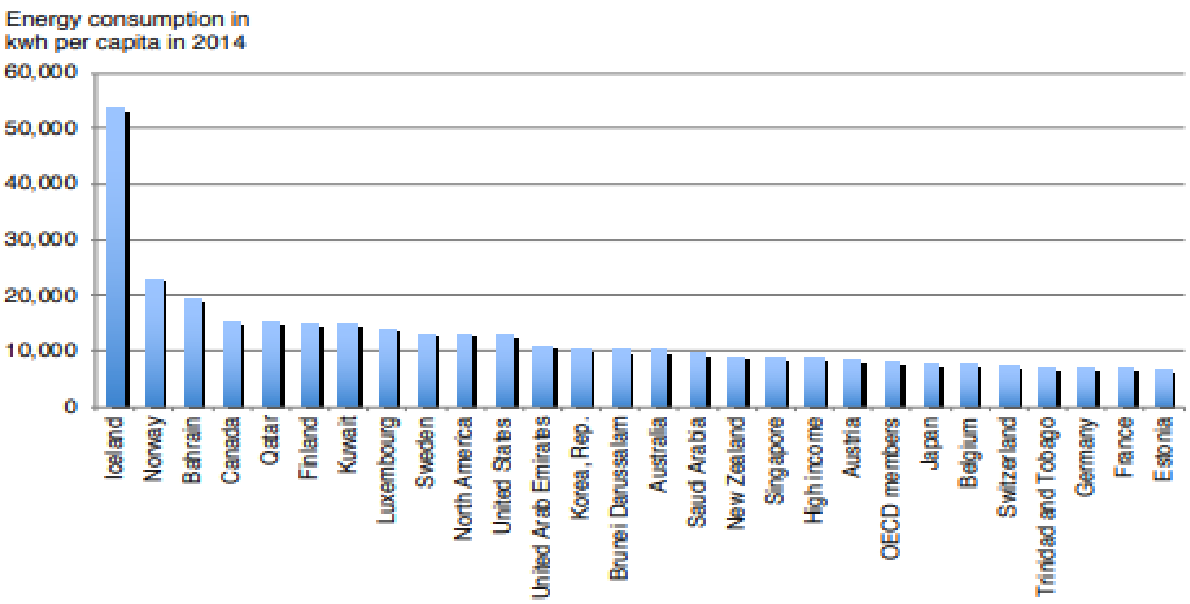
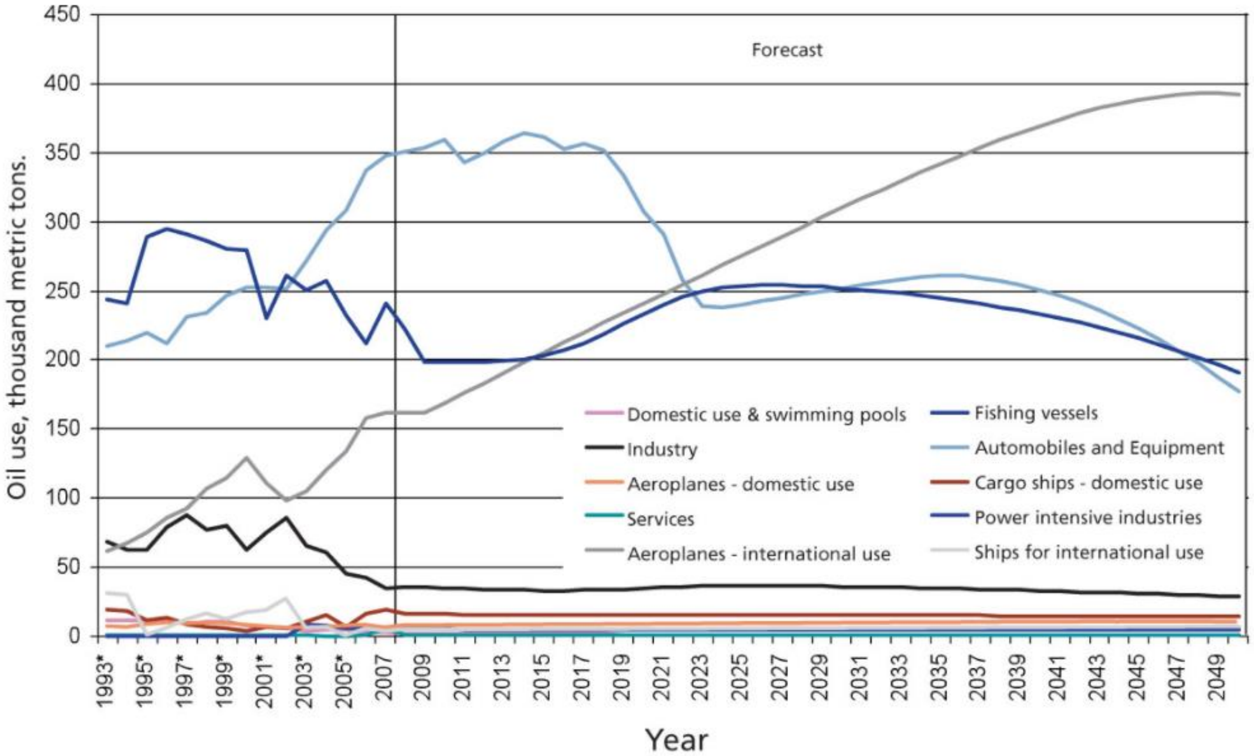


Figure 1 : The leftmost column (Iceland) considerably outnumbers consumptions in any other nation, with 53.83 Mwh/year/capita in Iceland, more than double that of Norway, which is 22.99, and 7.98 for the OECD average in 2014. The figure depicts the top 28 nations and country groupings according to the World Bank [4].

Iceland also has tremendous wind power potential, but, The use **of wind power** for electricity generation in Iceland has so far been limited to small wind turbines for off-grid use. Until recently, there were no large wind turbines in operation in Iceland. Despite Iceland having a favourable climate for wind power , detailed research into the wind power potential in Iceland is quite recent. Thus, Iceland's energy system is pretty stable and energy efficient in my opinion as the heating and electricity which are the most important energy demands, are already taken care of by geothermal(65%) and hydro energy(20%) respectively, the only remaining section of 15% would be to take care of the transportation and industrial sector bit which still relies on fossil fuels. Let us first see how Iceland is making use of the 15% energy source from Fossils for its various sectors.The following chart depicts estimates of the fuel consumption in Iceland for the period of 2008-2050 [5].



The consumption is divided into domestic usage, international transport, and estimated both for several consumption groups and various fuel types. All fossil fuels are imported, with oil accounting for the greater majority of fuel imports. The consumption is much less of coal, gas or alternative fuels such as methane or hydrogen. The forecast shows the share of fossil fuels that is presently being used. It is based on current population, economic growth, fishing, and domestic and international transportation figures and assumptions. The Fuel Forecast has been presented by the Energy Forecast Committee's fuel group, which is a meeting place for several of Iceland's major corporations, institutes, and energy organizations, including Statistics Iceland, the Icelandic Property Registry, and the Ministry of Finance.

In 2007, domestic oil usage (excluding residual oil) was 601 thousand tons, with 228 thousand tons of oil sold in Iceland for international shipping, including foreign fishing ships. Approximately 95% of oil is used for fishing and transportation, as there is no other alternative energy source. The greatest consumption group is **automobiles and machinery**, followed by **fishing vessels**. Fossil fuel consumption is predicted to have plateaued by the end of the forecast period, owing to the availability of new energy sources and saturation effects. International transportation consumption is expected to exceed domestic consumption at the conclusion of the forecast period [5].

In my opinion, a Decarbonised Icelandic energy system would consist of the present system but with a removal of energy use from fossil fuels mainly for the transport system in the country. Of the remaining 176Mt of CO_2 for the high end and 26 $MtCO_2$ for the low end (as calculated in assignment 2), it can definitely reach to zero emissions as this is quite an ample amount for this small country which is so sparsely populated. The amount of energy usage from geothermal and hydro sources should be retained or utilised even more if possible and further studies on available options for wind energy use should be done as well. For getting rid of fossil energy use we can start by first taking care of transportation, particularly automobiles as we have seen that this sector consumed the most amount. Plans can be devised for replacement measures such as using electrified cars, or use hydrogen-based fuel which are further discussed in the next section.

Since There are no public railways in Iceland, although there are bus services. The principal mode of personal transport is the car. The only ways of getting in and out of the country are by air and sea. Hence, it is important to pay particular attention to reducing emissions from planes and automobiles.

The various ways in which Iceland could possibly completely replace fossils for its various sectors are:

First option would be a probable shift to biodiesel in automobiles:

Biodiesel is made of a combination of diesel fuel and vegetable oil. It is a renewable, biodegradable fuel manufactured domestically from vegetable oils, animal fats, or recycled restaurant grease obtained from oilseed rape, sunflower, soy, or palm oil. This oil is converted chemically into VOME (Vegetable Oil Methyl Ester), which is then combined with diesel fuel. Diesel fuel can contain up to 5% VOME, according to European rules. The use of B30 biodiesel reduces CO2 emissions by 18% and particulate emissions by 22%[6]. Biodiesel is a liquid fuel often referred to as B100 or neat biodiesel in its pure, unblended form. Like petroleum diesel, biodiesel is used to fuel compression-ignition engines

Biodiesel use in vehicles

Vehicles that run on biodiesel and conventional diesel are one and the same. Although light, medium, and heavy-duty diesel vehicles are not technically alternative fuel vehicles, they can almost all run on biodiesel blends. The most popular biodiesel blend is B20, ranging from 6% to 20% biodiesel and petroleum diesel. However, B5 (a biodiesel mix containing 5% biodiesel and 95% diesel) is widely utilized in fleet vehicles. A majority of diesel vehicles can utilise B20 and lower-level blends without any engine modifications. Practically all vehicles running on diesel can use biodiesel blends.

Emissions

When utilized as a vehicle fuel, biodiesel can reduce greenhouse gas (GHG) emissions significantly. Sophisticated engine management and exhaust aftertreatment systems have helped to improve today's diesel vehicles' emissions performance. According to studies, emissions from 100% biodiesel (B100) are 74% lower than those from petroleum. The internal combustion engine and components are the same in all diesel vehicles, whether they are biodiesel or conventional diesel [6].

For our second option we can consider the use of Hydrogen as fuel.

Hydrogen, which has already been tried and tested in Iceland is another way of replacing fossil fuels.

Once hydrogen is produced, it generates electrical power in a fuel cell, emitting only water vapor and warm air. It shows great promise for growth in both stationary and the transportation energy sectors. Hydrogen-powered fuel cell electric vehicles emit no harmful substances such as nitrogen oxides, hydrocarbons, and particulate matter —only water (H_2O) and warm air [7].

STORAGE

Hydrogen's energy content by volume is low. This makes storing hydrogen a challenge because it requires high pressures, low temperatures, or chemical processes to be stored compactly. Overcoming this challenge is important for light-duty vehicles because they often have limited size and weight capacity for fuel storage. Typically, the storage capacity for hydrogen in light-duty vehicles enables a driving range of more than 300 miles to meet consumer needs. As hydrogen has a lower volumetric energy density than that of gasoline, storing this much hydrogen on a vehicle currently requires a larger tank at higher pressure than other gaseous fuels. Medium- and heavy-duty vehicles have more space for larger tanks .

COSTS OF PRODUCTION

In order to be competitive in the marketplace, there would have to be a decrease in the cost of fuel cells. Unlike batteries, where the majority of the cost is derived from the raw materials used to manufacture them, the most expensive part of a fuel cell is the making of the fuel cell stack itself—not the components used to manufacture it. For the market to support a hydrogen economy, the cost of building and maintaining hydrogen stations must also be reduced.

An example of transport systems that are powered by hydrogen is the Fuel cell electric vehicles (FCEVs). These are more efficient than conventional internal combustion engine vehicles and produce no emissions—they only emit water vapor and warm air. FCEVs and the hydrogen infrastructure to fuel them are in the early stages of implementation. FCEVs use a propulsion system similar to that of electric vehicles, where energy stored as hydrogen is converted to electricity by the fuel cell. Unlike conventional internal combustion engine vehicles, these vehicles produce no harmful tailpipe emissions. FCEVs are fuelled with pure hydrogen gas stored in a tank on the vehicle. Similar to conventional internal combustion engine vehicles, they can fuel in less than 4 minutes and have a driving range over 300 miles. FCEVs are equipped with several advanced technologies to improve efficiency, such as regenerative braking systems that capture the energy lost during braking and store it in a battery. Major automobile manufacturers are offering a limited but growing number of production FCEVs to the public in certain markets, in sync with what the developing infrastructure can support. Fuel cell electric vehicles emit only water vapor and warm air, producing no harmful emissions and thus are better alternatives.[7]

EXAMINING THE ALREADY EXISTING HYDROGEN USE IN ICELAND

As mentioned previously, Iceland has already tried implementing Hydrogen use for automobiles. The Icelandic Hydrogen and Fuel Cell Company Ltd was established with the sole purpose of investigating the potential for the replacement of the use of fossil fuels with hydrogen. Iceland therefore became a pilot country for demonstration of the hydrogen economy.

The Ecological City Transportation System (ECTOS) was a four-and-a-half-year initiative in Reykjavik, Iceland, that was launched in 2001[8]. The European Commission supported the initiative, which saw three fuel cell buses begin commercial service in Reykjavik as well as the development of a hydrogen refuelling station to provide service to the fleet. The project provided a valuable insight into the practicality of a hydrogen economy in Iceland. During the project's duration, the buses operated for a total of 5,216 hours and covered 89,243 kilometers. Small technical concerns arose unexpectedly but were easily resolved. Under the Clean Urban Transportation for Europe (CUTE) project, ECTOS became a predecessor to similar experiments in other European cities (2001-2006).

The buses in Iceland, were then put to use in the HyFLEET:CUTE demonstration project which was an extension of the ECTOS. It lasted between 2006-2009. Using the lessons learned from past hydrogen bus experiments, the HyFLEET:CUTE project assisted development of hydrogen powered bus technology and accompanying infrastructure. The project initiated 47 hydrogen powered buses (both fuel cell and internal combustion engine) in regular public transport services in the following cities: Amsterdam, Barcelona, Beijing, Berlin, Hamburg, London, Luxemburg, Madrid, Perth and Reykjavik. The project successfully proved the performance of hydrogen-powered buses with both fuel cells and internal combustion engines in public transportation systems across Europe. The project also demonstrated that the infrastructure needed to manufacture, deliver, and distribute hydrogen for transportation can be put in place quickly and without any setbacks. The HyFLEET:CUTE project thus paved a way forward for hydrogen through identification of the existing challenges which are necessary for the future successful integration of hydrogen fuelled public transport.

THIRDLY, WE SEE THE OPTION OF ELECTRIFYING VEHICLES

Electricity can be used to power plug-in electric vehicles (PEVs), which include both all-electric vehicles (also known as battery-electric vehicles) and plug-in hybrid electric vehicles. These vehicles can be charged by absorbing power straight from the grid or from other off-board power sources. Hybrid electric vehicles, on the other hand, run on liquid fuels like gasoline but utilize small batteries to regain energy lost while braking (ultimately boosting fuel economy) [9]. PHEVs can run on off-board electricity, making them a PEV, but they can also run on liquid fuels and operate like a HEV if necessary. Using electricity to power vehicles has the potential to improve energy security and reduce emissions. systems that use fuel cells.

Utilising electricity to power vehicles

One or more electric motors are powered by rechargeable batteries in PEVs. These batteries are charged using grid electricity and regenerative braking energy. Electric vehicles have no tailpipe emissions, but there are upstream pollutants related with energy production. Electricity-powered PEVs are currently more cost-effective than gasoline-powered PEVs, but they are often more expensive to buy.The cost of electricity varies depending on the region, generation type, time of consumption, and access point.

Benefits of Electric Vehicles

There are major benefits involved in using hybrid and plug-in electric vehicles such as improving fuel economy, saving on fuel costs, and reduction of emissions. Hybrid electric vehicles (HEVs) generally use less fuel as compared to conventional vehicles as they use electric-drive technologies to increase vehicle efficiency through regenerative braking. Both plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles (EVs), also known as battery electric vehicles, have the ability to run entirely on electricity generated from natural gas, coal, nuclear power, wind power, hydropower, and solar power.

Costs

Although energy costs for hybrid and plug-in electric vehicles are generally lower as compared to similar conventional vehicles, purchasing them can be more expensive. As production volumes increase and battery technology improve, prices are projected to be similar to conventional automobiles.

Emissions

Hybrid and plug-in electric vehicles can reduce emissions significantly compared to conventional automobiles. The benefits of HEVs in terms of emissions vary depending on the vehicle model and hybrid power system used. When in all-electric mode, EVs create no tailpipe emissions, and PHEVs produce no tailpipe emissions. An EV or PHEV's life cycle emissions are determined by the electrical sources used to charge it, which vary by region. Plug-in vehicles often offer a life cycle emissions advantage over identical conventional vehicles operating on gasoline or diesel in geographic areas where electricity is generated using relatively low-polluting energy sources [9].

This transitional change in use of Electric vehicles may however not be of equal footing for everybody as the vehicles are still quite expensive to purchase and maintain. So this may still need some further analysis to understand how companies can make affordable, mid-range vehicles for everyone to be able to use. Hence, the other two options may me more preferable.

The Aviation sector can also contribute to reducing emissions by using other alternative sources of fuel.

Firstly, it is important to know the type and properties of fuels that can be used in aviation. It is necessary that the replacement is compatible with existing fuel systems, storage conditions and fuel transfer process. The aviation sector uses petroleum-based kerosene which is also called jet fuel. Biodiesel and alcohols are the main alternative fuels that can be created from biomass in internal combustion engines, according to studies, Alcohols (mainly ethanol and butanol) can now be created by fermenting the same raw material that can be used to make biodiesel. Alternative fuels, which are made from the same basic ingredients as conventional fuels, have similar fuel attributes and characteristics. Ethanol or butanol, for example, can be added to diesel fuel/biodiesel mixtures in diesel engines. The amount of fuel consumed by aviation is significantly lesser than that consumed by ground transportation. Alternative aviation fuels should provide significant advantages in relation to feedstock selection, manufacturing processes, and fuel qualities.

The several Aviation fuel conversion and production methods are oil to jet fuel Hydro processed renewable jet fuels (hydro processed esters and fatty acids (HEFA)) and bio-diesel, alcohol to jet fuel (ethanol to jet and butanol to jet), gas to jet fuel, and sugar to jet fuel (fermentation of sugars to hydrocarbons).HEFA jet fuels are produced by the hydrodeoxygenation of vegetable oils, animal fats, waste grease, algal oil and bio-oil and the major side products are water and propane. HEFAs may be used in normal aviation engines without requiring any further engine modifications, and they do not cause any fuel quality difficulties. In engines, these fuels do not develop deposits as well. Owing to their cold flow qualities, HEFAs are beneficial for higher altitude flights. Because of the lack of oxygen and sulphur, their lubricity is poor, but this can be enhanced by mixing with regular jet fuel or adding additional chemicals [10].

In recent years, alcohols have emerged as viable alternatives to internal combustion engines. Alcohols derived from Biomass can be utilized in gasoline and diesel engines and are considered next-generation fuels. Bio alcohols are made from the biochemical and thermal fermentation of carbohydrates obtained by biomass hydrolysis. For the production of alcohol, direct sugar sources are fermented. A variety of biomass feedstocks such as wood, agricultural wastes, forest leftovers, and trash can be used to produce Bioalcohol. For usage in the aviation industry, alcohols require specialized supply infrastructure and storage systems. Due to the high volatility of ethanol and the poor fuel characteristics of ethanol, blending with traditional jet fuels is not a viable solution. Although alcohols have a poor calorific value and a high heat of vaporization, which are significant barriers to their use as aviation fuels, technological advances may allow them to adapt their chemical structures to make them ideal alternatives in the aviation sector.

For alternative fuels, there are a number of challenges to overcome such as environmental challenges, production issues, distribution problems, feedstock availability and sustainability, compatibility with conventional fuel. Of course, the most important obstacle is to protect the environment. Biofuels are the first feasible option for greenhouse gas emission reduction in aviation. Thus, alternative fuels in the aviation sector must meet all aviation fuel standards. Otherwise, the use of such fuels will be limited.

Now in recent times the use of electricity as an alternative fuel source for airlines is becoming more and more relative, it is even now possible to make hybrid-electric aircrafts. A US based company called Ampaire now owned by Surf Air is pioneering the future of hybrid-electric air transportation, this company is creating an alternative energy source for planes in hopes that one day in the future all air transportation will use exclusively electricity. The company promises that their electric aviation can help reduce emissions and noise, it can lower fuel by 90%, maintenance by 50% and noise by 60%. With the use of these new electric airplanes; flights will be more frequent, convenient and affordable. With all these benefits of making air travel electric, the future looks bright on electric air travel in making environmental, humanitarian and economic benefit. Even NASA has taken an interest in turning an Italian Tecnam P2006T aircraft to run on battery power, the aircraft known as the X-57 Maxwell is set to take its first flight in spring 2022, NASA administrator Bill Nelson Armstrong in an interview with The

Verge [11] stated that the technology in the X-57 will be an important milestone in the effort to decarbonizing the aviation industry[11].

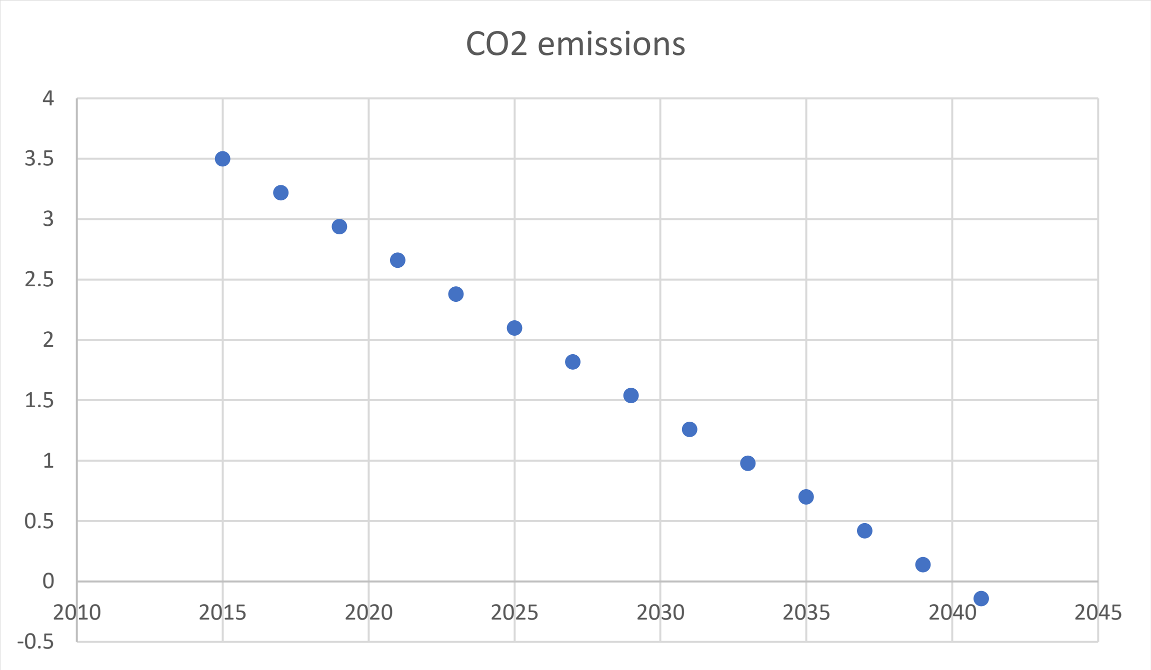
The fifth option that would help in reducing emissions would be to further reduce fossil fuel use in the Fishing sector

Fishing vessels are often the biggest carbon emitters in Iceland, Although there is no current replacement option for diesel use in these fishing vessels , in order to help reduce these carbon emissions, fishing gear design could be used to help reduce these carbon emissions. According to an article by the seafish.org,[12] gear technologist and fishers are working hand in hand to create a more efficient towing system for fishing vessels to reduce drag and this in turn the vessels would produce less carbon emissions. By improving the hydrodynamic properties of fishing gear components fuel consumption can be significantly reduced. Another way of reducing CO_2 emissions is by adopting a hybrid-electric fishing vessel, in 2015 a company in Norway that goes by the name Selfa Arctic built a one-of-a-kind hybrid fishing vessel named the Karoline. This vessel uses two battery packs that holds a capacity of 195 kWh as well as a 500-litre diesel engine which it uses to fish for a full day at the Norwegian Sea. This Hybrid fishing vessel has huge potential in reducing Carbon emissions and also huge market potential. According to the UN Food and Agriculture Organisation, there are around 2.5 million fishing vessels around the world and with the increasing use of hybrid and electric vehicles the market for electric fishing boats will be huge and it will also help decrease the CO_2 emissions indefinitely[13].

The mentioned transitions should be carried out by taking care of one sector at a time and not all at once since it would be really expensive to completely transition all at once. The transitioning for the fishing sector would most definitely be more challenging as there are no current alternatives. It would be advisable to continue with the hydrogen related projects for automobiles as it is already being carried out by the government of Iceland, followed by electrification and then moving forward with the fishing and aviation sectors.

CUMMULATIVE ENERGY SYSTEM CO_2 EMISSIONS ESTIMATE

The government has already set an emission reduction target of 35% by 2030 with an aim to be carbon neutral by 2040, which is ambitious but not unrealistic given Iceland's pioneering status in renewable energy. The Icelandic government have also appeared to be ahead of the mark in relation to hydrogen as the replacement of imported fossil fuels with domestically produced hydrogen or hydrogen-based fuels have been discussed extensively in Iceland.[8]



According to the United Nations Climate Change, [14] Iceland plans to reach carbon neutrality by 2040. In this scenario, for the purpose of my calculations I had used 2015 as the reference year so as to have a common baseline and to make it easier for my Carbon budget comparison with the results obtained in Assignment 2. Taking the total emissions of Iceland in 2015 which was equivalent to 3.5MtCO2, if the cumulative CO2 emissions were to be reduced by just 0.28% every two years, Iceland would easily be able to achieve this goal by 2040. In doing so, the country would still be emitting a total of = 3.22+2.94+2.66+2.38+2.1+1.82+1.54+1.26+0.98+0.7+0.42+0.14-0.14 $MtCO_2$. = 20.02 $MtCO_2$, which is still well below the low proposed CO_2 budget(26$MtCO_2$) from Assignment 2. We can also see and hope for negative emissions just from 2041 itself. This seems to be very advantageous for Iceland's journey to decarbonisation as it still has a lot of the remaining quota available which can be utilised for its transition process.

Comparing the estimate of cumulative emissions with the estimate of Iceland's "fair share" national CO2 quota from the previous assignment, it can be observed that the estimate is comparatively close to what had been calculated. It seems to be very accurate and viable for the case study. I am of the opinion that this is the case because Iceland has already paved a good pathway towards achieving its decarbonisation targets and there is not much left to change. The only remaining portion of the energy system which still depends on non-renewables also has already several proposed options and pathways. Hence, there was not much to add on and very little need for improvement in the country.

CONCLUSION

Iceland's accomplishment does not mean that every country experiencing an energy crisis would be equally as successful. However, developing countries around the world should take inspiration and optimism from Iceland's renewable energy. Environmental variables will dictate which renewable resources are the most efficient and how they will be best used for each individual country, much as geothermal and hydro power generation made sense for Iceland's energy transition. The good news is that the world is very well equipped and more than ready for the upcoming transformation. New and improved technology, as well as better funding strategies, are becoming accessible. Cooperation and knowledge sharing are becoming increasingly simple and fast around the world. A combination of these elements with historical lessons learnt, such as those from Iceland, will show to be a great tool for countries striving to achieve a more sustainable route.

As discussed above, we are aware of what importance transport plays in every day life and that although maximum emissions in Iceland are from automobiles, aviation and fishing vessels, their use is of utmost importance and hence the only other way to support Iceland in its goal to reaching zero emissions is by replacement measures instead.

REFERENCES

[1]"Geothermal Energy Iceland | Everything You Need To Know | Arctic Adventures", *Arctic Adventures*, 2021. [Online]. Available: https://adventures.is/information/geothermal-energy-iceland.

[2]T. Hammons and A. Gunnusson, "*Developments in Geothermal and Hydro Power in Iceland, Europe and Worldwide*" Pittsburgh, PA, USA: International Practices for Energy Development and Power Generation, 2008.

[3]"A Complete Guide to Hydroelectric Power Rivers in Iceland...", *Guide to Iceland*. [Online]. Available: https://guidetoiceland.is/history-culture/rivers-for-sale-the-future-of-iceland-s-nature

[4]E. Hreinsson, "*Harvesting the Benefits of Iceland's Energy Resources.*"School of Engineering and Natural Sciences, University of Iceland, Hjarðarhagi 6, Reykjavik, Iceland.

[5]"Fuel Use Forecast", *National Energy Authority of Iceland*. [Online]. Available: https://nea.is/fuel/forecast/

[6]"Alternative Fuels Data Center: Biodiesel Fuel Basics", *Afdc.energy.gov*. [Online]. Available: https://afdc.energy.gov/fuels/biodiesel_basics.html

[7]"Alternative Fuels Data Center: Hydrogen", *Afdc.energy.gov*. [Online]. Available: https://afdc.energy.gov/fuels/hydrogen.html

[8]*Ecological City Transport System (ECTOS) Reykjavik and Beyond*. Availablr : http://www.seafuel.eu/wp-content/uploads/2021/02/Iceland-Case-Study-Final-1.pdf

[9]"Alternative Fuels Data Center: Electricity Basics", *Afdc.energy.gov*. [Online]. Available: https://afdc.energy.gov/fuels/electricity_basics.html

[10]N. Yilmaz and A. Atmanli, *Sustainable alternative fuels in aviation*. Washington DC, USA, 2017.

[11]"NASA's tiny electrical aircraft is almost ready for lift-off", *The Verge*. [Online]. Available: https://www.theverge.com/2021/10/21/22738351/nasa-x57-maxwell-electric-airplane-bill-nelson-interview

[12]"How fishing gear design can help reduce carbon emissions | Seafish", *Seafish*. [Online]. Available: https://www.seafish.org/responsible-sourcing/climate-change-and-the-seafood-industry/how-fishing-gear-design-can-help-reduce-carbon-emissions/

[13]*The state of world fisheries and aquaculture*. Rome: Food and Agriculture organization of the United Nations, 2016 [Online]. Available: https://www.fao.org/3/i5555e/i5555e.pdf

[14]*Www4.unfccc.int*. [Online]. Available: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Iceland%20First/Iceland_updated_NDC_Submission_Feb_2021.pdf