PAPER

Geothermal Cultures in Para-Climate Change Iceland

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The road to decarbonization is a web of woven pathways – while the building sector works hard to reduce embodied and operational carbon, governments and utilities should pivot cities away from fossil fuels and incentivize renewable energy infrastructure. On this latter point, architectural design could play an important role on how renewable energy is adopted into the everyday life of its users. Beyond energy models and smart envelopes, design has an under-appreciated influence on how cultural value is perceived or produced through any given built infrastructure or utility. Furthermore, constructing a larger cultural framework around renewable energy systems helps to accelerate and substantiate the green transition. In questioning how architecture participates in this cultural rethinking, this paper focuses on Iceland integration of geothermal energy into everyday cultural practices and how architectural effects work in tandem to produce this cultural-infrastructural bind.

Iceland's survival through anthropogenic change is both age-old and ever-present. Volcanic eruptions and high rates of soil erosion provide scarce arable land, yet geothermal and hydroelectric power sustain the country with 85% renewable energy. Simultaneously bountiful and limited in resources, Iceland's integration of geothermal energy into multiple cultural spheres is a harbinger for a built environment practicing climate adaptation and survival. The research, conducted in Summer 2023, involves the documentation of geothermal sites (active geothermal fields, energy generation facilities, greenhouses, heritage sites, food vendors, etc.) and the analysis of material, formal, haptic, and tectonic qualities attached to these systems. As an ongoing project, Geothermal Cultures will continue to focus on how renewable energy systems, cultural practices, and architectural form work together to encourage public support towards renewable infrastructure.

PARA-CLIMATE CHANGE

Iceland is both abundant and scare in resources. From an energy standpoint, the island boasts an envious portfolio of 85% renewable energy consisting of 65% geothermal and 20% hydropower.[1] Its location over the Mid-Atlantic Ridge where the North American and Eurasian tectonic plates pull apart guarantees that the geologically nascent landform has an endless supply of magma-heated geothermal water and steam.[2] Despite having ample renewable energy, the island has very little means to cultivate food and lumber given the poor soil conditions brought about by over-extraction during the days of early settlement. Deforestation for construction and firewood, peat harvesting for heating, and large amounts of animal grazing greatly unbalanced Iceland's ecosystem and exacerbated soil erosion across the country. According to the Icelandic government, "45% of the land ecosystems are in bad condition…[and] 39% of the country is subject to considerable or extensive soil erosion."[3] Given these two extremes, the paper argues that Iceland exemplifies para-climate change conditions – meaning, it's undergoing its own cycles of resource depletion and climate disruption brought about by human intervention – AND is also seizing opportunities to fortify future stability through investment in renewable energy. These para-climate change trajectories are guided through by cultural practices and frameworks that have been in formation since Iceland's early settlement. Living under the destructive and generative potentials of volcanic landforms, Icelanders hold fear and appreciation at the same time for the telluric power that's underneath them. This paper hopes that by reviewing certain examples of how culture and energy are intertwined in Iceland, one can project towards other entanglements of renewable power infrastructure with forms of cultural appreciation.

RENEWABLE ENERGY LIVING

Economist Örn Daníel Jónsson[4] coined the term "geothermal living" in his eponymous book exploring the intersection of geothermal power and bathing culture in Iceland. Seemingly banal at first, the phrase implies that geothermal energy exerts some form of influence over Icelandic lifestyles. Yet when one tries to replicate this pairing of renewable energy and culture to identify other similar phenomena in infrastructural discourse, one begins to realize the uniqueness of Jónsson's proposition. Wind living? Solar living? Biomass living? These are all examples of

renewable energy, but they fall short of fostering cultural practices that synthesize into a recognizable lifestyle – at least not for now. Iceland's development of regional geothermal energy over the past 20 years has grown dramatically but it stems from humble beginnings located in cultural traditions: ways to stay warm, maintain hygiene, relax, and prepare food. In maintaining ways of geothermal living, Iceland serves as a case study for how renewable energy infrastructure can integrate more seamlessly into a decarbonized future that is often only considered through the lens of science and technology. Shedding unproductive boundaries between utility and public amenity, Icelanders practice geothermal cultures everyday by heating their homes with geothermal hot water, going to the public pool, cooking with greenhouse produce, etc. Using space heating, bathing, and foodways as three geothermal subcultures, this paper provides evidence for how governments, planners, and architects can introduce recreation and social benefit as points of desire guiding the manifestation of renewable energy infrastructures at scale.

SPACE HEATING

District heating is an undeniable manifestation of geothermal energy as a ubiquitous influence on cultural practices in Iceland. From small, neighborhood cooperatives to massive state-sponsored operations, the use of geothermal fluids for household heating and hot water has solidified Icelander's reliance on telluric energy as a way of survival. Although records have shown Icelanders harnessing geothermal resources since the 13th century, its application to district space heating has only merged since 1930s. Now, "roughly 30% of electricity and 90% of space heating comes from geothermal power plants and low-temperature fields," lending critical advancements to daily life.[5]

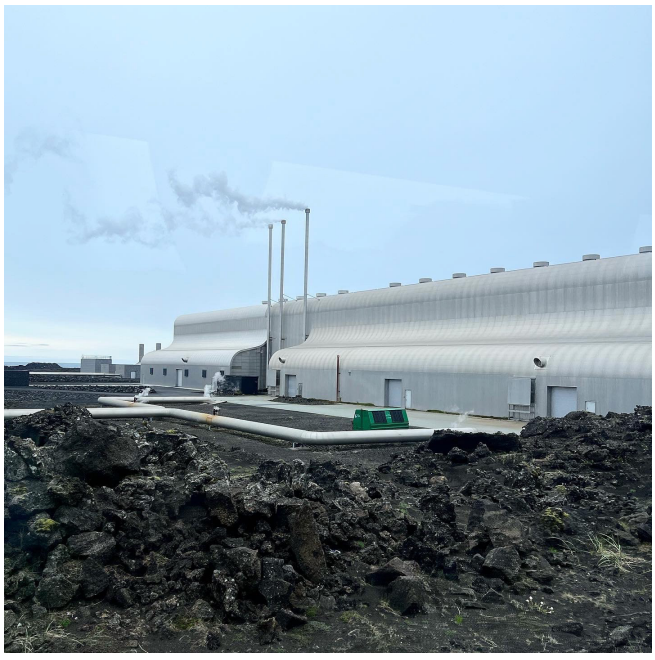

Figure 1. *Reykjanes Geothermal Power Plant on the southwest peninsula*.

In a context where high wind speed and frequent precipitation govern most of the weather, having a renewable and reliable source of space heating is essential to everyday comfort. In associating geothermal energy with comfort, Iceland has celebrated the presence of geothermal power through design, architecture, and other forms of cultural engagement.

One doesn't need to travel far outside of Reykjavik to witness how geothermal energy is beautifully embedded within daily life. Stretching away from the capital city, Seltjarnarnes Township (population ~4,600) occupies a peninsular landform to the west of downtown. Given its proximity to city center, this mostly residential area also accommodates the Grótta Island Lighthouse and the Golfkúbbur (Golf Club) Seltjarnarnes as local recreational attractions. Although the township can be considered an appendage to the capital city and thereby afforded the same district heating network supplying Reykjavik, Seltjarnarnes Township actually runs its own geothermal operation. The Seltjarnarnes Heating Company is owned by the Seltjarnarnes Township and has been in operation since 1971. The collective has drilled twelve geothermal wells since its inauguration but currently only rely on four wells to provide all of the township's heating, hot water, and energy. In fact, the well numbered "SN-12" produces almost enough hot water for the entire system.[6] Visitors to the Seltjarnarnes Peninsula hoping to enjoy the view from Grótta Island Lighthouse will undoubtably notice what first appears to be a subtle mural or folly reflecting an open expanse of the Icelandic sky. Yet upon further inspection, one discovers that this intentionally designed structure is in fact the pumping station for geothermal well SN-12. Erected in 2002, Pumping Station SN-12 was designed by architects Helga Bragadóttir and Agústa Sveinbjörnsdottir (Figure 2).[7] Two curvilinear planes in the ground, the walls of the pumping station are dressed in a holographic scene of clouds mimicking the skyline. Each wall also delicately offers a circular pane of iridescent glass as a viewpoint into the pumping station within. As if to whimsically demark and celebrate geothermal energy's role in the township's everyday landscape, the citizens of Seltjarnarnes have leveraged architectural design to establish an inextricable link between energy systems and cultural value. Even at the neighborhood scale, one senses an ease in occupying both utilitarian and cultural territories at the same time and wonders whether this cultural sheen to energy infrastructure is applied throughout Iceland. Furthermore, buried in the visitor description text at Pumping Station SN-12 is a reference to the higher salinity content in the water drawn at Seltjarnarnes as compared to that of Reykjavik, alluding to "balneological potentials" akin to other popular spas in Europe.[8] Such extensions of geothermal fluids to bathing and hygiene open up another dimension of geothermal culture which we'll discuss later on in the paper.

If Seltjarnarnes Pumping Station SN-12 helps establish evidence for geothermal culture at a neighborhood scale, Reykjanes Power Plant demonstrates this Icelandic phenomenon at a regional scale. Much like Seltjarnarnes, this district heating operation is

Figure 2. *Seltjarnarnes Heating Company - Pumping Station SN-12*. All images by author unless otherwise noted.

also located on a peninsula 70km outside of the capital in order to capture geothermal brine at high temperatures. Owned by HS Orka, the leading private electricity generator in Iceland,[9] Reyjkanes Geothermal produces 100MWe from two 50MWe turbines using steam and salt water from twelve wells supplying a reservoir at 290°C to 320°C.[10] These high temperatures, along with excessive amounts of mineral and salt content, prevent the geothermal fluid from going into district heating and hot water use. Instead, this facility, the third largest geothermal operation in Iceland, provides renewable energy to most of the Reykjanes region. Despite being in operation since 2006, the Reykjanes Geothermal complex still presents as an otherworldly, high-tech architectural attraction intentionally at odds with the volcanic landscape (Figure 1). Hugging the horizon of lava fields, the metallic cladding of the turbine halls flow fluidly in a clean line, perhaps as an ode to the oceanic waves into which the geothermal brine returns. If the cultural sheen at Seltjarnarnes was experienced as a delicate bridge between art, design, and infrastructure, the desire for cultural expression and participation becomes undeniably palpable in this instance. Geothermal energy, elevated through architectural intention, becomes relevant within cultural discourse in Iceland. This discourse is then propagated and exported through its support of educational programming and guided visits to tourist groups within their exhibition hall.[11] The high degree of architectural design invested in the facility seems to suggest that making a cultural mark was always at stake in declaring a geothermal future for the region, if not for Iceland at large. Architecture's role in substantiating renewable energy infrastructure in this case (and as with the case with Seltjarnarnes) becomes a productive precedent for governing bodies not yet aware of how to leverage cultural tactics to push renewable agendas forward.

Figure 3. *Laugardalslaug Geothermal Swimming Pool in Reykjavik*. Wikimedia Commons.

BATHING & HYGIENE

District heating and hot water often presumes a private or household level of consumption, but this public utility has natural (and pleasurable) extensions into social domains. As the Pumping Station in Seltjarnarnes suggests, geothermal hot water is used for bathing not only in practical applications but also for healing, relaxation, and public gathering. Historically, Iceland has long used geothermal water for bathing and laundry purposes. The main commercial street in Reykjavik, Laugavegur, is named as the "wash road" that women used to take their laundry to the hot springs for washing.[12] This practice of socializing around a telluric and renewable energy source, the hot springs, forms the foundation of how geothermally-heated pools (endearing called hot pots in Icelandic) function in Icelandic society today. Regardless of how small or large the community, sundlaugs, or swimming pools, are a constant typology with the built environment. As Nele Schacht aptly points out in *Tales from the Hot Pot*, "as strange as it may seem for a country just below the Arctic Circle, the pool is the social meeting point in Iceland, according to the locals."[13] Schacht's statement implies that despite (and because of) Iceland's harsh climate as dictated by its geographic location, hot pots possess a unique place in the cultural sphere of Icelanders because it helps to melt away the sharpness of living in such extreme conditions. The communal aspect of this typology is even more essential since residents are able to defy the realities of temperature, wind, or precipitation as a shared experience, collectively reaping the benefits of naturally heated hot water as a reward for their resilience (Figure 3). Sprinkled throughout the island, hot pots are the unshakable cultural ambassador of geothermal power to the point that "a community without a proper bathing facility, including a hot tub, is considered incomplete."[14] Such strong public appreciation for hot pots suggest that symbiotic relationships between relaxation, social recreation, and renewable energy exist. Back in 2007, 130 out of Iceland's 163 public swimming pools were heated with geothermal means. Studies in Iceland showed that while 60% of pool-goers went explicitly to swim, 37% of visitors went to relax, 22% went to access the hot tub, 21% used the pool to spend time with family, and 11% went meet their friends.[15] To project these studies forward, the typology of Icelandic geothermal baths raises the question of how renewable energy infrastructure can become positively engaged in services, programming, and amenities for the public's enjoyment in other regions using other energy sources. What other forms of cultural practices can we associate with practical utilities such as energy systems, and how might these linkages promote increased adoption of renewable energy infrastructure in general? And is there evidence

Figure 4. *Silica Hotel at the Blue Lagoon, with a glimpse of Svartsengi Geothermal Power Plant behind.*

for architecture's participation in accelerating this cultural-infrastructural evolution?

Promising connections between design influence, renewable energy, and enjoyment can be found by looking at certain premium experiences where a masterful blend of architectural design and hospitality successfully repackage excess geothermal by-products into luxury wellness destinations. The Blue Lagoon is the original and most popular of these spa retreats. Tapped into the Svartsvengi Geothermal Power Plant next door, the Blue Lagoon pumps geothermal seawater and its prized minerals into its various pools at 38°C. As the story goes, the benefits of bathing in the lagoon's "geothermal seawater were first discovered by people seeking comfort from psoriasis"[16] by dipping into open pools of geothermal fluid when the power station first started operating. Since then, the Blue Lagoon has transformed into a bonafide tourist destination complete with Michelin-starred restaurants, spa services, and high-end hotels. Named after the way the silica minerals reflect the sunlight, this geothermal spa espouses the rejuvenating powers of geothermal fluids contained in the silica, minerals, and algae found in the seawater. The silica mud is advertised to strengthen the skin's function and provide a radiant appearance while the mineral salts revitalize the mind and body. The algae found in the seawater promote collagen production for more youthful-looking skin.[17] While these specific health factors reflect a very different user group and motivation as compared to the typical sundlaug, the fundamental balneological benefits remain the same. Just like the average neighborhood hot pot, the Blue Lagoon leverages geothermally heated hot water to catalyze a public context for relaxation, recreation, and social engagement.

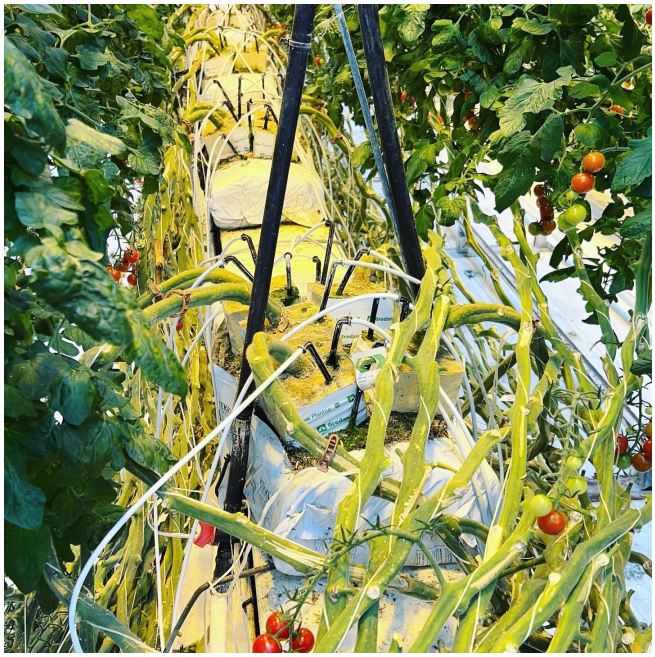

Figure 5. *Tomato vines growing from pumice at Friðheimar Tomato Farm in Reykholt.*

Architecturally, designers have gone to great efforts to obscure views of the Svartsvengi Geothermal Plant from the transportive experience of its steaming pools. Unlike the declarative posture of Reyjkanes Power Plant, the architecture of Blue Lagoon takes a back seat to its breathtaking context. Strategically located within 800-year-old lava fields, various aspects of the Blue Lagoon campus seem to create the sensation of bathing directly within volcanic ground (Figure 4). Pools form between clusters of moss-covered lava rock while the low-laying buildings acquiesce to the unique "moonscape" before them. In the instance of the Blue Lagoon and other luxury geothermal spas, the connection back to geothermal power is forfeited and replaced by a more primordial link to the volcanic landscape itself. Here, perhaps the connection between renewable energy and cultural practice is less imperative. Instead, this exuberant example of the public bath typology leapfrogs over the infrastructure-ritual intermediary and directly fosters broader cultural appreciation for the specific geological and thalassic conditions through which the renewable energy is produced.

FOODWAYS

Choices in cooking have an underestimated influence on alimentary traditions. For example, cooking with gas promotes drastically different food cultures as compared to cooking with electricity. Like other energy sources, geothermal heat has also influenced the foodways of Iceland since the time of its settlement. Without the presence of an open flame, geothermal heat and hot water have largely developed food preparation techniques reliant on steaming and boiling. Hveragerði Geothermal Park, located in a high-temperature region of Ölfus in southwest Iceland, is one cultural outpost of many sustaining these food practices through education and tourist programming. Since ancient times, residents of Ölfus would bake rye bread in so-called bread holes along the hot springs. As settlers established the town of Hveragerði in the 1930s, residents continued to use geothermal heat for cooking and baking – potatoes were boiled in canvas bags lowered into the boiling hot springs while breads, cakes, and other foods were cooked in wooden steam boxes or iron pots. Such domestic practices had the potential to grow in scale, as exemplified by the Hverabakari (bakery) in town known for pioneering the recipe for dark rye bread. Its famous hverabraud (hot spring bread) is still produced and sold in Hveragerði.[18] In a similar fashion, steam from the Bakkahver hot spring was channeled to the Molkurbú Olfusinga dairy farm to pasteurize milk and distill whey for making cheese.[19] These food traditions are still in practice today at the Geothermal Park. The visitor center doubles as a greenhouse that grows grapes, tomatoes, and tropical plants using geothermal heat. Visitors have the rare opportunity to boil their own egg by lowering it into an iron cage tapped into the boiling geothermal ground water below (80-90°C). After 10 minutes (recommended boiling time), visitors enjoy their geothermal egg with a side of freshly steamed rye

Figure 6. *Bio-effect Greenhouse in Grindavik.*

bread and greenhouse-grown cherry tomatoes (Figure 7). This sampling of geothermal delights in its present-day arrangement suggests a piecing together of celebrated staples (the rye bread) with contemporary agricultural products (cherry tomatoes) made accessible through technology (and more geothermal power!). The modest greenhouse / visitor's center, replete with grape vines on the ceiling and cherry tomatoes sprouting from the ground, demonstrates how geothermal energy's influence on food production in Iceland is stronger now than ever before.

The Hveragerði visitor center provides a small-scale example of geothermally-supported greenhouses, but Icelanders have been leveraging geothermal power for commercial food production since the 1920s. The Friðheimar Tomato Farm is the most well-known example of Iceland's application of geothermal heat towards domestic agriculture. Tourists are able to visit the farm and enjoy a vast menu of tomato-based food items – ranging from their famous tomato soup to cocktails infused with their signature fruit. Yet behind this roadside attraction is actually an extremely productive "farm" consisting of 11,000 square meters of highly-calibrated greenhouses reliant on geothermal heat and other bio-technological innovations. The Friðheimar facility produces roughly 700 tons of tomatoes a year, or 39% of Iceland's total tomato market. Perhaps surprising to outsiders, vegetable and flower growers like Friðheimar do not find Iceland's remote location in the north to be a detractor since the harsher conditions decrease the likelihood of plant pests, diseases, and weeds. However, in order to compensate for the limited natural growing conditions found in the outdoors, Iceland's agricultural industry has fully embraced a suite of technological advancements

Figure 7. *Geothermal delights consisting of steamed dark rye bread, steamed egg, and geothermally grown tomatoes.*

including geothermal heat, carbon dioxide, computer sensors, and other biological controls.[20] Radiators pumping geothermal hot water at 95°C warm the greenhouses which are minimally insulated with 4mm thick glass in order to optimize the amount of natural daylight entering the space. In addition, grow lights powered by renewable energy (either geothermal or hydropower) make up for shortfalls in natural light, ensuring year-round production on the farm. It's not only geothermal energy that makes greenhouse agriculture in Iceland an impressive example of a para-climate change ecology. The greenhouses at Friðheimar also use 400 tons of carbon dioxide (captured from natural steam) annually in order to stimulate plant growth. Without large amounts of arable soil, greenhouses across Iceland opt for locally sourced pumice (volcanic tuff) as a growing medium which provides better control moisture and fertilization (Figure 5). Even biological agents participate in this ecology that is half-organic and half-machine - mirid bugs irradicate pest populations while bumble bees pollinate the tomato plants. Computers monitoring heat, humidity, light, carbon dioxide, fertilization levels, and weather patterns make necessary adjustments to the greenhouse ecology so that production remains in optimal conditions.

In integrating the resources and tools mentioned above, the Icelandic geothermal greenhouse has drastically evolved since the 1930s, hugely impacting the way Icelanders procure and prepare their food. With a total of 18.5 hectares of greenhouses across the island, Iceland now produces 75% of their tomatoes and 90% of their cucumbers domestically.[21] Changes in domestic agricultural policies have also helped to ensure market competitiveness of Icelandic produce while securing income levels for local growers. At the same time, investment into new product development and marketing of "homegrown" vegetables[22] open up new avenues of alimentary and culinary development at home. As Professor Örn Daniel Jónsson attests in Nele Schacht's useful guide to Icelandic bathing culture, "five years ago, you had Icelandic tomatoes and they were seasonal. But now you have ten types of tomatoes and they grow all year round. So the [geothermal] water is not only used in the pools but also for agriculture…amongst other things…it's growing very rapidly."[23] Jónsson's statement beautiful draws the throughline of geothermal energy's cultural influence from bathing and hygiene practices to agriculture and cuisine. By tapping into geothermal heat, Icelandic horticulturalists are increasing access to fresh local produce that has secondary environmental benefits of recycling CO_2 emissions and protecting soil banks. As the architectural manifestation of this shift, the contemporary greenhouse helps to expand the definition of a geothermal palate and its potential to liberate the ways Icelanders eat.

Needless to say, these organic and mechanical calibrations have remarkable consequences on the architectural taxonomy of Iceland. Like beacons or lighthouses in the distance, these glowing glass extrusions embody a sense of steady optimism (scientific and cultural) against temperamental climate conditions and extreme circadian light levels. Arguably ostentatious,

the architectural affect is nonetheless an honest product of its pragmatism (Figure 6). It is uncanny to reconcile the fact that these futuristic jewel boxes are simply growing tomatoes, and that their otherworldliness is primarily an extension of the renewable energy source they rely on. The Friðheimar greenhouse and others of its kind have garnered architectural attention for multiple reasons. For the purposes of this paper, it catalyzes exciting questions of how architectural design in various sectors such as agriculture and industry present a frontier for designing with limited resources, climate awareness, and renewable energy systems in mind.

CONCLUSION

This survey of geothermal heating, bathing, and eating attempts to build the argument that utilitarian and cultural territories can exists in the same plane – and that critical levers for moving towards a renewable future, such as energy infrastructure, could benefit from occupying both domains. Iceland's approach to integrating geothermal energy into everyday life provides inspiring frameworks for how other governing bodies can blur the lines between infrastructural and cultural investment. Traditions of space heating, bathing, and food cultivation in Iceland are not strictly dictated by geothermal power, but Icelanders have certainly welcomed it's influence over the formation of daily rituals. On a commercial scale, operations like the Blue Lagoon and Friðheimar Tomato Farm, despite being intentionally marketed towards visitors, offer concrete examples of how cultural practices entrenched in renewable forms of energy can garner popularity and provide enjoyment at the same time. Through tourism and other opportunities of cultural exchange, architecture is then able to accelerate or mediate this green transition. Projecting into a renewable near future, the mind marvels at how new thinking in architectural design and cultural programming in other parts of the world can model Iceland's approach in placing cultural value in energy systems. Without the need to clearly distinguish between utility and culture, the slippage between practicality and pleasure becomes a productive space for exciting design work to happen.

ENDNOTES

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