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The Power of Water: A Study on the Integration of Geothermal and Glacial Resources in Iceland

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Abstract

Iceland's unique geographic location provides the people with one main source of energy to keep them powered: water. Iceland can harness the energy from both geothermal and glacial water sources providing a sustainable lifestyle influenced further by the country's culture. The water sources also provide a stable industry and economy for the population. Although easily accessible and plentiful, the water-based energy sources are carefully planned and constructed to prevent negative environmental impacts. Through a qualitative approach, research was conducted through field observations in country, interviews with natives, and through secondary accounts. These key water sources in Iceland essentially power the whole island. Future studies can be conducted as to the continued impact of these water sources, outside of Iceland. Future topics can include Iceland's energy grid contributing to the number of outside investors and joint ventures occurring in country, further environmental effects of harvesting hydropower, and a projected study on how the nation would survive without using hydropower.

BACKGROUND

Iceland is a beautiful country overflowing with incredible natural wonders that provide unique opportunities for the people. This research focuses on the power of water and its impact on Iceland's people in their lifestyles, economy, and the environment. Specifically, the researchers seek to identify and understand the numerous ways Iceland utilizes and protects the plentiful, natural water resources available in their daily lives and commerce. As a result, additional environmental factors were discovered that directly affect the sacred, source of energy for the people of Iceland.

Through qualitative research conducted in country, the importance of water on the well-being of individuals, businesses, and the environment by conducting interviews and collecting artefacts were witnessed through field observations. Iceland needed to begin developing a stable flow of energy to use throughout the country. Much of their energy depended on non-renewable sources, until the turn of the 20th century, where a local innovator built the first hydropower plant. This marked a historical milestone for Iceland as they took steps in stabilizing their economy and decreasing their dependence on petroleum and coal.

METHODOLOGY

Research was collected in country through Rapid Qualitative Inquiry (RQI) by conducting interviews and collecting artefacts through observations. Triangulation aids in identifying relationships, similarities and differences in the data collected in country relative to the information gathered in the literature review. Observations were constantly collected throughout travels in bus rides, transect walks through cities visited, and planned excursions. By visiting various renewable energy plants, companies, and businesses, supplemental research was provided through informative tours, videos or displays. This also led to opportunities for interviews with experts in the field, employees, business owners and a random population sample of Icelanders.

Interviews

The population chosen to interview were people born, living, or working in Iceland who are from various vocations and backgrounds. Participants were chosen as an opportunity to interview was presented, such as in restaurants, shops, museums, businesses and industries. By doing so, responses were varied and provided a detailed understanding of how water impacts the individuals of Iceland through different perspectives and lifestyles.

The interviews consisted of open-ended questions that led to unscripted, probing follow-up questions. Responses were recorded by hand and documented within field journals.

Questions included:

- On average, how often do you use any type of geothermal heated water sources?
- How does geothermal water impact your daily life, such as in a positive or negative fashion?
- How important are geothermal and glacial water sources, such as geothermal heated pool or glacier drinking water?
- What are some benefits or advantages associated with the water sources?
- Do you encounter any difficulties or disadvantages with the water sources?

Significant interviews conducted in country included the Educational Travel Adventures (ETA) trip leader, ON Orka

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Náttúrunnar tour guide, Flúðasveppir Farmer's Bistro owner, Friðheimar Greenhouse employee, and a Sólheimajökull glacial hike guide.

Artefacts

Field observations and collection of artefacts, such as photographic and video evidence, were gathered in country during travels. Personal observations were transcribed in field journals. Points of interest were chosen by the trip leader, Baldur Gylfason with ETA, based on student research topics. Places visited include, but are not limited to, local historical museums, energy production plants, national parks, environmental landmarks, and local businesses.

Literature Review

Initial research was conducted before departure in the form of a literature review, in order to evaluate the current, published findings surrounding the research topic. Various resources were utilized to gather sources of information to provide a foundation of knowledge to establish the research question and prepare for research in country. The literature review explored published research, in order to determine any gaps that the posed research question intends to fill. Published works reviews include studies conducted on the tourism sector's consumption of energy and their need for efficient solutions, and connections to sustainable energy use to the economic and public demand.

LIFESTYLE

The Icelandic resident's way of life is heavily impacted by water. Both geothermal-heated and hydro-powered energy is adopted into the routines and everyday lives for the people living in Iceland. Geothermal-heated water sources, do not only create energy to use to power homes but also provide constant warm water for bathing and recreational purposes. Because water is so easily accessible, swimming pools have become an integral part of Iceland's culture, contributing to both their physical and mental health.

Sustainability

Iceland's resources provide a unique opportunity for the people of Iceland to easily live a sustainable lifestyle. Powered mostly by geothermally-heated water, energy costs remain low and allow constant access to hot water. Water is further utilized within the home from showers to nourishment. The people take full advantage of the resources available from energy consumption to personal water usage.

Geothermal energy sources and glacier water sources provide a sustainable lifestyle for Icelanders, unlike any other country. Geothermal sources allow cheap energy costs and constant access to warm water. Ragnheður Georgsdóttir, the owner of Fluda Sveppir Farmer's Bistro, boasts of the extreme amount of water consumption required to operate her mushroom farm (Georgsdóttir, personal communication, 14 Mar. 2018). The farm alone utilizes one of six water outlets

drilled to access water in the area surrounding her farm; but she explains how important the access to water is for farming to nourish and grow crops, especially within Iceland's harsh environmental conditions (Georgsdóttir, personal communication, 14 Mar. 2018). Although energy costs are drastically lower compared to other countries, she must still be mindful of her energy consumption. She explained how "the power company rises prices to a 50% markup during the winter time" but only throughout the day, so to counteract she turns off all water access at 11 am (Martorella, personal communication, 14 Mar. 2018). The geothermal energy product and water resource is essential to keep the Fluda Sveppir farm operating.

Geothermal water is used in itself within the home mainly for bathing purposes. Showers are actually regulated to cool down first, before entering, as the water enters the pipes nearly scalding hot from the geothermal sources. The regulator tank has to cool the water down to an acceptable temperature and then can be adjusted to preference. On the other hand, the geothermal water is never used within the kitchen to prepare food due to high sulfuric levels. Baldur told a story of his childhood and how he was constantly reprimanded as a boy to never use the water to clean the silver, since the sulfuric warm water tarnishes metal and ruins the finish on the precious silver utensils (Gylfason, personal communication, 16 Mar. 2018).

However, as a commodity, glacier water is drinkable from the tap. One thing to note is that water from the glacial sources must be chemically processed, but not for traditional reasons. The water is actually too pure and must be processed to add essential minerals and natural elements. Because glacial water must have minerals processed into it, prolonged drinking of unprocessed raw glacier water will cause drinkers to become sick due to lack of vitamins and minerals. At the bare minimum, it must have magnesium or calcium in it, as indicated by a glacier hike guide, Nicco Segreto (personal communication, 15 Mar. 2018). He explained the need to carry packs of magnesium when hiking or camping on the glacier in order for the resource to provide the nutrients needed from water (Segreto, personal communication, 15 Mar. 2018).

Swimming Pools

Because of the vastly available water sources, Icelanders have developed a swimming pool culture. Icelanders all over the country have access to community pools and every Icelander interviewed expressed their love for the pools in the same demeanor. For most, they describe their relationship to the pool as a resource to better both their physical and mental health. Currently, there is an estimated 177 swimming pools located across Iceland; pictured below, in Photo 1, is a hot spring pool located in Hófsos built into the hillside and above the sea providing one of the most spectacular views of the ocean's edge.



Photo 1: Hófsos hot spring swimming pool.
(Wes Lewis, photograph, 12 Mar. 2018)

Not all of the swimming pools constructed are as beautiful as Hófsos, their purpose remains the same. are much warmer, naturally heated to about 27°C up to about 42°C. The pools are used every day in Iceland and all ages can enjoy them. In the city of Akureyri, their community pool comprised of nine separate pools: one Olympic sized training pool, one central pool, a kid's splash park and shallow pool, an indoor pool, three slides with a pool below, three hot tubs and one freezing pool (Martorella, personal communication, 11 Mar. 2018). An Icelandic woman interviewed on the street is a lifeguard at the local pool and explained how everyone enjoys the pools and frequent them regularly (Martorella, personal communication, 15 Mar. 2018).

The pools are also considered a social environment for kids to play, teenagers to hang out, and for others to meet and talk with the people in their city. Baldur Gylfason explained the typical interactions Icelanders have in the pools, which show similar signs to the relationships Americans make within the gym. Most people develop a routine when visiting the pool, such as the older seniors visit every day opening, whereas the kids and working adults will visit later after school or work. Because of their routine, they will make friends with those who come at the same time, but their friendship doesn't translate outside of the pool. And although most Icelanders are mostly shy and reserved, when at the pool they will talk or even argue with strangers on topics from the weather to politics (Gylfason, personal communication, 16 Mar. 2018). Many of these scenarios could be compared to the social aspect of the gym.

In regard to health, the pools serve a resource to better both physically and emotionally. The pools offer an outlet for physical activity through swimming laps or water aerobics. In the Akureyri city pool, a kid's area included a playground for kids to run and swim to play in. Most pools have a wet steam room where one can sit and sweat out impurities and refresh the skin from the freezing environment. The most interesting method for promoting health didn't involve physical fitness but

emotional stamina. A soccer player interviewed in a local pool explained a mindful process to test one's mental capabilities, a process he enjoyed practicing after training. After soaking and relaxing in the hottest hot tub, the soccer player moved to the sub-zero freezing pool and sat for a few minutes. He explained by immersing your body into the cold, you train your mind to ignore the temperature and shivering and just sit. He joked that after some time, you can trick your mind and actually feel warm (Soccer Player, personal communication, 11 Mar. 2018)! By doing this process, he was exercising his mental capabilities to resist the common reaction

ECONOMY

Iceland's economy is largely positively affected by the available renewable energy sources. These resources are popular with the general tourist population, overseas investors, and even the locals who are looking to seek an economic advantage.

Tourism

For the past ten years, Iceland has managed to recuperate itself from the 2008 Financial Crisis with a steady growth rate, coupled with a low inflation rate. The effects tourism has on the economy is large. As the number of tourists increases each year, so does the "strain on infrastructure" (Arion Bank, 2017). With more foreign currency being introduced to the country, the exchange rate of the króna, Iceland's currency, is also being affected. Typically, with the króna being higher in the general exchange rate compared with other currencies, this seems to show a "shortened...length of stay and [has] affected consumption patterns" (Arion Bank, 2017). The common sights to see in Iceland are based on Iceland's naturally occurring phenomena, nearly all of which involve water.

Asides from viewing the aurora borealis, also known as the northern lights, many tourists invest heavily on going to the hot springs, waterfalls, and glaciers, all scattered around the island. Many tourists even include them primarily in their tour packages when paying for a group trip or tour in the island. Even general access for a general adult visitor to the Secret Lagoon in Fludir, which is located in the Golden Circle area is 2800 ISK, approximately \$28 USD (Vargas Esposito, personal communication, 15 Mar. 2018). Tourist locations such as this one will have the prices set higher to bring in more money for the nation. As a comparison, the entrance for a local swimming pool in the city of Akureyri costs about 950 ISK, estimated to be \$9.50 USD (Vargas Esposito, personal communication, 11 Mar. 2018).

Locals with the proper land, investments, and certifications, can put their efforts into creating an attraction or service that will entice tourists to flock to Iceland. An example of this would be the handful of glacier hiking companies that offer tours to people who wish to scale glaciers and icy trails (Arcaham Glacier Tours, n.d.). Other attractions include the famous tomato farm, Friðheimar, and the only the mushroom farm on Iceland. Both agricultural attractions of the island were

established by locals to be toured about as well (Vargas Esposito, personal communication, 14 Mar. 2018).

Electricity

Iceland's water sources power the country through hydropower and geothermal plants. As naturally flowing water and glacial run-off water charge through rivers, hydro power plants use the mechanical energy produced there to power their surrounding cities. An example of a plant such as this is one owned Landsvirkjun in Ljosafoss.

Geothermal power plants, such as Orka Náttúrunnar's (ON Power, n.d.a) Hellisheidvirkjun power plant, take advantage of the heat produced by the Iceland's geography. The process is done using high powered drills and taking the steam from the high heated water to produce power. The power plant has direct access to the source of geothermal water and tasked with the distribution of geothermal water to the surrounding cities (Martorella, personal communication, 14 Mar. 2018). Below in Photo 2 is a cross-section of pipe used to transport the geothermal water throughout the city of Reykjavik from the Hellisheidavirkjun Power Plant.



Photo 2: Cross-section of pipe used to transport geothermal-heated water throughout Reykjavik from Hellisheidavirkjun Power Plant. (Julianna Martorella, photograph, 14 Mar. 2018)

This energy from the above-mentioned plant alone, produces 303 mega Watts of electricity and 133 mega Watts in thermal energy, and combined with all the other power plants, Iceland's produced electricity is in excess (ON Power, n.d.a). The United Kingdom has recently put into reconsideration in constructing an underground direct current line from Iceland to fix their own energy crisis which will take about four years to complete (E.L., 2014). It also means bringing in more income for the island.

The Icelandic government is committed to bringing foreign investors to the island. "This include a low 20 percent corporate tax"(ON Power, n.d.b). With this, and the ease of establishing a business with the lack of complex regulations,

further low taxes, and cheap energy costs, more and more foreign companies are coming to Iceland. (Promote Iceland, n.d.b)

ENVIRONMENT

The natural power of water is observed all over the world from rivers carving the Grand Canyon to the immense force of Gullfoss. Iceland utilizes the power of water to their advantage through the construction of energy production plants for hydroelectricity. Despite their energy progressive motives, Icelanders are active in the preservation and conservation of their fruitful environment. On the other hand, water's power can be destructive, as observed from the effects of soil erosion and climate change on the environment.

Construction

Iceland embraces the raw strength of water by harnessing its power through the construction of hydropower plants for energy production. In a visit to Ljosafoss Hydropower Station, built in 1937, an interactive exhibition explains the evolution of electricity and production with information about Landsvirkjun, the National Power Company of Iceland (Vargas Esposito, personal communication, 14 Mar. 2018). A practice regulated by the government for power companies is that they must plan ten years in advance to construct the proper edifices (Vargas Esposito, personal communication, 14 Mar. 2018). This is to ensure that they mitigate harm done to the environment. The process for this is that land is carefully studied and surveyed in detail to ensure a safe integration of technology in nature on the land. The environment provides Iceland with the ability to produce energy at low costs to the people; in return, Icelanders conduct careful research to observe the effects of construction on the environment (Promote Iceland, 2018).

Conservation Efforts

Evidence of Icelanders' strong consideration for human's effect on the environment can be found throughout Iceland's history. In addition to the government institutions, The Environment Agency of Iceland and the Ministry for the Environment and Natural Resources, the citizens of Iceland are proud to be involved in environmental conservation efforts.

Landvernd, an Icelandic Environment Association, is an "active participant in environmental decision making, strategic planning, and education in matters relating to land use, resources, and the environment;" with over 5,000 members, they strive to safeguard Iceland's natural beauty through the establishment of national parks (Landvernd, n.d.). Their main focus is protecting the Highlands, a hotspot for hydroelectricity production due the abundant resources and home to Gullfoss.



Photo 3: Redirection of the river flow, Soil Conservation Service of Iceland (Genesis Vargas, photograph, 15 Mar. 2018)

Gullfoss, shown above in Photo 3, is a massive waterfall fed by the Hvítá glacial river with incredible beauty as it flows down a three-step “staircase” into a canyon reaching up to 70 meters in height. Gullfoss is protected as a national park due to the continuous efforts of Sigríður Tómasdóttir, daughter of a sheep farmer who owned the property that included the waterfall. Sigríður is considered Iceland’s first environmentalist as she devoted her time and resources to void the rental contract with the Englishman who sought to purchase her father’s land for hydroelectric production. Sigríður spent her own savings for a lawyer and frequently walked over 70 km to Reykjavik to check on her case. Her efforts were not enough to win her case in court but influenced the attention of Icelanders’ to the importance of preserving nature. Luckily, the contract was void due the lack of rental fee payments and the waterfall was sold by Sigríður’s adopted son in 1940, then later designated as a nature reserve in 1979 (Martorella, personal communication, 15 Mar. 2018;).

Soil Erosion

In the past few decades, sea levels have been rising, within the past decade showing a significant rise in global temperatures. This rise in sea levels in the Arctic sea come from Iceland’s glacier water run-off. Soil erosion occurs as the run-off water gradually increase year by year that degrades vegetation and soil quality lowers. With the small amount of naturally developed soil in Iceland as is, Icelanders have had to safeguard the shores and river edges with boulders and strongly rooted plants to prevent greater harm to the soil. Primarily responsibility for this is the Soil Conservation Service of Iceland (SCS) within the Ministry for the Environment has conducted several scientific studies as to how to reinforce river banks that are being degraded year after year. Through these efforts, the “SCS has undertaken about 40 projects around the country to control rivers and river banks” (SCS, n.d.). Pictured

below, in Photo 4, is the shoreline of the city Borgarnes, which is heavily lined with large boulders for protection.



Photo 4: Shoreline protected by boulders in the city of Borgarnes. (Julianna Martorella, photograph, 13 Mar. 2018)

Climate Change

According to Arcanum Glacier Tours, “every year about 11 billion tons of glacial ice melts in Iceland alone because of global warming which is mainly caused by human influence” (Arcanum, 2018). The melted ice is classified as run off, the flow of meltwater from glaciers into rivers, lakes and oceans. Runoff water greatly impacts Iceland’s environment by decreasing pressure on underlying rocks causing the possibility of frequent volcano eruptions; as well as, contributing copious amounts of carbon flowing into the ocean which causes an exponential rise in sea levels (Arcanum, 2018).

Iceland’s environment is monitored for impacts of Arctic warming in the Arctic-HYDRA program, focusing on the hydrological cycle through modelling and assessment. Their main scientific goals focus on examining linkages, assessing responses and detecting changes within the Arctic Hydrological Cycle; one element studied is the change in mean annual runoff, as shown below in Figure 1.

Change in mean annual and seasonal runoff from 1961-1991 to 2071-2100; Mean of RegClim H/A2 and H/B2 scenarios.

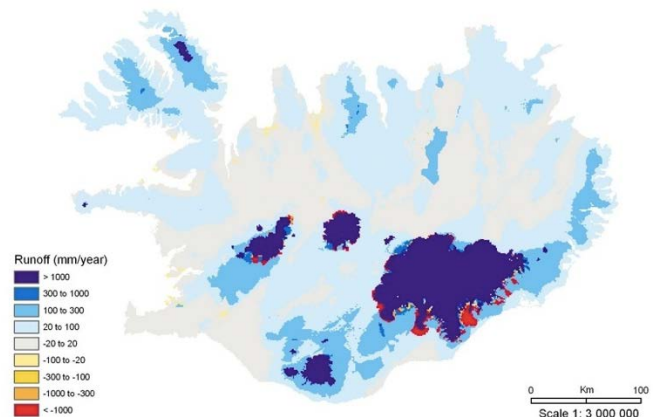


Figure 1: Change in mean annual runoff in Iceland. This figure color codes the change in the amount of runoff from 1961-1991 to 2071-2100 (Arctic-HYDRA Consortium, 2010).

Through hydrological models and data assimilation techniques, the Arctic-HYDRA program used collected data from 1961-1991 to compare the change with simulation for the years 2071-2100; Figure 1 is an example of the type of models created, showing the mean change in runoff amount by color. As shown in purple in Figure 1 above, there is a change in over 1000 mm per year, meaning there is a tremendous increase in loss of water creating an increased amount of runoff (Arctic-HYDRA Consortium, 2010).

The areas in purple are the locations of the glaciers throughout the country. Additional evidence of the increase of annual run-off can be observed from Mýrdalsjökull's glacier (identified in Figure 1 as the southern-most purple area) tongue, Sólheimajökull; Figure 2 below graphically shows the loss of height from 2015-2017 due to melting which contributes to the increase in the amount of runoff.

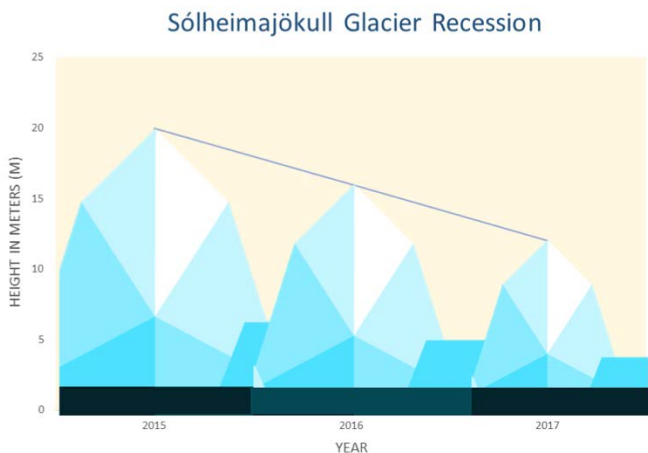


Figure 2: Graphic of the height loss of Sólheimajökull glacier. (Nicco Segreto, personal communication, 15 Mar. 2018)

After completing a glacial hike on Sólheimajökull, the researchers interviewed Nicco Segreto, a glacier guide with Icelandic Mountain Guides with a Bachelor's of Science degree in Geology, on his experience with climate change effects, specifically related to glaciers. According to data collected annually in May, the glacier consistently loses four meters in height every year. In addition to height, Sólheimajökull has receded 1255 meters since 1931 and continues to recede around 100 meters per year. As a comparison, Sólheimajökull is just 7.5 percent of Mýrdalsjökull glacier, which covers 600 km and classified as the fourth largest glacier in Iceland. If this one, small glacial tongue is suffering from the effects of climate change, imagine the effects on the largest glacier (Segreto, personal communication, 15 Mar. 2018).

CONCLUSION

Water is an integrated part in human and is especially pronounced for the residents of Iceland. The natural sources of the water power Icelanders' homes through its heat or motion, geothermal and hydropower, respectively. The water's action can lead to profitability for the island nation as well. Many citizens can exploit Iceland's water sources for its rareness in comparison to many other nations. The water's phenomenon, along with other natural sights in Iceland, brings an increasing number of tourists each year. Also adding to Iceland's economy is the number of outside investors capitalizing in country due to low electricity costs and few business regulations (Promote Iceland, n.d.a). This is partly due to the geothermal energy being the number one source of electricity in Iceland's metropolitan areas.

All of these positive effects of water are ideally good, however there are negative effects of the Iceland's water that causes irreparable damage. While hydropower is the second most important form of energy production on the island, how it comes about is becoming an issue. With global temperature rising, glaciers are melting at a faster pace than ever before. This causes an overall rise in sea levels and glacial rivers. An overall rise in water levels threatens the little vegetation that Iceland has, and calls for effective protection of river banks. Despite this, Icelanders are working to combat the issues relating to climate change as they come and predicting how to better protect their land. Iceland still has much to do for their water resources, and future studies can be done relating to predictions of how can Iceland survive without hydropower, or contributions of Iceland's electricity to outside investors, and how that affects their economy.

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Mr. Lewis serves as the Associate Director of Undergraduate Research for the Daytona Beach campus. He joined the Undergraduate Research team in February 2016 and has been a part of the ERAU community since 2012. Mr. Lewis enjoys working with students to help them achieve their goals through research and active participation within the university. Mr. Lewis earned his Bachelor's of Science in History from Northwest Missouri State University and his Master's of Art in Student Affairs Administration from Michigan State University.

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