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Cultural Trends Influencing the Future of Geothermal Energy in Iceland

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1. Between geothermal, hydroelectric, and other sources of energy, the tiny country of Iceland produces enough electricity to equal the output of twenty nuclear power plants ("Iceland Is Using"). In fact, according to Nathalie Spittler, a PhD Student from the University of Iceland, and her fellow researchers, in 2017, local renewable resources, specifically hydroelectric and geothermal power, were responsible for generating approximately 98% of Iceland's electricity and 81% of its entire primary energy supply (1081). Achieving nearly 100% renewable energy use is a truly astounding accomplishment that is largely due to Iceland's utilization of geothermal energy. Geothermal resources—defined by Merriam-Webster as "of, relating to, or utilizing the heat of the Earth's interior"—currently supply about 27% of the electrical yield of Iceland. (Spittler et al. 1081-82). According to Dr. Ruth Shortall, a postdoctoral researcher from Ireland, and her colleague, Dr. Ali Kharrazi, its base-load capabilities, indigenous nature, affordable operation cost, and low greenhouse gas emissions make geothermal energy highly attractive. Furthermore, it can be used for heating water in addition to generating electricity (104). In fact, the naturally heated groundwater of Iceland is used to heat around 90% of homes in Iceland and to power greenhouses that produce crops all year round ("How Geothermal"). Currently, electricity and heating in Iceland are relatively inexpensive, costing around 15 cents per kWh (kilowatt-hour) in the residential sector—an affordable amount for virtually

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everyone in the country. However, geothermal resources are not an unlimited source of energy. Spittler et al. write:

> The production cost of electricity from geothermal resources takes into consideration effects of geothermal resource dynamics. Geothermal resource dynamics arise from the stock-like nature of geothermal resources [10,11]. When the geothermal resource is utilized for electricity production, the resource stock decreases. Through natural recharging (i.e. heat inflow and pressure build up), the stock of the reservoir increases. (1083)

In fact, if the natural geothermal recharge rate is bypassed by the extraction rate, a decrease in use of geothermal reservoirs and resource availability will result. Additionally, as geothermal reservoirs are exhausted, more wells will have to be drilled to deliver the same output. This will affect production costs of geothermal resources over time, as constructing new wells and facilities involves significant expense (Spittler et al. 1081-83). Overall, due to Iceland's unique tectonic structure, geothermal resources are being utilized by Icelandic geothermal power plants of varying designs at unprecedented levels. Recent research uncovers that, though normally seen as an example of clean, renewable energy, geothermal energy may be at risk of overutilization by the Icelandic people, in search of short-term gain, potentially causing negative consequences for this small country—both environmentally and financially.

2. Iceland's unique tectonic structure allows for its high utilization of geothermal energy. According to Dr. Ronald DiPippo, Chancellor Professor Emeritus at the University of Massachusetts Dartmouth and geothermal expert, "Geothermal energy—Earth's heat—can be found anywhere in the world. But the high-temperature energy that is needed to drive electric generation stations is found in relatively few places" (3). For instance, in most areas of the world, the temperature increases by about 35 °C per kilometer underground. In Iceland, however, this figure is closer to 200 °C ("How Geothermal"). That is because underneath Iceland, the North American and Eurasian tectonic plates are slowly separating, causing the mantle—the extremely hot, molten layer of the Earth's structure—to rise closer to the surface. This results in many Icelandic volcanoes as well as the extensive geothermal potential found there ("How Geothermal"). The

rate of plate separation is around 2 cm a year. Though this may seem insignificant, it causes large bands of intense faulting that run from north to south to southwest (DiPippo 532). Finally, DiPippo reports, "Iceland, sitting astride the Mid-Atlantic Ridge with abundant active volcanism and a population of around 332,000, has the highest per capita concentration of geothermal energy of any country in the world" (531).

3. To employ such an abundant resource, many varieties of geothermal plants have been built in Iceland. On a very basic level, most geothermal generators function by pumping water around 3 km into the ground, allowing it to be quickly evaporated, and using the steam to turn turbines and generate electricity ("How Geothermal"). In order to build a commercially viable plant, a location must have a sizable source of heat, a permeable reservoir, access to water, an overlying layer of impervious rock, and a dependable mechanism for geothermal recharge (DiPippo 10). DiPippo states that the backbone of the geothermal power industry is the single-flash steam plant, as it is normally the first facility to be built at a recently developed liquid-dominated geo-thermal field (108). Within a single-flash plant, the geofluid—collected as a compressed liquid somewhere in the reservoir—undergoes a flashing process, rapidly vaporizing the majority of it. The two phases (liquid and gas) are then separated. The gas (steam) is then used to power a turbine which drives an electric generator (DiPippo 115). DiPippo also notes that the double-flash steam plant is an improved version of the single-flash plant. In the same location, with the same geothermal conditions, it can produce 15-20% more energy for identical geothermal fluid conditions. The plant costs more, is of a higher complexity, and entails more upkeep. However, the higher output potential of such facilities frequently warrants their installation (144). The addition of another flasher makes the double-flash plant distinct from the single-flash system. A low-pressure steam pipe runs from the flasher to the turbine, in addition to the high-pressure one that runs from the separator (DiPippo 147). DiPippo mentions that in a triple-flash plant, yet another flashing stage is added. As a result, the energy utilization is boosted to an even greater degree. However, the costs of this are higher complexity, additional equipment, and greater capital cost (144). The dry-steam plant, on the other hand, is the oldest type of commercial geothermal power plant. It was originally built by

Prince Piero Ginori Conti in the year 1904, utilizing the natural steam jets found in Larderello (Tuscany, Italy) to power a very small steam engine (DiPippo 170). A dry-steam plant is fundamentally identical to a single-flash plant after the steam is generated (DiPippo 179). Though a simple design, dry steam plants are still widely utilized in Iceland to this day. Also, DiPippo notes that, due to the closed fluid system, binary cycle geothermal power plants are (in thermodynamic principle) the most similar to traditional fossil fuel/nuclear power plants of all the geothermal power systems. In a binary cycle plant, the working fluid (specifically chosen for its thermodynamic properties) undergoes a cycle of evaporation, expansion through a prime mover, and condensation. Afterword, it is pumped back to the evaporator. Currently, the binary cycle plant is the most widely utilized type of geothermal plant in the world. However, this style of plant has not yet been widely developed in Iceland likely due to its relatively low power output (DiPippo 194-95).

4. The Icelandic people possess a cultural propensity for instant gratification that could lead to faster innovation of geothermal plants or potentially harm their country's natural geothermal assets. In order to quantify cultural trends, Shortall and Kharrazi bring up Hofstede et al.'s cultural dimensions theory, which uses cultural context to examine and compare two societies by scoring them against each other in six different dimensions. They are "power distance, individualism, masculinity, uncertainty avoidance, long-term orientation, and indulgence" (102). When scored against Japan, another country with high geothermal potential, Iceland's score on Hofstede et al.'s cultural dimensions framework is a 50 for uncertainty avoidance. This indicates a cultural attitude of both light planning and spontaneity. When it comes to geothermal energy development, Iceland has been a risktaker, consequently building up a body of knowledge and experience when it comes to utilizing the resource. Looking at long-term orientation, however, Iceland has a fairly low score when compared to Japan. As is suggested by their score of 28, the Icelandic people tend to seek immediate results. Furthermore, with an indulgence score of 67, Iceland is likely a culture with high hopes for the future. This score also infers that they have a propensity to go out and get what they want (Shortall and Kharrazi 105). On the whole, Shortall and Kharrazi argue that though its population is 400 times smaller than Japan's, Iceland has more fully utilized

its geothermal resources, implying a higher risk propensity overall (107). According to an Icelandic citizen interviewed during the *Power Play* program, "We're little gold diggers in Iceland. And we want everything, and we want it now, not later. We've exhausted our cod stocks, we've exhausted our herring stocks, and we're now attacking nature."

5. The fast development of geothermal energy in Iceland could potentially damage both their environment and natural landscape. It is important to note that the Icelandic people are deeply tied to their nation. As the *BBC EarthLab*'s presenter explains after a day exploring Iceland's unique landscape, "It has become really clear how connected the community is to the ground underneath their feet. It gives them the hot water in their homes, they create renewable energy from it, and now they even get their salad and vegetables using what's there—the geothermal energy." Nevertheless, according to Shortall and Kharrazi, issues regarding the influence of geothermal resources on the environment of Iceland have arisen recently; specifically, the effect of geothermal plants on the geology, hydrology, landscape, and natural beauty of Iceland (106). Geothermal energy, unlike hydroelectric power, is supposed to have virtually no environmental impact ("Iceland Is Using"). Shortall and Kharrazi bring up that 3.5% of global electricity production could be provided by geothermal resources by the year 2050, preventing nearly 800 megatons of carbon dioxide emissions every subsequent year (102). Moreover, Spittler et al. note that, though small because of the minimal effect it has on electric vehicle use, the use of geothermal energy is predicted to decrease overall emissions in the future if utilized (1088). However, it is vital to note that Icelandic ecosystems are very sensitive to small changes. Geothermal growth is, therefore, worrying to many scientists as development in that area is occurring far faster than scientists can measure its consequences ("Iceland Is Using"). Shortall and Kharrazi write, "Nonetheless activities like tourism and energy development exert pressure on Iceland's biodiversity: more than 290 species of flora and fauna are threatened, including nearly 40% of the bird species nesting in Iceland and 12% of the country's moss species" (106).

6. A perfect example of this threat is Iceland's aluminum industry, which currently comprises around 40% of Iceland's total exports ("How Geothermal"). Due to Iceland's jackpot of clean energy,

aluminum production has become a massive industry in this small country. Alcoa Fjarðaál, for example—just one of the many aluminum plants in Iceland—manufactures 1.3 million tons of usable aluminum per year, making it the second or third biggest aluminum smelter in Iceland. Due to pressure from new aluminum plants in the north, electricity companies plan to construct many new geothermal power plants in the region around Lake Mývatn, an area that is home to an extensive variety of migratory birds. Additionally, though no long-term side effects have been identified yet, some worrying changes to the groundwater chemistry and temperature gradient around Lake Mývatn are occurring due to high geothermal utilization—changes that could potentially damage this delicate ecosystem. Considering that the Lake Mývatn area serves as a nesting-ground for many bird species from both America and Europe, even slight alterations to this unique ecosystem could have global consequences. In the end, despite the fact that some of the largest aluminum companies in the world would gladly invest billions of dollars in Iceland's economy, many Icelandic citizens would give everything to save the unique environment of their home ("Iceland Is Using").

7. Although geothermal energy is a finite resource, and therefore not the solution to unlimited clean energy, it plays a vital role in the future of Iceland, and possibly the world. Shortall and Kharrazi write, "The country has made very good use of geothermal energy to create comfortable living conditions for the population, with an emphasis on abundance of heat and energy at low prices. While an unreasonable waste of energy cannot be said to occur, the use of energy in Iceland should not be described as frugal" (105). Furthermore, according to Spittler et al., geothermal overutilization can cause temporary resource expenditure. This delay, caused by geothermal drawdown, will become increasingly more significant as electricity demand increases (1085). If this trend continues, geothermal resources could drop in availability in the future due to higher GDP growth rates and an increased demand for electricity. This would lead to a significant rise in electricity production prices, and in turn, electricity costs (Spittler et al. 1089). Spittler et al. also mention that in four of the scenarios run in their simulation, geothermal resources have been fully developed, leading to a decline in electricity production overall (projected to be around the years 2046-48). This decline is due to geothermal drawdown and the drilling of new wells in order to

compensate for it, causing overall electricity production projections to be lower than they would be when not taking geothermal energy into account. With no further geothermal resource expansion, and a growing demand for electricity, wind energy will likely be utilized to a much larger extent (1085). In the end, Spittler et al. explain:

> In all scenarios, the results depict that when geothermal resource dynamics are considered, estimated average unit production cost will be higher in 2050 than when those dynamics are not considered. This effect occurs because excessive geothermal resource utilization leads to geothermal production capacity losses, which needs to be compensated by additional well drilling investment. (1087)

8. Paradoxically, due to the Icelandic nation's propensity to make quick, seemingly beneficial decisions, the future of both electricity prices and the well-being of the ecosystems in Iceland are thus uncertain. Depending on how this small nation proceeds with geothermal development, energy prices may rise significantly, and natural ecosystems may be adversely affected. It is the tectonic structure of this island nation that is responsible for its high geothermal potential. As a result of this, many different types of geothermal plants have been built all around Iceland at a faster and faster rate as time goes on. Studies show that this could cause unintended consequences environmentally, as exemplified by the Lake Mývatn area. Additionally, such geothermal overutilization is projected to cause an increase in both electricity production costs and consumer prices. over time. Geothermal energy remains a resource worth utilizing; it simply requires care and proper development in order to monitor environmental impacts and prevent geothermal drawdown. According to research conducted by Shortall and Kharrazi, Icelandic citizens interviewed agree that geothermal projects require civic contribution to establish public support and the continued improvement of the whole development process (106). This leads to the optimistic conclusion that the people of Iceland may very well unite to prevent some of the potential consequences of developing geothermal facilities at too fast of a rate. The future of geothermal energy in Iceland is in the hands of the people—it is up to them how it plays out.

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Instructions for the Research Paper Worth a Possible 20 Points

Due Dates:

If you attend and participate in all three days of Oral Presentations (3, 5 and 10 December), your final paper will be due in Canvas Assignments no later than Thursday, 12 December at 11:59 PM. If you don't fulfill this requirement, your paper will be due at the beginning of class on Tuesday, 10 December.

General Considerations:

1) You're to write an 8 to 12-page paper that's formatted in the MLA style. Make sure to include your Last Name and page number on every page.

2) Please place the Works Cited (WC) Page on the last page of your paper, and although that page will also be numbered, it won't figure into the page count of your paper. This means that if you've written an 8-page paper, it'll actually be 9 pages long. Similarly, if you write a 12-page paper, it'll actually be 13 pages long.

3) Make sure the Works Cited page is alphabetized (discounting any "A," "An," or "The" at the beginning of an entry). Use the hanging paragraph format, so that your alphabetizing will be immediately apparent. This is a courtesy you extend to fellow researchers, so that if they're looking for one of your sources, it won't take long to locate.

4) Make sure your entire paper, as well as the WC page, is double-spaced.

Parts of Your Paper:

5) Give your paper a Title that hints at the direction of your analysis to come. Consult "The Final Title" at:
https://library.sacredheart.edu/c.php?g=29803&p=185911

6) Introduction:

A) Please begin by using an anecdote, quotation, or startling statistic. Choose and deliver this well. Make sure your choice reflects the main point of your paper, tying it immediately into that main point.

B) Make sure to provide a larger context. (N.B. The following information derives from our Dartmouth materials already consulted in class.)

I) For instance: 1) begin by saying that Virginia Woolf's narrator has posed a problem for many of her critics; 2) provide a quick definition of the problem, as

others have defined it; and 3) declare your thesis (which states your position on the matter).

II) Furnish any background material important to your Freud argument. For example, give--in broad strokes--a description of Vienna circa 1900, avoiding irrelevant details. Instead, emphasize those aspects of Viennese society (such as sexual mores) that might have most influenced Freud.

III) If your entire philosophy paper focuses on the nature of reality, define "reality."

AND / OR

IV) Acknowledge your opponents. Summarize the point of view of your adversaries. Then state your own position in opposition to theirs—in your thesis.

C) Your thesis will represent the last sentence or two of your introductory paragraph.

D) A final thesis must: make your strong claim clear, present the logic and structure of your paper without causing subsequent repetition in your paper, and demonstrate what you want to emphasize.

Here's an example of a Final Thesis:

The purpose of the Russian Revolution was not only to revise Russia's class system, but to create a new world, and within that world, especially important was to occasion the rise of a new kind of human being.

7) Body Paragraphs:

A) Begin each paragraph by announcing one strong argument that's your own, and not one made by one of your sources.

B) Then support the argument by using solid evidence from your sources.

C) Weave together your pieces of evidence effectively—in a minimalist fashion, using (for the most part) Transition Markers, such as:

1. **To show place - above, below, here, there, etc.**
2. **To show time - after, before, currently, during, earlier, later, etc.**
3. **To give an example - for example, for instance, etc.**
4. **To show addition - additionally, also, and, furthermore, moreover, equally important, etc.**
5. **To show similarity - also, likewise, in the same way, similarly, etc.**
6. **To show an exception - but, however, nevertheless, on the other hand, on the contrary, yet, etc.**

7. **To show a sequence - first, second, third, next, then, etc.**
8. **To emphasize - indeed, in fact, of course, etc.**
9. **To show cause and effect - accordingly, consequently, therefore, thus, etc.**
10. **To conclude or repeat - finally, in conclusion, on the whole, in the end, etc.**

D) Don't forget that you can also manipulate your signal phrases to facilitate your weaving. Remember that this is *your* paper. You're telling the story of what your evidence makes clear.

E) As you weave together evidence to support each paragraph's argument, avoid tangents/digressions. Instead, make sure your sentences look backward as well as forward. In other words, link each sentence firmly to the sentence that came before. And end each paragraph by making your strongest point.

F) Offer enough evidence to support each paragraph's argument. Don't provide too much or too little evidence, and edit out any repetition.

G) Supply definitions or clarifications to help us understand your points. Remember that we aren't budding experts like you are in your field of inquiry.

H) Make sure your order of evidence goes from least important point to most important point.

I) Remember that each paragraph's argument must support the thesis without ever mentioning it.

J) Place your paragraphs in the correct order, so that your arguments gradually come to a crescendo just before you draw conclusions. And please DON'T draw conclusions prematurely. Drawing conclusions is the exclusive job of your concluding paragraph.

8) Overall:

A) Your paper must be coherent. In other words, it has to flow, and your arguments need to be understandable. Avoid making us read and reread any part of your paper because we're finding it hard to make sense of what you've written.

B) Strive toward a nice use of the modes of arrangement below that avoids confusedly mixing any of them. (For example, you wouldn't want to describe a process while listing its effects.) Employ the modes appropriately, please.

1. **Narration: telling a story**
2. **Description: relating what you see, hear, taste, feel, and smell**
3. **Process: describing a sequence of steps necessary to a process**
4. **Definition: illustrating the meaning of certain words or ideas**

5. **Division and Classification: grouping ideas, objects, or events into categories**
6. **Compare and Contrast: finding similarities and/or differences between topics**
7. **Analogy: making a comparison between two topics that initially seem unrelated**
8. **Cause and Effect: explaining why something happened, or the influence of one event upon another**

9) Conclusion:

A) At a minimum, your conclusion needs to accomplish the following:

1. **First, state what your paper has *actually* proven. This will go well beyond your thesis because you've argued a lot of significant points since then.**
2. **Now state the essence of each of your body paragraph's arguments. Use other wording, but address paragraph arguments in their correct order.**
3. **Leave us with something pertinent to consider further. This must come from your research, and please don't use any rhetorical questions.**
4. **Your final sentences should leave your ideas resounding in our minds. Give us something to think about. Let your language ring.**

B) Remember that in your conclusion, if effective, you might also:

I) Return to the ongoing conversation, emphasizing the importance of your own contribution to it.
II) Consider again the background information with which you began, and illustrate how your arguments have shed new light on that information.
III) Return to the key terms and point out how your research has added some new dimension to their meanings.
IV) Use an anecdote or quotation that summarizes or reflects your main idea.
V) Acknowledge your opponents - if only to emphasize that you've beaten them.

Good luck, and please let me know how I can help.