Electricity costs of energy intensive industries in Iceland

A comparison with energy intensive industries in selected countries

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Electricity costs of energy intensive industries in Iceland – a comparison with energy intensive industries in selected countries

Project coordination

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1 Introduction

There are ongoing disputes about electricity prices and their impact on the competitiveness of energy intensive industry. As energy intensive industries produce relatively homogenous goods or services that are at the upper end of the value chain, and as they trade their products or provide their services in the global market, they face global competition. Main input factors such as labour and electricity are - up to a certain point- only accessible and available at a regional level. Therefore, the global competition of energy intensive industries is highly affected by regional factors. This means that energy intensive industries will try to pass their competitive pressure on to regional energy suppliers and the labour markets.

The supply of electricity is bound to a network/infrastructure entailing significant investments. Thus, regulatory frameworks are needed to avoid monopolistic behaviour and to ensure a secure energy supply. Therefore, an appropriate design is deemed to be necessary for a competitive regional electricity market, which enables market access and exit for a variety of actors, low interdependences between energy supply, transmission and distribution, as well as transparency for consumers.

Overall, there is a common agreement that an outstanding energy structure and low energy prices are strong competitiveness factors and will increase foreign investment and thereby economic prosperity in the country. On the other hand, there is general consensus that the costs of electricity supply should be recovered by respective and fair electricity prices for all types of consumers.

Against this background, the Icelandic Government has approached Fraunhofer to study the impact of electricity prices on the competitiveness of their energy intensive industries. The study will provide an overview of factors that influence (impact) electricity prices for power intensive industries in Iceland, of specific features of the Icelandic energy market and energy mix (i.e. the role of 100% renewable energy), the share of electricity cost in the operation cost (business cost) of power intensive industries in Iceland, the composition of electricity costs in Iceland and a comparison of electricity costs as well as competitiveness of power intensive industries in Iceland, Norway, Germany and Canada (Quebec).[1]

Access to data regarding specific energy intensive industries as well as some power companies in Iceland was coordinated or initiated by the contracting authority. The following companies were consulted, and information requested from, in the writing of this report: ISAL (Rio Tinto), Norðurál (Century Aluminium), Fjarðaál (Alcoa), Elkem, PCC Bakki, Borealis (Etix), VerneGlobal, Advania data centre, TDK (Becromal), Landsvirkjun, HS Orka, Orkuveita Reykjavíkur, ON Power, Landsnet. The overwhelming majority of them provided the requested information and all power purchasers except for one provided information on pricing. Data in this regard is confidential. Electricity prices and costs are denoted in US Dollar (USD), the currency exchange rates used are shown in Annex A.1.4.

The study is structured as follows:

1. to provide an understanding of the factors that affect electricity prices, the Icelandic electricity market, with respect to supply, demand, price mechanisms and supports, is outlined
2. the electricity price components are described for each of the competing countries with respect to energy intensive industries
3. electricity prices of energy intensive industries in Iceland are compared with Norway, Germany and Canada
4. factors determining electricity prices in Iceland are discussed
5. recommendations are provided

[1] Canada encompasses several electricity sectors/markets, which are organised along provincial and territorial lines. Because Quebec is the province with the largest electricity generation and consumption share, and displays the lowest electricity prices, and holds a high share of energy intensive industries in Canada, we focus in the analysis on Quebec as the main competing region. https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/electricity-facts/20068:

2 Description of the electricity market and prices in Iceland

Studies published by the European Commission[2], as well as other studies, have highlighted the significance of supply factors, demand, market design, policy interference and regulations with respect to electricity prices. In this chapter, we outline the electricity supply, demand, market design, price components and present the main factors that drive electricity prices in Iceland.

2.1 Electricity supply and demand

Consumption

Over decades there has been a significant growth of the net electricity consumption in Iceland, which reached the level of 19.28 TWh in 2018. As shown in Figure 1 a), slightly over half (51-54%) of the total electricity consumption was consumed by heavy industry between 1990 and 1997; this proportion increased to 60-71% between 1998 and 2007, and has been stabilising at around 79% since 2008. Figure 1 b) shows a more detailed picture of electricity consumption by sector from 1998 to 2018 in Iceland. The industries' electricity consumption shows a continuous growth, with a strong increase in 2008. In 2018, it accounts for around 81 % of the net electricity consumption. The service sector has the second highest consumption (around 9 %), followed by households and utilities (both about 4 %).

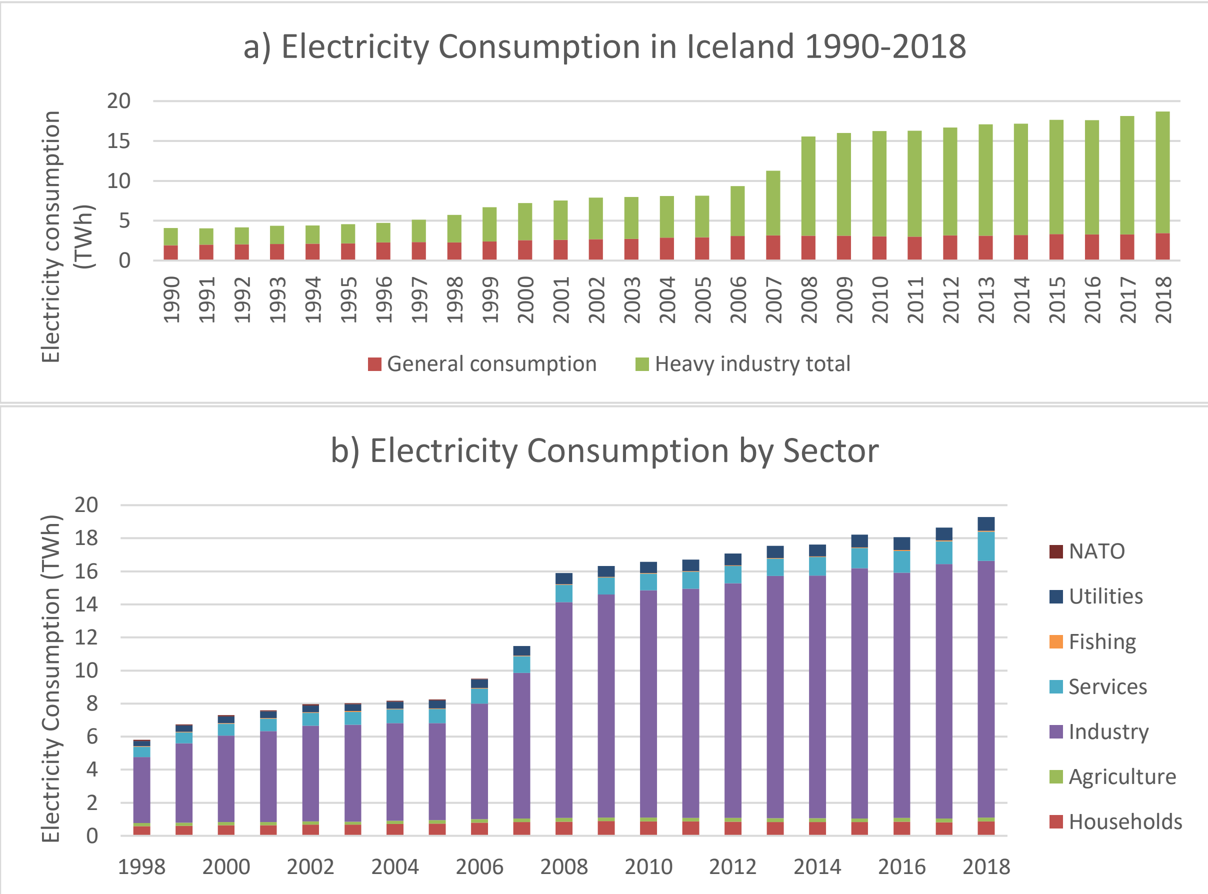

Figure 1: Electricity demand in Iceland [source: Energy Authority of Iceland]

[2] https://ec.europa.eu/energy/data-analysis/energy-prices-and-costs_en?redir=1

The high electricity consumption in the industrial sector is a result of the rapid expansion of energy intensive industries in Iceland. Aluminium production has been increasing for over half a century, which can be traced back to the expansion of the existing Rio Tinto Alcan smelter, originally built in 1969[3], and two new smelters, Century Aluminium and Alcoa, started operation in 1998 and 2008 respectively[4]. In 2018, aluminium smelters accounted for around 67 % of the total Icelandic electricity consumption, followed by ferroalloy industry (around 5 %) and aluminium foil industry (4 %). Until 2018, electricity consumption by a new industry, data centres, is growing in Iceland. However, the data reveal a decrease of 2.33 TWh (of which 1.64 TWh from oil, 0.36 TWh from hydro and 0.31 TWh from geothermal energy) in primary energy use in 2019 compared to 2018[5]. This is mainly due to great reduction is sale of aviation fuel and heavy fuel oil. Also partly a result from decreased electricity consumption in the energy intensive industry. In 2020, slumps in energy consumption are anticipated due to the Covid19 pandemic.

Accordingly, the entire energy intensive industry was responsible for around 80 % of the total Icelandic electricity consumption from 2008 to 2018.

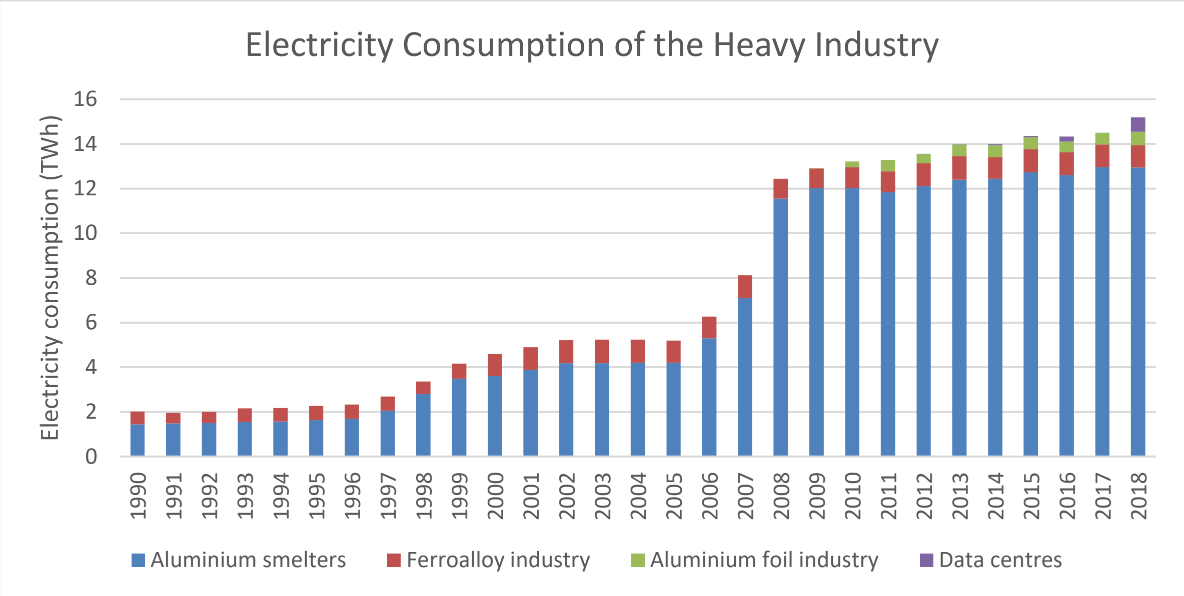

Figure 2: Electricity demand in the Icelandic industrial sector [source: Energy Authority of Iceland]

Generation

Statistics show that Icelandic electricity generation has been increasing since 1915, when 0.04 GWh were generated exclusively using oil; hydro energy began its contribution with 0.5 GWh in 1920.[6] In 2018, the total power generation reached about 19.83 TWh, mostly hydro energy (around 69.66 %) and geothermal energy (around 30.31 %) and only 0.03 % from wind and fossil fuels (Figure 3).

Wind energy was introduced into Icelandic energy generation in 2013 with a contribution of 2.8 GWh; it increased and peaked in 2015 at 10.89 GWh (0.06 % of total production) and then decreased to 4.36 GWh (0.02 %) in 2018. Oil is used mainly for reserve power and power generation in rural areas which are not connected to the national grid. Power generation from fossil fuels has decreased from 5.5 GWh (almost 0 % of total production) in 2013 to 1.87 GWh (0.01 %) in 2018.

[3] https://www.landsvirkjun.com/media/enska/about-us/Energy%20and%20aluminum%20in%20Iceland.doc

[4] https://arcticecon.wordpress.com/2012/02/15/aluminium-smelting-in-iceland-alcoa-rio-tinto-alcan-century-aluminum-corp/

[5] https://nea.is/the-national-energy-authority/energy-data/data-repository/

[6] https://www.statice.is/statistics/environment/energy/production-and-consumption/

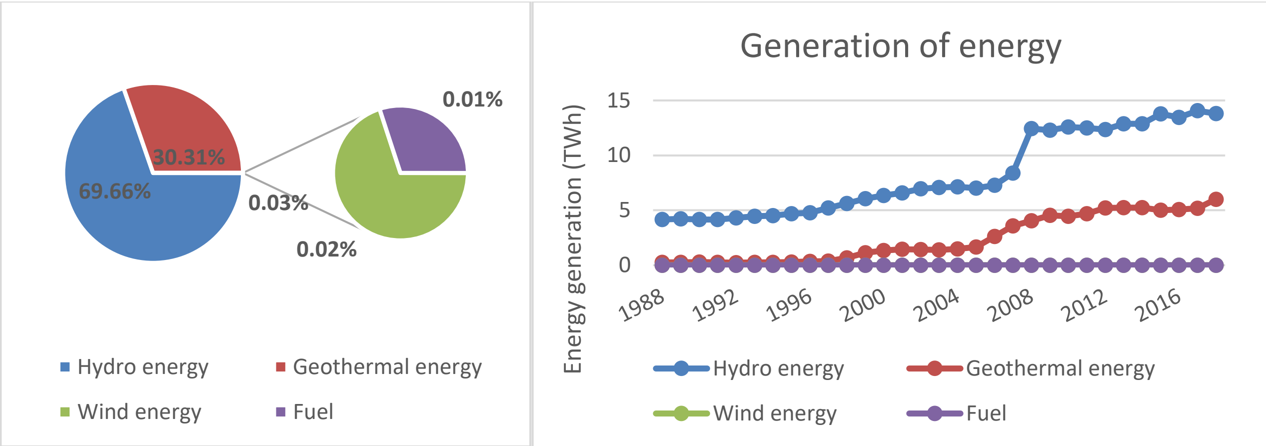

Figure 3: Source of energy generation in Icelanic public power plants in 2018 [source: Statistics Iceland]

Iceland's electricity supply and demand is unique, as the Icelandic government has stated: "Iceland is the world's largest green energy producer per capita and the largest electricity producer per capita, with approximately 55,000 kWh per person per year. In comparison, the EU average is less than 6,000 kWh."[7]

Table 1 General information and electricity information regarding Iceland, Norway, Germany and Quebec (Canada) in 2018

Category	unit	**Iceland**	**Norway**	**Germany**	**Quebec (Canada)**
General information					
Population*	thousand	334	5,338	83,124	8,299
Area*	km²	100,250	365,268	348,560	1,542,056
GDP**	bn. USD	26	434	3,950	357
Electricity generation					
Gross Electricity production	TWh	19.83	146.56	641.59	213.7
Hydro	TWh	13.81	139.51	24.14	203
	%	69.64%	95.19%	3.76%	95%
Geothermal	TWh	6.01	0.00	0.18	
	%	30.31%	0.00%	0.03%	< 1%
Wind	TWh	0.004	3.88	109.95	8.5
	%	0.02%	2.65%	17.14%	4%
Electricity consumption					(2017)
Final consumption	TWh	18.49	115.91	512.93	174,17

IS, NO, DE electricity relevant data are from Eurostat
*https://www.worldometers.info/population/europe/; Canada (Quebec): Statistics Canada
**https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2017&start=1960; Canada (Quebec): https://www.statista.com/statistics/577535/gdp-of-quebec-canada/
Canada: focus on Quebec: https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/qc-eng.html

Compared to the comparison countries and Quebec (see Table 1), Iceland has a small population. The gross electricity production in Iceland is significantly lower than in Norway (7 times), Quebec (11 times)

[7] https://www.government.is/topics/business-and-industry/energy/

and Germany (32 times). Similarly, final electricity consumption in Iceland is 6 times, 9 times and 28 times lower than in Norway, Quebec and Germany, respectively (Table 1).

The shares of hydro power are high in Iceland (73%), Quebec (95%) and Norway (96%). However, in Iceland glaciers play a major role as "batteries" for the hydropower system. Glaciers melting into water during warm and dry weather, which reduces the dependency of hydropower on precipitation and thus balances generating capacity in hydro power plants. In contrast, the hydro power plants in Norway depend on precipitation and snowmelt, and droughts have already caused significant price increases in the Norwegian electricity market (and Nord Pool area).[8] Geothermal energy use for electricity production is significant only in Iceland, while wind power application in the electricity sector is almost negligible. In contrast, with a share of 4%, wind power is the second largest source of electricity generation in Quebec; the remaining share comprises natural gas, which is mainly consumed during peaks in winter time, diesel for remote communities, and biomass.[9]

Regarding electricity consumption (see Figure 4), the industry sector holds the highest share in all three countries and in Quebec, but unlike in Iceland (84%), the shares of the industry sector in Norway (41%), Germany (45%) and Quebec (48%) are not more than half of the final electricity consumption. Commercial and public service sectors have the second highest electricity consumption in Iceland (7%) and in Germany (27%), the third highest in Norway (22%) and in Quebec (13%). These shares in 2018 have not changed much in comparison with 2017.

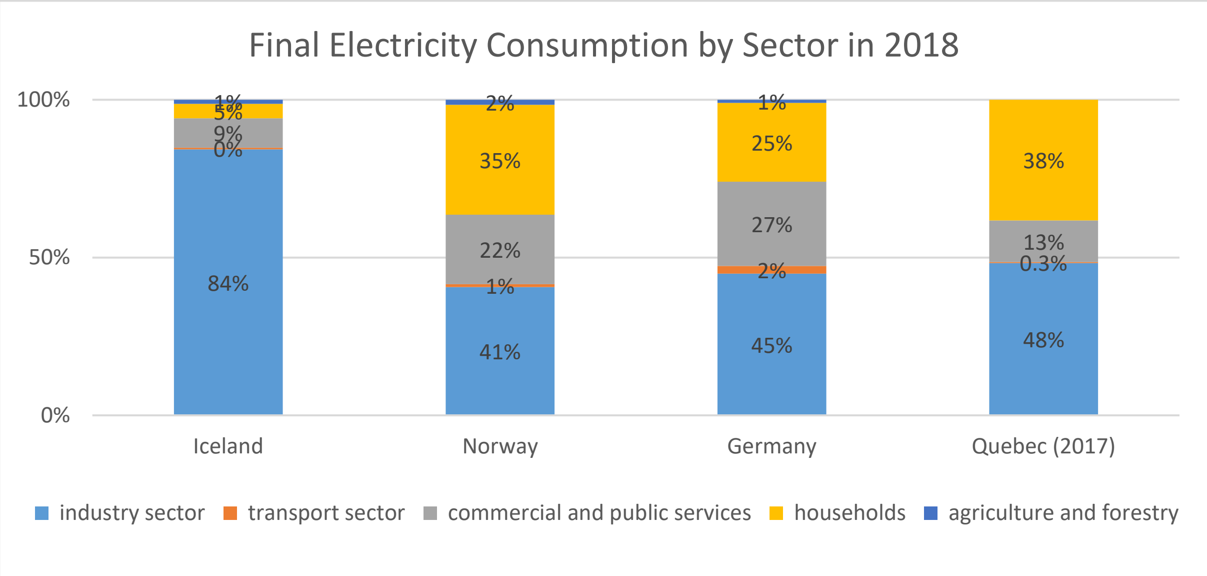

Figure 4 Final electricity consumption by sector in Germany, Iceland and Norway in 2018 [source: Eurostat] and in Canada (Quebec)[10] in 2017

2.2 Electricity market

Figure 5 below shows the structure of the Icelandic electricity market. In Iceland, most of the power companies are in public ownership. The National Power Company Landsvirkjun (state owned) holds the highest power generation share (71 %), followed by Reykjavik Energy ON (19 %). HS Orka, as a partly-public owned power company, contributes around 7 % to the electricity generation.

[8] https://www.si.is/media/orku-og-umhverfismal/Iceland-Energy-2030.pdf

[9] https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/qc-eng.html

[10] https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/qc-eng.html

Landsnet (Icegrid), the regulated national Transmission System Operator (TSO), is responsible for balancing between production and consumption. It is owned by Landsvirkjun (64.73 %), the Icelandic State Electricity (22.51%), Reykjavik Energy (6.78%) and the Westfjord Power Company (5.98 %).[11] There are five distribution system operators and only one (HS Veitur) of them is not in fully public ownership. Besides the power generators and distributors, the grid is also directly connected to 10 power intensive users.

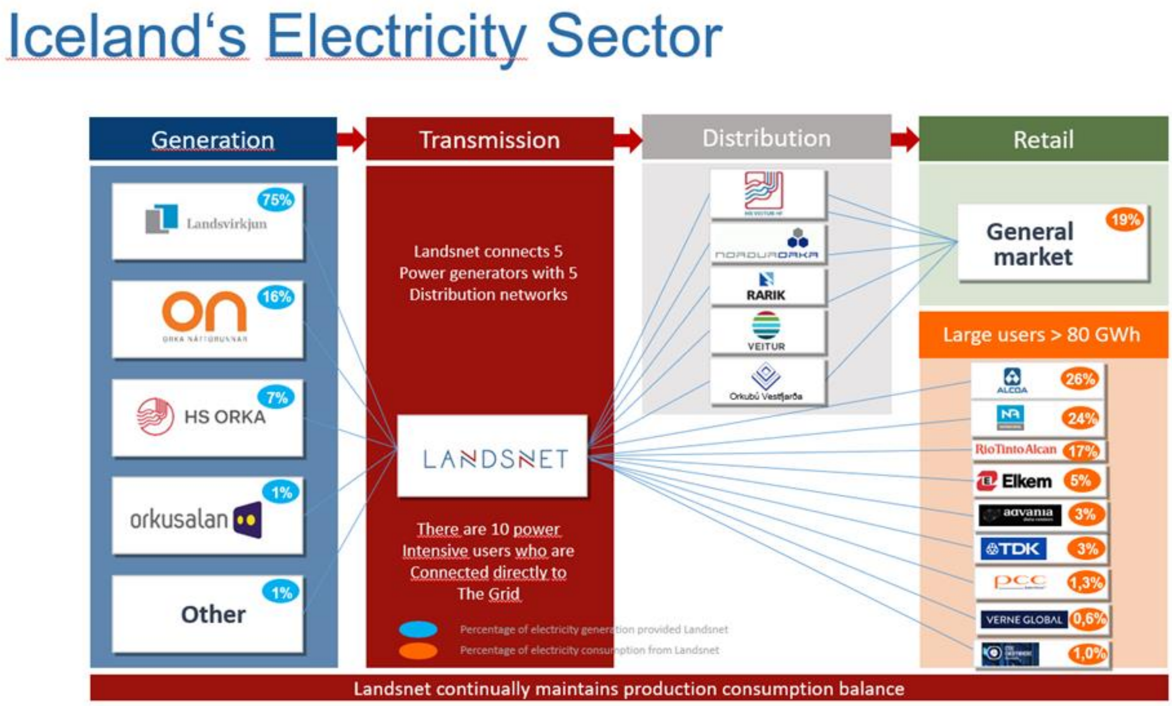

Figure 5: The Icelandic electricity market

Source: Landsnet

A licence issued by the public authority Orkustofnun is required in order to construct and operate any electric power plant – this includes hydropower plants. Orkustofnun is responsible for monitoring and regulating compliance by companies operating under issued licences. Furthermore, Orkustofnun is responsible for supervising the transmission and distribution companies. A respective Act specifies what can be included as operating expense and provides a framework for an income cap of energy companies. This includes also the regulation on potential returns on capital. Orkustofnun is responsible for checking the tariff calculations (cap) while it simultaneously requires increased rationalization and cost efficiency.[12]

Distribution utilities in operation during the time that the Act had been enacted will retain their previous rights to construct and operate distribution systems. The same tariff shall apply for the distribution of electricity in each predefined tariff area. With permission, distribution utilities can apply to Orkustofnun for higher tariffs in rural areas, where the distribution costs are higher than in densely populated areas."[13] All power stations larger than 10 MW must be connected to the national transmission grid, but many owners of smaller stations also feed electricity into the grid for sale through distribution system operators (DSOs).

[11] https://nea.is/hydro-power/legal-and-regulatory-framework/

[12] https://nea.is/hydro-power/electric-power/

[13] https://nea.is/hydro-power/legal-and-regulatory-framework/

The Icelandic electricity market is quite liberalized, in the sense that all consumers (incl. individuals, businesses, public organizations and energy-intensive industries) can choose their electricity supplier. Currently, Iceland's electricity market is dominated by long-term bilateral power purchase agreements (industrial consumers), similar to Norway before it joined the Nordic Market.

Iceland is neither integrated nor interconnected with any neighbouring power systems.[14] A wholesale electricity market is being developed and it is at the stage of market design and roadmap according to the project plan.[15]

NordREG is the organization of Nordic energy regulators; it includes Iceland. The aim of this entity is to facilitate transmission and trading across the affiliated counties by respective regulations. However, Iceland is not connected to the European grid.

Norway is part of the joint Nordic power market with Sweden, Denmark, Finland and the Baltic States and is traded through Nord Pool, which is Europe's largest power market measured in terms of its traded volume. More than 80% of the electricity consumed in the Nordic countries is traded through this exchange platform.[16]

This Nordic market is integrated into the European power market. Intraday and day-ahead trade takes place at the Nord Pool electricity exchange market, while the Norwegian Transmission System Operator (TSO) Statnett runs the balancing market in Norway. Similar to the German market (EPEX), the cost of producing the last unit of power determines the price of electricity (marginal cost). Large electricity consumers can participate directly in the wholesale market, or have bilateral contracts with electricity producers or suppliers. Small consumers can choose between different energy suppliers and tariff types. The power system is unbundled, and there are various suppliers in the market, thus competition is high. However, the large share of hydro-power in the Nordic market makes prices sensitive to variations of water availability, i.e. precipitation. But wind (speeds), as well as seasonal variations (high demand during winter time), also impact on the market prices.[17] Compared to the EPEX, price variability is determined more by predicted long-term precipitation cycles than by prices of fossil fuels. [18]

Germany is part of the European Power Exchange (EPEX) and European Energy Exchange (EEX), where electricity is traded on the spot and future market. The price on the exchange market is determined by supply of and demand for electricity.[19] To minimize the cost of electricity supply, the installations generating electricity with the lowest variable costs are dispatched first on the electricity market (merit order). The price of electricity (marginal cost price) on the exchange generally corresponds to the variable costs of the most expensive generating installation (marginal installation) in use. On the other hand, companies can sign supply contracts with electricity producers directly, and this trading is called over-the-counter (OTC).[20] Furthermore, there is a balancing market where private participants, such as large consumers and generators, can offer balancing energy (e.g. reduction of load or increase of generation).

Hydro Quebec (Quebec, Canada) is a public utility in Quebec, of which the Government of Quebec is the sole shareholder; it generated around 175.5 TWh in 2018[21] and accounted for almost one third of Canada's electricity generation (647.7 TWh, of which 532.2 TWh were consumed in Canada)[22]. Besides Hydro Quebec, some private generation sites (contracts with distribution companies) and municipal networks exist in Quebec, but their role is minor. Hydro Quebec has several divisions encompassing generation,

[14] European Commission (2016): METIS Technical Note T4, Overview of European Electricity Markets, Brussels

[15] https://www.landsnet.is/vidskipti/vidskipti/vidskiptaumhverfi/throun-a-vidskiptaumhverfi/raforkumarkadur/

[16] https://www.si.is/media/orku-og-umhverfismal/Iceland-Energy-2030.pdf

[17] https://www.regjeringen.no/en/topics/energy/renewable-energy/id2000124/

[18] https://verneglobal.com/uploads/VG-Mind-the-Gap-Energy-Availability-and-the-Disconnect-with-Data-2016.pdf

[19] https://www.epexspot.com/en/basicspowermarket#day-ahead-and-intraday-the-backbone-of-the-european-spot-market

[20] https://www.smard.de/en/wiki-article/5884/5976

[21] Sustainability Report 2019 Hydro Quebec, URL: https://www.hydroquebec.com/sustainable-development//#bloc-rapport

[22] https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/cda-eng.html

transmission, distribution of electricity. Independent power producers operate several smaller hydroelectric plants as well as all of the biomass and wind facilities. Hydro Quebec offers electricity tariffs for residential and industrial consumers, which include network charges based on connection capacity, electricity supply, and voltage level. The tariff structure is published on the company's website and offers various options for different types of consumers and reduced tariffs in the framework of economic/business development programmes. Besides the standard tariffs, Hydro Quebec has agreed to special tariffs for energy intensive production facilities, which are indexed, e.g., to the global aluminium price.[23] There is no stock exchange in Quebec. But Hydro Quebec trades with electricity markets in the Northeast of the US and Ontario. Furthermore, bilateral agreements between private consumer and suppliers also exist. Overall, the exchange with other countries is small compared to Norway and Germany (see Table 2).

Overall, Norway, Germany and Quebec are interconnected with other electricity markets. This exchange – export and import – has a two effects: in times of excess or shortage of electricity, adjacent markets buy or sell electricity and thus reduce price fluctuations in the domestic market. However, any factors, such as carbon prices, renewable support policies, and high demand, that affect electricity prices in neighbouring countries, also exert an influence on the domestic market. Iceland is not exposed to any such indirect effects as it has no interconnection.

Table 2 Electricity exchange situation in Iceland, Norway, Germany and Quebec in 2018

	unit	Iceland	Norway	Germany	Quebec
Import	TWh	-	8.34	31.73	0.18
Export	TWh	-	18.49	80.46	27
Ratio of import/export to total electricity consumption					
Import	-	-	1:14	1:16	1:968
Export	-	-	1:6	1:6	1:6

*Source: Eurostat database for Iceland, Norway and Germany; Quebec (Canada): https://apps.cer-rec.gc.ca/CommodityStatistics/Statistics.aspx?language=english

[23] Annual Report 2019 Hydro Quebec

2.3 Retail electricity price

The development of retail electricity prices for non-household consumers is shown between 2016S1 and 2019S1 for consumption up to 20 000 MWh[24] (Figure 6).

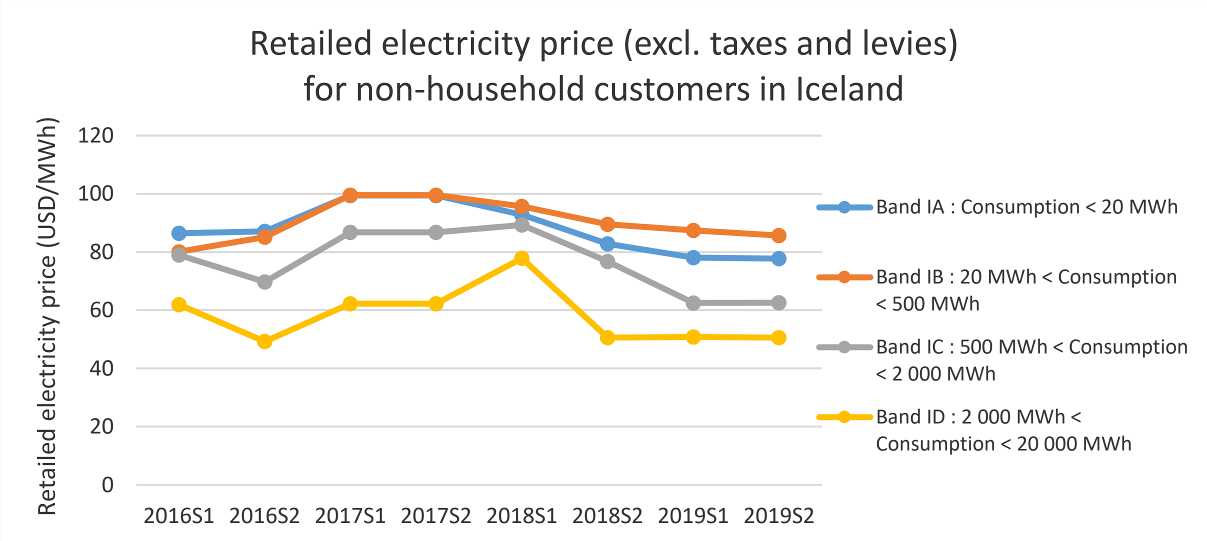

Figure 6: Development of retail electricity price (excl. taxes and levies) for non-household consumers in Iceland [source: Eurostat][25]

Figure 7 shows that the retail electricity prices in Iceland are competitive in all consumption bands especially among the selected European countries. The electricity prices in Canada (Quebec) are based on a tariff for large consumers and might differ if another tariff is selected.

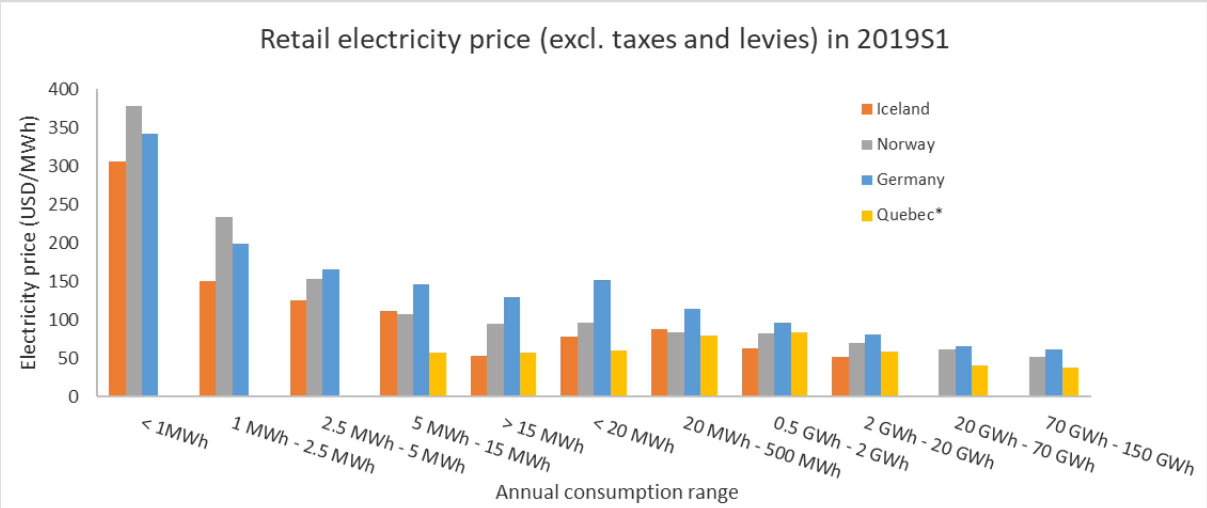

Figure 7: Comparison of retail electricity price (excl. taxes and levies) in 2019S1 among Iceland, Germany, Norway and Quebec [source: Eurostat; Electricity Rates 2019,Hydro Quebec]

Note: * Prices for Quebec are calculated average prices of the corresponding consumption levels. The retail price in Quebec comprises a variety of tariffs that offers different options for consumers, such as residential, commercial, small and large industrial consumers. It is composed of an energy price component and a power price component that covers network costs.

[24] The price for Iceland is only available for consumption up to 20 000 MWh per year

[25] The same values in 2017S1 were taken for 2017S2 due to the lack of data; value for Band IC in 2018S2 was adjusted according to the adjustment of the unrealistic network cost from 3 Euro/MWh to 30 Euro/MWh

The power intensive industries in Iceland are free to select their electricity suppliers for long-term price contracts. Currently, Landsvirkjun has the highest market share of these long-term price contracts (Figure 9). Further, energy intensive industries can purchase electricity through short-term contracts from Landsvirkjun or from any other energy supplier. Similarly to the power intensive industry, small private and public consumers can also freely choose their electricity retailer, which in turn buys electricity from an energy generator.[26] The pricing scheme of contracts between the energy intensive industries and energy suppliers is to varying degrees based on the price of aluminium at the London Metal Exchange (LME), the consumer price index (CPI) or producer price index (PPI) (mainly US), power prices at the Nord Pool power exchange and currency exchange rate.

2.4 Situation and costs of the network

Although Iceland is sparsely populated, the whole country is connected to the power grid. The Electricity Act provides exclusive transmission and distribution rights to the transmission system operator (TSO) and the distribution system operators (DSOs). Landsnet owns and operates the entire transmission system, comprising lines from 33kV up to 220 kV.[27]

The transmission fee is composed of several components (see also Annex A.1.1):

1. A fixed annual delivery fee for all points of delivery that are connected to the transmission system, both infeed and outfeed points.
2. A capacity charge for out-feed based on the average of the four highest 60-minute monthly power-peaks of the year for each delivery point.
3. An energy charge is calculated for each MWh transferred through Landsnet´s system.
4. In addition, there is a fixed charge for transmission losses and ancillary service per KWh (outfeed). This fee is used to cover Landsnet´s purchase price for these services at any given time.

The first three components (fixed annual fee, capacity charge and energy charge) of the transmission charges for consumption by power-intensive industries are denominated in US dollars, while the charges for transmission losses and ancillary services are denominated in Icelandic kronur (ISK). Moreover, the tariff for DSOs, as well as for other items, is denominated in ISK.[28]

The transmission tariffs are calculated based on the revenue cap determined by the National Energy Authority of Iceland. The TSO-tariff applies to Distribution System Operators (DSOs) and to power-intensive industries. Transmission fees are independent of the distance travelled by the power through the grid as well as the distance between the sites where the power is injected into and drawn from it. According to Eurostat, 40 % of the network costs for non-household consumers in 2018 is attributed to transmission and 60 % to distribution in Iceland.

There are 5 distribution system operators, which are mainly in public ownership. Besides the distributors, there are also 5 energy-intensive users directly connected to the grid. Special tariff conditions are:

1. Interruptible load (curtailable transmission): no capacity charge is levied on customers with curtailable transmission; they only pay an energy charge, and a 17% discount is granted on the charge for ancillary services.
2. Supply voltage discount: A discount of 5% is granted on the capacity charge and energy charge pursuant to which electricity is delivered to distributors at a nominal voltage over 66 kV.

[26] Helge Sigurd Næss-Schmidt, Martin Bo Westh Hansen, Bjarke Modvig Lumby (2018): IMPROVING ELECTRICITY MARKET FUNCTIONING IN ICELAND, Future-proofing the electricity market and improving security of supply for households, Copenhagen Economics

[27] https://nea.is/hydro-power/electric-power/transmission/

[28] https://www.landsnet.is/english/business/transmission-tariff/

3. Delivery charge discount: A discount is granted on the out-feed delivery charge if the maximum power out-feed is as follows:
    1. In the range of 3.0 – 6.0 MW the discount is 40%.
    2. In the range of 1.0 - 3.0 MW the discount is 70%.

There are some special regulations: "If energy is transmitted directly to a power intensive user from a power plant connected to the transmission system, the energy is not transmitted through the transmission system, and the transmission system does not contribute to connecting costs of the power intensive user, the out-feed charge shall be 60% of the power intensive out-feed transmission charge. A higher discount is permitted if the power intensive users' out-feed is totally reliant on energy coming from the power plant.[29]

2.5 Electricity tax

In general, the value-added tax (VAT) in Iceland is 24 %, which is levied on electricity. The VAT is not exempted for large electricity consumers, but for enterprises that exporting their goods and services (which include most large industrial electricity consumers).[30] According to the data from Eurostat, VAT is the only tax component in the Icelandic electricity price composition, and it amounted to 27.16 USD/MWh (ranging from 18.31 USD/MWh to 81.61 USD/MWh) for household consumers and 10.51 USD/MWh (ranging from 8.39 USD/MWh to 11.81 USD/MWh) for non-household consumers in 2018.

2.6 Promotion of renewable energy sources

Although there are no direct incentive schemes in place in Iceland to stimulate the growth of renewable energy,[31] there are some indirect measures to promote the use of renewable energy sources in the electricity sector:

Taxing:

1. The Oil tax (*olíugjald*), must be paid on gas-, diesel-, and kerosene oil that can be used as fuel for vehicles.
2. The General Excise Tax on Fuel (*almennt vörugjald af eldsneyti*) and the Special Excise Tax on Fuel (*sérstakt vörugjald af eldsneyti*) apply to gasoline.
3. The Vehicle tax (*bifreiðagjald*) is levied on all motor vehicles registered in Iceland. Based on the registration of CO_2 emissions of a vehicle, measured in grams per kilometre driven.
4. The Carbon Tax (*kolefnisgjald*) is paid on liquefied petroleum. Liquid fossil fuels are gas and diesel oils, gasoline, fuel oils and LPG.

Everyone that import, produce or manufacture the above-mentioned products has to pay the tax, whether it is for resale or for personal use.

The fuels (except for diesel) used to generate electricity are generally not taxed, and the consumption of electricity is not taxed either. Since the electricity consumption from taxable resources is negligible, it is not reflected in the electricity price.

[29] https://www.landsnet.is/library/Vidskipti/Gjaldskra/Gjaldskra-Landsnets-2019/Tariff%20for%20the%20Transmission%20of%20Electricity%20and%20Ancillary%20Services%20no%2033%20October%201st%202019.pdf

[30] https://www.rsk.is/english/companies/value-added-tax/

[31] https://www.si.is/media/orku-og-umhverfismal/Iceland-Energy-2030.pdf

Climate Fund: established by law in 2012 and entered into force in 2019 for the support of projects in the field of green technology innovation and public education.[32] No impact of the climate fund on electricity prices is observed.

Guarantee of origins (GOs): a European system certifying the origin of electricity from renewable energy sources in order to increase renewable energy generation and reduce greenhouse gas emissions. GOs are issued and sold by some of the power companies. Landsvirkjun has stated the GOs revenues will be used to support a 100% renewable system in terms of improving the efficiency of the system and increasing renewable energy generation and the availability of renewable energy for energy intensive industries in Iceland.[33] The revenues from the GOs represent an incentive for investors or energy suppliers to generate electricity from renewables. They could affect electricity prices, although they do not necessarily do so, as they cover part of the generation costs, and hence suppliers could offer electricity from renewables at lower prices.

2.7 Conclusion

In Iceland, the specific electricity generation costs on the supply side are driven by the costs of hydro power and geothermal energy sources, which have higher upfront investments and lower operational costs than electrifying from conventional fossil fuels for example gas or coal fired plants. Low variable cost of electricity generation entails some risks: since hydro power requires high investments with a long-term payback period and entails low operational costs, there is some risk exposure for suppliers to agree on electricity prices that do not cover all investment expenditures. The sunk costs – the investment expenditures once investments have taken place – in combination with very low operational costs induce suppliers to accept prices that cover only their operational costs. With a very powerful demand side, i.e. large individual consumers, such as energy intensive industries, and a low share of small consumers on top of it, the pressure to accept low prices becomes stronger. Given these circumstances, the electricity price in Iceland is affected by the energy source and the market constellation. Moreover, this short-term reaction could lead to a market failure, as in the long-run suppliers will refrain from necessary investments, and thereby endanger electricity supply. As this topic is beyond the scope of this report, no further analysis was conducted in this context.

Besides this potential long-term planning failure, there is no functioning market mechanism, i.e. a market place where a variety of suppliers and consumers meet and exchange information, and transparency on prices is lacking. Although a wholesale electricity market is being developed, it is still in an early stage. Instead, a dominating electricity supplier faces few large energy consumers and enters into confidential contracts. In general, it should be borne in mind that a functioning price mechanism and trust in the electricity market can be ensured by market transparency and clear trading rules, i.e. information on prices and quantity, a sufficient number of suppliers and consumers and market governance. For example, the establishment of a power exchange entails clear regulations and price setting mechanisms that cannot be re-negotiated, while bilateral contracts could be appealed.

Unlike the other countries in this study, Iceland’s electricity price is not affected by cross-border trading, i.e. neither the EU Emission Trading System (ETS), nor changes in load or generation problems of neighbouring countries affect electricity prices. On the other side, supply or load variations cannot be balanced trough exports or imports, but require relatively high reserve capacities if there are resource-induced fluctuations in electricity supply.

Furthermore, in contrast e.g. to Norway, Iceland is less dependent on precipitation, but has experienced also (some) dry year(s) , as it can rely mainly on its glaciers, but in the long term adjustments and investments to mitigate the impact of climate changes (melting of glaciers) might be necessary as well.

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[32] https://www.government.is/library/Files/Icelands%20new%20Climate%20Action%20Plan%20for%202018%202030.pdf

[33] https://www.landsvirkjun.com/productsservices/guarantees-of-origin-from-iceland#:~:text=Guarantees%20of%20Origin%20(GOs)%20is,renewable%20energy%20sources%20in%20Europe.&text=As%20Iceland%20is%20an%20isolated,the%20efficiency%20of%20this%20system.

3 Electricity price components of energy intensive industries

This section outlines the different components that are finally responsible for the electricity cost of energy intensive industries. The energy intensity of an industry is defined according to its energy consumed per unit of gross output; metrics such as electricity used in kWh per tonne of primary aluminium produced are often used. Privileges for different cost components and the qualification of applying for the ETS compensation are related to the energy intensity; this will be outlined in Section 3.2 to Section 3.5. These components include:

1. energy component - market prices of industries (with focus on energy intensive industries)
2. network component and fees
3. taxes
4. levies due to renewable energy sources (RES) promotion, energy efficiency (EE) promotion, environmental protection
5. emission trading system (ETS) compensation: compensation for indirect costs due to the ETS

Regarding the term "electricity" prices, this includes the cost component energy, the network component and fees, taxes, and levies that are added directly on top of the energy price component. The energy component is supposed to cover at least all costs of electricity generation and supply, and may include a profit margin of suppliers or generators.

3.1 Calculation of the energy component

Average prices based on Eurostat database

Energy costs are an important component of company expenses, especially for industries with high power consumption. Industrial companies with relatively small energy consumption obtain their power from power utility companies. In such cases the electricity price is composed of the procurement costs and a margin passed on through utility companies. The procurement prices (excluding taxes, levies and network charges) vary as they depend on the power that is negotiated between suppliers and the industrial companies. The energy and supply costs for non-household consumers from the Eurostat database are depicted to give an idea of the procurement prices for small industrial electricity consumers (see Figure 8) in comparison to Germany and Norway.

The data show that in comparison to Germany and Norway, Iceland had the lowest electricity procurement costs, with an average price of 45.11 USD/MWh for all non-household consumption classes up to 150 GWh. Germany had an average procurement price of 46.30 USD/MWh and was the second lowest, with an exception for consumption below 0.02 GWh. Norway had the highest costs among these three European countries, with an average of 53.38 USD/MWh in 2018. Data for consumption above 150 GWh are not available for these three countries, and for Iceland, the detailed consumption class specific statistics are only available for consumption levels up to 20 GWh.

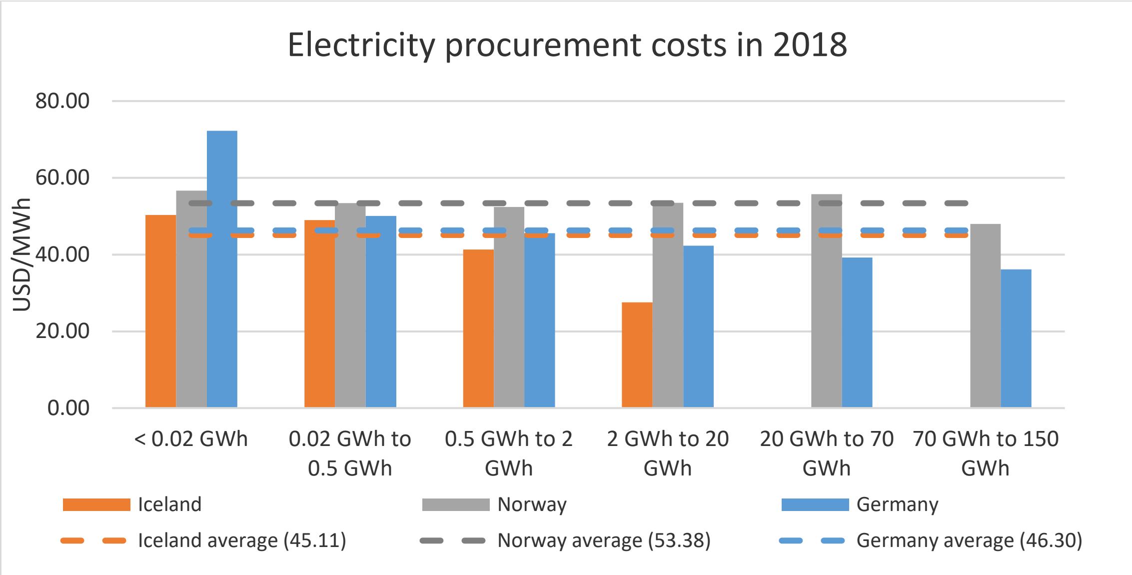

Figure 8: Electricity procurement costs for different consumption classes in 2018 [source: Eurostat]

Energy intensive industries

To assess the energy component of large energy consumers, publicly available data are partially used. Case data obtained through research, interviews and directly from the industries are confidential.

Table 3: Electricity procurement costs for energy-intensive industries 2018/2019

Energy component 2019	Iceland (average 2019)	Norway*	Germany	Quebec (tariffs & EDP)
(USD/MWh)	25.7	36.1 -44	39 - 50	19- 20.9

Note: IS: average price based on price information received, own calculation; NO: price range based on average of fixed contracts and spot market-tied prices that are; about one to two thirds lower in 2020; DE: comprises base and peak load prices and contracts before 2017 and recent contracts; Quebec:: includes tariffs for large consumers and the Economic Development Rate or Electricity Discount Programme (EDP) covering 2019/20

*source: https://www.ssb.no/en/energi-og-industri/statistikker/elkraftpris; depending on the contracts; the electricity prices in the wholesale market were significantly higher in average (38 NOK øre/kWh) in 2019, while in 2020 the prices were about 15 NOK øre/kWh due to a mild, wet and windy winter.

Iceland: No power exchange exists in Iceland. Over 80% of the energy is sold through long-term Power Purchase Agreements (PPAs) with large users. The weighted average duration of PPAs is currently 15 years, while the longest PPA in Iceland is a contract with a duration of 40 years (see Figure 9 below). Therefore, the average electricity procurement cost paid by energy-intensive industries in Iceland (Table 3) relies on a substantial share of long-term PPAs signed over 10 years ago. The price of the energy component varies depending on the pricing scheme, consumer or contract-specific features of long-term power purchase agreements. The energy price will be discussed further in Section 5.

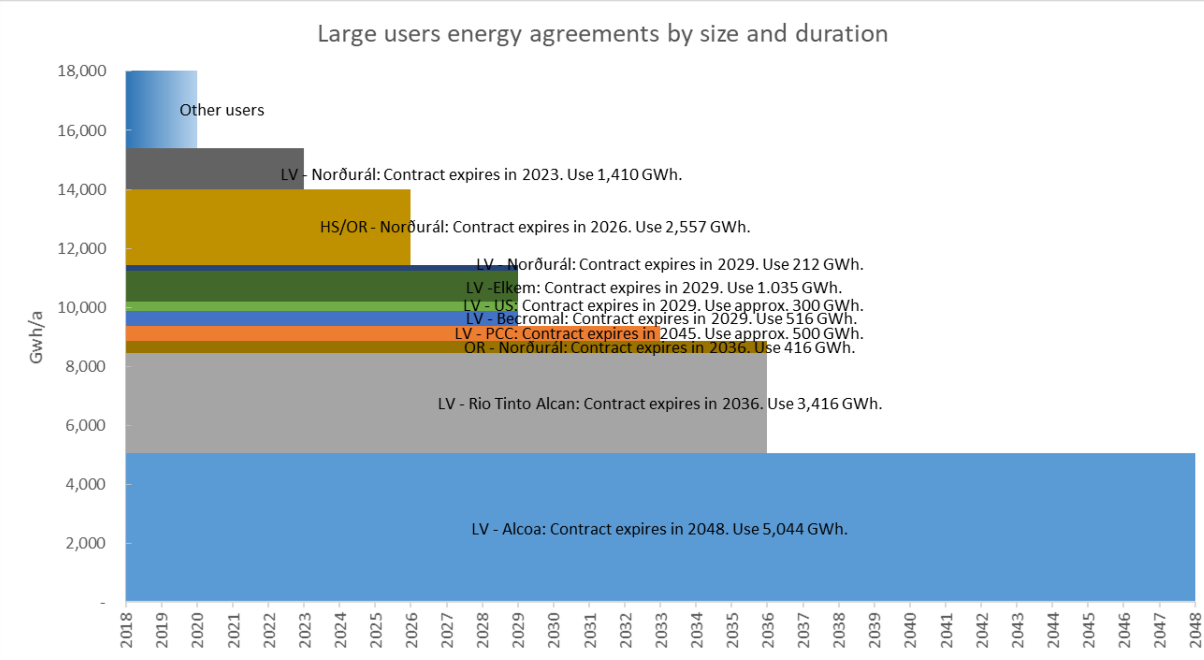

Figure 9: Contract agreements by size and duration, Iceland (excluding data centers)

Own compliant, source: https://www.si.is/media/orku-og-umhverfismal/Iceland-Energy-2030.pdf; information from the industries and power suppliers.

Germany: Talks with German industry representatives reveal that a typical purchasing strategy of energy intensive industries relies on a combination of spot and future market purchases, i.e. about 80% long-term contracts (1-5 years) and 20% spot market purchase. Large consumers directly trade on the electricity exchange or have bilateral agreements with large suppliers (OTC), and contract prices are closely related to marginal pricing. To assess electricity prices for large European industrial consumers, the spot price, plus a spread for forwards, is applied. This was also confirmed by a study conducted by the Belgian regulator, CREG, published in 2015. Therefore, declining or rising prices on the spot market do not have an immediate impact on the procurement costs of large industrial companies. For Germany, spot and forward market data of the power exchange EPEX are applied, and the base load accounts for the load profile of the manufacturing industry, while for the data centres to a small extent the peak load is included. The results for 2019 are depicted in Table 3 above. It should be noted that compared to 2018 the average future price in 2019 has increased by 8 percent for the peak load, and by 9 percent for the base load, and this is a result of the rapidly increasing CO_2 cost.

Norway: The spot market prices (about 45-52 USD/MWh) in 2018 and 2019 were higher than average end-user electricity prices for energy intensive industries in the same period (about 36-39 USD/MWh). This is a result of the long-term power contracts for energy-intensive industries in Norway having a longer contract duration than that of most European countries. Another reason for the high spot market prices in 2018 and 2019 was the relatively dry weather in these years, since the Nordic electricity prices strongly depend on the availability of water resources for hydropower and consumption. This became obvious particularly during the first months of 2020[34], when the weather was wet and windy. The supply of wind and hydropower resources strongly increased, and thus, the prices declined in the Nordic market. This in turn affected power prices in Continental Europe.[35]

[34] In spring and summer 2020 additional events such as the lock down (due to COVID) could also have an impact on prices

[35] https://www.hydro.com/globalassets/download-center/investor-downloads/ar19/annual-report-2019-web.pdf

The actual electricity prices in the end-user market for energy-intensive manufacturers are summarized and published by Statistics Norway[36]. Wholesale prices for fixed-price contracts and own electricity supply are also published. They show a price range of, on average, 40 to 44 USD/MWh in 2019 (about 38-54 USD/MWh in 2018) and of 15 to 37 USD/MWh in 2020. This reflects the potential range of prices for electricity, as a company's electricity supply might be based on a mix of long-term (on average 80%) and short-term contracts, on the power exchange. For instance, in the aluminium industry, long-term contracts run for 7 to 20 years and may be indexed to LME product prices and exchange rates. In 1999, Alcoa (primary aluminium producer) entered a long-term power contract covering 90% of its anticipated power requirements up to 2020. The power price is linked to the primary aluminium price and the US dollar exchange rate. In another case, Hydro Aluminium can cover about one third of their electricity consumption by self-generated electricity (hydro-power). Despite the low cost of self-generation, the price of self-consumed electricity is equivalent to the electricity market price as it could have been sold at the market.

Quebec, **Canada,** has a very competitive electricity supply, as the volatility of fossil fuel prices is irrelevant and variable costs are low due to the high share of hydropower. The domestic demand is high in winter due to electric heating, while electricity export (US or Canadian states) is high in summer due to cooling needs in states located in more southern latitudes. In addition, flexibility of generation is very high due to large pump storage facilities. Overall, electricity is available at low generation and external costs (low greenhouse gas emissions).

Hydro Quebec offers a standard tariff for large industrial consumers that combines an energy (used MWh) price component and a power (MW) price component[37]. In addition, the electricity supplier Hydro Quebec and the Quebec Government offer two programmes for large electricity consumers - Economic Development Rate or Electricity Discount Programme (EDP) - which enables a reduction of the electricity costs of up to 20% over a period of four to eight years until 2032. The large electricity consumers have to fulfil certain criteria, such as minimum investments and power demand, improvements or adjustments in production, such as conversion of production processes, increases in productivity or energy efficiency or new products.

For excess demand, large industrial consumers face special rates, such as rates for short-term electricity needs, for extension or revitalisation of production facilities, for addition or testing of new equipment (Additional Consumption, Industrial revitalisation, Equipment testing, Running-in of equipment), which amounts to between 0% to 4% above the base rate for energy. Furthermore, payments are made for interruptions of electricity consumption upon request (interruptible electricity option)[38].

In addition, there are special contracts with the aluminium companies. According to reports from Hydro Quebec, the electricity price is indexed to the global primary aluminium price. In Annex A.1.2 the historic price of electricity and power is depicted, which is based on the tariffs for large industries and the special tariffs for aluminium industries. In other cases, the deal with aluminium companies includes special electricity tariffs or water rights concessions, signed between the Government of Quebec and the companies, which in turn agreed to invest in Quebec facilities or modernize instead of shutting down production sites. Further bilateral private agreements between private generators and industries are also feasible, but details are unknown.

The price of the electricity component (without the power component) for large industrial consumers in 2019 and 2018 was around 25 USD/MWh. Accounting for the special rates of the EDP, the electricity price ranges around 20 USD/MWh (2019) for large energy consumers. Assuming the same credits for the specific voltage of aluminium industries, the electricity price (component) is assumed to be below the official tariff for large industry, ranging around 19 USD/MWh. The generation costs of electricity from concessionary, self-consumed hydro-power is lower than the official electricity market prices. But as self-

[36] https://www.ssb.no/en/statbank/table/09366/

[37] In physics, energy is the work done, or the amount of energy you consume when switching on the light, while power refers to the capacity that is needed to make the bulb shine.

[38] Fixed rate: 13$ per kW; variable rate; 20-30 per kWh, increasing with the number of subsequent interruption hours

consumption implies a foregone revenue from electricity sales (where private generators participate in the market), the market price of electricity, i.e. in this case the special electricity tariffs, should be applied for comparisons. The electricity prices (energy and power price component) in Quebec are depicted in Annex A.1.2.

3.2 Network component

Average fees based on Eurostat database

Network costs for **Iceland** are only available in detail for categories with consumption up to 20 GWh in the Eurostat database; however, an average network cost (around 19 USD/MWh) based on all the consumption categories is available and it was the cheapest in comparison to the average network costs of the other two European countries in 2018. Eurostat estimated that for non-household consumers 40% of the network costs resulted from transmission and 60% from distribution in Iceland, which was similar to the ratio revealed in the report of EFLA project.[39] Based on this estimation and the available Eurostat data on network costs, a transmission cost of around 9.2 USD/MWh was assumed for consumers with an annual electricity consumption between 2 and 20 GWh.

Regarding the other two European comparison countries, the network costs for consumption between 2 GWh to 20 GWh were around 18 USD/MWh and 34 USD/MWh in Norway and in Germany, respectively. According to the available data for these two countries, with consumption between 70 GWh and 150 GWh, Norway had a lower network cost of 5.9 USD/MWh, whereas Germany had a network cost of 20 USD/MWh. However, these data still could not reflect the actual network costs for energy-intensive industries, whose electricity is in many cases transmitted directly from suppliers through a transmission network and therefore nearly no distribution costs are expected.

Differentiated grid charges are also used in other European countries. The differentiation of companies' network charges is often linked to technical characteristics, in particular the voltage level of their grid connection. The hours of electricity use, as well as the timing of demand and peak loads within one year, are also factored into the calculation of network charges. For example, some large consumers are directly connected to the high voltage grid, or are very close to generation sites (and are not connected to the distribution grid), or do not have peak loads and thus do not put additional strain on the grid. This implies lower costs for grid operators, which translates into lower fees; they do not necessarily mean that companies are privileged compared to other customers, but reflect the lower network costs per kWh for consumers. Since network charges depend on the time of demand, among other things, the quantification relies on the availability of data.

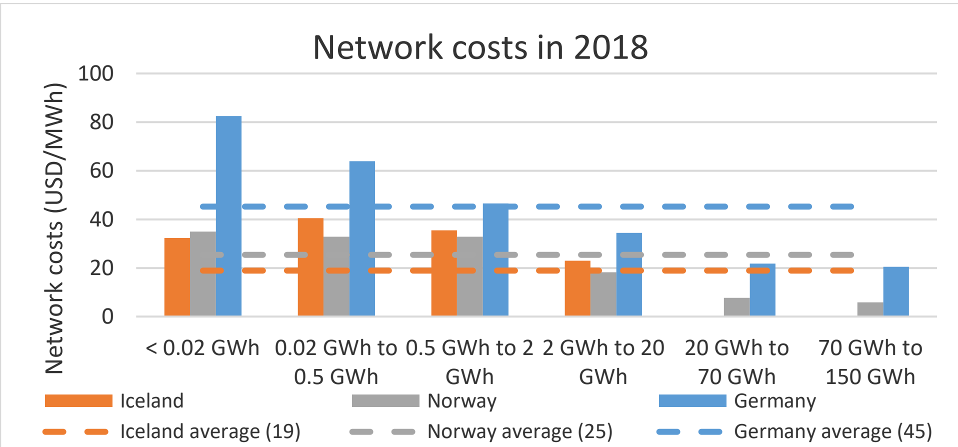

Figure 10: Network costs for non-household consumers in 2018 [Source: Eurostat]

*A possible data mistake has been adjusted for consumption between 0.5 GWh and 2 GWh in Iceland (also see footnote 25)

[39] https://www.stjornarradid.is/library/02-Rit--skyrslur-og-skrar/190410%20%C3%9Er%C3%B3un%20raforkuver%C3%B0s%20og%20samkeppni.pdf

Energy intensive industries:

Table 4 Costs of network components for energy-intensive industries 2019

Network component 2019	Iceland	Norway	Germany*	Quebec (power component)
(USD/MWh)	4.73-5.9	2.8-3.3	3-4.5	6-16

*Network component in Germany incl. network costs, concession fee, §19 StromNEV-surcharge

Data from Landsnet[40] (**Iceland**) (Figure 11) reveal transmission costs of around 4.92 USD/MWh and 4.73 USD/MWh for energy-intensive industries in 2018 and in 2019, respectively, which were almost half as much as the transmission fee for small electricity consumers (see Figure 10). Data on transmission costs were sparsely available[41], thus it is unclear whether the costs for losses and auxiliary services were included or not. In Annex A.1.1 the details of the transmission fees are listed. On the other hand, rough estimates based on some selected cases point to an average cost of 5.9 USD/MWh in 2019.

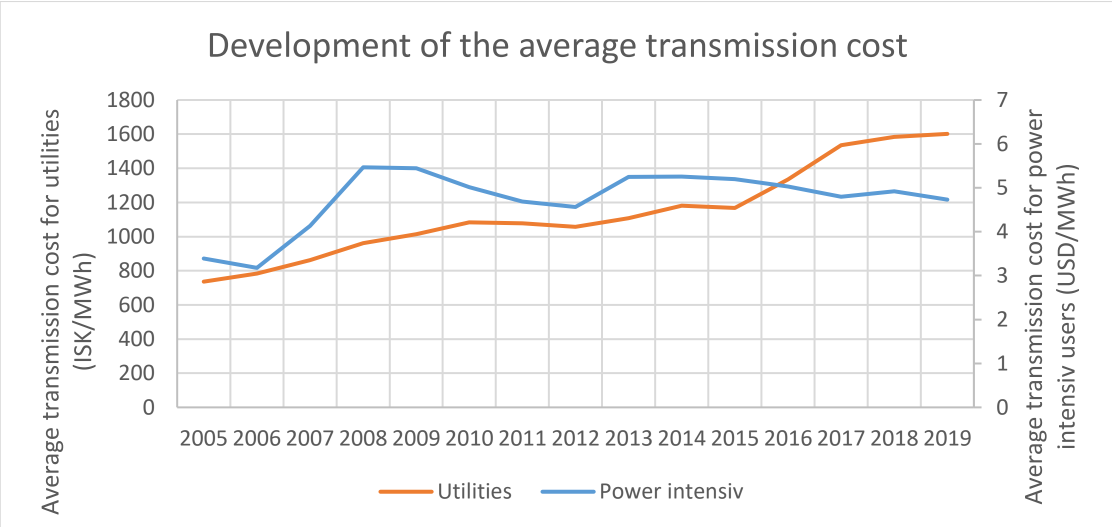

Figure 11: Development of the average transmission cost in Iceland

Source: Own illustration with data from Landsnet's Database (https://www.landsnet.is/vidskipti/vidskipti/gagnabanki/)

In **Norway** the transmission network costs comprise a variable component, depending on the amount of electricity, and a fixed component, depending on the connected power. The fixed component depends on the stability and consumption pattern of large consumers, such as hours of utilisation during the year and day. The variable component is calculated based on the traded electricity price in the respective market zone and a marginal loss rate (location of connection), which is symmetric around zero. Subsequently, consumers with high power (> 15MW for more than 5000 hours per year) are offered a reduction on the basic tariffs (up to 75% of tariff reduction, flexible consumption is not included).[42] [43] Apart from energy intensive industries, most other customers are connected through the distribution grid and thus pay transmission and distribution fees.

Network costs are verified/surveyed by an official authority in **Germany**. For industrial customers they vary according to power consumption and peak load. If the peak load of a consumer differs from the

[40] https://www.landsnet.is/default.aspx?pageid=51165518-f5f6-11e7-9423-005056bc530c

[41] Publicly data were used. Despite the inquiries of the Ministry and Fraunhofer, only few data is provided.

[42] https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/mc-documents/190626_MC_TOP_7.2_TTO_Synthesis2019.pdf

[43] https://www.statnett.no/en/for-stakeholders-in-the-power-industry/tariffs/how-we-calculate-the-tariff/

annual system peak load in time, consumers with an annual consumption of at least 10 GWh and annual full load hours of at least 7,000 hours may apply for individual network charges. As regulated in paragraph 19 of the Electricity Grid Access Charge Ordinance (German: *StromNEV*), the minimum rates for these reduced network charges depend on the power consumer's full load hours:

- Rate for full load hours > 7,000 h/a: 20% of the published tariffs;
- Rate for full load hours > 7,500 h/a: 15% of the published tariffs;
- Rate for full load hours > 8,000 h/a: 10% of the published tariffs;

The reduction of network charges for eligible customers is financed by the §19 Electricity Network Access Ordinance surcharge, which is paid by all consumers. The rate was 3.4 USD/MWh in 2019 and is 3.9 USD/MWh in 2020. For consumption above the threshold of 1 GWh/year, consumers pay 0.5 €/MWh (equivalent to 0.55 USD/MWh in 2020). Production enterprises, as well as rail infrastructure and transport companies, whose electricity costs have exceeded four percent of their turnover in the previous calendar year, pay 0.25 €/MWh (equivalent to 0.27 USD/MWh in 2020) for the consumption above 1 GWh.

In addition to network costs and surcharge, a concession fee is charged to compensate for the usage of public transport routes, and a rate of 1.2 USD/MWh is applied for industrial customers. The concession fee can be exempted for special contract customers who have purchase prices below the published price threshold.[44]

In Quebec, **Canada**, the transmission and distribution network is managed by Hydro Quebec, apart from several smaller, municipal networks. Network costs are included in the power price (per MW) and are displayed as part of the electricity price in the tariff schemes.

In addition, companies connected at a higher voltage level receive a credit on the price of power. The base price for large industrial power consumers is CAD$/kW 12.9 (2018/2019, equivalent to 9 721 USD/MW in 2019); at the voltage level 80-170 kV a credit of CAD$/kW 2.679 (equivalent to 2 019 USD/MW in 2019) is granted, while the credit amounts to CAD$/kW 3.54 (equivalent to 2 668 USD/MW in 2019) for a voltage level above 170 kV (in 2019, 2018, 2017)[45]. Thus, the resulting cost of power per consumed electricity depends on the voltage level, the connected power and the total electricity consumption.

Given an annual electricity consumption between 40 -1700 GWh and a connection power between 5 - 200 MW at a voltage level of 200 kV, the price for power is about CAD$/MWh 14 (equivalent to 11 USD/MWh in 2019); at the voltage level 100 kV the price for power is about CAD$/MWh 15 (in 2019, 2018, 2017, equivalent to 11 USD/MWh in 2019).

3.3 Taxes

In **Germany,** the reduced electricity tax of 15.37 €/MWh (equivalent to 17 USD/MWh in 2020) is applicable for industrial consumers if the discounted amount is over 250 Euro[46]. For metal manufacturing as well as processing industry, a tax relief can be applied for[47].[48]

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[44] https://www.bdew.de/media/documents/20200107_BDEW-Strompreisanalyse_Januar_2020.pdf

[45] http://www.hydroquebec.com/documents-data/official-publications/

[46] As regulated in paragraph 9b in the Electricity Tax Act (German: *StromStG)*

[47] As regulated in paragraph 9a in the Electricity Tax Act (German: *StromStG)*

[48] https://www.bdew.de/media/documents/20200107_BDEW-Strompreisanalyse_Januar_2020.pdf

In Quebec, **Canada**, a tax on goods and service, also known as value-added tax, of 5% on the electricity and power price is levied, but is refundable for industries. The provincial sales tax (9.98%) is also refundable for the manufacturing sector and commercial and industrial consumers (with revenues above 10 million CAD$). No other electricity charges or taxes are levied[49].

In **Norway,** electricity consumption is taxed. For manufacturing, mining, data centres and other purposes there is a reduced rate of 5.05 NOK/MWh (equivalent to 0.52 USD/MWh in 2020), while certain energy intensive processes such as chemical reduction, electrolysis, metallurgical processes are exempted from the tax.[50]

As introduced in chapter 2.5, Iceland levies a value-added tax (VAT) on electricity. Large industrial consumers are not specifically exempt, but all exporting industries (which include most large industrial consumers) are de facto exempt since the VAT-collection system only applies to goods and services sold in Iceland.[51]

3.4 Levies: Promotion of renewable energy sources, energy efficiency and environmental protection

In general, financing of renewable energy policies can occur in several different ways: 1) RE-levy as a billed additional retail price component or 2) included in electricity purchase price or, 3) financed through the state budget.

Table 5 Levies for energy-intensive industries 2019

Levies 2019	Iceland	Norway (USD/per connection point)	Germany* (total of levies USD/MWh)	Quebec
	-	90.96	1.1-80	-

*Levies in Germany incl. EEG surcharge, CHP surcharge, Offshore network surcharge, abLA-surcharge. The level of privilege of each surcharge is different depending on the industry.

In Germany, the Netherlands and France, all support costs (feed-in payments etc.) are published, and levies are assessed based on a published calculation scheme. The levy is then added to the electricity costs and billed as an additional charge for RE (option 1). In Quebec and Norway, certificate systems and/or Feed-in Tariffs (FIT) are applied, and the expenditures are firstly borne by utilities. The utilities then pass on these costs via electricity prices to final consumers (option 2). Since almost 100% of Iceland's electricity comes from renewable sources, electricity consumption is not subject to such charges or support systems.

Norway has introduced an Electricity Certificate Scheme. It is a national market-based support scheme and aims at promoting electricity production from renewable energy sources. The scheme is applied together with Sweden. Producers of renewable energy are entitled to a certificate which they can sell in the market. All electricity suppliers and certain categories of end-users are required to purchase certificates for a certain percentage of their electricity consumption (quota) which they factor into their prices (about 3.1 USD/MWh in 2018). This quota will be gradually reduced until 2035, while the scheme

49 https://www.oecd.org/tax/tax-policy/taxing-energy-use-2018-canada.pdf

50 https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/electrical-power-tax/

51 https://www.rsk.is/english/companies/vat/

will be terminated in 2036 in Norway. [52] Electricity used for manufacturing processes in energy intensive industries is exempt from this levy.[53] In addition, there is a fee of about 10 NOK/MWh (equivalent to 1 USD/MWh in 2020) paid by households to support ENOVA (Energy Fund), a state enterprise that funds and advises on energy and climate projects. Companies pay a fixed amount of about 800 NOK (equivalent to 82.09 USD in 2020) per metering point, which is negligible.

Germany: The Renewable Energy Resources Act (German: *Erneuerbare-Energien-Gesetz*, EEG) surcharge funds payments to operators of renewable energy installations. In 2019, the surcharge was 72 USD/MWh and was increased to 74 USD/MWh in 2020. Companies classified by EEG as "electricity cost intensive" are qualified to apply for a "special equalisation scheme" to reduce payments. The first GWh electricity consumption is always charged with a full EEG surcharge rate; the reduced EEG surcharge rates for electricity consumption after the first GWh are 15-20% of the standard rate, depending on the proportion of electricity costs in the company's gross value added (a proportion of 14% being the minimum to qualify for a reduced rate).

A cost cap is applied so that the EEG surcharge payment does not exceed 0.5% of gross value added if the electricity intensity of the company is higher than 20%; or 4% of the gross value added if the electricity intensity of the company is less than 20%. Minimum rates are 0.5 €/MWh (equivalent to 0.55 USD/MWh in 2020) for non-ferrous metal producers and 1 €/MWh (equivalent to 1.1 USD/MWh in 2020) for all others. For self-consumed electricity produced by the consumers themselves, a certain reduction on EEG surcharge is granted as well.[54]

The combined heat and power (CHP) surcharge (German: *KWKG-Umlage*) scheme is based on the act on for the preservation, modernisation and expansion of combined heat and power (CHP Act). It funds additional costs of combined power and heat generation, as opposed to separate production. The CHP surcharge is recalculated every year and amounted to 3.1 USD/MWh in 2019 and 2.5 USD/MWh in 2020. A similar "special equalization scheme", as with the EEG surcharge, can be applied for by the same groups of companies. The first GWh electricity consumption is always charged with a full CHP surcharge rate, the reduced CHP surcharge rates for the electricity consumption after the first GWh can be referred to in the EEG surcharge reduced rate rules described above. A similar cost cap as for the EEG surcharge is also applied to the CHP surcharge payments. The minimum rate for the CHP surcharge is 0.3 €/MWh (equivalent to 0.33 USD/MWh in 2020).[55]

An offshore network surcharge (German: *Offshore-Netzumlage*, it was referred to as the offshore liability surcharge until 2018) is paid to compensate for the costs resulting from disruptions or delays in the connection to offshore wind facilities and the costs of offshore network installation and operation. The tariff was 4.16 €/MWh in 2019 (equivalent to 4.7 USD/MWh) and in 2020 (equivalent to 4.6 USD/MWh). The rate reduction, as well as the minimum rate, are referred to as the CHP surcharge.[56]

Last but not least, the Interruptible load allocation surcharge (German: *abLA-Umlage*) was introduced in 2013 to improve power grid stability and power supply security. This surcharge is to compensate TSO for their payments to the providers for the so-called "load interruption services". These interruption services are provided by, for example, industrial companies that can waive their supply of electricity for an agreed period, or even at short notice if there is not enough electricity in the power grid. The TSO compensates the providers and transfers the costs to all final consumers. In 2019, the tariff was 0.056 USD/MWh, and increased to 0.077 USD/MWh in 2020.

Canada: For renewable energy generation, private power purchase agreements are made with distribution companies (mainly Hydro Quebec) whose prices are set in the framework of a tender process.

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[52] https://energifaktanorge.no/en/regulation-of-the-energy-sector/elsertifikater/#:~:text=The%20joint%20Norwegian%2DSwedish%20electricity,electricity%20production%20in%20both%20countries.&text=The%20electricity%20certificate%20scheme%20started,by%2028.4%20TWh%20by%202020.

[53] https://energifaktanorge.no/en/norsk-energiforsyning/kraftmarkedet/

[54] https://www.bdew.de/media/documents/20200107_BDEW-Strompreisanalyse_Januar_2020.pdf

[55] As regulated in paragraph 27 in KWKG 2016

[56] As regulated in paragraph 17f paragraph 5 EnWG (the Energy Industry Act)

As with any other private power purchase agreement, the price of renewable energy is taken into account in the final electricity price calculation of Hydro Quebec, and no additional charge is levied. In addition, as 99% of the electricity generation is based on renewable sources, CO_2 emissions are a minor cost factor. To deploy wind power, the Government of Quebec, **Canada**, has called for tenders, and power purchase agreements have been signed between the tenderer (private generators) and Hydro Quebec. There is no additional levy or charge for renewables on top of the energy price component.

3.5 EU Emission Trading System compensation

The EU emission trading system (EU ETS) was introduced in 2005 as a climate protection strategy to reduce greenhouse gas emissions cost-efficiently. It is the world's first and currently largest carbon market. All EU countries, as well as Iceland, Norway and Liechtenstein, are part of the EU ETS. Emission trading has increased electricity prices by up to 50 percent in periods with high emission-allowance costs in Europe, including the Nordic market. Even electricity markets with a large share of renewables (low carbon emissions) are affected, as they are interconnected with other carbon-intensive markets.

A high risk of relocating industrial installations, business or production to other countries with laxer emission constraints, also known as carbon leakage, is likely in certain energy intensive industries (e.g. the aluminium industry) under the EU ETS.

To ensure the competitiveness of industries covered by the EU ETS and reduce the risk of carbon leakage, companies in certain sectors and sub-sectors can receive a higher share of free emission allowances in comparison to other industrial installations. In addition, a financial compensation for increasing electricity costs under the EU ETS (also known as indirect emissions through electricity consumption) can be applied for the most electro-intensive sectors (including iron and steel industry and non-ferrous metal industries) through national state-aid schemes, which need to be established in accordance with EU guidelines (2012)[57] and be approved by the EU Commission. Figure 12 gives an overview of the compensation paid by Member States and Norway in 2018. A revision of the EU ETS state-aid guidelines has been initiated by the Commission for phase 4, which will extend from 2021 to 2030. In phase 4, the carbon leakage list will be adopted and more support will be provided to sectors with the highest exposed risk.

In Germany, the State Aid Directive was adopted by the Federal Ministry for Economic Affairs and Energy[58]. 50 applications involving 156 installations from the iron and steel industry (amounting to 63 million USD) and 50 applications involving 111 installations from non-ferrous metal industries (amounting to 45 million USD) were granted for state-aid compensation for indirect CO_2 costs in 2018[59].

Although the power supply in Norway is mainly hydro power and almost free of CO_2 emissions, the Norwegian power price is still influenced by the carbon price as a result of market coupling and trade. In 2013, the Norwegian compensation scheme was established by the Norwegian Ministry of the Environment. 43 companies have received compensation for the accounting year of 2013 and the number of companies receiving compensation increased to 45 in 2018, with a total compensation amount of 62 million USD.[60] Self-consumed electricity is not compensated.

Applications for state aid are evaluated according to the national state-aid schemes. The CO_2 costs for the purchase of 1 GWh of electricity per year per installation are subtracted from the total aid amount of the undertaking. The maximum state-aid amount per installation is calculated as follows:

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[57] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012XC0605%2801%29

[58] Directive on aid for companies in sectors or subsectors deemed to be exposed to a significant risk of carbon leakage due to EU ETS allowance costs passed on in electricity price (aid for indirect CO_2 costs) of 23/07/2013, official part of the Bundesanzeiger (Federal Gazette AT) 06/08/2013 B2, last amended by the second Amendment of Directive of 21/08/2018, Bundesanzeiger (Federal Gazette AT) 28/08/2017 B1. (URL: https://www.bmwi.de/Redaktion/DE/Downloads/P-R/richtlinie-beihilfen-co2-kosten.pdf?__blob=publicationFile&v=3)

[59] https://www.dehst.de/SharedDocs/downloads/EN/spk/Auswertungsbericht_2018_Englische_Version.pdf?__blob=publicationFile&v=2

[60] https://www.regjeringen.no/contentassets/49d2580072464762aa82aea1892ed29d/co2kompensasjon-vedlegg.pdf

a) For products with product-specific electricity consumption efficiency benchmarks (e.g. primary aluminium):

$$Amaxt = Ai_t \times C_t \times P_{t-1} \times E \times BO$$

b) For products eligible for aid without a benchmark (e.g. basic iron and steel and ferro-alloys, aluminium production):

$$Amaxt = Ai_t \times C_t \times P_{t-1} \times EF \times BEC$$

Amaxt: State aid in accounting year a (in Euro)

Ai_t: State aid intensity for the accounting year t

C_t: CO_2-emission factor in the accounting year t (in t CO_2/MWh)[61]

P_{t-1}: the emission allowance price (EUA-forward price) for the year t-1(in EUR/t CO_2)

E: the applicable product-specific electricity consumption efficiency benchmark (in MWh/t product)

BO: Baseline output (in t product) [62]

EF: the fall-back electricity consumption efficiency benchmark (fallback factor)

BEC: Baseline electricity consumption (in MWh)[62]

The state-aid compensation depends strongly on the state-aid intensity (0.85 from 2013 to 2015, 0.80 from 2016 to 2018 and 0.75 from 2019 to 2020) and on the relevant EUA price, which was 6.1 USD/t CO_2 in 2017, 6.94 USD/t CO_2 in 2018 and 18.09 USD/t CO_2 in 2019.[63]

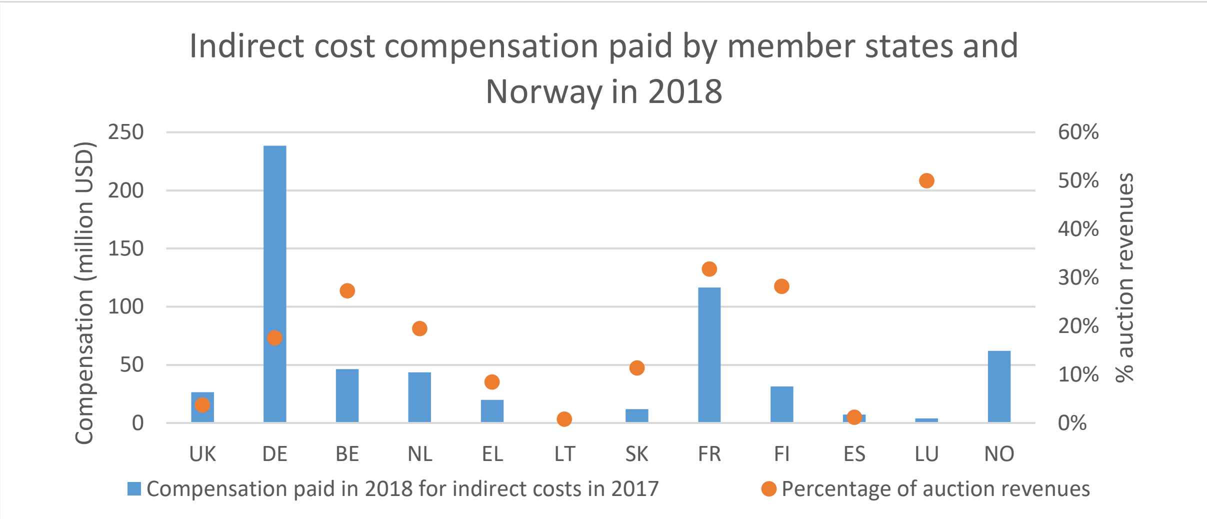

Figure 12: Compensation for indirect costs

Own compliant (source: https://ec.europa.eu/transparency/regdoc/rep/1/2019/EN/COM-2019-557-F2-EN-MAIN-PART-1.PDF; https://www.regjeringen.no/contentassets/49d2580072464762aa82aea1892ed29d/co2kompensasjon-vedlegg.pdf)

[61] The maximum CO2-emission factor depends on different geographic area and it is 0.76 tCO2/MWh for Germany (in middle and western Europe) and 0.67 tCO2/MWh for Norway (in northern Europe) (URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012XC0605(01)&from=DE)

[62] According to the guideline: "'baseline output', in tonnes per year, means the average production at the installation over the reference period 2005- 2011 (baseline output) for installations operating every year from 2005 to 2011. A given calendar year (e.g. 2009) may be excluded from that seven-year reference period. If the installation did not operate for at least one year from 2005 to 2011, then the baseline output will be defined as yearly production until there are four years of operation on record, and afterwards it will be the average of the preceding three years of that period. If, over the aid granting period, production capacity at an installation is significantly extended within the meaning of these Guidelines, the baseline output can be increased in proportion to that capacity extension. If an installation reduces its production level in a given calendar year by 50 % to 75 % compared to the baseline output, the installation will only receive half of the aid amount corresponding to the baseline output. If an installation reduces its production level in a given calendar year by 75 % to 90 % compared to the baseline output, the installation will only receive 25 % of the aid amount corresponding to the baseline output. If an installation reduces its production level in a given calendar year by 90 % or more compared to the baseline output, the installation will receive no aid"

[63] https://www.dehst.de/SharedDocs/downloads/EN/spk/Auswertungsbericht_2018_Englische_Version.pdf?__blob=publicationFile&v=2

No such compensation scheme exists in Iceland, which is not surprising given that electricity production in Iceland is not subject to the CO_2-emission costs which such schemes are designed to offset, and no cross-border electricity trading exists to directly expose the Icelandic market to such costs. It could be argued, however, that Icelandic electricity prices are partly influenced by such costs to the extent that Icelandic power prices are indexed to other European markets, either directly (through power purchase agreements) or indirectly (through the pricing strategy of power producers).

4 Competitiveness of Iceland's energy-intensive industries

Electricity costs and the impact of electricity prices on the competitiveness of energy-intensive industry are illustrated for selected types of industries. These include the primary aluminium production, ferrosilicon and silicon production and data centres.

The technical specifications of the respective industries are the basis for the assessment. The electricity prices of these selected energy intensive industries are calculated as if these Icelandic industries were located in the respective countries – Canada (Quebec), Norway and Germany. In addition, very country specific features of energy intensive industries are included, e.g. potential self-generation and consumption.

4.1 Method

One of the main factors that determines the competitiveness of energy intensive industries facing global price competition is their costs of energy. The costs are the product of quantity and prices. Therefore, not only energy prices, but also energy efficiency (consumption) are key factors for their competitiveness. Efficient use of energy is depicted by consumption per product unit, e.g. kWh/tonne aluminium, or power usage effectiveness (of data centres).

To estimate electricity prices, information on the technical specifications are required from the energy intensive industries. They are listed in Annex A.1.3. The analysis comprises technical data on the following industries in Iceland:

1. (primary) aluminium production
2. ferrosilicon production
3. data centres

Information on prices is also available on these industries as well as on the silicon industry. As a small number of companies have provided data on electricity prices per industry, we have taken averages, in some cases even across industries, if only one single company reported input. Additional information was collected through desk research and interviews.

The electricity prices presented in Section 4.3 are decomposed into components, which include:

1. Price of energy: price that companies pay for the energy they consume (USD/MWh);
2. Price of networks/power: transmitting and distributing electricity are services and consumers pay a fee for these services. The fee could be a fixed fee based on the connected power (USD/MW), or a variable cost based on the consumed amount of electricity (USD/MWh). The latter applies in most cases. In Quebec there is no transmission fee, but a price for the power (USD/MW) and it is included in this category;
3. Taxes: some countries collect taxes on electricity consumption and sales of electricity (USD/MWh);
4. Levies: come countries place levies for the promotion of renewables, CO_2 emissions reduction, energy efficiency, innovations in energy technologies etc. (USD/MWh);
5. ETS compensation: to avoid carbon leakage in energy intensive industries, compensations for the indirect costs arising from the CO_2 price on electricity are paid in some countries (USD/MWh)

The different cost components add up to the total electricity price an industry has to pay. The ETS compensation is depicted as a reduction of the electricity price. As there is no uniform pricing rule for these industries among the selected cases, different electricity prices are selected, depending on the pricing scheme or contract, for example old or new contracts, price indexation or fixed prices/special tariffs, or in the case of limited data, average prices of the respective industry or across energy intensive industries and their status of privilege regarding taxes and levies.

4.2 Energy consumption

Data Centres:

Unlike the manufacturing industries, the level of electricity consumption of this industry depends on the geographic location of the building housing the data centre. This is due to the fact that up to half of the energy consumed is for cooling servers, and many data centres utilize cool air from outside to minimize power consumption. A positive correlation between the power usage effectiveness (PUE) and the average temperature has been shown in the Nordic high performance computing system in Iceland (Figure 13).[64] Therefore, besides electricity price, another important factor affecting the expenses of a data centre – be it operating or investment expenses – is the ambient temperature.

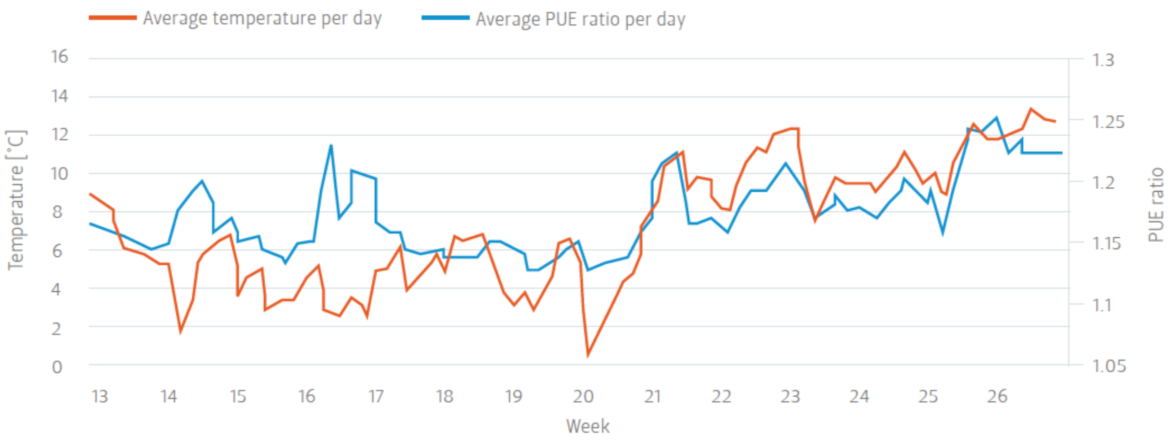

Figure 13 The correlation between average temperature and average PUE of an Icelandic data centre (Source: Verne Global, 2016)

Greater use of the internet is driving up demand for data centre services and energy use (mostly electricity), with multiplying effects. It is said that for every bit of data that travels the network from data centre to end users, another 5 bits of data are transmitted within and among data centres (Cisco, 2016). Based on the current development of efficiency of hardware and data centre infrastructure, the electricity demand of global data centres is projected to decrease slightly to 191 TWh in 2021 (Cisco, 2018; Masanet et al., 2018; Shehabi et al., 2016). This is despite a projected 80% increase in data centre traffic and 50% increase in data centre workloads over the next three years (Cisco, 2018).[65]

As large-scale electricity consumers, data centres qualify for relatively low electricity prices in their respective markets. According to information from Hydro-Quebec (2019), and press reports at that time, Hydro-Quebec offered industrial rates for its very large users in the range of 30-40 USD/MWh. The Nordic markets are cost-competitive, with recent fixed prices to data centres in Norway being offered under ten-year contracts in the 45 USD/MWh range[66], which is less than half the price in the U.K. Contracts tied to spot-market prices are around 37 USD/MWh (2019)[67]. Information is available which shows

[64] https://verneglobal.com/uploads/VG-Mind-the-Gap-Energy-Availability-and-the-Disconnect-with-Data-2016.pdf

[65] https://www.iea.org/reports/tracking-buildings/data-centres-and-data-transmission-networks

[66] https://www.datacenterdynamics.com/en/news/norway-operator-goes-after-power-conscious-data-center-market/

[67] In 2020 about one third lower.

that Landvirkjun (the National Power Company) could offer price contracts for the energy component similar to those in Quebec in 2019.[68] [69]

Aside from prices, data centres have some difficulties with the common contract duration in Iceland. Unlike aluminium producers, data centres face uncertainties regarding forecasts of their long-term energy demand. Therefore, they prefer short-term contracts and flexible energy, while energy suppliers prefer fixed, long-term agreements. On top of it, any short-term spike entails transmission tariff penalties.

Aluminium production

In Norway, the aluminium smelter Norsk Hydro states that internal supply contracts between own hydropower production operations and its aluminium metal business covered about half[70] of the energy consumption of its wholly owned Norwegian smelters in 2019. The remainder was mainly covered by an external supply contract with Statkraft, a Norwegian electricity company. The contract expires in 2020.

To replace the Statkraft contract, Hydro has entered into various new supply contracts, adding up to a total annual supply of 8.4 TWh for the period 2021-2030, 5.6 TWh for the period 2021-2035, and 5.1 TWh for the period 2036-2039. "This secures a significant part of the power consumption, in addition to our own hydropower production, that is required by our Norwegian smelters for these periods. The new contracts comprise a mixture of hydropower and wind power."[71]

In Canada – mainly in Quebec -, a large share of the global primary and secondary aluminium production takes place. In Quebec, several large aluminium companies have production sites, for example Rio Tinto, Alouette and Alcoa, holding more than the half of North America's production capacity. To ensure employment in the industry, the government of Quebec, Hydro-Quebec and aluminium producers have agreed on competitive electricity prices that are linked to the aluminium price in the London Metal Exchange (LME-price).

In addition to Quebec and Norway, Iceland is also among the world's top aluminium producers. Its aluminium industry contributes a large share to the Iceland's GDP and hence plays a significant role in the economic sector. In Iceland, several long-term contracts have been concluded between the energy suppliers and aluminium producers. Late contracts are mainly long-term, re-negotiated and linked to the LME-price or to the Consumer (Producer) Price Index (CPI, PPI) of the US. Recently, and beyond the aluminium industry, contracts are also linked to the electricity wholesale price at the Nord Pool power exchange.

Energy efficiency in aluminium production offers a competitive edge in the world markets. The energy efficiency per metric ton of aluminium in Quebec ranges around 14 200 kWh/t, in Iceland around 14 500 kWh/t in average, while some production sites with their respective technologies could significantly go below 14 000 kWh/t aluminium as displayed in Figure 14. One example is Hydro in Norway. Using new technology, Hydro has decreased its energy consumption to about 12 300 kWh/t primary aluminium, which is below the current global average of about 14 100 kWh/t in 2019.[72]

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68 https://www.datacenterknowledge.com/archives/2014/06/16/iceland-utility-touts-cheap-clean-energy-lure-data-centers/

69 https://verneglobal.com/uploads/VG-Mind-the-Gap-Energy-Availability-and-the-Disconnect-with-Data-2016.pdf

70 Other sources say one third

71 https://www.hydro.com/globalassets/download-center/investor-downloads/ar19/annual-report-2019-web.pdf

72 https://www.hydro.com/en/about-hydro/stories-by-hydro/the-worlds-most-energy-efficient-aluminium-production-technology/

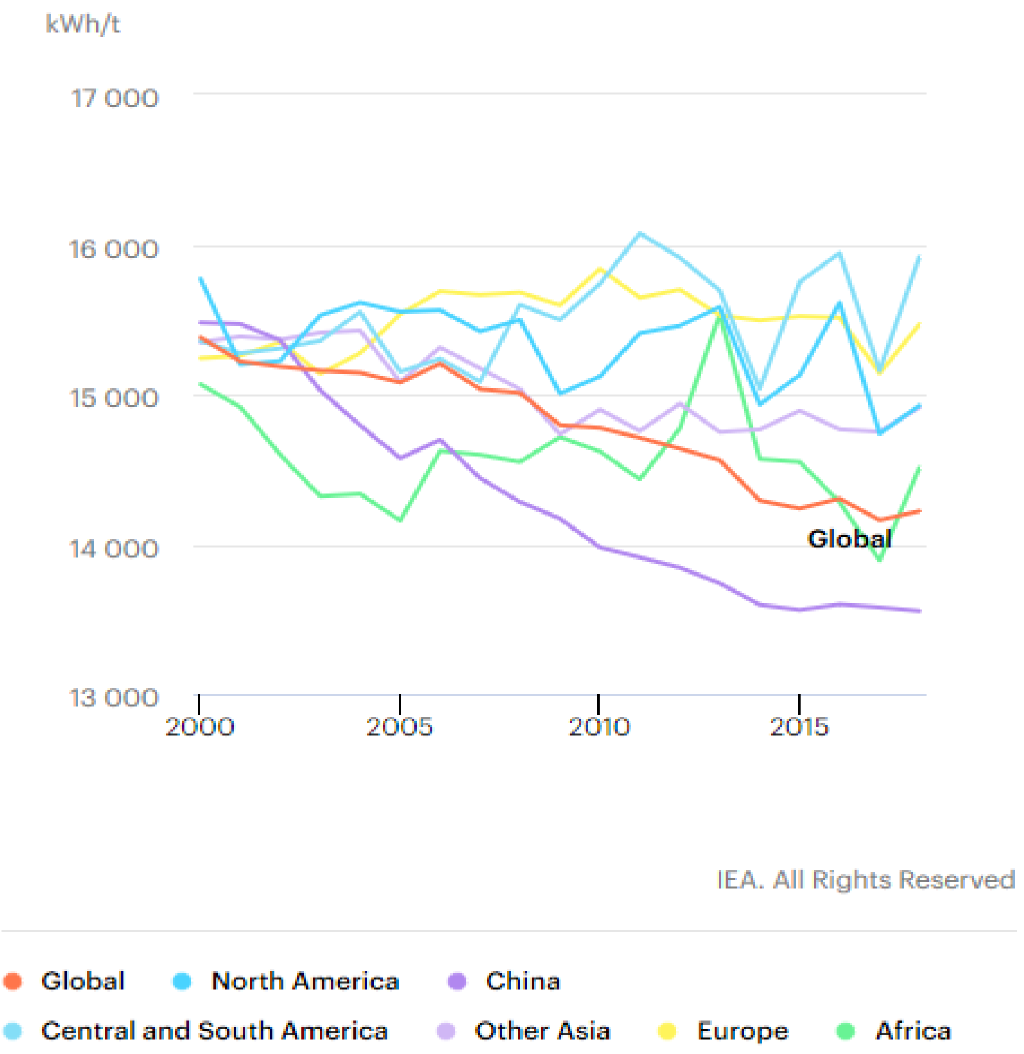


Figure 14 Electricity intensity of primary aluminium smelting by region, 2000-2018

Source: IEA Tracking Report 2020[73]

4.3 Results

The results are depicted by countries, industries and different types of contracts. The electricity cost components[74] are illustrated as positive values, while the EU ETS compensations are displayed as negative values in the following Figures. To get the electricity cost net of ETS compensations, the ETS compensation should be deducted from the electricity costs components.

Overall, the final electricity prices of **data centres** are very competitive in Quebec, if the data centre industry qualifies for the economic development programme. Otherwise, Quebec and Iceland offer similar prices, while in Germany, data centres pay the highest prices.

The **aluminium industry** (smelters) enjoys or has enjoyed special tariffs and regulations in all four countries to varying degrees. Depending on the pricing scheme in Iceland, electricity prices could be as competitive as in Quebec. Due to the EU ETS compensation, the electricity price in Norway is close to Iceland's prices although generally slightly higher. In Germany, although aluminium smelters are privileged

[73] https://www.iea.org/reports/aluminium

[74] These figures are based on individual information and public data. They represent different pricing or contract schemes and not weighted averages, maximum or minimum, and individual contracts could be above or below these values.

as regards levies and taxes, and enjoy the EU ETS compensation, the prices of electricity nevertheless result in higher prices than in Iceland.

Regarding other **energy intensive industries**, such as silicon or ferrosilicon production, only a limited comparison within the industry is possible due to the low number of cases. Estimated averages that are based on some available technical specifications and price data, point out that electricity prices are the most competitive in Quebec, and the least competitive in Germany under the given assumptions.

Norway

The differences of energy prices between new and old contracts (before 2019) of data centres are minor, all other price components are the same. The contracts of the aluminium industry are partly long-term agreements (fixed contract in Figure 15) and partly tied to the spot market.[75] In addition, self-consumption of about one third of the energy consumption is assumed for an aluminium smelter case, which reduces the EU ETS compensation consequently. For the other energy intensive industries, an average price is assumed for all energy intensive industries in Norway[76]. Data centres, the industry with the highest electricity prices, are not exempted from levies and taxes.

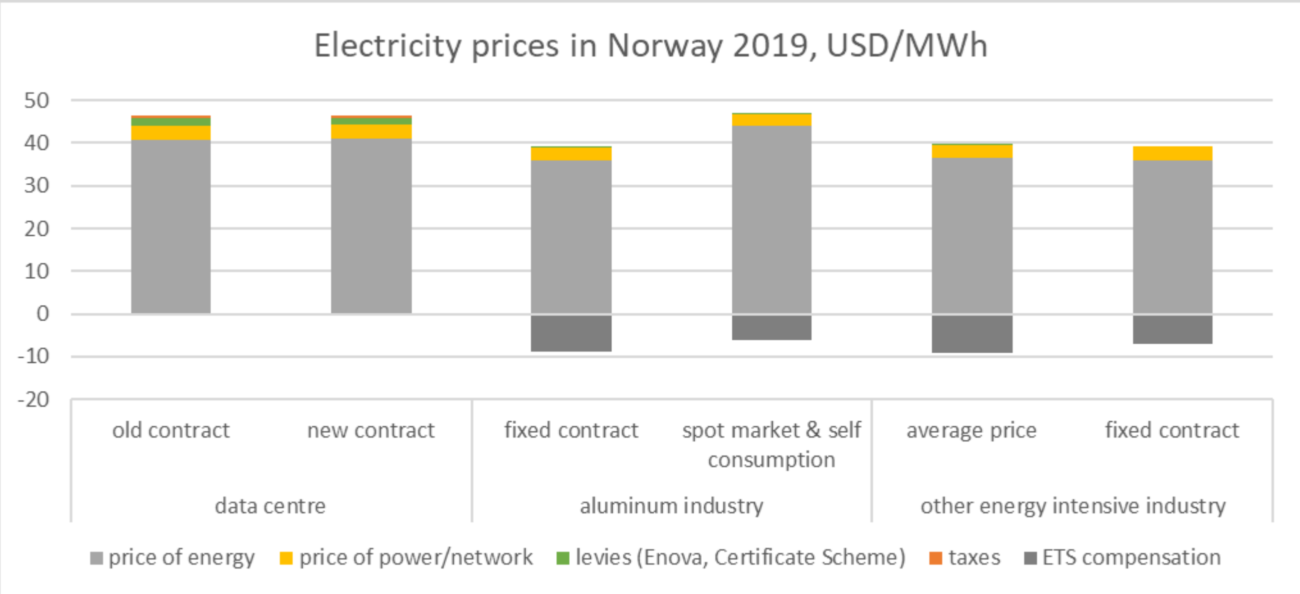


Figure 15: Electricity prices of energy intensive industries in Norway

Source: own illustration

Quebec

Figure 16 below shows power and energy prices that are the result of special and official offered tariffs and the economic development programme (EDP). It should be noted that the tariff structure in Quebec differs. The electricity prices include a variable component (energy) and a fixed component (power). The latter could be understood as a cost for the connection. Detailed information is given in chapter 3.1.

[75] It is to note that the spot market price of electricity (Nord Pool) has dropped by more than two thirds in 2020 compared to an average electricity price (2017- 2019), in Norway.

[76] https://www.ssb.no/en/statbank/table/09366/

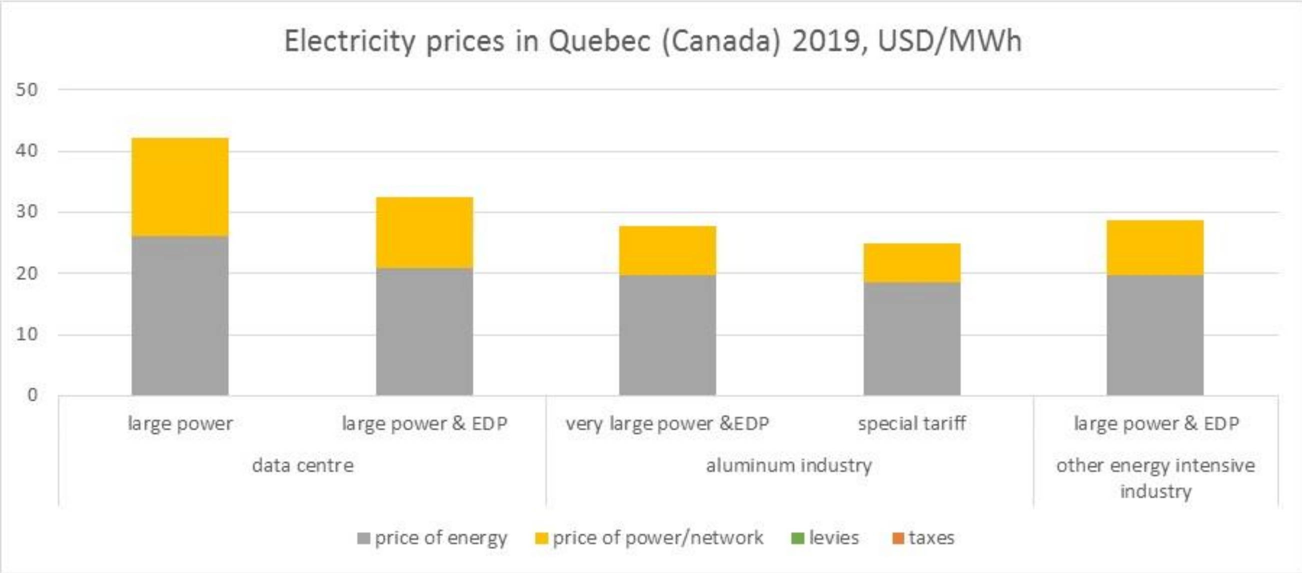


Figure 16: Electricity prices of energy intensive industries in Quebec

Source: own illustration

Germany

In Germany the dominating factors of energy prices are taxes and levies, if companies are not exempted (not privileged). While the aluminium industry is mainly exempted from levies and fees, data centres face relatively high total electricity costs, of which more than 60% comprise taxes and levies. The costs of other energy intensive industries depend on special regulations regarding the technical specifications of the industries (which were only partly available). The EU ETS compensation partly reduces the electricity prices paid by those energy intensive industries that are eligible for the compensation scheme, such as primary aluminium production and ferrosilicon production. Data centres are, however, not eligible for EU ETS compensation.

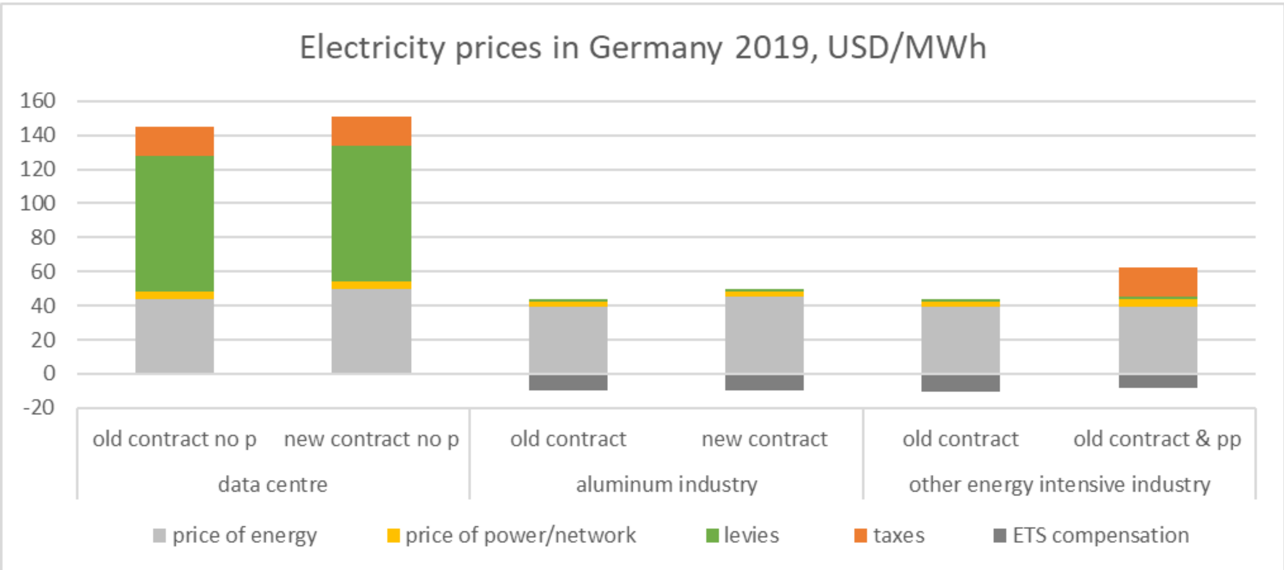


Figure 17: Electricity prices of energy intensive industries in Germany

Source: own illustration
Note: no p: no privilege regarding the RE and CHP levies; pp: partly privileged regarding the RE and CHP levies; new contract: contract between 2017 and 2019; old contract: before 2017

Iceland

Figure 18 shows the electricity prices of data centres and other energy intensive industry in Iceland. After consultation with stakeholders, it was decided to present the Icelandic electricity prices of the aluminium industry in a different manner (Table 6). Due to a low number of cases in other energy intensive industries, an average price is shown for these industries, for which some data are available. For data centres, the more recent contracts display below average prices. Due to limited available data regarding transmission costs paid by data centres, they are not separately displayed, but depicted together as energy and network costs.

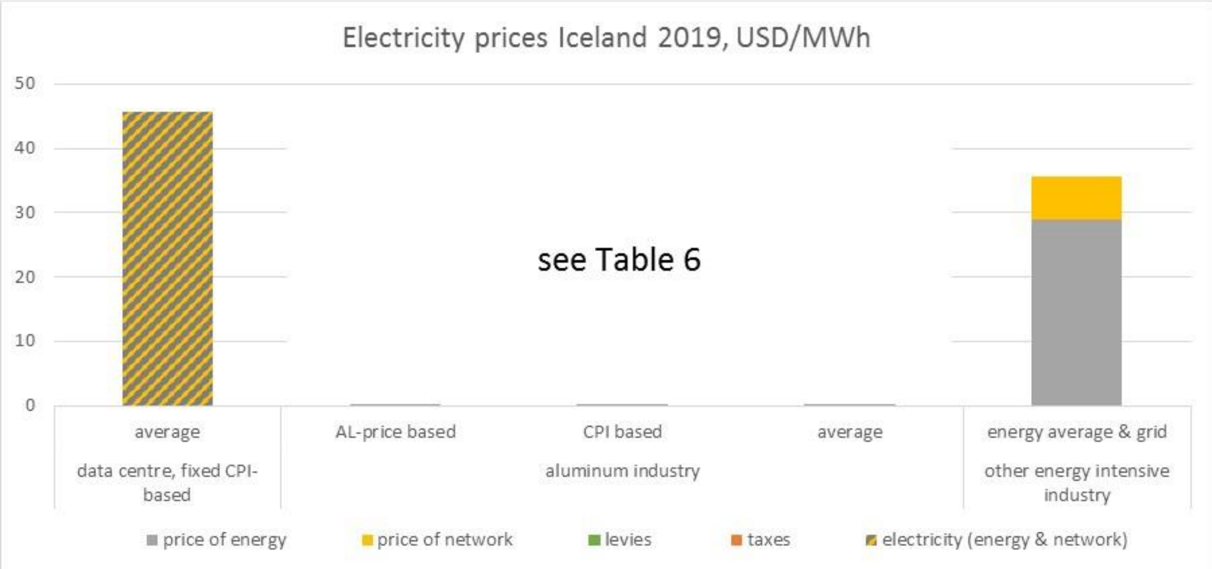


Figure 18: Electricity prices of energy intensive industries in Iceland

Source: own illustration
Note: AL-price means contract indexed to the aluminium price at the LME

Table 6: Electricity prices of aluminium producers in Iceland in comparison to Quebec, Norway and Germany

Iceland to … / *Cost component*	**Quebec**	**Norway**	**Germany**
Energy	some price schemes are very competitive in Quebec, some price schemes display slightly higher costs than in Iceland	similar, many price schemes display lower costs in Iceland, but some higher costs	lower energy costs in Iceland
Network	network costs and power connection costs are comparable	higher network costs in Iceland	higher network costs in Iceland
Taxes and levies	lower in Iceland		
ETS compensation	not applicable to Iceland (and Quebec)		
Total: Electricity costs in Iceland are ….	**competitive in average terms (slightly higher), but examples of lower and higher cases**	**competitive in average terms (slightly lower), but examples of lower and higher cases**	**lower**

Additional Information – China, the world's largest aluminium producer

In China, the electricity price is set nationally. Provinces can ensure that their electricity prices are above or below the national electricity price via subsidies and price premiums. Unlike in other countries, the electricity price for industry is in general higher than for households at the national level. The price for energy intensity industry was slightly lower in 2018 but slightly higher in 2019 than for households. The government of China has tried to regulate the industrial electricity price by lowering taxes and levies. For energy intensity industry, such as the aluminium (electrolysis) industry, a lower electricity price can be negotiated with private industrial (e.g. coal-fired) power plants, which supply electricity directly to the industries without transmitting through the national grid. Many aluminium manufacturers moved to Province Xinjiang and Province Neimenggu, where the grid infrastructure is not well developed and which are rich in coal resources, in order to minimize their electricity bills through power supply directly from coal-fired power plants.

Currently, the ratio between electricity supply from grid and electricity from own power plant is 23% to 77% for the aluminium industry in China. In 2019, the national average electricity costs for energy intensive industries were 76.5 USD/MWh, while the national average electricity costs for the aluminium industry were 47 USD/MWh. Moreover, in Xinjiang Province, the electricity production costs of own power plants from aluminium producers were less than 27 USD/MWh and the electricity costs with connection to grid were less than 31.8 USD/MWh, the lowest in China.

5 Electricity prices in Iceland

5.1 Current electricity prices

This chapter focuses on the development of electricity prices in Iceland. That is, it addresses questions, such as "Do companies with a long-term customer relationship with their power supplier face higher electricity prices than newcomers? Does the number of contracts, duration of contract, or level of energy consumption have an influence on the electricity price? Which contract-specific factors affect electricity prices in Iceland?"

The analysis relies on long-term energy supply data provided by Icelandic energy intensive industries and energy suppliers. Due to the low number of cases, a brief descriptive analysis is conducted. Energy prices, transmission costs and the total of both components are depicted by selected features and over time.

Energy component:

The analysis shows that the energy price component depends to a large degree on the pricing scheme, i.e. whether it is linked to the consumer price index (CPI, of mostly US), or to the price of aluminium at the LME (Al price) or to the price of the electricity exchange (P-ex) and exchange rates. In general, the energy price component varies more over time if it is indexed to the Al price, and less if it is linked to the CPI. The energy price continuously increases over time if it is linked to the CPI, while indexation to the aluminium price entails a higher volatility, i.e. price decreases and increases of the energy component. Furthermore, in nominal terms, legacy contracts tend to reveal a slightly lower price than recent contracts, where the pricing scheme has changed in some cases. The indexation to the wholesale power price of the Nord Pool exchange results in higher volatility if no caps or floors are included.

Transmission:

Analysis of the available data suggests that the costs of transmission are rather stable over time for base loads. Consumers with varying loads (mixed load) tend to contract high capacities (with high capacity charge) for their peak times, which increases their transmission fees, while consumers with a constant load (base load) can fully exploit their contracted capacities and hence face lower fees per energy unit. The analysis does not disclose a clear effect of any other factors (such as contract year, contract duration or consumption on the level of the grid fees), but it becomes clear that low usage of the contracted capacity (usage rate) has a cost impact. The data displayed in Figure 19 shows the relative development of transmission costs over time, but not the actual level of the prices. It is to note that only a limited set of data were available for this illustration.

Figure 19: Average transmission costs

Source: own illustration based on information from participants
Note: The indicated transmission costs are the average of energy intensive industries with different load patterns. It is to note that only few data sets were available; t 1 – t 10 stands for time periods.

The main finding of the analysis is that the pricing scheme has changed over time, but there is no indication that these changes are supplier or customer specific. Further findings of the analysis are:

1. The *load profile* affects electricity prices through the energy price component and transmission fee.
2. The *duration of a contract* is not necessarily linked to energy prices, i.e. some long-term contracts display higher prices than mid-term contracts and vice versa, because of their pricing scheme.
3. Similarly, a long-standing *client relationship* does not necessarily imply lower or higher energy prices.
4. There is no clearly identified relationship between electricity prices and the *number of contracts, contracted volume, or type of energy supplier*.
5. Finally, prices seem to be lower in older contracts. However, there is an indication that the load profile as well as the pricing scheme correlate with the *contract year,* implying that there is no established direct link between contract year and prices.

5.2 Outlook

The SET-Nav Study on Energy Systems: Supply Perspective (2019[77]), Brainpool studies[78] on energy outlook, climate packet and power purchase agreements, as well as the long-term scenarios and German lead study,[79] consider a bundle of factors affecting costs and prices of electricity. These factors include the degree of decarbonisation of the electricity sector, the share of renewables and the development of technology cost, carbon and fossil fuel prices, system bottlenecks and the diversity of actors and systems.

The market value of electricity is estimated in different scenarios. Under a strong EU or state directed energy transition, accompanied by a strong EU framework, the market value of electricity is estimated to range around 31 Euro/MWh in 2030, 86 Euro/MWh in 2040 and 71 Euro/MWh in 2050 for 30 countries. When undergoing a more decentralised energy transition with a large variety of actors, the market values

[77] http://www.set-nav.eu/sites/default/files/common_files/deliverables/WP7/D7.8_SET-Nav_SummaryReport_WP7_final.pdf

[78] https://blog.energybrainpool.com/eu-energy-outlook-2050-wie-entwickelt-sich-europa-in-den-naechsten-30-jahren-2-2019/

[79] https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/leitstudie-strommarkt-2015.html, https://www.bmwi.de/Redaktion/DE/Downloads/B/berichtsmodul-0-zentrale-ergebnisse-und-schlussfolgerungen.pdf?__blob=publicationFile&v=6

tend to be higher and range around 55 Euro/MWh (2030), 82 Euro/MWh (2040), and 86 Euro/MWh (2050). These market values differ from region to region as they are also influenced by regional or national characteristics of the system, such as availability of resources and interconnectedness. Estimations of the German lead study reveal market values for electricity of 55-60 and 58-70 Euro/MWh for 2030 and 2035, respectively. Similarly, an assessment based on Brainpool indicates electricity prices rising from about 60 Euro/MWh in 2030 to roughly 80 Euro/MWh in 2050. However, regional prices might differ significantly due to unequal shares of renewables, and monthly or seasonal variations show significant spreads (about 65 – 100 Euro/MWh in 2050) due to high loads in winter times.

To ensure low-cost and carbon-free electricity, many large electricity consumers (companies) enter into power purchase agreements (PPAs) with wind or solar power generators, as the strong increase of PPAs in Norway (in 2016) reflects[80]. The market values of wind and solar power are expected to stay slightly below the electricity market prices. The costs of wind and solar power are decisive factors for the deployment of these technologies and, thus, for PPAs. Future levelised costs of electricity (wind) are assumed to range around 20 Euro/MWh in 2050 (depending on risk exposure).

Due to abundant natural hydro power resources, increasing shares of wind power and already a high share of renewables in Norway and Quebec, electricity prices are mainly driven by factors outside the national boundaries, namely by demand and prices of neighbouring countries. In Norway, the market value of electricity will probably remain in the lower range of the above-mentioned price path, while Germany's is likely to rise above Norway's market value. Iceland, with no interconnection to other markets, its high share and considerable renewable potential, will be relatively less affected by this price trend as long as it can employ and exploit its natural renewable power potentials. Coming challenges will be to satisfy an increasing demand, especially from power intensive industries interested in establishing a production or service sites or expanding their current production capacity or service ability (from already established plants or companies) in Iceland to benefit from competitive electricity prices and low risks. As corporate PPAs for renewable power entail some risks for both seller and buyer (including annual and seasonal weather fluctuations, financial viability of electricity consumers, price trends in electricity markets of other regions, market prices of energy intensive products, etc.) long-term agreements with power suppliers could to a certain degree reduce uncertainties and risk exposures for both parties, energy suppliers and consumers. However, who will finally benefit more from long-term agreements depends on the contract details. For example, indexation to the CPI couples prices to the general economic development, while indexations to the Al-price (LME) account for changing turnovers of aluminium producers due to changing aluminium market prices. Further risk mitigation measures, such as loose or tight take-or-pay clauses, reward consumers or suppliers, respectively.

[80] https://www.energybrainpool.com/services/white-paper-download.html

6 Conclusion

The extent to which electricity costs impact the competitiveness of manufacturers depends on two aspects: a) the price of electricity, and b) the quantity of electricity consumed, i.e. the energy intensity of production. This latter factor is driven by the share of energy input in relation to all inputs (energy intensity), and the energy efficiency of production compared to competitors. As all producers of an industry face a similar level of energy input share (energy intensity), energy efficiency in production becomes a crucial factor for competitiveness. Moreover, apart from energy costs, industries have further means of strengthening their competitiveness, for example setting up new business models, reducing CO_2 emissions, and using alternative materials as inputs or fuels.

This section outlines the three aspects of competitiveness in the selected industries:

1. Energy intensity
2. Electricity prices including the price components
3. Other factors affecting competitiveness

Energy intensity

Regarding energy intensity, the three energy-intensive aluminium producers in Iceland display on average an energy intensity[81] above the global average (but some companies are close to the global average). This varies with their annual production and capacity utilisation. In Norway, the energy intensity of the main aluminium producer Hydro[82] is significantly lower due to the implementation of latest equipment and technology, which has been and still is being promoted by the state-owned energy fund (ENOVA). Although Hydro has already achieved a low energy intensity in its production (see Section 4.2), it is testing another variant of its new technology, which is likely to reduce energy consumption to about 11 500 kWh per tonne of primary aluminium.[83] Regarding the use of this innovative technology, Icelandic aluminium providers are not competitive.

Iceland's cold climate is very favourable for data centres' energy needs as it reduces energy needs for cooling purposes. Therefore, the preconditions for strong competitiveness are good. Compared to the European average self-reported PUE of 1.58 and the most energy efficient European data centres with PUE below 1.1[84], the PUE of Icelandic data centres are above the European average and even in the range of the most efficient data centres in Europe.

Electricity prices

Given the almost 100% carbon-free electricity generation and the high potential of natural energy resources, energy supply in Iceland is very cost-competitive[85] compared to other, less resource-rich countries such as Germany. In addition, electricity generation costs in Iceland are not directly impacted by external factors such as fuel, carbon prices or adjacent power markets. In Iceland, costs of electricity generation mainly depend on investments, cost of capital and the expected life cycle of a plant and less on operating expenditures. Given the generation costs and market conditions, the electricity prices are

[81] Unweighted average based on available data provided by the aluminium industry in Iceland

[82] https://www.hydro.com/Document/Index?name=Annual%20report%202019%20web.pdf&id=506433 Annual Report Norsk Hydro, energy intensity of electrolysis for aluminium

[83] https://www.hydro.com/en/about-hydro/stories-by-hydro/the-worlds-most-energy-efficient-aluminium-production-technology/

[84] Koronen, C., Åhman, M. & Nilsson, L.J. Data centres in future European energy systems—energy efficiency, integration and policy. *Energy Efficiency* 13, 129–144 (2020). https://doi.org/10.1007/s12053-019-09833-8

[85] Prices in Iceland are lower or about the same level as in other countries

set by supply and demand in Iceland.[86] Thus, energy suppliers and large consumers operate in a rather stable environment (no direct price shocks) in which changes can be anticipated. However, electricity prices are indirectly affected by external factors, e.g. through suppliers' pricing strategies based on foreign strategies of energy suppliers, or power purchasing agreements indexed to external (market) factors.

The pricing schemes, or mechanisms, negotiated in long-term contracts determine prices and allocate market risks between energy suppliers and industrial consumers. Given the specific factors on which the pricing schemes are based upon, electricity prices depend on the trend or development of these specific factors. Therefore, some schemes are more favourable under the current conditions, others might be more favourable under changing conditions in the future. Regarding risk allocation (aluminium industry), in Quebec, the energy supplier bears the risks (aluminium price indexed electricity), while in Iceland the risks are alternatively slanted towards the suppliers or the consumers. In Norway, self-generation by aluminium producers entails a market price risk, as the self-consumed electricity is valued at its opportunity costs, e.g. market prices at the Nord Pool exchange.

Beyond price risks, energy suppliers face further risks, such as counterparty risks, or market (sales) risks, which can be addressed through guarantees (parent company) in long-term contracts. Long-term contracts can also address take-or-pay-clauses, which shift the risk of fully using the contracted energy to either the buyer or seller. This is a risk exposure of the respective party, since, due to the market size, structure and contract, (re)selling of the unused power is not or hardly possible. Overall, long-term contracts do not necessarily reduce risks for both parties, but make the allocation of risk exposure and the mitigation or shift of price risks for the respective parties very clear and therefore provide a certain predictability and comfort for both parties, although they may be subject to re-negotiations.

For reasons of comparability, the energy price component is reduced by the ETS compensation, where applicable in Figure 20 and shows the average electricity costs the industries are facing. Two aspects should be considered: first, the level of electricity prices and, second, the development of the price-setting indices.

Currently, the most favourable Icelandic electricity prices paid by aluminium producers are those that are indexed to the Al-price and based on legacy contracts. However, some years ago CPI-indexed prices were lower than Al-linked prices. Network fees are lower in Norway and Germany than in Iceland (note: low number of data for Iceland), but fees and taxes are higher in Norway and Germany. The ETS compensation paid to Norwegian and German industries does reduce the costs, but not sufficiently enough to stay below Iceland's price level, at least not consistently in the case of Norway. Overall, German aluminium producers face the highest electricity prices among the selected cases, in spite of the ETS compensation. Nevertheless, the ETS compensation increased rapidly in 2019 and will likely increase further, due to the increasing EUA allowance price. This may further reduce the costs for industries in Norway and Germany and challenge the competitiveness of Icelandic electricity costs.

With respect to data centres, electricity prices seem to be more competitive in Quebec than in Iceland when the comparison is based on the average prices paid by data centres. However, certain individual contracts might still be as competitive as the offered tariffs in Quebec. A similar situation is also observed in Norway: although the average Icelandic electricity price is more competitive than the Norwegian average, certain pricing schemes in Norway provide more attractive prices to data centres than in Iceland. In Germany, electricity prices are higher, mainly due to taxes and levies. However, in countries with a stock exchange, contracts could be concluded covering short-term (day-ahead) or medium-term (futures) demands at market prices, while in Iceland rather long-term contracts with a take-or- pay-clause do not account for the demand uncertainties of data centres.

[86] At electricity exchanges price setting is based on marginal costs (variable operational costs). If there is an excess supply of electricity, prices will drop as long as variables costs are still covered. If there are many generation plant with low variable costs such as wind, solar and hydro power, prices can fall significantly below the levelised costs of electricity (which include also investment costs). I prices remain below the levelised costs of electricity, no investments will take place in the long-term as the costs are not covered.

For other energy intensive industries, prices are difficult to compare as the number of cases analysed was low but the heterogeneity of these other energy intensive industries is high. While in Norway the charging of levies and taxes increases prices compared to Iceland, the energy component in Quebec is lower.

Finally, other aspects, such as the number of suppliers and consumers in the market, affect the market power on both sides. If there is an imbalance, the price setting mechanism might not work properly and thus prices might be distorted. However, this issue is beyond the scope of this study and will not be further elaborated here.

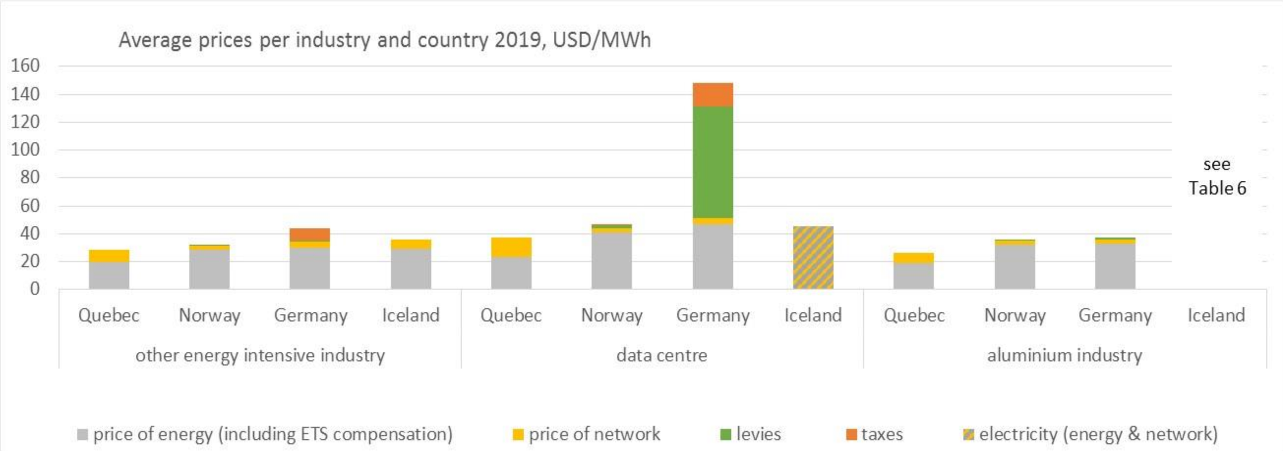


Figure 20: Overview of average electricity prices of energy intensive industries in comparison

Source: own illustration, based on diverse data and sources
Note: average prices: averages taken from the prices depicted in Figure 15-18. Price of energy (including ETS compensation): the energy price component is reduced by the ETS compensation where applicable.

Overall, data centres and aluminium producing industries have relatively competitive electricity prices in Iceland when compared at a global level. Only a few countries or regions in North America or Europe benefit from similar abundant and natural energy sources as Iceland – hydro power and geothermal energy. In contrast to Norway and Quebec, Iceland's electricity price is not affected by adjacent electricity markets. Both aspects together provide favourable preconditions for low-cost and secure energy supply and stable energy prices.

Other factors affecting competitiveness

Flexible use of power can be costly, especially if no alternative uses of unused power exist. A balancing market that manages fluctuating generation (due to wind and solar power) and demand for electricity is established in many countries or regions. The participation of industrial consumers (e.g. temporary load reductions) could increase the flexibility potential of the electricity system and provide new business opportunities for large consumers - as is the case in Germany, where a large aluminium smelter (TRIMET) participates with its load capacity in the balancing market. TRIMET has developed and established a special demand-response technology (EnPot), which could be seen as a virtual battery concept. It relies on installing adjustable heat exchanges that can maintain the energy balance in each electrolytic cell, irrespective of alternating power inputs.[87] This investment (new business model) generates additional revenues and improves the primary aluminium producer's competitiveness

A further factor that strengthens the competitiveness of energy prices in Iceland is the fact that electricity is almost 100% renewable and carbon free. As sustainability and climate issues become more and more the concerns of shareholders and financing institutions, clean energy is increasingly gaining significance, and thus translates into a competitive advantage – also for Icelandic industries.

[87] https://www.hydro.com/en/about-hydro/stories-by-hydro/the-worlds-most-energy-efficient-aluminium-production-technology/

In the context of climate change, technological innovations, such as inert anode technologies that reduce CO_2 emissions in aluminium production, further strengthen the competitiveness of producers. With respect to climate change, contesting regions increase their competitiveness by using new heat generating technologies relying on renewables (concentrated solar power) or biomass, e.g. Australia.

Finally, energy savings and reduction of CO_2 emissions through expanding secondary production through scrap collection and sorting is another strategy that other regions or companies pursue to increase their competitiveness. However, there is a limit to the potential for secondary production, which is low in Iceland, but even regions with high amounts of scrap have limits.

Conclusion

In summary, electricity prices in Iceland vary across industries and contracts. The prices within an industry show similar levels or ranges compared to their competitors in the comparison countries and do not negatively impact the energy intensive industries' competitiveness in general. However, there might be specific cases (contracts) that pose challenges to Icelandic companies.

With respect to other drivers of competitiveness, such as energy efficiency, flexibility and circular economy, Icelandic industries and energy suppliers generally have advantages. Nevertheless, there is in some cases room for improvements. Besides energy prices and efficiency, many other factors, such as state subsidies, tax reduction for operation or investment, reduced pollution standards, grants for investments or research and development efforts, economies of scale, proximity to markets, etc., affect the competitiveness of companies. But these factors are beyond the scope of this study.

7 List of figures

8 List of tables

A.1 Annex

A.1.1 Network fees

In force since April 1st 2019 (https://www.landsnet.is/library/Vidskipti/Gjaldskra/Gjaldskra-Landsnets-2019/Tariff%20for%20the%20Transmission%20of%20Electricity%20and%20Ancillary%20Services%20no%2031%20April%201st%202019.pdf):

Article 4

4.1 Transmission charges[1]

In-feed:

Delivery charge per year.. ISK 6.346.925

Out-feed:

Distribution system operators:

Delivery charge per year .... ISK 6.346.925

Capacity charge per MW per year .... ISK 6.516.566

Energy charge per MWh ....ISK 471,87

Power intensive users

Delivery charge per year ....USD 50.409

Capacity charge per MW per year ....USD 29.364

Energy charge per MWh .... USD 1,485

Charges for ancillary services and transmission losses are not included in the transmission charges above and are collected separately pursuant to Section 4.2.

4.2 Charge for Ancillary Services and transmission losses[2]

Ancillary services per MWh... ISK 57,28

Transmission losses per MWh .... ISK 98,11

In force since January 2020 (Landsnet: https://www.landsnet.is/english/business/transmission-tariff/tariff/)

In - feed

Delivery charge per year	ISK 6.346.925

Out - feed

Distribution system operators	
Delivery charge per year	ISK 6.346.925
Capacity charge per MW per year	ISK 6.516.566 kr.
Energy charge per MWh	ISK 471,87

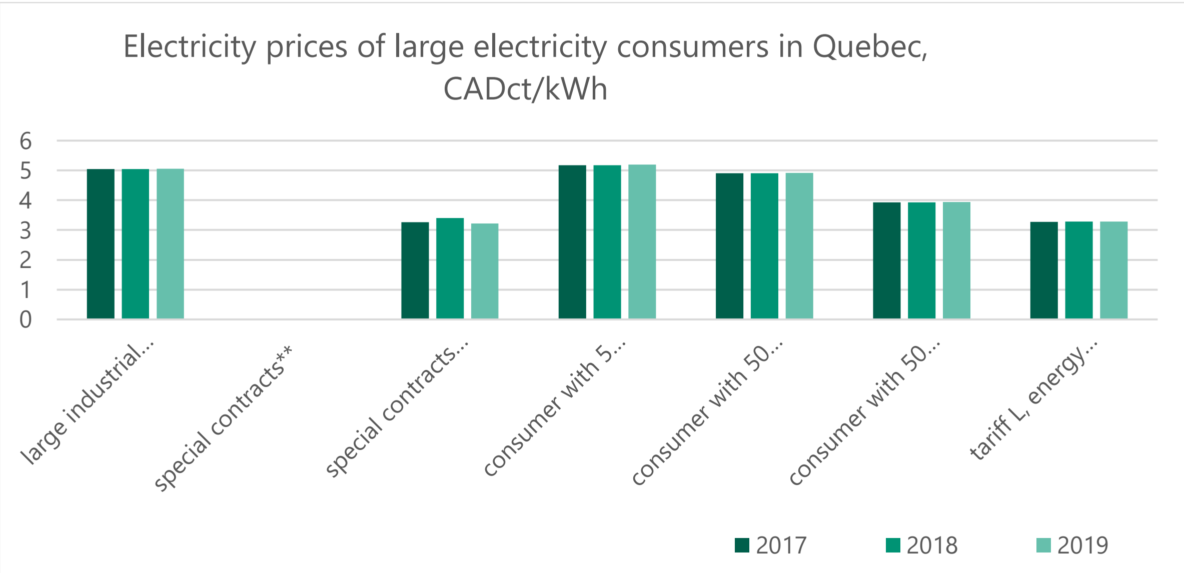
Power intensive users	
Delivery charge per year	USD 45.620
Capacity charge per MW per year	USD 26.574
Energy charge per MWh	USD 1,344

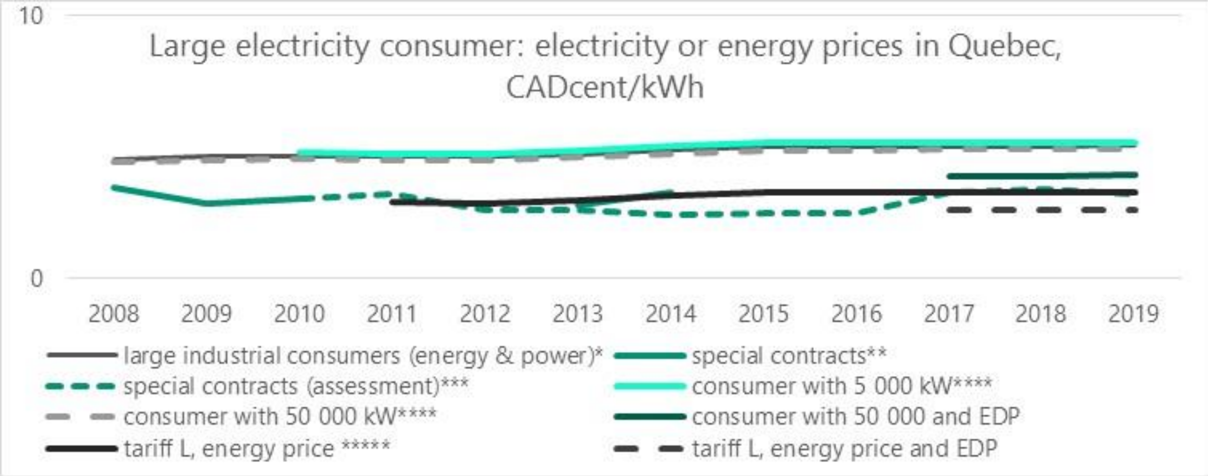
Curtailable transmission	
Energy charge if utilization time exceeds 4500 hours/year	512,00 ISK/MWh
Energy charge if utilization time is below 4500 hours/year	1.349,00 ISK/MWh

Charge for Ancillary Services and Transmission losses

Ancillary services per MWh	ISK 57,28
Transmission losses per MWh	ISK 107,30

A.1.2 Electricity prices in Quebec





Source: * official data, includes energy and power price of large, industrial electricity consumers
** with energy intensive industry based on publications, Hydro Quebec Distribution Rapport annuel 2010, Historique des ventes, des produits des ventes, des abonnements et de la consummation
*** own assessment based on indexation on global AL-price
**** official data for large energy consumers; Source: Comparison of electricity prices, http://www.hydroquebec.com/documents-data/official-publications/ *****official data 2016-2019; own assessments; source: http://www.hydroquebec.com/documents-data/official-publications/electricity-rates-conditions-electricity-service.html

A.1.3 Technical specifications

required information	unit
average electricity consumption per annum	GWh
contracted power consumption	GWh (year)
contracted power connection	MW
voltage level you are connected	kV
load factor (share of consumed electricity to contracted electricity volume)	%
constant electricity consumption at 7 days per week	yes/no
if no: peaks over the week	weekdays
constant electricity consumption - over 24 hours per day	yes/no
if no: peaks during the day	time of day
electricity consumption per unit output, e.g. kWh/t aluminium, silicon, alternatively power usage efficiency (Data Centre)	kWh/unit output

A.1.4 Currency exchange rate

	1 unit CAD = x units USD	1 unit NOK = x units USD	1 unit EUR = x units USD	1 unit ISK = x units USD	1 unit CNY = x units USD
31 Dec 2010	0.970701	0.165661	1.327386	0.008194035	0.147711338
31 Dec 2011	1.011464	0.178596	1.392705	0.008615491	0.154666361
31 Dec 2012	1.00023	0.171924	1.285697	0.007996801	0.158466852
31 Dec 2013	0.971164	0.170267	1.328464	0.008181298	0.16254105
31 Dec 2014	0.905912	0.159195	1.329165	0.00856531	0.162386853
31 Dec 2015	0.782992	0.124226	1.109729	0.007584376	0.159143756
31 Dec 2016	0.755107	0.119053	1.10656	0.008287064	0.150533083
31 Dec 2017	0.771282	0.121066	1.130051	0.00936505	0.147998921
31 Dec 2018	0.771588	0.122946	1.181011	0.009226795	0.151059752
31 Dec 2019	0.753598	0.113701	1.120129	0.008153282	0.144722157
27 May 2020	0.732938	0.102608	1.097226	0.007457122	0.142376926

Sources: https://www.ofx.com/en-au/forex-news/historical-exchange-rates/yearly-average-rates/ https://www.cb.is/?PageId=6909b7bd-5189-45dd-bf5b-c76ea33496ef