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Literature Review: Hydropower and Iceland's Environment

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Abstract

This paper seeks to answer the question: To what extent do hydropower plants affect the surrounding environment? Through a literature review and personal accounts found on blogs and website articles, there were many conclusions that came from this research. A review of literature indicated that use of hydropower influences the ecology around the plant. The power plant's redirection of the river's water flow and reservoir submergence cause many problems for the surrounding environments. Hydropower plants can change the landscape due to the fact that the water they use is no longer providing the right nutrients to the previously flourishing landscape as a result of the rerouting of rivers. Specifically, the hydroelectric power plants affect soil sediment around the plants, destroys habitats, impacts certain fish migration patterns, and ruins water quality. The plants were also found to uproot flora, change the sediment content and cause erosion, disrupt nesting grounds, and change whole migration patterns of some birds. These factors all contribute to the negative effects of hydropower on the nearby ecosystems. Research has identified that the change caused by the redirected and distributed water flow affects animals and vegetation in the adjacent areas and, eventually, leads to the destruction of habitats. The researcher briefly researched how this could affect eco-tourism, which was found to be quickly growing and a huge part of Iceland's economy. These affects also play a negative role in Iceland's nature tourism industry, as it is changing much of the wildlife sought out by these tourists.

It must be stated above all that plants do have a great negative effect on the environment and surrounding ecology.

How can this problem be mitigated? A few suggestions made were to move the plants to more isolated countries or implement nature preservation programs directly correlated to the plants. There have been few speculations on how to mitigate the effects of the power plants on the animals that reside in the water areas around the plant. One of the suggestion is to make "small adjustments to river flow regimes might help to restore river ecosystems" (Poff & Schmidt, 2016).

Further research also suggested since not many studies were conducted on this topic, especially ones that were originally written in English.

Introduction

As renewable energy becomes more vital to the conservation of the planet, it is becoming more popular with many countries. However, the utilization of renewable energy, in all forms, is still being assessed for the level of environmental impact it will have on surrounding areas. Iceland is one of the countries that has wholeheartedly transitioned to renewable energy with both geothermal energy and hydropower. This paper will specifically address the question: To what extent do hydropower plants effect the surrounding environment? This question is vital because the vast majority of Iceland's use of renewable energy is in the form of hydropower.

In order to answer this question, the researcher performed a literary analysis; this analysis was based on a review of 12 articles found in publications, journals, and books. The articles are categorized into four themes: effects on flora, fauna/sediment, tourism, and the social implications of the hydropower plants.

Hydropower Background

According to The Independent Icelandic and Northern Energy Portal, almost 100% of all Iceland's electricity consumption is produced by renewable energy resources, mainly hydro- and geothermal power. Close to 85% of all Iceland's power is produced by hydro- and geothermal power. Out of all the electricity produced, 73% comes from hydropower (The Energy Sector, 2017). This data shows the essential role that hydropower plays in the everyday life of the Icelandic people. The plant's employs many natives and supply all of Iceland with need electricity and heat for the harsh climate.

Fauna/ Sediment

The indigenous fauna is even smaller, major highlights are the arctic fox, pink-footed geese and, mink. Of the most popular species in Iceland is the Atlantic Salmon, which is a very widely known fish to catch and eat (ThÃrhallsdÃttir, 2007).

Much of the wildlife mentioned above, depends on rivers for their source of water, food, and habitat. When the river flow direction, hydrological continuity, or levels, are changed for the hydropower plants, it affects the wildlife directly and indirectly. At and below the dams, the sedimentation, hydrological continuity, and river flow patterns can be changed or disrupted. Other environments connected to the rivers, such as riverine and coastal wetlands, may also be impacted. These changes can start coastal erosion and affect the nearshore environment through chemical and biological change. The change in water flow creates very muddy or very dry areas in places that use to be the exact opposite. Polluted groundwater and, as a result, the endangerment of the Icelandic people's famous fresh water, is also a potential result (ThÃrhallsdÃttir, 2007).

Because of these changes, the spawning grounds of fish stocks, such as salmon -- very important to the Icelandic economy – may be threatened (ThÃrhallsdÃttir, 2007). This article does not address the direct effects that the hydrological changes have on the Atlantic salmon; however, this paper will take data from other areas and make assumptions about how they are affected in Iceland. Many of the common effects that hydropower plants have on the Atlantic Salmon population is drying up of riverbeds, stranding fish with the change of water flow, and smolt, adolescent salmon, mortality because of migrating through turbines (Aas, 2011). As the water levels are low during the winter this increases the chances of the salmon eggs to be stranded and high-water levels in the spawning season also contribute to stranding. The negatives

effects on the spawn and the eggs have a hugely negative effect on the overall population of the Atlantic Salmon.

Along with changing the water levels and flow within the spawning grounds of the native Icelandic fish, hydroelectric power stations can drastically change the temperature of the water. The change in temperature can also impact the adult salmon and their survival. An example of this phenomenon can be seen in Norway. Rivers that are below the power plant located in Norway can be 1-5 degrees Celsius lower in midsummer and 0.5-2 degrees Celsius higher during the winter (Aas, 2011). An example of a body of water that has seen flow and temperature changes due to a nearby hydropower plant is Lake Lagarfljót. According to an article published by the University of Massachusetts at Amherst, the lake experienced, "Increased volumetric flow (less seasonal fluctuations) – higher water level – decreased lake retention time, increased turbidity due to increased inflow of glacial water with higher suspended solids, decreased mean water temperature (about 0.5 – 1°C)," and decreased productivity (Jonsson, Gudbergsson, Gudjonsson, & Arnason, 2017).

Although one could measure the change in the environment by tracking the change in temperature or the change in the flow, these methods might not show the direct impacts that the plants have on the fauna in that specific body of water. One way to specifically tell the negative effects of the fauna in a body of water is by looking at specific organisms that can show the overall health of the body of water through their health. We do this by looking at these organism's: richness/diversity, rarity, size, completeness, pristineness. This method of environment evaluation can be seen in a study that looked at two hydropower developments: Skatastadir and Villinganes. Through this assessment of looking at these organisms, the study found that both versions of hydropower utilization lead to the whole area was placed into

conservation category mainly because of the: "Impact of the larger version [of the dam] would destroy the catchment area above the dam [and] the impact of both potential developments on species (fish, aquatic invertebrates, plants, and birds) below the dam (the flood plains) would be very great, as such floodplains are now rare in Iceland" (Gíslason, Skúlason, Eiríksson, & Einarsson, 2017).

Flora

The Icelandic flora is comparatively small. It is comprised of 480 indigenous vascular plants and 600 species of moss (ThÃrhallsdÃttir, 2007). The flora in the areas around the power plant are impacted in two ways: with a reduction and fragmented effect on the hydro-flora and also it opens up areas for the encroachment of terrestrial flora into lands that was formerly a floodplain and a decline in wetland vegetation, due to the decrease in water in certain areas in order to increase water levels in others (Gracey & Verones, 2016).

Unfortunately, this change in flora can impact many of the terrestrial animals that eat these plants, mentioned above in the fauna section. The change in habitat around these plants would also change migration patterns and nesting ground locations for the pink-footed geese and reindeer. This is not only a loss for the environment but for eco-tourism as well. Below, in Figure 1, shows an image of the pink-footed geese migration. As one can see, Iceland is a very important and frequently visited spot of their migration and changing their usual environment could be very detrimental to their survival.

Figure 1: Pink-footed goose migration (Mere, 2017)

Social Implications

Along with the pure environmental impacts that the power plants can have on a surrounding area, the plants can also bring about major social conflicts. Although hydro-power can seem like a good idea from an environmental standpoint, there are many underlying issues that might not be foreseen right away. Many times when a new plant is in the process of being established, citizens that don't agree with the implantation often will protest or boycott the plant. Some others don't see a problem with the plants, especially if considered at a surface level, the plants seem all positive. These split ideals can cause harsh social divides and conflicts.

Since this topic can come with much conflict, an outline of the key governmental and social events can shed some light on the social impacts of the plants. According to the global nonviolent action database, in December 2001, Iceland's prime minister overturned the rejection of the hydropower project which brushed over major negative environmental impacts. After the minister rejected this there were many protests across the country. One very influential protest

was by an Icelandic singer's mother who would on a hunger strike for 10 days. In 2003, 63 candles were lit outside of Reykjavik parliamentary buildings. 54 of the candles are blown out to represent all the people who did not vote against the project. These protests carried slogans such as "stop destruction now". Some of the protest groups even stopped construction on some of the sites while others protesters went to the 10th annual World Aluminum Conference in Reykjavik. These protesters were joined by the "stop! group" and other influential people within the Icelandic community. The total number and attendance was more than 5,000 people ((Muth, 2003).

A statement from a protestor and environmentalist Susan De Muth can help capture the sadness that Icelanders feel when thinking of the power plants:

> "We gathered on high ground overlooking the construction site. Bulldozers crawled across the scarred sides of Karahnjukar mountain, their distant rumble interspersed with birdsong. We could see the famous Dimmugljufur canyon, Iceland's Grand Canyon, which will be partially destroyed by the dam. The southern part has already been demolished and the northern stretch, carved by the river through time, will become dry" (Muth, 2003).

Economic Value

Just as the power plant installations can cause social turmoil, they can also impact the economy in multiple ways. An economic approach can also be taken to look at how the citizens “value” the area in which the power plant is to be established.

Economic Value Assessment

By looking at how the power plants impact the environment, one can look at the economic value of an area as well. According to Costanza et al. (1997), "The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly,

and therefore represent part of the total economic value of the planet." This article has quoted the biosphere at a value of USD 16-74 trillion (Costanza et al., 1997). Since this is a dated source, thus resources have been further depleted and with inflation, the value has gone up.

It is important to assess the impacts of environment-changing implementations from all angles and the economic approach is one of them. It is also important to look at the civilians' willingness to pay (WTP) for the preservation of the area around the newly established power plants. According to a study done in Iceland and run by Cook et al. (2018), the researchers used a "contingent valuation method to estimate willingness to pay for the preservation of two high-temperature geothermal fields likely to be developed in the near future: Eldvörp and Hverahlíð." Although these are geothermal sites, the same idea can be applied to the willingness of civilians to pay for the preservation of hydropower plant areas. Cook et al. (2018) applied "interval regression using log-transformation" in order to predict WTP for the preservation of the geothermal fields mentioned above (Cook, Davíðsdóttir, & Kristófersson, 2018). They found the estimated mean of WTP to be $8,333 and $7,122 Icelandic Krona (ISK) for Eldvörp and Hverahlíð respectively. The researchers did further extrapolation of the data and found, through using the population of Icelandic taxpayers, that the estimated total economic value of 2.10 and 1.77 billion ISK respectively (Cook, Davíðsdóttir, & Kristófersson, 2018). The results from this study can affirm that the economic value should be taken into consideration when making decisions on when and where to place new renewable energy plants.

economic legislative implementation.

The Organization for Economic Co-operation and Development (OECD) is an organization to help stimulate economic progress and world trade. The OECD wants Iceland to run more cost-benefit assessments, to better assess what environmental impacts future energy

projects might have on Iceland's natural landscape (Cook, Davíðsdóttir, & Kristófersson, 2016). According to Cook et al., "failure to value economically the environmental impacts of energy project proposals leads to the monetary gains of projects being compared against the entirely qualitative nature of their environmental impacts." By comparing monetary gains to qualitative natural impacts, this can provide a skewed idea of how the plants would truly impact the environment. There is also a risk of untrue conclusions from cost-benefit assessments when developers of these plants are involved in the assessment process (Cook, Davíðsdóttir, & Kristófersson, 2016).

Cook et al. have suggested that Iceland adopts the "imposition of legislation requiring an independent preparation and submission of a cost-benefit assessment to decision-makers" (2016). By applying a standardized policy system, cost and benefit proposals would limit the room for interpretation and better inform the public. Once this standardized policy is established the public will have a consistent idea on how exactly the plants will impact the environment in the future. This is important for the public to have access to so that citizens will be able have an informed vote when deciding if establishing a plant in an area will ultimately have benefits. This policy would also hold contractors and government official accountable for the decisions they make regarding plant implantation, ultimately having all the possible environmental impacts, qualitative and quantitative, at their disposal.

There are many upcoming valuation studies on the geothermal areas of Hverahlíð and Eldvörp in Iceland. These studies will help illustrate a "carefully conceived methodology that could be applied to a future Icelandic energy project"(Cook, Davíðsdóttir, & Kristófersson, 2016). Most of these studies will occur in remote areas, which means that "their total economic value may derive from non-use value" (Cook, Davíðsdóttir, & Kristófersson, 2016). In all cases,

it is important to perform some kind of value analysis to determine the economic and environmental impacts of the power plants.

Tourism

Most of Iceland's major attractions are the untouched natural areas of the country. Just within the past 10 years eco-tourism became an established industry that is one of the main economic drivers for Iceland. In 2009 Iceland attracted 464,000 tourists, but by 2017, Iceland had grown its tourism population to nearly 1.8 million and the growth is still climbing (Moore, 2017). However, it could become a concern if the nation continues to build power plants and piping. These could permanently change landscapes that haven't even been built on or just through the trickle-down effect from changing the waterways. This paper does not delve into how much the change in the environment could change eco-tourism, however, for further investigation could be a great topic.

All forms of sustainable energy can have an impact on the environment around them, therefore impacting the views that tourists come to see. An article published in the *International Journal of Sustainable Energy*, talks about how wind turbines have an effect on tourism in Iceland. Although the article is not directly addressing hydropower plants as the mechanism of renewable energy, it speaks to the consequences of all forms of machinery that must be established within Iceland's pristine environment for energy production. The researchers take into consideration the "size and proximity of wind turbines, and the landscape in which they are situated" (Sæþórsdóttir, Olafsdottir, & Smith, 2017). These considerations are interesting because maybe if the size and the proximity to humans was a respectable size and distance, it might not affect tourism. However, the study found that, "one-third of the travelers would be less likely to visit the Southern Highlands if a proposed wind farm were built, and two-thirds think

that wind turbines would decrease the area's attractiveness" (Sæþórsdóttir, Olafsdottir, & Smith, 2017).

Positive Effects

Although this paper focuses mainly on negative aspects of the hydropower plants in relation to the environment, there are many positive effects that must be considered. Not only does the use of hydropower decrease greenhouse gas emissions and provides modern technologies with a renewable energy source, it can help the environment around it.

One example of the positive effects that the hydropower plants can have on the surrounding environment is the River Blanda. Before the hydropower plant was established in this river the flow of the glacial river was unstable, high during the summer and then low in the winter. It also had unstable turbidity which is the cloudiness or haziness of a fluid caused by large numbers of individual particles (Gíslason, Skúlason, Eiríksson, & Einarsson, 2017). Both of the fluctuating flow and turbidity of the river caused low productivity. After the hydropower plant was established, researchers saw less fluctuating flow and less turbid water. These conditions, causes by the hydropower plant, actually improved migratory conditions for the fish due to higher visibility and stability within the river. In turn, this increased the Atlantic Salmon's population density in the river (Gíslason, Skúlason, Eiríksson, & Einarsson, 2017).

Conclusion

After reviewing available resources, it is clear that there are many negative effects that come from the installation and utilization of hydropower plants on the ecology surrounding the plants. It affects many of the flora and fauna in the area, which in turn, affects other flora and fauna that depend on the others for food and/or competition. Beyond the ecological issues, hydro power also creates major social and political problem within Iceland, such as the protest in the

early 2000s, which remain relevant today. It can also be deducted that since much of Iceland's tourism is ecotourism, the changes that the power plants cause in the environment, could have a major impact on Iceland's tourism industry. When considering the environmental impact, it is also important to look at the economic side. Although there are negative effects, through this study, the researcher found there are also some positive environmental impacts of the hydropower plants. In some cases, the hydropower plants can help limit the change in the body of water which reduces flow and turbidity, which in turn helps increase productivity and population of the freshwater fish.

Even though there are some positive effects, the negative impact might outweigh the positive impact the plants have on "clean" electricity. Some suggestions that could be made are to move the plants to Greenland, which is more isolated and would affect less flora. Another suggestion is more politically driven and could stop the protests. The government could implement nature preservation programs that are directly related to the power plants and could create somewhat of a 5-year plan to keep Iceland a mysterious, wonderland forever. Further research in this area is needed to provide a more comprehensive analysis of the effect so the plants on the environment around the plants.

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