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Iceland's Renewable Energy Sources & Climate Change

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Abstract

Nearly all of Iceland’s energy comes from renewable resources, with the majority being hydroelectric energy, and the remainder being geothermal. For several months undergraduate student researchers from Embry-Riddle Aeronautical University, aided by faculty from the Office of Undergraduate Research, conducted secondary-source research on the effect climate change has on Iceland’s renewable resources currently, and progressing throughout the century. Additionally, research was conducted on how the Icelandic Government plans on responding to these eminent changes. Earth's rising temperatures are causing a shrinkage of Iceland’s glaciers, and changing the water runoff from their glaciers at an alarming rate. Iceland’s dams are currently overflowing from the surge in glacial runoff, but soon, the flow rate will peak, and begin to recede throughout the century, until the glaciers have completely melted.

In order to discover more about the repercussions of climate change, the researchers travelled to Iceland, and conducted in-person interviews with both industry professionals, and common Icelanders. Using a combination of secondary-source research, and primary source interviews, it was concluded that the regression of their glaciers will render a multitude of Iceland’s hydroelectric power stations inert within the turn of the century, and decrease their total electric production by over 70%.

Introduction

Iceland is coined “The Land of Fire and Ice,” for good reason. It’s home to dozens of active volcanoes, and blanketed with dozens of glaciers, and ice caves; all physical features of land that would be considered insignificant nuances to the environment of other countries, but prove advantageous to Iceland. With a population of over 180,000 people in Reykjavik alone, and over 215,000 other inhabitants spread out amongst various cities across the country, Iceland has power demands comparable to any other country, except with the unique disposition of readily accessible natural resources (Reykjavik Population, 2017). With a clever sense of ingenuity, they designed a way to meet these demands unlike any other country. Iceland turned what was an underutilized resource, into the single-most efficient system in the world for meeting the power demands of its people, and industry. In 1904 Iceland pioneered hydroelectric energy, which was shortly followed by geothermal energy in the 1970s (Askja Energy, 2017). However, with climate change taking rampant effect in the 21st century, their way of life is being threatened. Iceland’s glaciers are receding at alarming rates, and taking their primary source of energy with them. If Iceland is to maintain its position in the world, then they will need to adapt, and overcome the challenges imposed by their disposition before the close of the century.

Currently, 72% of Iceland’s renewable energy is generated by hydroelectricity, whereas geothermal energy only accounts for approximately 28% (Sveinsson, 2016). The problem, however, comes from how the energy is distributed throughout the country. Hydroelectricity is implemented directly into their cities, whereas geothermal energy is primarily being allocated to their industries, such as aluminum and silicon refinement. As of today, the majority of Iceland’s revenue comes from both their smelting and refinement of aluminum, or from their fishing industry. Therefore, for them to lose the input of their hydroelectric plants into their cities could hold a potentially devastating effect, because geothermal energy will be forced to substitute the dividend. Which would prove detrimental to their industry because currently over 70% of their geothermal energy is being allocated to aluminum and silicon refinement plants. For that reason, Iceland has revamped their production of geothermal energy over the past decade by making the process cleaner, more efficient, and properly directed toward the people. The only question that remains to be seen is will it be enough to sustain their population as it continues to expand, whilst simultaneously accommodating a larger industry (Orkustofnun, 2013).

Methodology

There were two methods used conducted the research for the topic. The main source was primary interviews conducted with industry professionals and 'regular' citizens. The questions asked during these interviews were tailored to best fit the interviewees' technical level of knowledge. The interviews with the industry professional were geared more towards how the country plans to adapt to these changes and what their future plans are. The interviews with the 'regular' citizens were geared towards the cultural impact of this energy crisis and what they thought the future of Iceland's energy sector should take. The questions from these interviews can be found below in Table 1. The second form of research was secondary research done about the history and current state of Iceland's renewable energy.

Industry Professional Questions	**Citizen Questions**
How will geothermal energy be affected by climate change?	What do you envision the future of Iceland's energy sector becoming?
Is it possible for geothermal to expand?	Are you concerned about the effect of climate change on Iceland's glaciers?
How viable is wind power?	What are your opinions of wind power?
Can wind power replace/cover the energy that will eventually be lost from the decline of hydroelectric power?	Do you think Iceland will lose some of its identity with the decline of hydro power?
How is Iceland going too adapted to the influx of hydro energy as the flow rates increase?	How do you envision future businesses being affected?

Will hydro facilities be modified to harness the increase in energy?	How do you feel about Iceland sharing some of the energy produced by hydro power?
Will Iceland use that energy or perhaps sell it to another country?	

Table 1: Interview Questions

Results

The results of this research were the findings from the interviews. The interviewees ranged in age from mid 20s to late 50s. Two of the interviewees were industry professionals, working at a geothermal plant and hydroelectric plant. The third interviewee was a glaciologist, and the fourth was our tour guide who did not work in the energy field. Within the general population of Iceland there appears to be a noticeable lack of urgency regarding the issue. It is clear that Icelanders pride themselves on a degree of ruggedness, which has been formed from centuries of extreme environments, natural disasters, and harsh living conditions. This attitude leads Icelanders to the conclusion that they will deal with the issue when it arrives.

The two industry professionals that were interviewed think that geothermal and wind energy can cover the deficit created by hydro power. However, there is large amount of push back to install more wind turbines from the general population. The main concern is that if wind turbines were to occupy the north eastern region of Iceland they would destroy the barren planes that currently occupy that area. Along with their rugged heritage Icelanders take great pride in their effort to preserve the environment. This point of contention between energy companies and the general public could lead to a potential halt in the development of wind power. It is worth noting that the industry professionals are very hesitant to admit that hydro power will eventually decline. However, this is to be expected since hydro currently occupies 72% of Iceland's current energy sector (Sveinsson, 2016). It is possible for wind to cover the energy deficit, but with such a large cultural push back it may be difficult for the proper legislation to be passed in order to make wind turbines a reality in Iceland.

Discussion

Glacier Reduction and Hydroelectric Power for the 21st Century in Iceland

Iceland hosts the cleanest and most efficient systems of power generation and distribution in the world to date. Their ability to do so comes from their unique standpoint geologically, from which they are given a major advantage over the majority of the world. Iceland rests upon the division of the two largest tectonic plates in the world, Eurasia and North America. The plates themselves are separating, and Iceland experiences all of the residual effects: volcanic eruptions, land expansion, and an abundance of locations where the Earth's molten core is exposed, and readily accessible to harness. Equally as advantageous, the main body of Iceland sits on the 65th parallel of the world, only one degree from what is considered the Arctic Circle. These conditions yield some of the most spectacular conditions of Artic nature, including the development of massive glaciers that take up a significant portion of Iceland's land-mass. However, that distinction is being challenged by the growing effects of climate change. What has become a staple for Iceland over the past decade will cease to exist within the close of the century. As the world continues to heat, Iceland will lose the majority of its advantages in energy production, unless they are to answer the problems posed by climate change with unprecedented solutions. Iceland's response within the next decade will be paramount to counteracting the impending effects coming to the country.

The temperature in Iceland is predicted to rise 2.5 Degrees Celsius over the next 100 years as a direct result of climate change (Sveinsson, 2016). This rise in temperature will inevitably lead to the deterioration of Iceland's glaciers. Currently the runoff from these glaciers is increasing, but the capacity of Iceland’s hydroelectric power plants is not sufficient enough to harness this influx of flow. Eventually, the glaciers will melt so much that the runoff will begin decreasing until the glaciers are completely gone. A case study done by Dr. Oli Gretar Blondal Sveinsson estimates that by 2050 the glacier runoff will increase by 15% of the data taken in 2010. However, the current hydroelectric capacity is only capable of handling 30% of that 15% energy increase. Dr. Oli Gretar Blondal Sveinsson anticipates that within the next 50 years the flow rate will peak and then begin to decline (Blondal, 2015). The International Hydropower Association also estimates a very similar glacier deterioration timeline. They predict that by 2080 the flow rate will begin to decrease (Sveinsson, 2015). Once the glaciers begins to decline, they will be completely gone by the year 2200 (Sveinsson, 2015, Blondal, 2015).

Geothermal Energy Advancement and Expansion in Iceland

Iceland has been using renewable energy resources longer than any other country in the world. What makes them the world’s foremost leaders in renewable energy though, is the innovation that they have developed with the abundance of resources provided by their island; both tangible and theoretical.

Iceland recognizes that within the turn of the century their glaciers will recede tremendously from global warming, and they will lose a substantial amount of their current energy resources. Iceland also recognizes that luckily, geothermal energy will remain relatively unabated by climate change. Therefore, they have linked the development of their most coveted exported resource to the use of geothermal energy. Aluminum refinement plants are, for most countries, a costly and unprofitable endeavor. However, for Iceland, they are nearly an entirely profitable entity. By employing advanced and new geothermal factories, Iceland is harnessing the heat of the geothermal reservoirs beneath its surface, and allocating their power directly into bolstering its economy. Additionally, they have drilled deeper than ever before in search of hotter, and more consistent and sustainable geothermal wells, and they have accounted for the environmental effect of carbon emissions from their geothermal facilities by implementing CarbFix; a method to trap carbon into stone after processing (Landsvirkjun, 2017).

In 2016 Iceland proposed an innovative solution to the United Kingdom for the profit, and future sustainment of their country’s energy needs. The Icelandic Submarine Cable, or IceLink, is a proposed linkage to Scotland’s power grid by means of a 1000 kilometer cable submerged underneath the ocean that will bring Iceland into the electrical pathway of all of Europe for the foreseeable future. First conceived in 2001, this cable would allow for Iceland to profit off of their soon-to-be energy spike, and sustain their energy needs in the distant future. They’ve achieved an above-ground version with the Sultartangi Transmission Line, a 130 kilometer power line, that currently transmits power directly from their hydroelectric power plants across the country to every major city (Landsvirkjun, 2016). Therefore, why not employ IceLink?

Accounting for over 2% of the world’s aluminum refinement since 2012, the aluminum industry for Iceland has been as important for their sustainment as fishing has since its founding (Allen, 2012). Iceland’s largest aluminum company, Century Aluminum, has created the world’s hottest geothermal power plant to date after a process that took well over 25 years to achieve. Krafla, the brain-child of Iceland’s geothermal technology, was created, and modified as a testament to the possibility that Iceland could become 100% independent of fossil fuels. The station at one point only produced 7 MW’s of its theoretical output of 55 MW’s as of 1974. However, with modifications to the depth at which the geothermal wells are dug, the station has progressed to remain consistently above 50 MW’s since volcanic activity resumed in the region, and one of the turbines was repaired in 1999 (Nielsen, et al.. , 2000).

Finally, there was a recent initiative that Iceland underwent to further strengthen their geothermal harnessing. The Icelandic Deep Drilling Project (IDDP), a mission to drill down several miles in order to reach a molten hot magma reservoir detected with seismic devices, was completed on the 25th of January, 2017 after 176 days of continuous drilling. By delving nearly three miles in the Reykjanes Peninsula in Iceland, the IDDP reached a well of liquid hot magma, where pressures were recorded to be nearly 5000 psi, and temperatures reached over 800 Degrees Fahrenheit. At these conditions, future geothermal plants can extract the stored energy stored within the reservoir, and utilize it in anything from the synthesizing of aluminum alloys, to the heating of homes (Friðleifsson, 2017).

Icelandic Dependency on Renewable Energy

72% of Iceland’s renewable energy comes from hydroelectric power. By 2080 the glacial reduction in Iceland is predicted to have worsened to the point that their facilities will no longer be operating at potential. Without the energy these systems provide, Iceland will be left with a fraction of what once supported their society. The response from the Icelandic Government has been a significant investment into the research and response to the effects of climate change in their country. Over 100 scientists from 30 different companies and organizations are currently researching ways to combat the demise of the power industry in Iceland. (Sveinsson, 2016)

The ramifications of the loss of hydropower will also be experienced on an industrial level. Dr. Oli Sveinsson from Landsvirkjun stated that “77 percent of all electricity generated in Iceland goes to power intensive industries...” (Sveinsson, 2016). Mitigating that loss will be one of the most challenging endeavors for the Icelandic industries not linked to the geothermal power over the coming century. These systems will be left solely on heavy precipitation that Iceland experiences only seasonally. However, where these events are increasing in tendency, they are not a consistent, reliable source of energy going forward in the future, and will only provide up to a fraction of what the plants were generating in the lifetime of the glaciers (Brynjólfsson & Ólafsson, 2009).

Solutions to Future Energy Crises in Iceland

With the inevitable deterioration of Iceland’s hydropower, the Icelandic people must find an alternative source energy to replace hydropower. The current hydropower plants must be expanded to accommodate for the increased flow rate. Essentially, Iceland has to harness as much energy as possible from glacial runoff before they are completely gone. By expanding the current hydropower plants, Iceland will be able to harness more power from the glacial runoff. Iceland could also potentially export this energy in exchange for monetary gain through systems like IceLink. The pipeline would stretch over 1000 km and have an 800-1200 megawatt capacity. If completed, this project would largely contribute to the green energy initiative in Europe, and give Iceland a temporarily sustainable source of income, whilst simultaneously providing them a channel with which they could substitute power deficits in the future (Landsvirkjun, 2018). Likewise, they could introduce wind energy production as well. Being one of the windiest country in the world, Iceland has the potential to harness yet another phenomenal resource that could consistently meet their energy needs.

Another interesting circumstance is that within the general population of Iceland there seems to be a lack of focus and urgency on their future energy problems. As a direct result from their tolerance to natural disasters, and extreme environments, many Icelanders tend to hold the outlook that, as one of our interviewees stated, “*We will deal with it when it comes*” (Einarsson

E, personal communication, March 15, 2018). Industry professionals seem to think that geothermal and wind energy can cover the deficit created by hydropower, but are hesitant to admit that hydropower is declining. Elinar Einarsson, a representative of the Hellisheiði Geothermal Power Plant, refused to comment on how hydroelectric power will decline in the future. However, he did say that wind and geothermal power are on the rise, and could potentially cover any energy deficit created in the future. Though frustrating, his response was to be expected, seeing as he is representing his country’s energy sector. This became even more apparent, because Sunna Olaudóttir from the Ljósafossvirkjun Hydroelectric Power Plant held a similar demeanor to Elinar. She stated that wind energy has great potential for development, but did not want to acknowledge that hydroelectric energy is declining (personal communication, March 15, 2018). This lack of urgency could negatively impact Iceland’s future, when responding to problems in energy production.

Finally, wind power currently occupies less than 0.1% of Iceland renewable energy. Though expanding, there is a large amount potential with wind energy in Iceland (Sveinsson, 2016). In 2013 Landsvirkjun, the national energy company of Iceland, erected its first two wind turbines in Iceland. This was part of an effort to expand Iceland's wind power and further research about Iceland’s capability to harness wind energy. It is clear that a direct solution to Iceland’s future energy problem is to expand both wind and geothermal energy, while continuing to tap as much as possible out of hydroelectric power.

Conclusion

Iceland is the only the country on earth to produce 99% of its electric energy from renewable energy resources, with the limitation being that their primary mode of transportation is still fossil fuel burning vehicles. Though impressive, Iceland’s push toward renewable sustainability was not fueled by their desire to reduce emissions world-wide. Today, Iceland takes great pride in its zero emission status. However, the main drive to reform the country's energy was the fluctuation of oil prices in the 1970’s. Landsvirkjun, the national energy company of Iceland, goes in-depth on the history of Iceland. In 1970 the first steam-driven turbines were constructed and in 1972, five hydropower plants were constructed; all in an effort to reform the country's energy towards renewables. An article published by *The Guardian* in 2008 explains that in the 1970s an increase in oil prices led Iceland to invest in the research of hydropower and geothermal energy (Aldred). *The United Nations Chronicle* confirms that the 1970’s oil crisis led the country to turn their eye toward renewable energy (UN Chronicle, 2015).

Iceland is about to undergo a slew of challenges in the near-future, and their response over the upcoming decades will directly affect the future of the country. The implications will stretch across environmental challenges, societal variances, and a variety of economic dilemmas for generations to come. Direct results will be a product of the next 50 years, but by the turn of the century, there will be a multitude of 3rd and 4th order effects experienced by the people of Iceland, the degree of which will be determined by the actions of its government.

The data supports that Iceland will soon be experiencing a deep and detrimental loss in their most pivotal resource, but they are far from helpless to the issues impeding upon their lives. If they continue their technological efforts, expanding their innovation, and maintain a completely renewable energy-based society, then they will have pulled off a true miracle. If the current population decides not to act then the ramifications could be huge for future generations.

For future research regarding Iceland’s energy sector the team would recommend interviewing academic experts in the field, as well as government officials. The government official interviews would give insight into where Iceland’s leaders plan on taking the energy sector. By meeting with academic experts, one would be able to outline exactly how Iceland could adapt to the future energy crisis.

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