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INSIGHTS INTO THE ICELANDIC ENERGY MARKET

OWNERSHIP AND ASSET MANAGEMENT STRATEGIES FOR AN ISLANDED GRID

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Note from authors: This paper represents our best effort to characterize the Icelandic energy market in its relevance to the Alaska Railbelt Grid. Our sources encompass a wide range of historical and contemporary materials, including regulatory filings, published works, and insightful discussions with key stakeholders within the Icelandic energy sector. As we gather additional insights, respond to questions from stakeholders in Alaska, or acquire clarifying information, we are committed to continuing to update this document. Responses to specific question are included in Appendix C.

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1.0 Introduction

The utilities serving Alaska's Railbelt Grid are facing mounting pressure to reduce power costs while simultaneously transitioning to lower-carbon energy sources for power generation. These twin goals are difficult to achieve in an environment where our systems lag considerably behind the rest of the U.S. in crucial resilience metrics and best practices for grid management and ownership. Transforming how we use and produce power hinges first on modernizing our transmission infrastructure. This modernization encompasses not only the physical infrastructure of our grid, but also pertains to the governance, ownership, and cost recovery methods of the entire system.

Successfully modernizing Alaska's Railbelt grid benefits residential consumers, but is also key to our ability to be competitive in a changing global economy that is increasingly reliant on accessible, affordable, and low-carbon energy sources. A host of local, national, and international factors are compounding the urgency to act now. Most significant is the near-term opportunity for federal funding for transmission upgrades. If leadership is unified and well organized, there is a good chance Alaska can benefit significantly from generational investments planned through the Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA). However, even if Alaska is successful in winning federal funds, a significant state investment will be required as match. The Railbelt utilities cannot undertake these investments independently[1]; thus, state-led coordinated action is vital for successful execution. This presents a distinct opportunity to unify around a comprehensive strategy, addressing the Railbelt's investment needs and re-evaluating the ownership and operation of our current assets in anticipation of future demands.

Adding to this urgency are the uncertainties surrounding future natural gas supplies in Cook Inlet and the growing customer demand for lower carbon sources of energy – demand that encompasses both residential consumers and key industrial anchor customers, whose contributions to cost containment are often underappreciated[2]. Combined with the Governor of Alaska's stated goal of lowering the cost of power to consumers to 10 cents/kWh[3], it is clear that business-as-usual practices are not adequate.

Drawing from the experiences of regions that have successfully navigated similar energy transitions can help guide Alaska towards an environmentally sustainable and economically thriving future. Iceland's Ring Grid serves as an instructive model for Alaska's Railbelt Grid due to their shared attributes and historical parallels, especially when no direct U.S. analog is apparent[4]. Both grids have similarities in installed capacity, grid length, population served, and a mix of publicly owned local utilities, larger state-owned assets, and independent power producers. Notably, until the mid-1990s, the electrical markets and generation of both Alaska and Iceland tracked closely. Yet, their paths diverged over the past three decades due to two pivotal factors: Iceland's strategic move to anchor heavy industry to its

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[1] All the Railbelt utilities have considerable debt, and upgrades to the transmission system won't solely benefit one entity. Given this, the State of Alaska will likely have a pivotal role in any scenario. Currently, the Alaska Energy Authority owns key components of the Railbelt Grid.

[2] If the Kinross Fort Knox and Pogo Mines outside of Fairbanks ceased operation, rates to electric consumers in Fairbanks would increase an estimated 40% overnight. Many international corporations like Kinross have aggressive goals for reducing their carbon footprint, and are putting pressure on utilities to decarbonize their energy supply. Should they choose to downsize or cease operation in Alaska, there would be significant implications for our energy markets, including higher rates.

[3] The Governor recently charged the Alaska Energy Security Task Force with developing strategies or pathways for achieving 10 cent/kWh power across the state.

[4] The Alaska Railbelt is by far the smallest independently operated grid in the country, with no comparable systems in the U.S. To put this in perspective, the Texas Interconnection, which is the smallest Lower-48 grid and is also a single-state system, has a peak load of 85,000 MW – two orders of magnitude greater than the Railbelt Grid.

economy and fortify the energy sector, and its compliance with mandatory European Union deregulation policies.

Today, Iceland's energy market exemplifies what Alaska aspires to develop. Most strikingly, the average price of delivered power in Iceland stands at less than 10 cents/kWh (see Appendix A for additional detail on rate structure). Iceland's Ring Grid, managed by a state-owned Transmission System Operator (TSO)[5], operates under the principles of open access, transparent pricing, and non-discriminatory transmission. This paper delves into the elements that shaped Iceland's present energy landscape, its current market dynamics, and the insights Alaska can glean as it navigates its own energy transition.

2.0 Comparative Overview: Alaska's Railbelt Grid and Iceland's Ring Grid

The Alaska Railbelt Grid and Iceland's Ring Grid share many historical and structural similarities. Their small size and lack of electrical interconnections makes them each outliers when compared to other systems in the U.S. and Europe. Both grids, however, are efficient, functioning systems characterized by a diverse range of geographically spread generation sources and load clusters. Each region features multiple local public utilities responsible for power distribution to end-users. These clusters are primarily centered around populated areas that, historically, operated autonomously. In Iceland, these are primarily municipally owned, while in Alaska they are organized as member-owned cooperatives[6]. Additionally, both regions see generation assets held by a mix of local utilities and Independent Power Producers. Notably, very large grid-scale projects in both contexts tend to fall under state ownership.

	Installed capacity	Length (linear)	Annual sales (total, 2022)	Annual sales (per capita)	Delivered cost of power
	[MW]	[Miles]	[GWh]	[MWh/capita]	[$/kWh]
Railbelt Grid (AK)	~2,000	~700	4,900	9	$0.19 - $0.26
Ring Grid (Iceland)	~2,900	~2000	19,100	54	$0.7 - $0.13

Table 1. Basic comparison of Alaska's Railbelt Grid to Iceland's Ring Grid today. The difference in delivered cost of power and per capita sales represent the most significant difference.

One of the most significant structural difference between Alaska and Iceland lies in the governance and ownership structure of their respective transmission networks. Iceland's Ring Grid is a publicly owned asset, wholly owned and managed by the state-owned company Landsnet which serves as Iceland's Transmission System Operator (TSO)[7]. The Railbelt transmission network, in contrast, is treated as a private good, with portions owned and operated by each of the four independent cooperative utilities – Homer Electric Association (HEA), Chugach Electric Association (CEA), Matanuska Electric Association (MEA), Golden Valley Electric Association (GVEA), and the State of Alaska through the Alaska Energy Authority (AEA).

[5] In this paper, we consistently use the term "Transmission System Operator" (TSO) when referring to Landsnet. This terminology aligns with common European parlance. In contrast, the U.S. often uses the term Regional Transmission Organization (RTO). While both TSOs in Europe and RTOs in the U.S. share the fundamental responsibility of ensuring reliable and efficient electricity transmission, the nuances of their roles, market operations, and regulatory environments diverge significantly due to the distinct contexts of Europe and the U.S.

[6] The cooperative model is a business and governance model featuring a not-for-profit mission, equity capital raised from members, and no outside shareholders.

[7] Transition of ownership of these assets has taken place over two decades, with the last section expected to be sold to Landsnet before the end of 2023.

The present ownership and, by extension, operation of the Railbelt Grid is similar to Iceland's structure twenty years ago. Iceland's journey, transitioning from a system akin to Alaska's Railbelt to a unified, state-owned TSO, and the subsequent benefits for consumers in terms of cost reduction and a more open energy market, may offer valuable insights for Alaska. This paper is dedicated to uncovering those lessons.

There are, to be sure, some additional important distinctions between Iceland and Alaska's energy markets that need to be highlighted. Notably, Iceland's grid is predominantly powered by renewable energy, with hydroelectricity accounting for approximately 80% and geothermal energy making up about 20%. There is no fuel cost associated with these sources of generation, and unlike intermittent sources like wind and solar, the majority of this power is dispatchable. This greatly simplifies their ability to achieve high penetration levels of renewable energy. This is in contrast to the Railbelt, which today is primarily reliant on natural gas, with only approximately 13% of generation coming from renewable energy, mainly hydroelectric. While future renewable generation in the Railbelt may include hydroelectricity, it's also likely to integrate wind and solar. This introduces complexities that Iceland hasn't grappled with.

Use of renewable energy is not limited to electric power generation. Almost all of Iceland's space heating is supplied by geothermal resources, totally about 90% in total[8], which are in many cases managed in conjunction with power generation which further enables economies of scale in production, management and distribution of energy. For remote areas without access to geothermal district heating, electric heating is common and discounted through a subsidy program.

Another noticeable difference is the extremely large difference in annual sales, especially on a per capita basis, coupled with the comparatively low cost of delivered power in Iceland. These two factors are intrinsically intertwined, and are made possible by buildout of the grid and the restructuring of Iceland's energy market. However, the restructuring alone did not create these outcomes. Deregulating energy markets can create an environment that fosters competition and can reduce costs. However, restructuring, by itself, typically yields modest incremental benefits to consumers.

Restructuring is not solely explanatory for the low cost of power in Iceland, but it can be seen as a necessary precondition. Instead, the main factors are the high volumes of production and sales, which foster greater efficiencies and economies of scale than currently seen in Alaska. Notably, this disparity has emerged only recently. Up until the mid-1990s, Iceland's and Alaska's electric production, as well as the cost of delivered power, were largely in sync. Post that period, their paths diverged markedly in terms of both annual production and sales, as shown in Figure 1. This shift has mirrored in Iceland's consumer power costs, which have steadily decreased over the past three decades.

[8] Orkustofnun (2021). *OS-2021-T012-01: Space heating in Iceland by energy source 1952-2020*. From a policy perspective, the Iceland Geothermal Drilling Fund was very instrumental in reducing risk and enabling the expansion of geothermal development for space heating, beginning in the early 1980s.

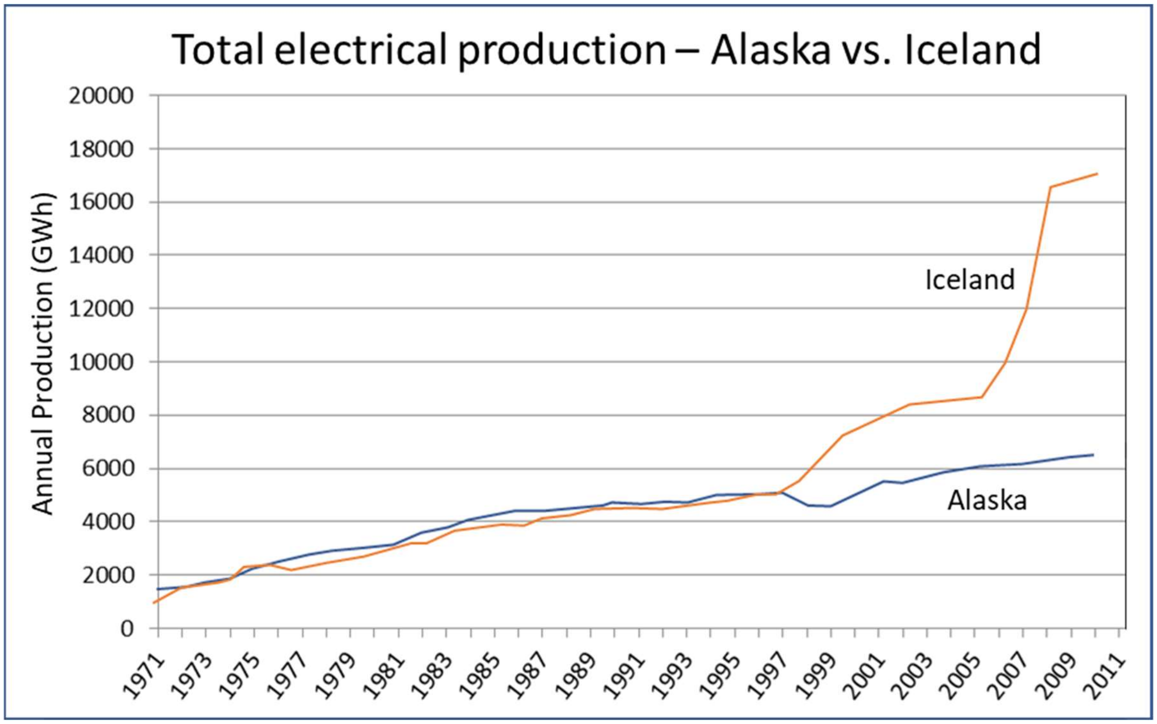

Figure 1. Between the early 1970s and the mid 1990s, Iceland's electricity production was similar to Alaska. On a per capita basis, Iceland produces more power than any other country in the world as a result of their robust commercial and industry (C&I) customer class energy demands.

Today, over 75% of electricity produced in Iceland is for the commercial and industrial (C&I) sector (Figure 2a)[9]. This is almost entirely due to Iceland's aluminum smelting industry. Producing aluminum from raw bauxite ore is very energy intensive[10]. This is why aluminum-producing companies strategically locate their smelters in regions with affordable and consistently priced energy. Iceland has positioned itself to be one of these locations, and as a result bauxite ore is transported by ship to Iceland from as far away as Australia to be refined. If you exclude the C&I sector, Iceland's energy intensity on a per capita basis is nearly identical to the Railbelt (Figure 2b).

[9] Orkustofnun (2020). *OS-2020-T013-01: Electricity consumption in Iceland 2019*

[10] This underscores the value in recycling aluminum cans. Recycling aluminum uses only about 5% of the energy required to produce aluminum from bauxite ore. Therefore, every ton of recycled aluminum saves several thousand kilowatt-hours of electricity.

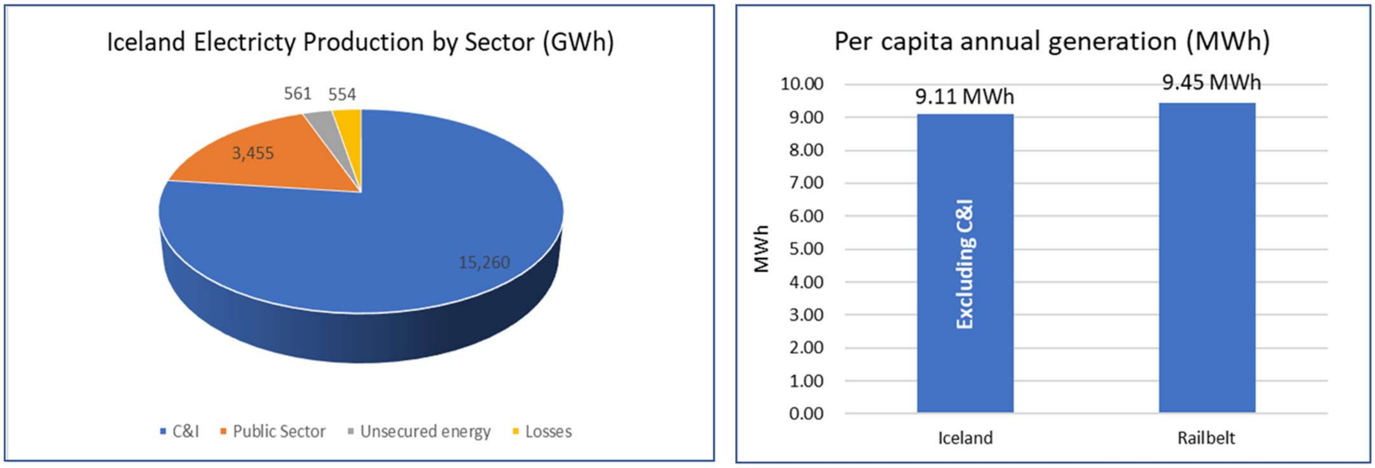

Figure 2a and 2b. Iceland electricity production by sector (2021). Commercial and industrial consumers account for more than 75% of sales. If C&I sales are excluded, Iceland and the Railbelt produce and consume similar amounts of power per capita. This means that residential consumers and small businesses use about the same amount of electricity in both markets.

3.0 Alaska and Iceland – a similar early path 1970-2000

The Railbelt Grid and the Ring Grid followed similar trajectories in their early years, and both are not dissimilar to the pattern of electric grid expansion that occurred in much of the U.S. and Europe. Initially, urban areas were electrified, followed by a gradual extension to more rural areas. This expansion fostered interconnected grids that reduced costs and improved reliability by enabling more reserve sharing[11], and the ability to interconnect new, often large generation assets that afforded greater economies of scale[12]. This section describes the parallel history of the Railbelt Grid and Ring Grid up until the early 2000s, when their paths diverged.

3.1 Formation of Alaska's Railbelt Grid

The Alaska Railbelt Grid serves roughly three-quarters of Alaska's population and accounts for about 80% of the state's power generation. Despite its modest size compared to many energy markets, its management intricacies and the diversity of involved parties resemble those of far larger systems. This complexity stems from its origins: an assortment of independent grids each owned and operated by local utilities. These grids, over time, became interconnected, leading to the intricate, multi-stakeholder energy framework we see today. This distinct evolution has profoundly influenced the Railbelt Grid's operational dynamics and stakeholder relationships.

Historically, electrification began in urban centers with the establishment of municipally-owned utilities in Anchorage and privately-owned utilities in Fairbanks[13]. Cooperative utilities were later organized to provide electric power to more outlying rural areas, mirroring a pattern seen in the rest of the U.S. Over time, these once-independent utilities underwent consolidation and interconnection. Today, five service

[11] Reserves are additional generation capacity that can be mobilized on short notice. By sharing reserves, utilities or load balancing areas have access to a larger pool of backup resources than they would if they operated independently.
[12] In many cases these generation assets were large hydroelectric facilities.
[13] Fairbanks Electric Light and Power Company (FE Company) was the first electric utility in Fairbanks.

territories remain, managed by four cooperative utilities and the City of Seward[14]. Although now interconnected, each of these utilities retains its unique identity, characterized by its individual management structure, organizational culture, commitment to its members or customers, and historical context. Their relationships with each other are also complex and have been shaped by their shared and individual histories.

From an electrical standpoint, the Alaska Railbelt Grid comprises three discrete load balancing areas: the northern region (Fairbanks-Delta Junction), the central region (Anchorage-MatSu), and the Kenai Peninsula. The southern and central regions interconnected in the early 1960s when CEA built the Cooper Lake Hydroelectric project and signed a power sales agreement with HEA, necessitating a transmission link. The capacity of this line increased with the development of the Bradley Lake project. The Alaska Intertie was constructed by the State of Alaska in the mid-1980s to interconnect the northern and central regions, and is owned by the Alaska Energy Authority. The Northern Intertie was later constructed by the state between Healy and Fairbanks, which more than doubled the capacity of existing transmission owned by GVEA[15]. A primary objective of the Alaska and Northern Intertie's development in the mid-1980s was connecting the three major generation hubs and facilitating new interconnected generation. This encompassed the Bradley Lake hydroelectric project and the yet-unrealized Susitna-Watana hydroelectric project[16].

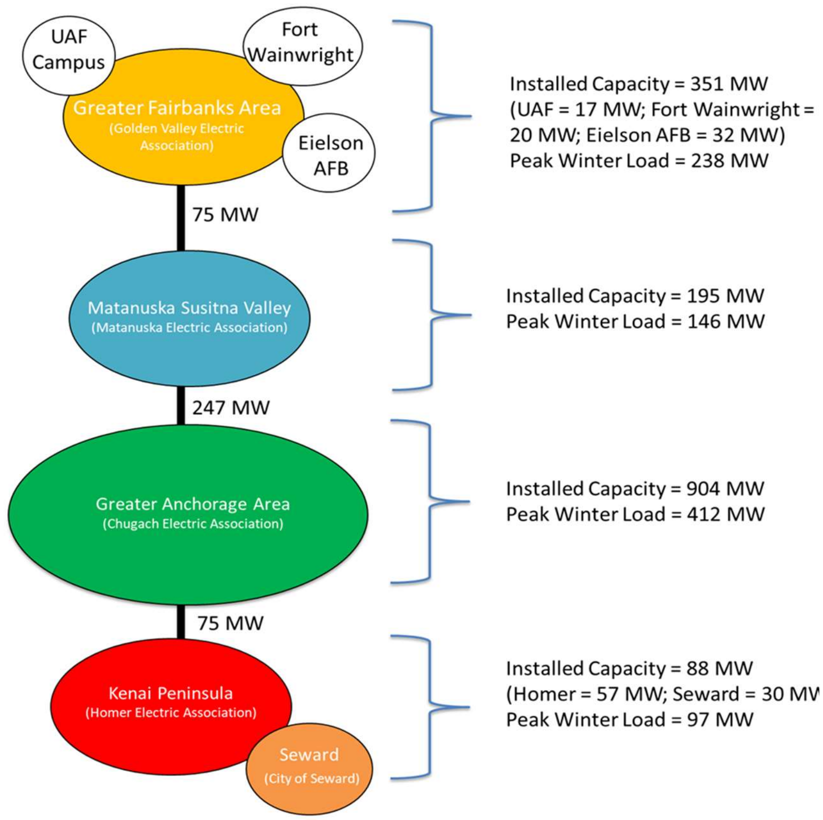

Figure 3. Alaska's Railbelt Grid

[14] The City of Seward, operates its own municipally-owned utility, is also part of the Railbelt but primarily functions as a distribution utility with power purchased and transmitted from Chugach Electric Association and constitutes less than 2% of total Railbelt energy consumption.

[15] This was part of a larger investment in new generation in Healy (HCCP) along with a large Battery Energy Storage System to reduce outages in Fairbanks and take advantage of inexpensive mine-mouth coal supplied by Usibelli.

[16] The Alaska Intertie was constructed to interconnect the northern and central regions to the planned three-dam Susitna-Devils Canyon-Watana hydroelectric project - originally conceived as a 1200 MW project - thus its construction to 345kV design criteria.

Over the past decade, all Railbelt utilities have increased their generation capacity, resulting in constraints and congestion at different network points. As a result, a broad consensus has emerged that investments in transmission upgrades and new infrastructure are crucial for modernizing Alaska's Railbelt grid and broadening its generation mix with more renewable sources.17

The Railbelt grid faces operational inefficiencies at two basic levels:

1. Economic Dispatch Limitations: Restrictions exist on prioritizing the use of the most cost-effective generation, termed 'economic dispatch.' Ideally, one would first utilize the least expensive generation sources to ensure economic efficiency[18].
2. Fragmented Transmission Asset Ownership: The grid's varied ownership results in 'pancaking rates' — the stacking of transmission cost recoveries. While the rates that individual utilities charge for transmitting power through their territories are cost-based and should, in theory, remain consistent regardless of ownership, the challenges of navigating multiple entities when transmitting power both north and south have hindered strategic investments, especially by IPPs. Moreover, utilities can exercise some discretion in allocating costs between transmission and other areas, potentially reallocating costs to transmission used by other utilities rather than raising rates for their own customers.

Additionally, the grid's design poses resilience challenges, particularly in the face of natural disasters or distinct weather-related events. Illustrative examples include the 2018 Swan Lake Fire, which compromised the Soldotna-Quartz (SQ) Creek line bridging the Kenai and central regions. Similarly, issues such as the sporadic unbalanced snow loading on the Alaska Intertie highlight the grid's susceptibilities. These events emphasize the grid's fragility and underline the imperative for targeted reforms and investments to enhance its reliability and efficiency.

The recently established Railbelt Reliability Council (RRC) addresses several, but not all, of these concerns. Established due to legislation (SB 123) passed in 2019, the RRC is responsible for formulating and upholding reliability standards, devising a transmission cost allocation method, and supervising long-term strategies, ensuring the Railbelt grid's reliability and efficiency. This includes crafting an Integrated Resource Plan (IRP). It does not change the ownership or governance structure of the transmission system itself, the extent to which its responsibilities pertain primarily to generation or transmission planning remains a topic of debate.

The current ownership, governance, and management of the Railbelt grid today is very similar to Iceland's Ring Grid in the early 2000s, prior to the restructuring of its energy market.

3.2 Formation of Iceland's Ring Grid

Iceland's Ring Grid followed a similar pattern of buildout to the Railbelt Grid. In the early 1970s, four independent load balancing areas had emerged, centered around major population hubs: the North (near Akureyri), the Westfjords, the East (around Egilsstaddir), and the South/southwest (around Reykjavik, the capital). These were not interconnected and operated independently from one another, much like the

[17] Notably, the existing transmission system was developed around three primary fuel sources in addition to hydro: gas (Cook Inlet), coal (Healy) and oil (HAO and Naphtha from the pipeline) Fuel diversification away from these sources will require significant modifications to the transmission system.

[18] The utilities have self-organized approaches to partly addressing this issue, through both bilateral agreements and through the south-central power pool.

three independent load areas in Alaska prior to 1985[19]. Electric generation within those isolated electrical "islands" was primarily a combination of hydropower and diesel plants that were owned by the state, local municipalities or private developers. High costs resulted from the limited size of the grids and a significant reliance on diesel generation.

The oil crisis of the 1970s had a significant impact on Iceland, which still relied heavily on imported diesel fuel for power generation and heating. Given its modest GDP, predominantly anchored in the fishing industry, the oil crisis dealt a severe blow to Iceland.[20] In response, policy makers designed and implemented a comprehensive energy strategy designed to significantly decrease reliance on imported fuels, and instead focus on building out Iceland's domestic renewable energy resources.

To maximize the advantages of Iceland's indigenous hydro and geothermal resources, transmission became a pivotal component of this strategy. This led to a rigorous 12-year transmission infrastructure development plan from 1972 to 1984, primarily focusing on interconnecting the isolated electrical "islands" and augmenting the use of geothermal water for space heating.

Similar to Alaska, the state funded these new transmission assets and placed them under the ownership and management of the state-owned power company, RARIK. Established in the late 1940s, RARIK focused on small-scale generation and distribution in Iceland's rural areas, which, at the time, lacked modern electrical infrastructure.

Landsvirkjun, the National Power Company of Iceland, was established in 1965 to back investments in new large-scale generation assets, aligning with a broader strategy to attract heavy industry. During the 1960s, as post-WW2 U.S. Marshall Plan assistance in Iceland neared its end, the nation recognized the need to diversify its economy and attract foreign investments. The result was development of Iceland's heavy industry sector, including the establishment of its aluminum smelters. To meet increasing demand from industry, Landsvirkjun was formed to play a leadership role in facilitating additional investments in electricity generation. Consequently, Landsvirkjun owned several major state-owned power stations, primarily catering to the C&I sector's demands, along with sections of the transmission network constructed with state funds. Smaller municipally owned distribution system operators (DSOs) continued to operate in parallel, and still do today. These systems are a legacy of the initial islanded electrification of individual communities and regions before interconnection. These were typically owned by either the state or local municipalities. However, private independent power producers have consistently held a significant role in Iceland's energy landscape. Currently, IPPs, primarily small run-of-river hydroelectric projects, supply about 9% of the generation.

[19] The southern and central load balancing areas on the Railbelt had been operated as a single LBA since the 1960s when they were interconnected, until the end of the wholesale contracts between CEA and neighboring utilities in 2013-14.
[20] Imports of coal was also sharply curtailed during WWII, and it was clear to Iceland that continued reliance on imports for energy production was not a smart strategy, and indeed posed a threat to future economic growth and stability.

Producer	Total production [MWh]	Ownership: State	Ownership: Municipalities	Ownership: Private
Landsvirkjun	13.437.420	100%		
Orka Náttúrunnar	3.580.921		100%	
HS Orka	1.517.763			100%
Orkusalan	254.092	100%		
Smávirkjun / Small scale	195.579			100%
Orkubú Vestfjarða	95.224	100%		
Fallorka	44.127		100%	
Rafveita Reyðarfjarðar	-			
Landsnet	904	93%	7%	
RARIK	1.131	100%		
Norðurorka	-		100%	
HS Veitur	140		50%	50%
Orkuveita Húsavíkur	-		100%	
Total	**19.127.302**	**72%**	**19%**	**9%**

Figure 4. Power Production in Iceland (2020): Breakdown by Ownership Category.[21].

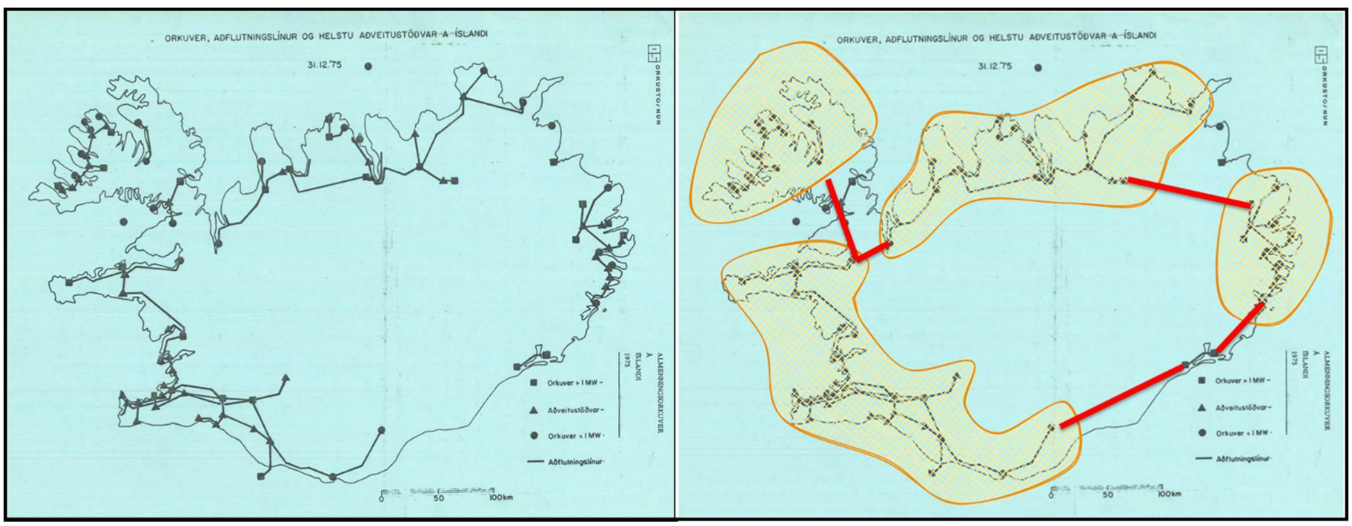

Figure 5a and 5b. Iceland "grid" prior to 1975 (left) [22], and interconnected segments to form the Ring Grid (authors edit).

[21] Orkustofnun (2021). OS-2021-T014-01: Installed capacity and electricity production in Icelandic power stations in 2020 and public financial statements.
[22] Orkustofnun (1976). Electrical powerplants, annual status report.

After the Ring Grid was completed in 1984, its physical framework, including the ownership of transmission, distribution, and generation assets, bore a close resemblance to today's Railbelt[23]. In the Railbelt, key assets such as the Bradley Lake hydroelectric power plant and critical portions of the transmission grid are owned by the State of Alaska through the Alaska Energy Authority. This is akin to how Landsvirkjun owned pivotal generation and transmission assets on the Ring Grid. However, this landscape shifted post-2000, and not by Iceland's voluntary decision

4.0 Restructuring of Iceland's Electric Power Industry: 2003-2023

In the 2000s, the power industries in many European countries underwent substantial restructuring, targeting the dissolution of existing monopolies to promote competition. This evolution mirrored trends in the U.S., motivated largely by similar factors. This section delves into the primary reasons behind these shifts, examines their impact on the Icelandic energy sector, and traces the evolution of these changes in Iceland up to today.

4.1 The Big Picture – Why Restructure and What Does That Mean?

Traditionally, the utility industry operated as a regulated natural monopoly. This is due to the high costs of infrastructure investments and the extended time horizons for returns from using that infrastructure. However, technological advancements and other innovations paved the way for a wider array of market participants, leading to increased competition. For this reason, many countries began to lean towards applying free-market principles to the production and sale of electric power.

Broadly, electricity market restructuring encompassed two main policy directions:

1. Unbundling of Generation, Transmission and Distribution Assets: The aim is to segregate the transmission system from other assets. The goal in doing so was to operate these assets as more of a public good offering open access, which meant retaining elements of the regulated monopoly model. Previously, transmission assets were owned by a wide patchwork of different entities, constraining free use of the system. Under this new model, charging arbitrary tariffs for the use of an individual's portion of the system became obsolete. This approach recognized that competition within transmission doesn't yield consumer benefits, much like having competing interstate highways wouldn't. An optimal solution entails a unified transmission system governed by transparent rules, ensuring universal access.
2. Deregulation of Electricity Production and Sales: The areas where competition and consumer choice add value, namely the production and sales of electricity, were deregulated. Standardization and transparency were introduced to ensure equitable access to the market.

Alaska has mostly sidestepped market restructuring. Its lack of grid connections to Canada or other states means the Federal Energy Regulatory Commission (FERC) doesn't regulate its transmission networks. Likewise, Alaska isn't part of the North American Electric Reliability Corporation (NERC).

In contrast, Iceland's affiliations with the European Union (EU) mandated certain changes. Although not an EU member, Iceland—alongside Norway and Liechtenstein—belongs to the European Economic

[23] It should be noted that there are significant resiliency gains from the configuration of the Ring Grid, as a circle, compared to the linear layout of the Railbelt. This is because power can be sent both ways around the ring, so in the case of a break in the system there are alternatives to how power can be moved. This is not the case for portions of the Railbelt, and makes a good case for why a Roadbelt intertie would increase resilience of the grid as a whole.

Area (EEA). This membership allows them to engage in the EU's internal market, provided they adopt most single market-related laws. For Iceland, a small nation, access to the EU's internal market is crucial, pushing it to align with EU energy regulations. This alignment unfolded over a decade in multiple phases, forcing Iceland to adhere to the new EU electricity market directive, whether it initially wanted to or not.[24]

4.2 Restructuring Iceland's Energy Market and Formation of Landsnet

The unbundling of the European Union (EU) energy market, which aimed at creating a single European market for gas and electricity, was realized through a series of three legislative packages. These packages sought to progressively open up the energy market, ensure competition, and improve regulatory oversight. The first package (circa 1996-1998) was the EU's initial step towards liberalizing the electricity and gas markets. It introduced measures to open up the electricity and gas sectors to competition and was meant to be implemented by Member States by February 2001 for electricity and August 2000 for gas. Iceland was slow to conform to these new regulations, but in 2003 and 2004 the Icelandic parliament ratified legislation designed to comply with these reforms, including mandating the legal and functional unbundling of competitive activities (such as the production and sales of electric power) from activities related to grid operation.

The most significant outcome of this legislation was the separation of state-owned generation and transmission assets. Consequently, the national power company, Landsvirkjun, split into two separate entities. The law initiated the creation of a singular Transmission System Operator (TSO) in Iceland, known as Landsnet. This TSO was structured as a Limited Liability Company (LLC), or "Hlutafélag (hf.)" in Icelandic terms, with the Government of Iceland and several major municipalities as primary stakeholders.

Upon Landsnet's founding in 2004, entities holding transmission assets of 66 kV or higher were required either to transfer these assets to Landsnet in exchange for an equity stake, or to lease them to Landsnet. Importantly, the establishment of Landsnet did not alter the ownership or governance structures of local Distribution System Operators (DSOs). Moreover, Landsnet lacked the mandate to sell power directly to end-users. Its primary function was to manage, maintain, develop, and own the transmission system up to the interconnection points with local DSOs and C&Is. The DSOs function and operate similarly to Landsnet, in line with the prevailing electrical legislation. Within their respective areas, the DSOs operate as monopolies.

Landsnet is to be connected only with electrical generators, DSOs and C&I users. Generators with installed power of 10 MW and more are obligated to feed their generation to the TSO according to the legislation. Connection threshold for C&I users is annual electrical consumption of 80 GWh or more.

[24] https://www.europarl.europa.eu/factsheets/en/sheet/45/internal-energy-market

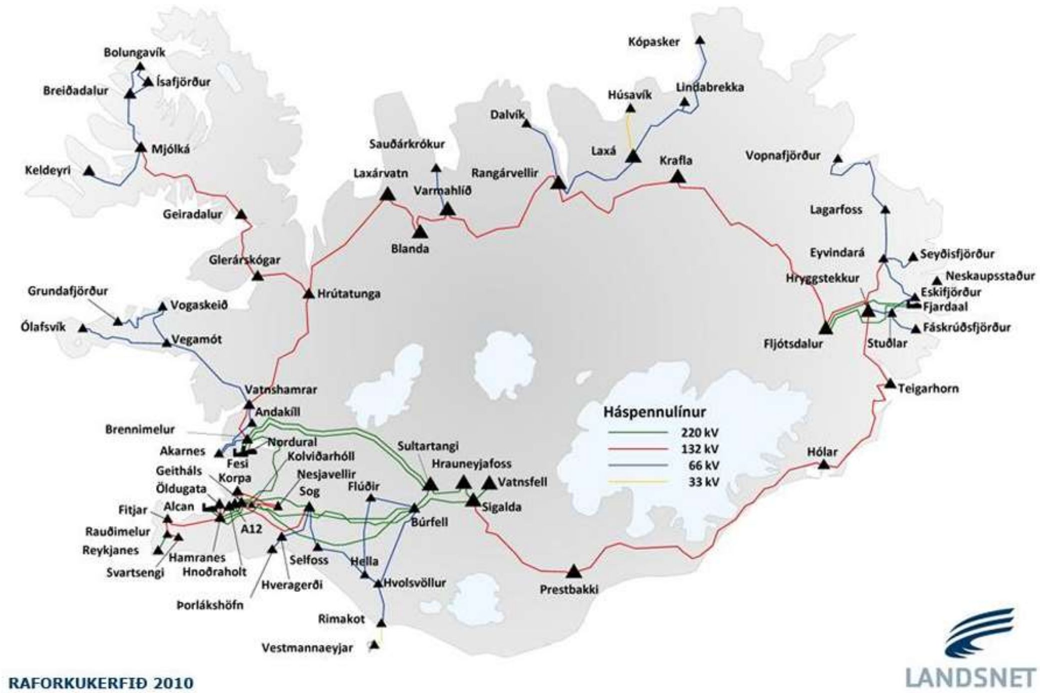

Figure 6. Landsnet transmission network, totaling approximately 2000 miles including 570 miles of 220/230 kV lines, 800 miles of 132/138 kV lines, 600 miles of 66/69 kV lines and 25 miles of <62kV connecting the small community of Húsavík.

During the preliminary stages leading to Landsnet's establishment, concerns arose about the viability of straightforwardly selling transmission assets to Landsnet. For Landsvirkjun, this concern was especially pronounced due to particular clauses within their long-term debt contracts. These stipulations dictated that any significant changes in their asset holdings would automatically result in a default on their obligations. Furthermore, many of these long-term agreements included cross-default provisions. Given these constraints, a direct sale of their transmission assets was untenable for Landsvirkjun. As a result, they chose to exchange these assets for an equity position in Landsnet.

4.3 Original Ownership Structure of Landsnet

As dictated by the new legislation, the majority of transmission asset owners chose to transfer their assets to Landsnet in exchange for an equity stake. However, there were two notable exceptions: Orkuveita Reykjavíkur (OR, Reykjavik Utility Services) and HS-Orka (Reykjanes Peninsula Utility Services), who elected to lease their transmission assets to Landsnet. Specific lease agreements were subsequently established between Landsnet and both OR and HS-Orka.

By two years later, Landsnet had purchased the transmission assets from OR and HS-Orka. While HS-Orka fully converted their equity share to cash, OR adopted a hybrid strategy, combining cash with an exchange of newly issued shares, reflecting their 2005 equity interest in Landsnet. This ownership structure persisted until 2022 when the Icelandic Parliament initiated further distinctions between Landsnet and other entities in the Icelandic energy sector.

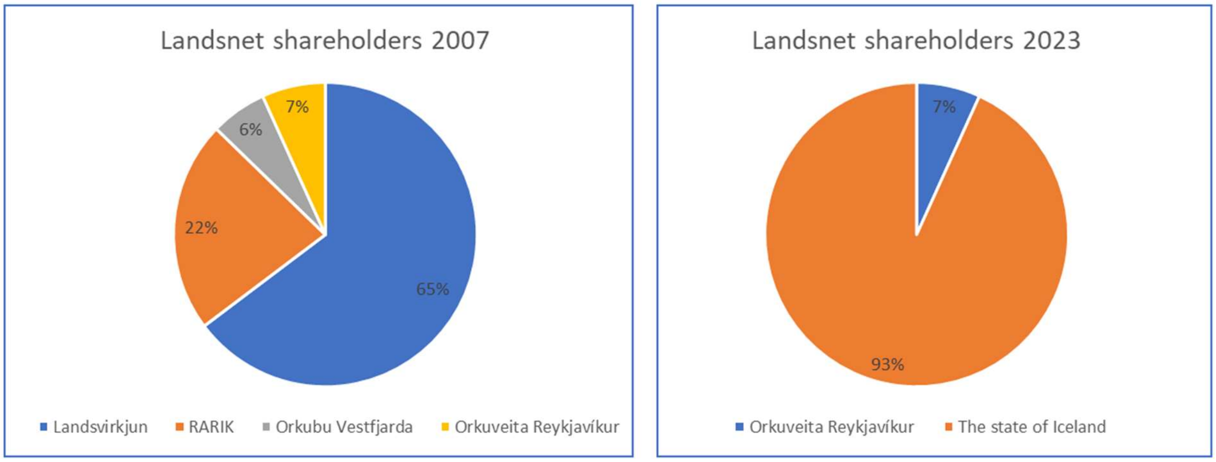

Figure 7. Evolving ownership of Landsnet. It is expected that by the end of 2023, Landsnet will be wholly owned by the Icelandic state.

4.4 Landsnet as a State-Owned Corporation

In 2022, the Icelandic government revised the 2004 legislation that established Landsnet, the Transmission System Operator, with the aim of ensuring clearer demarcation between the grid and its users. This amendment required that Landsnet's ownership be entirely vested with the state, promoting a more transparent energy marketplace. Several stakeholders within the Icelandic energy domain had raised concerns about potential conflicts of interest, particularly with the dominant power producer holding a majority stake in the TSO. Consequently, the Icelandic state resolved this issue by purchasing 92.3% of Landsnet's shares for $439M in December 2022. The final transition of the 6.8% share held by OR, the Reykjavik Utility Services, is anticipated to occur by the close of 2023. The subsequent section provides more details regarding the present governance and structural framework.

This recent shift in ownership dynamics is intriguing and underscores the need for a deeper exploration of its underlying causes. Preliminary insights from governmental insiders suggest that the compact size of Iceland's market, combined with its intricate web of professional and personal associations, complicates the practicality of achieving meaningful separation when individual entities wear multiple, at times conflicting, hats in the marketplace[25].

The model of a fully state-owned system is not the only mechanism through which EU countries have implemented reforms (see Figure 8). There is considerable diversity in who owns and operates the relevant TSO, and other components of the energy market. Most similar to Iceland is Norway, which has the same relationship with the EU as Iceland does. Norway's TSO is called Statnett, and is structured almost identically to Landsnet. Statnett is under full ownership of the Norwegian Ministry of Petroleum and Energy. It is governed by the Norwegian Energy Regulatory Authority (RME) in a similar manner as the Icelandic TSO. Annually RME sets revenue limits for Statnett which account for their operational cost, investment, and development according to law[26].

In Sweden Svenska Kraftnät serves as the TSO and is also fully owned by the state. In Denmark Energinet serves as Denmark's TSO under full ownership of the state or the Danish Ministry of Climate

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[25] Personal communication with Guðni Jóhannesson (1951-2023), former director of Orkustofnun, the National Energy Authority of Iceland with Gwen Holdmann (circa 2019).
[26] https://www.statnett.no/en/about-statnett/investor-relations/main-figures/

and Energy. Similar to Norway and Iceland, Energinet is a nonprofit entity, where revenue is based on operation, maintenance, and development cost.

The rest of Europe has handled TSO ownership in different ways, with some EU member states choosing not to take a full ownership stake in their TSO[27]. France, for example, recently sold 49.9% of their TSO (RTE) to a private entity a brief overview of ownership of EU TSOs can be seen in Figure 8 below[28]

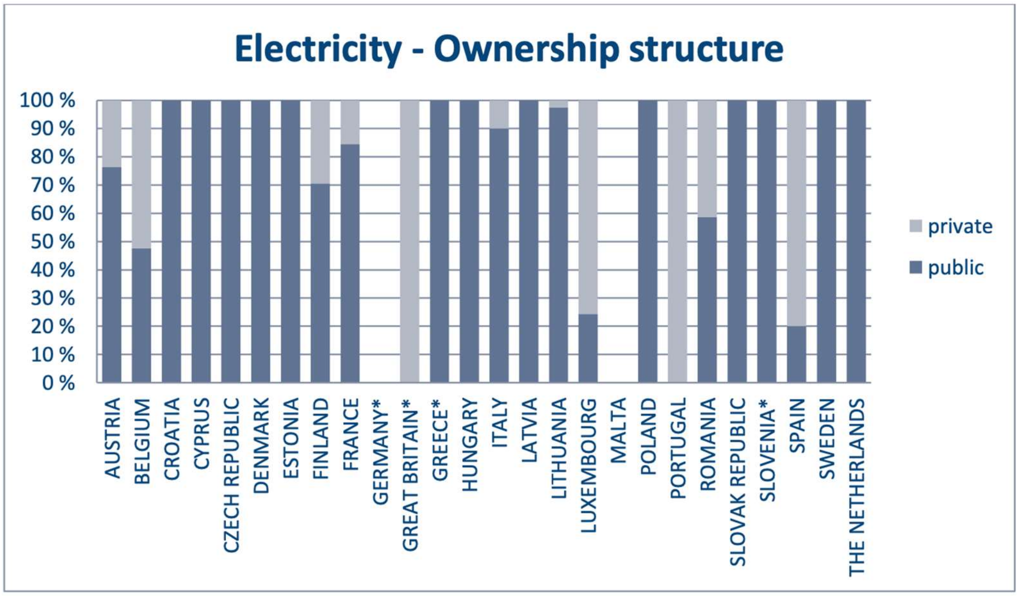

Figure 8. Proportion of public vs. private ownership of the electricity sector for most European countries. Note that municipalities are counted as public ownership, and play an important role in the energy markets of many European countries.

4.5 Landsnet Governance and Structure

Currently, the Icelandic Ministry of Finance and Economic Affairs owns 93% of Landsnet's shares. It's anticipated that the Ministry will own the entirety of the shares once the acquisition from OR – the Reykjavik Utility Services – concludes.

The governance of Landsnet involves a board comprised of five members, appointed annually by the Minister. While, in theory, these could be partisan appointments, in practice the board exhibits a diverse representation from various political parties and affiliations. Most members possess relevant professional backgrounds or have previously engaged in municipal governance roles. Notably, unless significant shifts arise from national elections, board membership tends to remain relatively stable[29].

The board's primary responsibility is the appointment of Landsnet's CEO. This CEO subsequently oversees an executive team responsible for six key functional domains: 1) Finance; 2) Development and Engineering; 3) Operations and Assets; 4) System Control; 5) IT and Technology; and 6) Human

[27] https://www.ceer.eu/documents/104400/-/-/f69775aa-613c-78a5-4d96-8fd57e6b77d4
[28] https://www.ceer.eu/documents/104400/-/-/8f18879a-411e-2fd8-c367-1fa66e3739ed
[29] Based on phone interview with Gudjon A. Gudjonsson, lawyer at Landsnet (8/15/23)

Resources and Quality. This collective constitutes Landsnet's executive board, tasked with managing day-to-day operations[30].

Landsnet is not a small organization. To shed light on the organization's structure and scale, Landsnet employed 150 permanent staff members as of 2022. Of these, 100 held college degrees. The average duration of employment at Landsnet stands at 11 years, and the typical employee age is 46 years.

4.6 Regulation and Oversight in Iceland

Landsnet operates under the regulatory purview of Orkustofnun, Iceland's National Energy Authority. Contrasting with the Alaska Energy Authority, Orkustofnun serves as a holistic regulator for the entire energy market. Its role amalgamates functions of the AEA, the Regulatory Commission of Alaska, and elements of the RRC into one overarching entity. This positions Orkustofnun with expansive influence and jurisdiction over Iceland's energy regulations and strategic planning. Specifically, Orkustofnun's main responsibilities in relation to Landsnet encompass:

1. **Monitoring and Compliance**: Orkustofnun ensures that institutions like Landsnet adhere to established legal, technical, safety, and environmental standards governing the electricity grid's operations.

2. **Tariff Regulation**: Landsnet's proposed tariffs for using the transmission system undergo scrutiny and approval by Orkustofnun.

3. **Technical Standardization**: Orkustofnun either prescribes or endorses technical standards to safeguard the grid's stability, security, and dependability.

Furthermore, Orkustofnun is tasked with ensuring energy infrastructure projects, encompassing grid-related developments, align with environmental, safety, cost-efficiency, and reliability benchmarks. This solidifies Orkustofnun's role as a central player in Iceland's energy planning, especially concerning transmission grid matters.

4.7 Transmission Cost Recovery Structure

A substantial aspect of the legislation that birthed Landsnet was its focus on cost structures and a judicious approach to cost recovery. Landsnet was formed with annually reviewed revenue caps, as determined by Orkustofnun. This foundational principle, standard to many utilities, is uniquely applied in Landsnet due to its maintenance of two distinct asset portfolios: B (heavy industrial) and A (all other users). These portfolios, for the most part, function independently. The WACC (weighted average cost of capital, a metric that considers both equity and debt costs) is computed separately for each asset category, A or B. This WACC helps determine the permissible rate of return or revenue limit for each asset group. While one might assume significant divergence between these portfolios, the recent difference in their WACC was a mere 0.8%.

For 2023, the following pre-tax WACC values apply[31]:

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[30] https://www.landsnet.is/english/about-us/landsnet-s-executive-board/
[31] Orkustofnun document #OS2022040059/10.2

- TSO to C&I sector: 5.15%
- TSO to DSO sector: 5.92%
- DSO to general users: 5.96%

The distinctions primarily arise from the C&I sector's lower risk-free rate of return (denoted as 'rf') and reduced long-term financing rates (referred to as the 'rD' component) [32]. The dual-asset framework ensures that investments in specific transmission assets, such as those bolstering connections to rural regions, influence the pricing for all DSOs. Conversely, the costs remain neutral for C&I customers, and the reverse is true for investments catering to the C&I sector. Hence, if a unique investment sways electricity pricing in the capital area, those residents bear that cost increment. Similarly, if unexpected yet costly repairs are needed for heavy industry's transmission infrastructure, the burden, mirrored in a higher WACC, is shouldered exclusively by that sector. Typically, it's the general consumer-related asset portfolio that gets impacted by the mentioned investments. However, the heavy industry sector is perpetually liaising with the TSO to strategize on enhancing and securing their power supply efficiently. This structure underscores a commitment to ensuring that costs tied to system development and investments are judiciously attributed to the system's users.

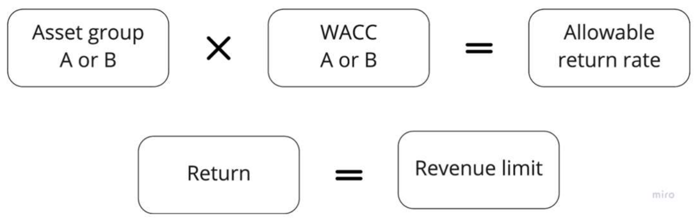

Figure 9. Landsnet's revenue limits are sum of operation cost, depreciation and reasonable return.

4.8 Transmission Planning

Landsnet's key statutory responsibility centers around planning future grid investments. Orkustofnun, after soliciting public feedback, must approve these plans. Landsnet biannually rolls out updates to both their decade-long investment vision and a nearer-term, 3-year implementation strategy, often termed "execution project planning." Both plans undergo a transparent review process led by Orkustofnun. These documents are foundational, mapping out how Landsnet aims to oversee, nurture, and evolve a secure Icelandic transmission network.

The long-term plan delineates large-scale infrastructure investments suggested by Landsnet, bucketed into renewals and development. While the projects in this plan generally receive initial approval, many still await the green light for construction from involved municipalities or private landowners. Some even remain pending final environmental evaluations by the Icelandic Environmental Agency. Challenges in obtaining permits or land access rights can be considerable obstacles, sometimes leading to project postponements or even terminations. In general, there's a trend favoring minimal transmission infrastructure expansion, especially when these impede scenic vistas or encroach upon pristine landscapes.

The process for crafting and approving a new long-term plan is rigorous. Once an initial plan is available, it undergoes public review and scrutiny. Feedback flows in from diverse stakeholders—

[32] Orkustofnun revenue cap: https://vefskrar.orkustofnun.is/Raforkueftirlit/Akvardanir_Raforkueftirlits/Tekjumork/2023/wacc_14_05_2023.pdf

municipalities, major industries, power generators, potential future power generators like private wind farm developers or other power generation visionaries, and the general public. Orkustofnun meticulously reviews all comments during this period. If they deem these comments valid, they either seek a detailed response from Landsnet or request plan modifications. Consequently, the evolution of the long-term plan often becomes a back-and-forth exercise. For instance, for the long-term plan spanning 2021-2031, Landsnet addressed 54 topics based on feedback from over 21 entities. This feedback consisted of inputs from 11 municipalities, three power producers, two government institutions, and a DSO.

Municipalities, in particular, have a considerable say in the projects featured in the long-term plan. This is because the plan typically encapsulates holistic future grid development strategies. Hence, local governments are deeply invested in the infrastructure projects, seeing them as potential catalysts for attracting new commercial ventures or investments, or as a means to bolster local energy reliability.

5.0 Potential Lessons, Key Takeaways, and Further Steps

It has been 30 years since Iceland embarked on its journey of energy industry restructuring and the formation of Landsnet. Over this period, it has fine-tuned its approach through incremental changes and has witnessed notable growth, robust economic development, and a reduction in power costs for consumers. Iceland's comprehensive energy planning strategy, given its Arctic location, comparable size, and challenges akin to Alaska in terms of geography and climate, offers instructive lessons. Some key takeaways include:

- **External Catalysts:** Beneficial structural changes often require an external catalyst. For Iceland, EU regulations served this purpose. For Alaska, it's the potential federal and state investments in grid modernization, along with a transition to a diversified energy source mix and ownership structure.
- **Transmission System Operator in Railbelt:** Creating a Transmission System Operator (TSO) that adopts a comprehensive, system-wide planning approach makes sense for the Railbelt. State ownership of new assets aligns with the principle of public resource management, ensuring open access to all qualified market players and a transparent cost recovery mechanism. While the next major transmission investments will likely be state assets, existing assets don't necessarily need a transfer. Leasing them to a TSO, mirroring Iceland's initial approach, remains a viable alternative, provided the rates align with market value.
- **Cost Recovery Mechanism:** Iceland's "postage stamp" rate for transmission, akin to models like Texas's ERCOT, distributes transmission costs directly to the end-use consumers. This reduces the potential for negative impact on electricity generators or economic dispatch decisions and not only ensures a fair cost allocation but has also been credited with promoting the growth and efficient transfer of clean energy across Texas.
- **Governance Framework:** The governance structure of pivotal entities like a TSO is crucial as it sets the tone for addressing challenges and dispute resolutions. Iceland's evolution in this area offers instructive nuances. The Bradley Project Management Committee (BPMC), a committee comprising the Railbelt utilities and the AEA, might serve as a guiding model. While BPMC's exemption from regulation has sparked debates, its resilience, including in dispute management, is noteworthy. A regulated version of the BPMC, perhaps with a stakeholder advisory board, could lay the groundwork for a Railbelt TSO[33].

[33] The 5-person governing board of Landsnet is politically appointed.

- **Promoting Load Growth:** To stimulate economic growth, fostering an environment for substantial load growth is key. While a comprehensive load growth plan isn't a prerequisite for establishing a TSO, numerous promising avenues deserve exploration. These include the adoption of electric heating, potential connections like the Donlin to the Railbelt grid, or efficient server farms suitable for Alaska's cold climate. As perspective, while a 3% annual load growth in Alaska would double the load by 2045, Iceland saw over 20% annual growth from 1995 to 2010. Taking a cue from Iceland, Alaska might think about offering competitive rates to incentivize managed load growth, targeting both native loads like heat pumps and EVs, as well as promoting expansion in key industrial sectors.

Drawing on Iceland's Experience: A Five-Step Strategy for Alaska could include:

1. **Establishing a Transmission System Operator (TSO) Structure:** Alaska should explore suitable structures for a TSO, possibly using the BPMC as a foundational model. While BPMC offers a precedent, its exemption from regulatory oversight contrasts with the expectation that a TSO's would be regulated. In addition, there are important questions about where such a state-owned organization would reside, as well as how and by whom it would be regulated[34].
2. **Define RRC's Role Vis-a-vis TSO:** Senate Bill 123, addressing the establishment of an Electricity Reliability Organization, needs slight adjustments to distinctly delineate the roles of the Railbelt Reliability Council (RRC) and the TSO. RRC's main function encompasses framing and maintaining reliability standards, which includes compliance, enforcement, and long-term planning. It's essential to specify their purview concerning the transmission system, setting it apart from generation and distribution. This distinction means modifying the RRC's involvement in integrated resource planning (IRP) to exclude transmission, aligning with traditional IRP processes.
3. **Maximize federal funding opportunities.** Alaska should continue to rigorously pursue all avenues for federal funding for grid-related upgrades. Currently, the Railbelt Electric Utilities, and the Alaska Energy Authority are pursuing funding from the *Infrastructure Investment and Jobs Act* (IIJA), and other Federal programs, as well as from the State of Alaska and traditional utility funding sources. The total scope of these transmission infrastructure improvements is estimated to cost approximately $2.9 billion. If successful in leveraging federal funds, state match of at least 30% will be required. An organized approach and funding package will need to be developed. This package could take the form of a general obligation bond, encompassing various elements. These could include infrastructure essential for ensuring short- to mid-term gas supply for Southcentral Alaska, final permitting for the Susitna hydroelectric project, and funding for early site licensing pertaining to one or more potential micronuclear reactor projects.
4. **Encourage rate experimentation to incentivize load growth.** Amendments to the state statutes governing the RCA could enable more flexibility in rate-setting and could explicitly allow and encourage experimental rate structures. Specifically, The RCA could consider authorizing pilot programs that test innovative rate designs focused on load growth and efficient use of network infrastructure, such as off-peak EV charging. Data and feedback from these pilots can provide valuable insights, guiding more extensive rate changes in the future.

[34] State statutes as currently written may prevent one state agency from regulating another.

5. **Reviving the Emerging Energy Technology Grant Fund (EETGF):** The Alaska State Legislature created the Emerging Energy Technology Fund (EETF) in 2010, aiming to fund demo projects for novel energy technologies with potential cost-reducing implications. It ceased in 2015 due to a lack of reauthorization. If reactivated, the EETF could act as a matching fund, augmenting federal funding endeavors, fostering a diverse technology evaluation landscape, and promoting aggressive innovations like long-duration storage, particularly vital given Alaska's unique energy patterns.
6. **Re-establish the Emerging Energy Technology Grant Fund (EETGF)**. The Emerging Energy Technology Fund (EETF) was established by the Alaska State Legislature in 2010. Its purpose was to provide funding for demonstration projects of new energy technologies in Alaska that had the potential reduce the cost of energy across a wide range of renewable and non-renewable technologies. The program sunsetted in 2015 after not receiving reauthorization. If revived, the EETF could complement federal funding initiatives, acting as a matching fund source. This would enhance the competitiveness of Alaskan proposals and stimulate a multifaceted landscape of technology evaluation and implementation. Long-duration storage is one example of where Alaska’s unique load and resource patterns require aggressive innovation unlikely to occur in the much larger, summer-peaking grids of the lower-48 states.

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APPENDIX A: CHARTS OF ICELAND ELECTRICITY SECTOR

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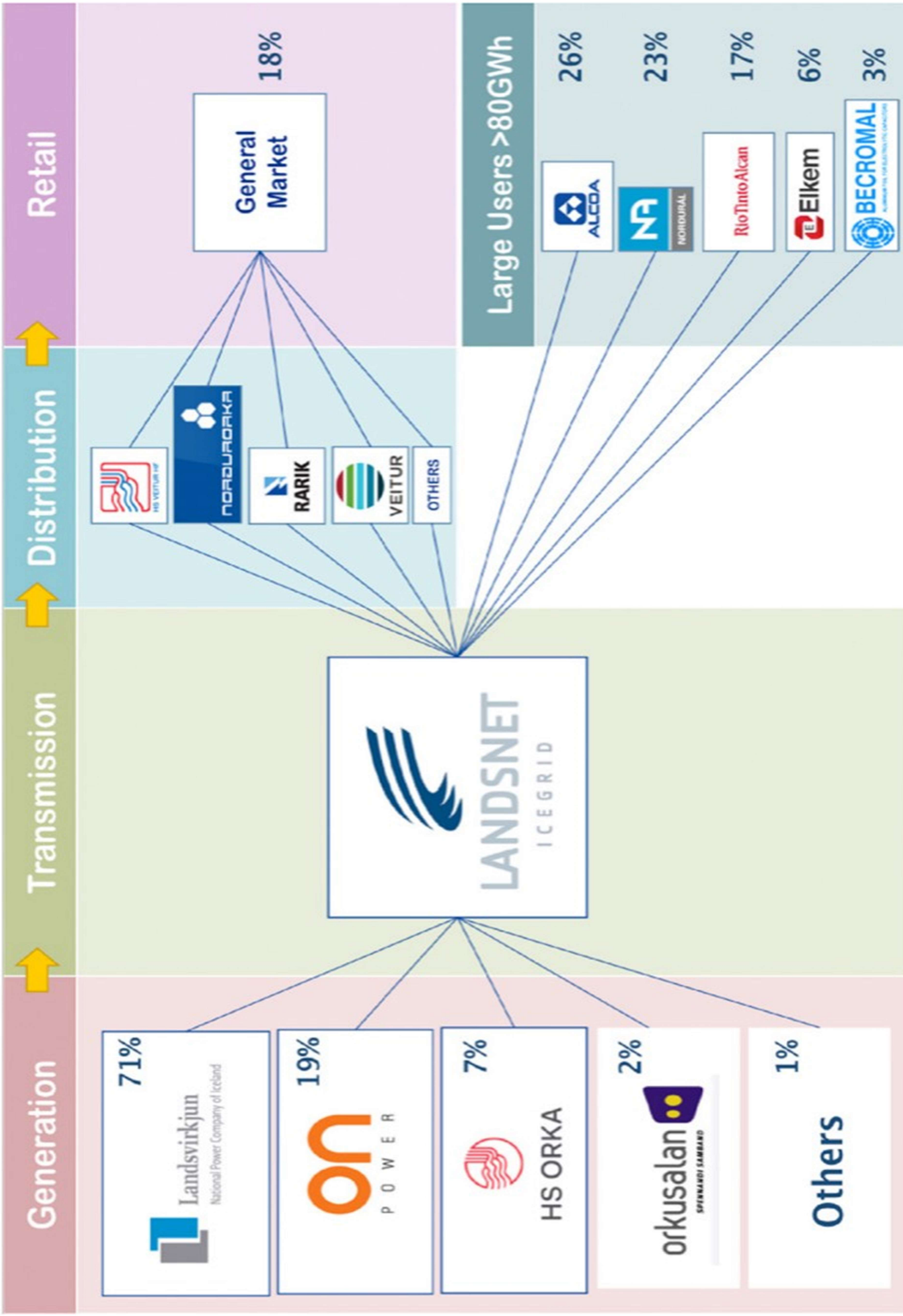
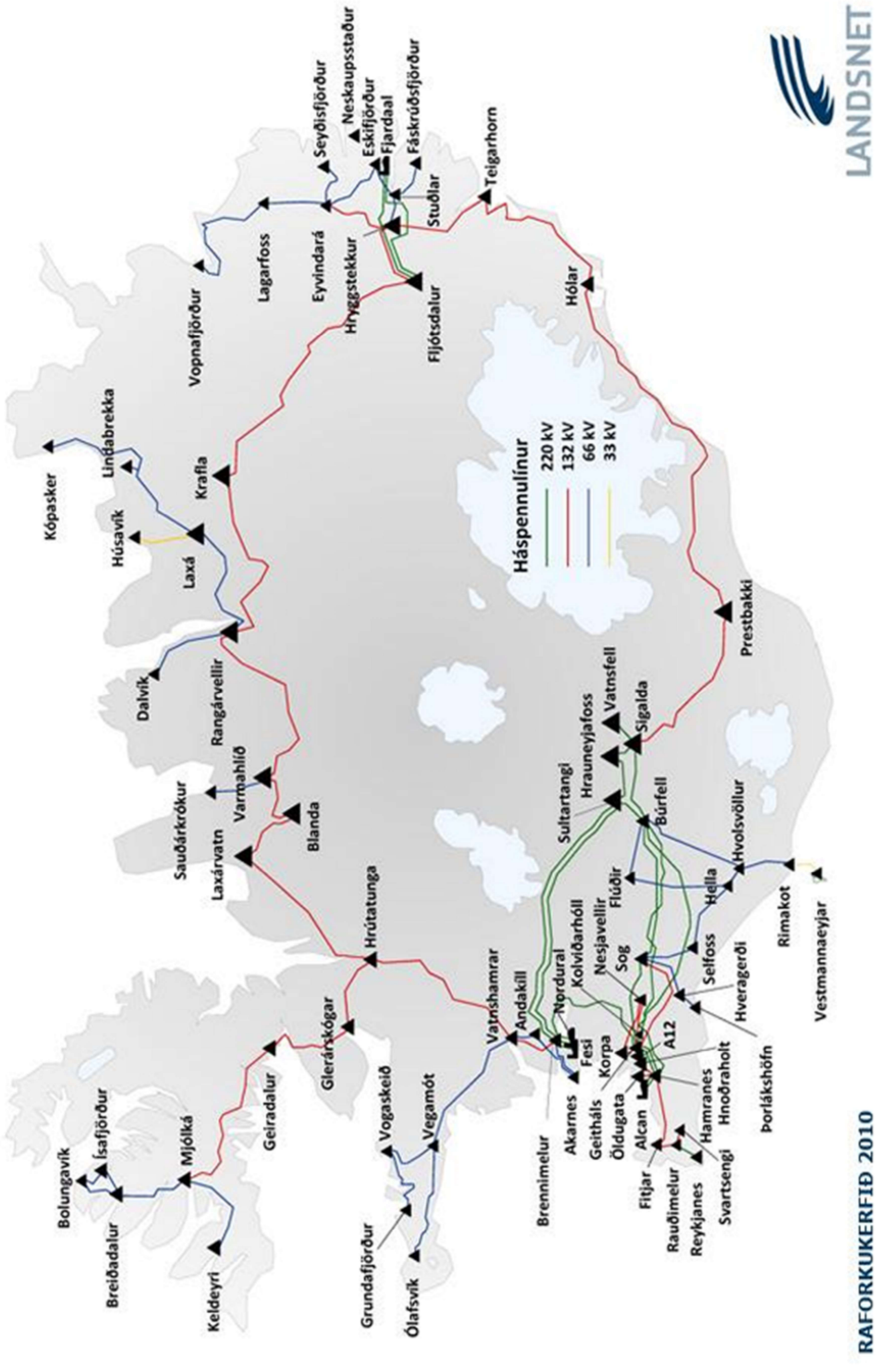


Generation
Transmission
Distribution
Retail
71%
Landsvirkjun
National Power Company of Iceland
19%
ON POWER
7%
HS ORKA
2%
orkusalan
1%
Others
LANDSNET
ICEGRID
HS VEITUR HF
NORDURORKA
RARIK
VEITUR
OTHERS
General Market
18%
Large Users >80GWh
ALCOA
26%
NORDURAL
23%
RioTintoAlcan
17%
Elkem
6%
BECROMAL
3%


RAFORKUKERFIÐ 2010
LANDSNET
Háspennulínur
220 kV
132 kV
66 kV
33 kV
Kópasker
Lindabrekka
Húsavík
Laxá
Krafla
Vopnafjörður
Lagarfoss
Seyðisfjörður
Neskaupsstaður
Eskifjörður
Fjarðaál
Fáskrúðsfjörður
Eyvindará
Hryggstekkur
Stuðlar
Teigarhorn
Fljótsdalur
Hólar
Prestbakki
Dalvík
Rangárvellir
Varmahlíð
Sauðárkrókur
Blanda
Laxárvatn
Hrútatunga
Vatnsfell
Sigalda
Hrauneyjafoss
Sultartangi
Búrfell
Hvolsvöllur
Flúðir
Hella
Rimakot
Vestmannaeyjar
Nesjavellir
Kolviðarhóll
Sog
Selfoss
Hveragerði
Þorlákshöfn
Norðurál
Fesi
Korpa
A12
Hnoðraholt
Hamranes
Svartsengi
Reykjanes
Rauðimelur
Fitjar
Alcan
Öldugata
Geitháls
Akarnes
Brennimelur
Andakíll
Vatnshamrar
Glerárskógar
Geiradalur
Mjólká
Ísafjörður
Bolungavík
Breiðadalur
Keldeyri
Vogaskeið
Vegamót
Grundarfjörður
Ólafsvík

APPENDIX B: BILLING EXAMPLES FROM ICELAND (RESIDENTIAL, BUSINESS, INDUSTRIAL)

Note: FX rate used in the appendix is 140 ISK/USD.

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Overview

Rates in Iceland are based on customer class and geographic location (which dictates their local distribution utility, or DSO). This appendix provides a basic overview of how the market works from a consumer perspective, including residential, business, and light industrial consumers – essentially, the Icelandic domestic market. Note this appendix does not relate to C&I industries, which have long-term wholesale contracts with Landsvirkjun or other power producers.

Generally speaking, consumer rates are divided into the cost for power generation, and delivery of that power (transmission and distribution). Icelandic consumers have a choice in vendor related to generation, but not their DSO/TSO. These are set up as monopolies. Landsnet is the TSO for Iceland, but there are a total of five DSO (distribution utilities) in Iceland that serve specific regions. Three of these are municipally owned. The exception is RARIK and Orkubu Vestfjarda , which are state-owned DSOs for rural areas outside municipal boundaries.

In addition, Iceland has a subsidy for rural and remote areas, a discounted price for electric heating in areas that do not have access to geothermal district heating, and a value-added (VAT) tax that is applied to billing. Additional detail and sample billing for various customer classes is provided below.

Generation

Icelandic consumers across all classes are able to select the vendor from whom they wish to purchase power (see Figure B1). There are currently 8 retail sellers operating in the Icelandic market, although only five of these actually own power generation. These are highlighted in green in Figure B1. The remaining three – Straumlind, N1 Rafmagn, and Orka Heimilanna – are all resellers/brokers with no generation of their own who buy electricity wholesale from the market (usually from Landsvirkjun).

Most Icelanders heat with hot water, but those that do not have access to district heating use electric space heating and electricity for space heating is provided at a discounted rate (-10.5%). For consumers that heat using electricity, they have a single meter but the discounted rate is apportioned at a 85/15% split. In other words, it is assumed 85% of power is used for space heating, and only 15% for other (conventional) loads.

For residential and small business customer classes the cost for generation equates to about ~$0.05-$0.07/kWh. For small industrial customers it is lower (<$0.0352/kWh), and C&I industries pay the lowest rate.

	Supplyer	Energy price (general)	Energy price (general)	Energy price (heating)	Energy price (heating)	Heating discount
		kr/kWh	*cents/kWh*	*kr/kWh*	*cents/kWh*	%
	Straumlind	6,98	**4,99**	6,25	**4,46**	10,5%
	N1 Rafmagn	6,98	**4,99**	6,25	**4,46**	10,5%
	Orkubú Vestfjarða	7,50	**5,36**	6,72	**4,80**	10,4%
	Orka Heimilanna	7,30	**5,21**	6,54	**4,67**	10,4%
	Fallorka	8,67	**6,19**	7,56	**5,40**	12,8%
	Orkusalan	9,16	**6,54**	7,68	**5,49**	16,2%
	HS Orka	9,24	**6,60**	7,79	**5,56**	15,7%
	Orka náttúrunnar	9,18	**6,56**	8,04	**5,74**	12,4%

Figure B1. Example of market choice for Icelandic customers have in purchasing electric power. The rates provided here are for residential customers and are based on May-June 2023 rates (USD values are bolded, Icelandic rates are x100kr). Icelandic consumers can switch suppliers whenever they wish to with no penalty. However, in practice most Icelanders stick to a single supplier

Transmission and Distribution (T&D) costs

Landsnet charges a flat fee per kWh for transmission, plus a connection fee. For residential consumers, this is combined with local DSO costs (broken out as T&D fee in the sample billing). The regional difference is due to disparity in cost structure for local DSO operations. In Reykjavik, the capital city, the local DSO benefits from economies of scale and thus can offer lower rates than those experienced by customers in more rural areas. Note choice in the Icelandic market is limited to energy sales; the TSO and DSO remain monopolies. There is a total of five DSO utilities in Iceland today.

Equalizing fee/Gov subsidy costs

A fee of ~0.29 cent/kWh (0.41 ISK/kWh) is collected from all customer classes, and used to subsidize sales for consumers in rural areas that have a higher electric rate, and customers that use electric power for heating. In that case, electric space heating is metered and billed separately.

Valued-added tax (VAT)

Value added tax of 24% is applied to generation and T&D lines on billing. This equates to ~$0.03/kWh for residential consumers.

Sample Bills – Residential

Figure B2 summarizes cost structure for two different residential consumers, also illustrating choice in vendor. Example 1 and 2 is from a farmer living in the Westfjords in a remote area near the town of Hólmavík. This example represents one of the most expensive delivered cost of electric power in Iceland. Note that due to the choice in energy supplier, Example 1 and 2 represent rates from different suppliers; this is the only difference in the delivered cost of power in these two examples. T&D costs remain the same because there is no choice in service provider. Example 3 is a consumer living in the capital city of Reykjavik, which has the cheapest delivered cost of power. This is due to economies of scale in their local DSO, which means the T&D fee is significantly lower despite the fact that the transmission component, though not broken out, is the same for each.

An equalizing fee is charged to all kWh sales, but then applied as a discount (Government subsidy) for the rural consumer to reduce the cost of delivered power. Much like the PCE program, this subsidy is passed through directly to end users through the TSO.

Iceland Residential Bill Examples

		Example 1	Example 2	Example 3
Energy unit price	cent/kWh	5,32	4,02	4,02
VAT		1,28	0,97	0,97
Total	cent/kWh	6,60	4,99	4,99
T&D fee	cent/kWh	10,78	10,78	4,66
Equalizing fee	cent/kWh	0,29	0,29	0,29
Gov. subsidy	cent/kWh	-3,93	-3,93	
VAT		1,71	1,71	1,19
Total	cent/kWh	8,86	8,86	6,14
Total cost	cent/kWh	15,46	13,84	11,12
	ISK/kWh	21,64	19,38	15,57

Figure B2. Example of three different representative residential bills (June 2023 prices).

Sample Bills – Commercial

Figure B3 summarizes cost structure for two different commercial consumer classes. First is a small business located in north Iceland with ~150 MWh annual consumption. The second example is an industrial customer located in the capital area with ~1200 MWh consumption annually. In most cases general customers only see the combined TSO+DSO fee on their bill from their local utility, exception from that can though been seen in the second example. The TSO charge almost the same fee for transmission. The TSO has a basic connection fee applied to anyone who is connected their system, plus a fee per kWh. Further information about infeed and connection fees to Landsnet are available on their website in English[35].

[35] https://www.landsnet.is/english/business/grid-codes/b1-tariff/

Bill Example: Small Business

Electricity bill brake down

Usage	Qty	Unit	Unit price	Unit	Total (USD)	VAT	Total w. VAT (USD)
Energy (general)	14.114	kWh	4,99	cent/kWh	704,79	24%	873,94
Total usage	14.114	kWh			704,79		873,94

Transmission

Usage	Qty	Unit	Unit price	Unit	Total (USD)	VAT	Total w. VAT (USD)
Connection fee (general)	31	Days	2,32	USD/day	71,93	24%	89,20
Transmission (general)	14.114	kWh	4,51	cent/kWh	636,14	24%	788,81
Equalizing fee	14.114	kWh	0,29	cent/kWh	41,33	24%	51,25
Total usage					749,41		929,26

To be payed per month (USD)	1.803,21

Average price (cent/kWh)	12,78

Bill Example: Light Industrial

Electricity bill brake down

Usage	Qty	Unit	Unit price	Unit	Total (USD)	VAT	Total w. VAT (USD)
Energy (general)	100.013	kWh	3,52	cent/kWh	3523,46	24%	4.369,10
Total usage	100.013	kWh			3523,46		4.369,10

Transmission

Usage	Qty	Unit	Unit price	Unit	Total (USD)	VAT	Total w. VAT (USD)
Connection fee (general)	28	Days	2,32	USD/day	64,97	24%	80,57
TSO fee	100.013	kWh	0,62	cent/kWh	623,37	24%	772,98
DSO fee	100.013	kWh	1,16	cent/kWh	1.159,80	24%	1.438,15
Equalizing fee	100.013	kWh	0,29	cent/kWh	292,90	24%	363,19
Total usage					2.141,03		2.654,88

To be payed per month (USD)	7.023,97

Average price (cent/kWh)	7,02

Figure B3. Example of two business customers representing different rate classes and geographic locations, with the small business example (construction company) from northern Iceland and the light industrial (steel fabrication) example from Reykjavik. In both case, there is a daily connection fee. In the case of the small business in northern Iceland there is the case of the light industrial user.

APPENDIX C: RESPONSE TO QUESTIONS

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Question 1: *GVEA has heavy industry customers in the form of mining operations and government defense systems that almost daily swing our grid around from all the tripping/restarting they do. Is this similar in Iceland with your heavy industry and if so, how is that mitigated?*

The Icelandic heavy industry uses about 77% all generated electricity in Iceland (Orkustofnun, 2021). Landsnet, as Iceland's transmission system operator (TSO) is responsible by law for keeping electrical generation and consumption in balance. One of many ways they accomplish this is to classify significant users and generators on the Icelandic electrical market as "equalization responsible entities". Referencing Appendix A, this includes the categories of Distribution/Retail Utilities, Large Users >80GWh, and larger generators with multiple power stations.

Equalization responsible entities are required to submit a week-ahead schedule of their planned hourly generation or usage by 2:00 pm on Friday each week in order to aid with operational planning and coordination. These entities are permitted to alter their plan with 2 hours' notice, but are then subject to spot market pricing for anything that falls outside their schedule. This enables Landsnet to control where and how the grid is loaded, including issuing notices of capacity when available generation exceeds demand.

Each of the equalization responsible entities are entitled to place bids on the equalizing spot market. Typically, Landsnet requests quotes on fixed intervals for that market. When generators make such a contract with Landsnet, they are obligated to provide a certain quantity of electricity to the equalizing spot market with no notice. For larger power deviations, Landsnet has contracts with the power generators to provide backup power that can be available within 15 minutes. The generators bid for the backup power market as well on fixed intervals. In most cases such power is diesel generated.

It is generally perceived that this method of managing supply and demand on the electricity market has been quite successful. Total turnover on the spot market for equalizing power is insignificant in proportion to the electrical market as a whole. The equalizing spot market is a zero-sum market with no direct value creation. Furthermore, it is also accepted that this methodology contributes to lower electricity prices. This differs from other Scandinavian countries where deviations on both the generation side and demand side are charged separately by the TSO. The two-sided system prevalent in Scandinavia puts much more pressure on the planning phase of generation/consumption of electricity. The zero-sum market has more flexibility and no value creation, with the result of lower overall energy prices.[36]

Question 2: *How has Iceland incentivized heavy industry customers to continue to bring on load without negatively impacting the residential or other customers rates? I'd like to understand if Iceland had found a way to incentivize heavy industry growth but also promote these customers to become more reliable as far as system stability is concerned*

In general, the cheap energy that Iceland can offer is a strong motivator for attracting energy intensive businesses, especially those that might benefit from using "green energy" in their production.

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[36] Halldórsson, K. (2010). Icelandic Journal of Engineering. *2010*, *1*(1), 261–267.

The method described in Question #1 above has been quite successful for the grid's load management. Over time, the remote location of Iceland and corresponding shipping costs has been an issue for industrial production. A common question among Icelanders is the lack of value-added processing, since the largest component of C&I industries is the production of raw aluminum. The industry players are not immune to this criticism; for example, in 2021 Century aluminum decided to invest in a new casting line at their operation facilities in Grundartangi. These cast aluminum billets can then be used in extrusion processes by a variety of end-uses, including the automotive industry. To enable this additional processing, Century entered into a 10 MW energy contract with Landsvirkjun, increasing their total installed capacity to 182 MW.[37] This is the first value added investment by the aluminum sector in many years that is not directly linked to increased bulk production. It can be assumed that the heavy industry has significant bargaining power when it comes to such value added business development.

In recent years data centers have been growing in Iceland as distance has limited effects on their location compared to conventional industrial activities. In addition, the rather cold weather in Iceland is an asset, reducing the necessity for active cooling. The national power company, Landsvirkjun, has, however, restricted future contracts with data centers that engage in crypto mining. For this reason, some Icelandic data centers have been diluting or are planning to eliminate entirely all crypto operations as part of their portfolio. Some industry experts have estimated that the crypto sector occupies significant portion all data center's capacity in the world. Concerns have arisen that there could be disproportionate risk of outages due to damage of data cables and associated infrastructure. This concern is heightened by recent incidents related to terrorist attacks on submerged assets in Europe related to the situation in Ukraine. This has sparked concerns and speculations regarding stability of data center operations, and their role within future growth sectors of Iceland's economy.

Increased global awareness of the value of sustainable processes has enable Iceland to benefit from and gain leverage through the sales of guarantees of origin certificates. Such origin certificates are of significant value to many of the entities that are located in Iceland and use Icelandic green energy for their operations.

Iceland has seen relatively modest changes in the price for electricity related to investments in the power sector. Consumer power bills are considered an insignificant cost compared to food and house mortgages, and as a result there is limited focus on energy cost. For a mid-sized home in Iceland annual electricity consumption is about 5000 kWh/year, which equates to less than $1000 a year on average across the country, with residents in Reykjavik benefiting from the cheapest rates, estimated at about $700/year. The cost for heating annually is similar. In comparison, a mid-sized home is probably paying $1000 per month for a home mortgage, and a similar amount for food.

Question 3: *Can we associate specific or general growth spurts or additions of new loads with changes in the transmission?*

If we look at electrical production in Iceland between the years 1972 and 1984 (construction of the Ring Grid) we see on average 8% annual growth in electricity production compared to only 2% average

[37] Century Aluminum. (2023, July 5). *Nordural*. Nordural. https://nordural.is/en/new-production-line/

growth in the next 13 years after (1985-1997). Interconnection of all major electrical generation assets did replace diesel generators, which then only served as backup in case of outages.

It's not easy to correlate changes in electrical generation to the specific event of Landsnet's establishment (2004) because several major generation investments were brought into service around that same time, corresponding to annual production and load growth of 14% (2006), 21% (2007), and 38% (2008) respectively. Additional insight is provided in the response to the next question.

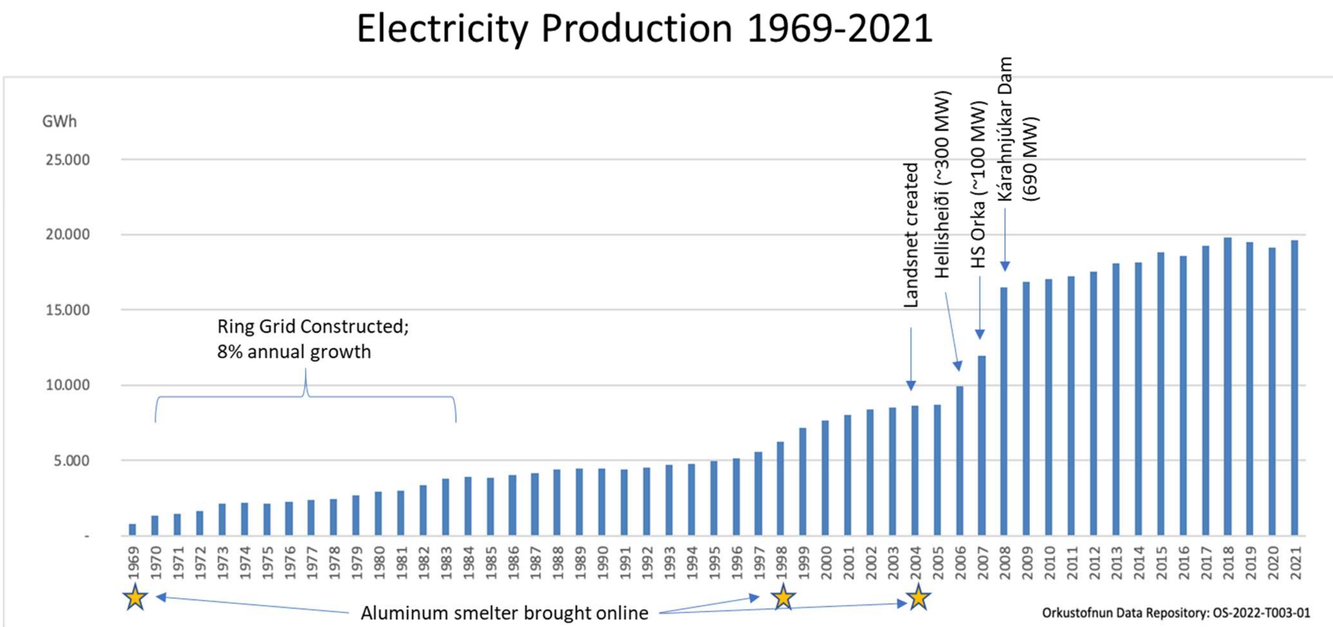


Figure B2. *Electricity production in Iceland and notable events, including completion of several large projects close to the time when Landsnet was created.*

Question 4: *Can we point to stories about how hydro or geothermal was able to displace diesel when the transmission was expanded or access was improved?*

Looking at primary energy use in Iceland during the years when the Ring Grid was established there is clear evidence of increased energy from hydro and geothermal and less usage of oil. By filtering out the years around the Ring Grind investment we see the portion of oil in Iceland's primary energy usage decreasing significantly around 1980. This is the result of more and more remote communities that formerly used diesel generators converting to electricity and/or district heating (Figure B2). Another chart from the Icelandic Energy Authority shows a clear reduction in oil consumption for space heating in Iceland (Figure B3).

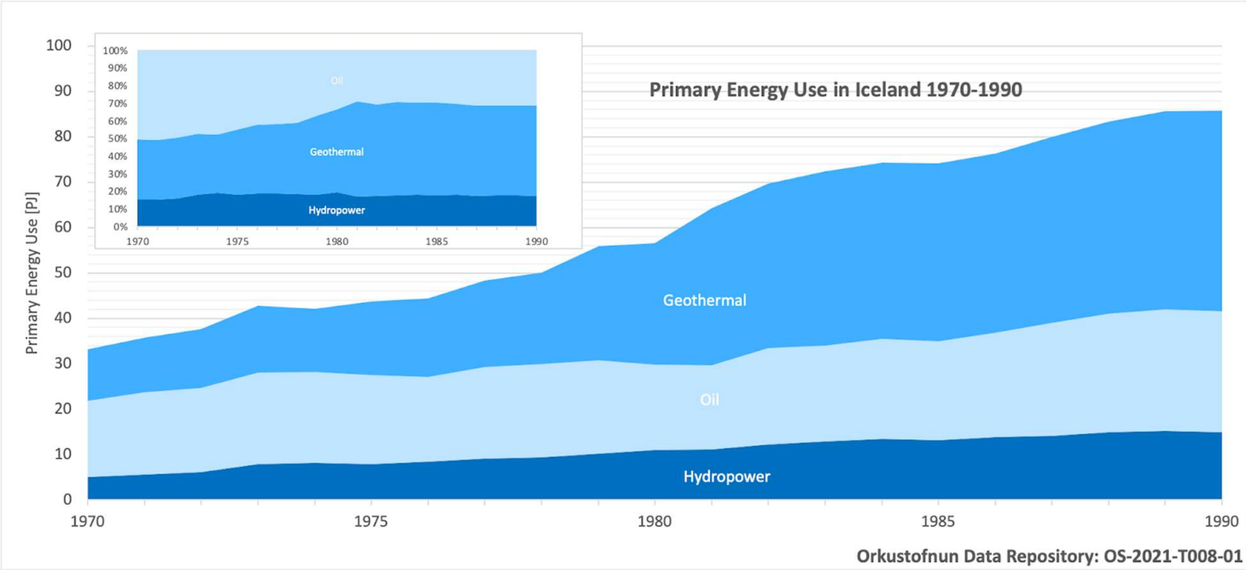


Figure B3. *Primary energy use in Iceland from 1970-1990. Note inflection point in 1980. At this time, many places where geothermal heating could readily be developed were completed (see Figure B4), reducing reliance on fuel for heating although it was and still is a major component of the transportation sector.*

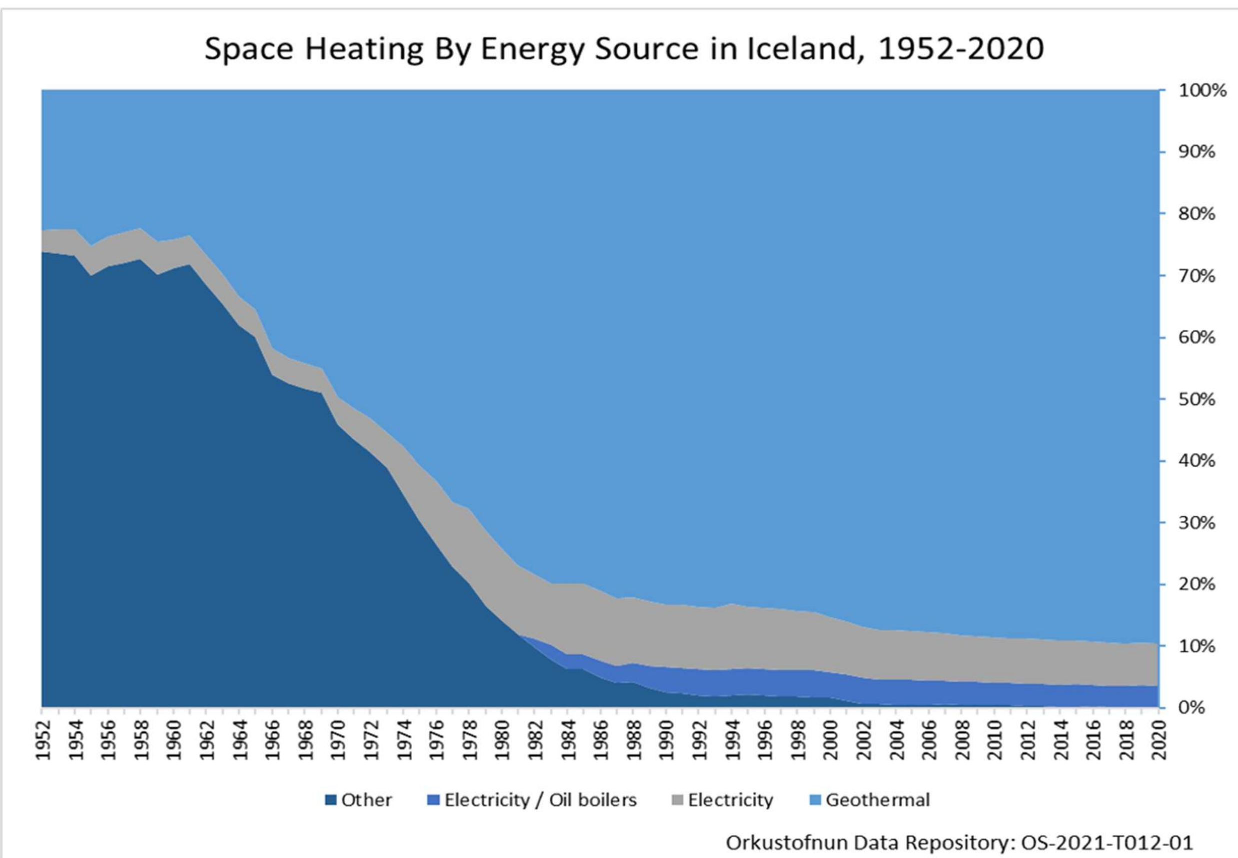
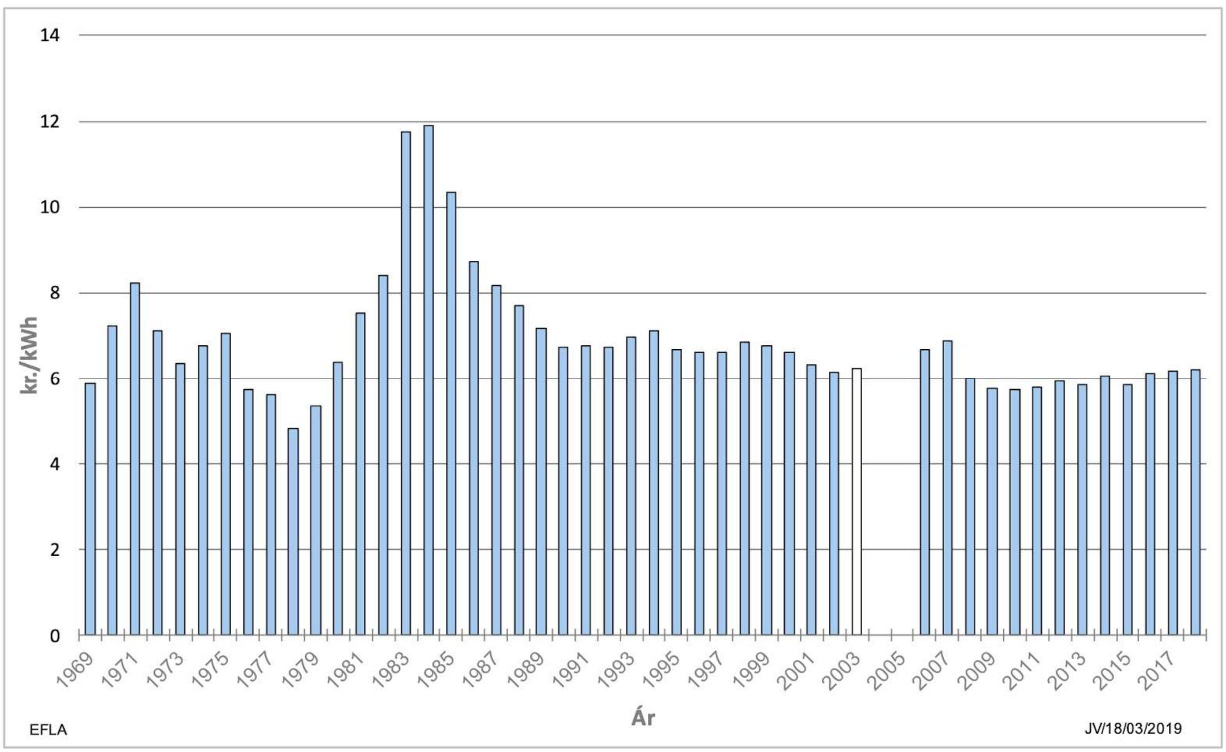


Figure B4. *Primary energy use in Iceland from 1970-1990. Note inflection point in 1980. At this time, many places where geothermal heating could readily be developed were completed* *(see Figure B4), reducing reliance on fuel for heating although it was and still is a major component of the transportation sector. It should be noted that the category "Other" in this chart represents mainly oil but also includes very tiny proportions of wood and gas. After the year 2000 oil had almost been eliminated as an energy resource for space heating.*

Question 5: *Is there any evidence forming Landsnet reduced the cost of delivered power to consumers?*

Generally speaking, the pricing of electricity in Iceland is getting lower when adjusted for CPI changes. Landsvikrjun presents this whole sale price data on their website where past prices have been adjusted to CPI accordingly. See Figure B5 below. On average, between 2009 and 2022 the price of wholesale power was $0.047/kWh and has been trending downward for the past 16 years[38].

The Icelandic Ministry Environment, Energy and Climate had one of Iceland's engineering consulting firms make a report of how successful the liberalization of the Icelandic energy market was with notice of pricing. One of the report's conclusions is that electricity prices from 2006-2017 is about 6% lower than it was in the previous 12 years before the deregulation process began[39] (see Figure B5). Prices can be shown here in ISK/kWh and have been adjusted for 2018 CPI. In the table below we have combined wholesale prices from Landsvirkjun before establishment of Landsnet (during the year's transmission cost was included in the electricity price). After the establishment of Landsnet in 2004 the authors of the report collected unit prices from Landsvirkjun and Landsnet separately and combined them.



[38] https://www.landsvirkjun.is/heildsolumarkadurinn/heildsoluverd (in Icelandic)

[39] https://www.stjornarradid.is/library/02-Rit--skyrslur-og skrar/190410%20%c3%9er%c3%b3un%20raforkuver%c3%b0s%20og%20samkeppni.pdf (in Icelandic)

Figure B5. *Electricity prices in Iceland have been trending downward over the past 16 years, and have been independently calculated to average 6% lower after the establishment of Landsnet than the average of the 12 preceding years, corrected for inflation. Note this chart is presented in Icelandic kronar. The average exchange rate ISK/USD in 2018 was $0.92/ISK.*

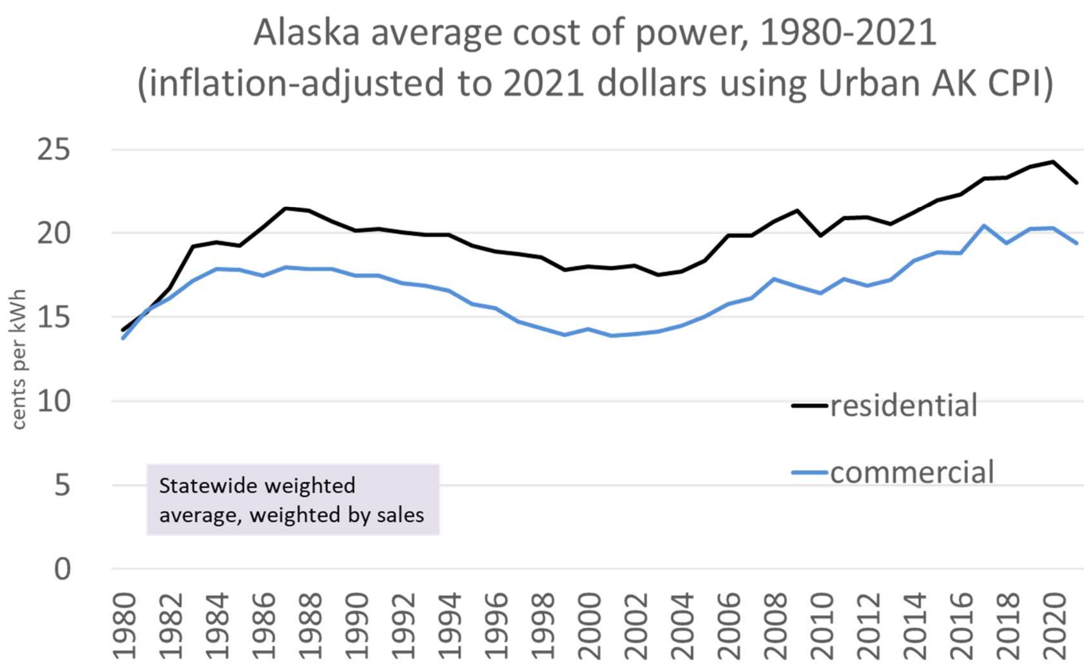


Figure B6. *For a point of comparison, the delivered cost of power has trended upward over the last 40 years, increasing approximately 30% over the last 16 years compared to the 5% decrease experienced over this same time period in Iceland.*