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No wasted energy

Uncovering the electricity efficiency potential in Iceland

Landsvirkjun

Stjórnarráð Íslands
Umhverfis-, orku- og loftslagsráðuneytið

ORKUSTOFNUN

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The project is a collaborative effort involving the Icelandic Ministry of Environment, Energy, and Climate, the National Energy Agency of Iceland, and Landsvirkjun. It was initiated and financed by Landsvirkjun. The analysis was conducted by the Danish consultancy Implement.

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Highlights

- The abundance of energy resources in Iceland has been increasingly challenged. Future developments such as e.g. the acceleration of the transition to green energy is likely to aggravate this, putting pressure on electricity supply.
- Expanding electricity generation capacity and investing in energy efficiency are complementary pathways to address this challenge.
- We identify a potential for 1,500 GWh/year in electricity savings from improved energy efficiency (~ 8% of electricity consumption in 2022).
- 24% of this potential is deemed realisable over the next 5 years and a further 53% over the next decade.
- There are efficiency gains in most sectors, including services, households as well as energy intensive industries
- Lack of detailed data on energy consumption at the end-use level has been an important limiting factor. The collection, aggregation and publication of these data would provide a valuable contribution to the energy efficiency debate in Iceland

Executive summary (1/2)

Iceland is a country of abundant renewable energy resources. Renewable energy for both electricity and heat have been easily available at a low cost. More recently, however, the country's energy supply, particularly the supply of electricity, has come under increased pressure. Electricity demand has been growing steadily for a number of years (about 15% over the last 10 years and about 40% in sectors other than aluminium), and power curtailments have become a more frequent occurrence. This has spurred a prominent conversation about the security of electricity supply.

At the same time, Iceland is crafting its future role in the green transition. Activities such as domestic production of e-fuels will require substantial amounts of new renewable electricity capacity. Estimates vary widely but point to a need for between 4,000 and 24,000 GWh of additional demand (with the higher estimate representing more than a doubling of current demand).

Faced with these drivers of change, two supplementary pathways could be pursued: Expanding renewable electricity generation capacity *and* implementing measures to become more efficient in the consumption of electricity. In this study, we are investigating how large a role measures to improve electricity efficiency could play going forward.

We conclude that there is a sizeable potential to increase energy efficiency in electricity consumption, but that this does not take away the need and requirement of looking to expanding electricity generation. **In total, we identify savings potentials of about 1,500 GWh per year (which corresponds to approximately 8% of total electricity consumption in Iceland in 2022).** This means that largely the same services and economic activity could be sustained using 1,500 GWh less, if a series of initiatives and investments are taken. These initiatives require resources and may not all be economic given the relatively low cost of energy in Iceland and might therefore need a policy push to be implemented.

We find that savings of about 356 GWh (~2% of total consumption in 2022) can be achieved with well-known technologies and without detrimental costs. These potentials are mainly in the service sector (excluding data centres). These can be reaped through a combination of measures such as LED lighting, more efficient electric appliances, and improved cooling, ventilation, and building management systems.

Executive summary (2/2)

In addition to these, savings of about 797 GWh (~3% of total consumption in 2022) are also possible – but harder to realise. The largest potential in this category is found in better utilisation of industrial waste heat (357 GWh). This heat can either be used to generate electricity directly or used with higher efficiency to provide usable heat, which, e.g. in locations without district heating, could reduce the need for electric heating. Another important potential is in the heating sector (178 GWh) followed by a number of sectors with more limited potential including agriculture, grid losses, and fish-meal factories.

We also identify a large potential for energy savings in the aluminium industry but find that only around 24% of it (112 GWh) is likely achievable in the next decade. The remaining potential is identified as a gap between the energy efficiency of Icelandic smelters and the EU benchmark for the most efficient operations in the sector. These efficiencies are closely linked to the age and size of the smelters and are very unlikely to be achievable without a major refurbishment or even substitution of current equipment.

We do not take into account the likelihood that a measure to conserve energy can be met with a partially offsetting increase in consumption (often referred to as the rebound effect). As an example, by adopting LED-lighting that consume much less electricity per hour, consumers might increase the number of hours the light is on.

An important finding in our work is a significant lack of studies, analyses and statistical foundation about electricity consumption and efficiency potentials. This has proven to be a significant limitation in determining the nature and composition of the electricity savings potentials. To build an even better foundation for understanding and tracking electricity efficiency it would be beneficial to enhance the granularity of the collected data e.g. by adding information about the source of the consumption activity.

Our findings are, to a large extent, based on high-level information about each sector’s electricity consumption from detailed data provided by Orkustofnun or reported directly by individual companies. This information is compared with relevant international benchmarks that vary from sector to sector. This comparison is imperfect, as it can hide differences between the benchmark and actual operations, such as a different mix of energy carriers or the manufacturing of different product variations. Consequently, this analysis provides a rough estimate of the overall savings potential. It is not a detailed, bottom-up assessment of the performance of specific technical equipment or production processes.

Objectives and approach

Implement has been asked to provide an analysis of the potential for electricity savings through improved energy efficiency across the Icelandic economy.

The objective is to map possible efficiency potentials that are realisable within a short to medium term. With realisable, we mean possible solutions and measures that are both technically and economically possible, but not necessarily economically attractive under current prices and regulations.

We have adopted a sector-based approach to accommodate for the significant differences that exist in the activities of different sectors such as public services and primary metal production. Due to a lack of detailed, bottom-up data for a large number of sectors, we have chosen a top-down approach based on two methodologies:

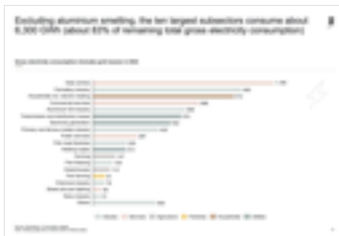
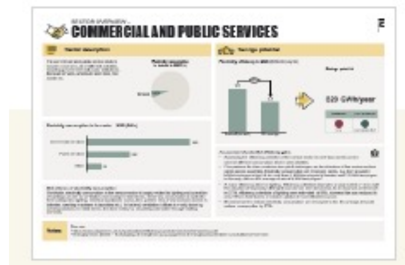
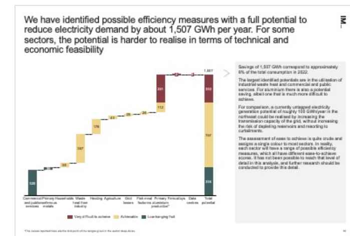
- The comparison of Icelandic sectors to relevant industry benchmarks at a European level.
- Stakeholder interviews to validate our findings and provide specific input relating to the reality of the sector in Iceland.

In some instances, we have had to rely on the comparison industries in Iceland to that in other, comparable countries or on information from industry stakeholders directly when no other information was available. Neither method is perfect. International comparisons can mask important differences in the composition and operation of the sector in different countries. On the other side, information provided by industry stakeholders can be difficult to validate.

Despite these challenges, we believe this exercise serves two valuable purposes:

- Providing an important first approximation of the potential for electricity savings that can be achieved in Iceland through improved energy efficiency
- Identifying significant data gaps and indicating avenues to strengthen the knowledge of Icelandic performance and potential progress in electricity efficiency.

The methodology for this study has been structured around three pillars

	Define baseline electricity consumption	Analyse the structure of Icelandic electricity consumption	Identify key efficiency measures and abatement potential
			
Objectives	• Define current and projected electricity consumption. • Map which sectors and subsectors are consuming the most electricity.	• Identify the exact drivers of electricity consumption in all relevant sectors and subsectors.	• Shed light on the possible size of the potential to become more efficient in electricity use across different sectors and subsectors. • Highlight the fact that not all efficiency potentials will give rise to an actual reduction in consumption but might be met with increased output/value instead.
Focus	• Conduct deep dive into statistics from Orkustofnun (National Energy Agency), Hagstofa Íslands (Statistics Iceland) and individual company information. • Have information validated by stakeholders.	• Conduct interviews with key stakeholders in all sectors as well as substantial desk research.	• Desk research into the best available technologies and best practices abroad as well as in-depth analyses of the specific Icelandic structure where possible.

The project involved several rounds of extensive stakeholder involvement

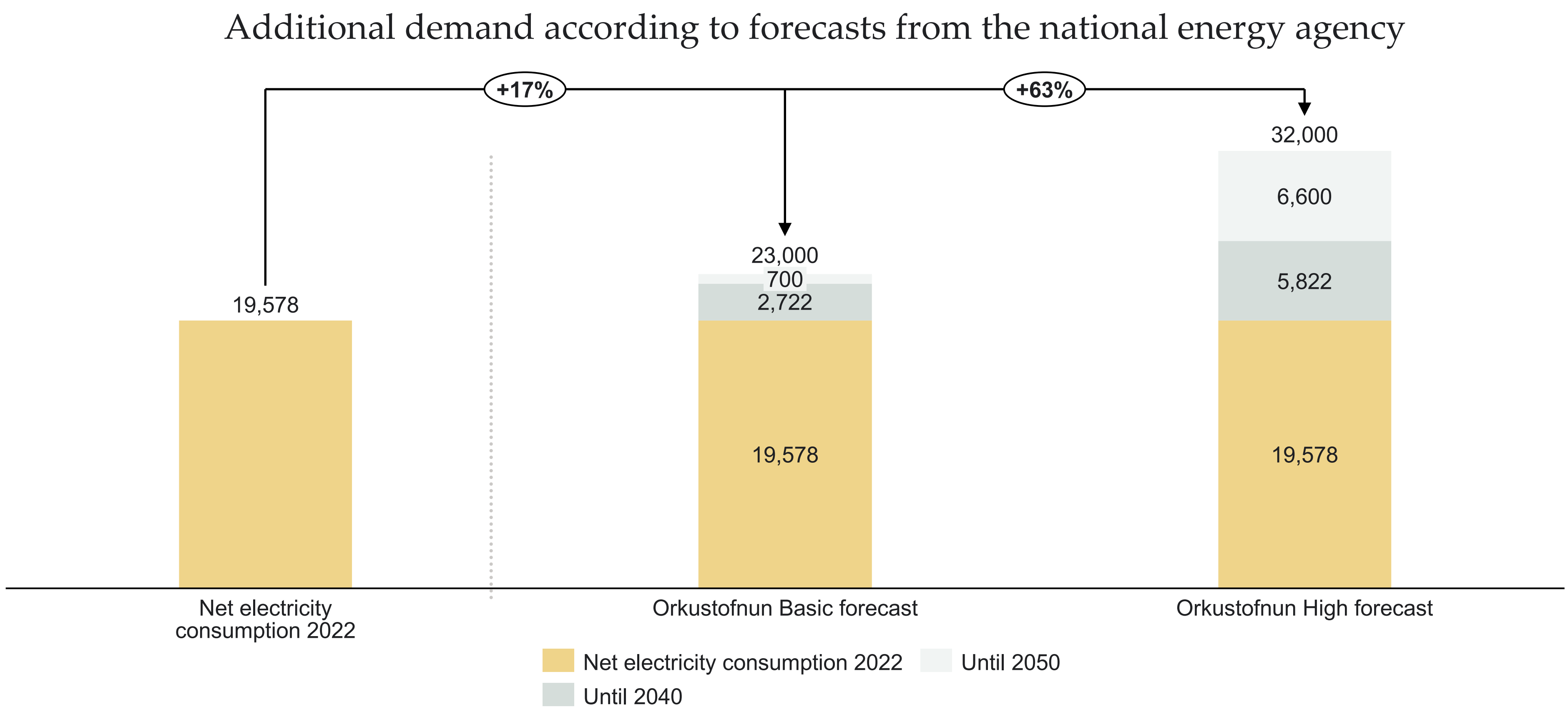
Stakeholder engagement was a key element of this study, which involved 28 different entities in various capacities. They have provided and validated data, and entities in each sector were provided with the opportunity to review and comment on the findings in their respective sectors prior to publication.

Entities contacted…		… and involved in data collection and validation…		… and sent preliminary results for the sector they are involved in.		
Ministries and governmental agencies	Fisheries Iceland (SFS)	Efla	the Icelandic Ministry of Finance and Economic Affairs	The Icelandic Housing and Construction Authority (HMS)	Landsnet	The Horticulturists' Sales Company (SFG)
Icelandic Association of Local Authorities	the Federation of Icelandic Industries (SI)	Rarik	The Government Property Agency (FSRE)	the Icelandic Federation of Trade & Services (SVÞ)	Data Centers Iceland (DCI)	The Icelandic Farmers Association
Nature conservation organizations	Corporate associations	The Icelandic Association of Fishmeal Manufacturers (FÍF)	University of Iceland	BRIM	PCC	Elkem
Individual companies	Consultancy firms	The Icelandic Federation of Energy and Utility Companies (Samorka)	The Association of Icelandic Aluminium Producers (Samál)	ÍSAL	Alcoa	Norðurál

Baseline electricity consumption

Demand forecasts show that electricity consumption in Iceland could significantly increase going forward

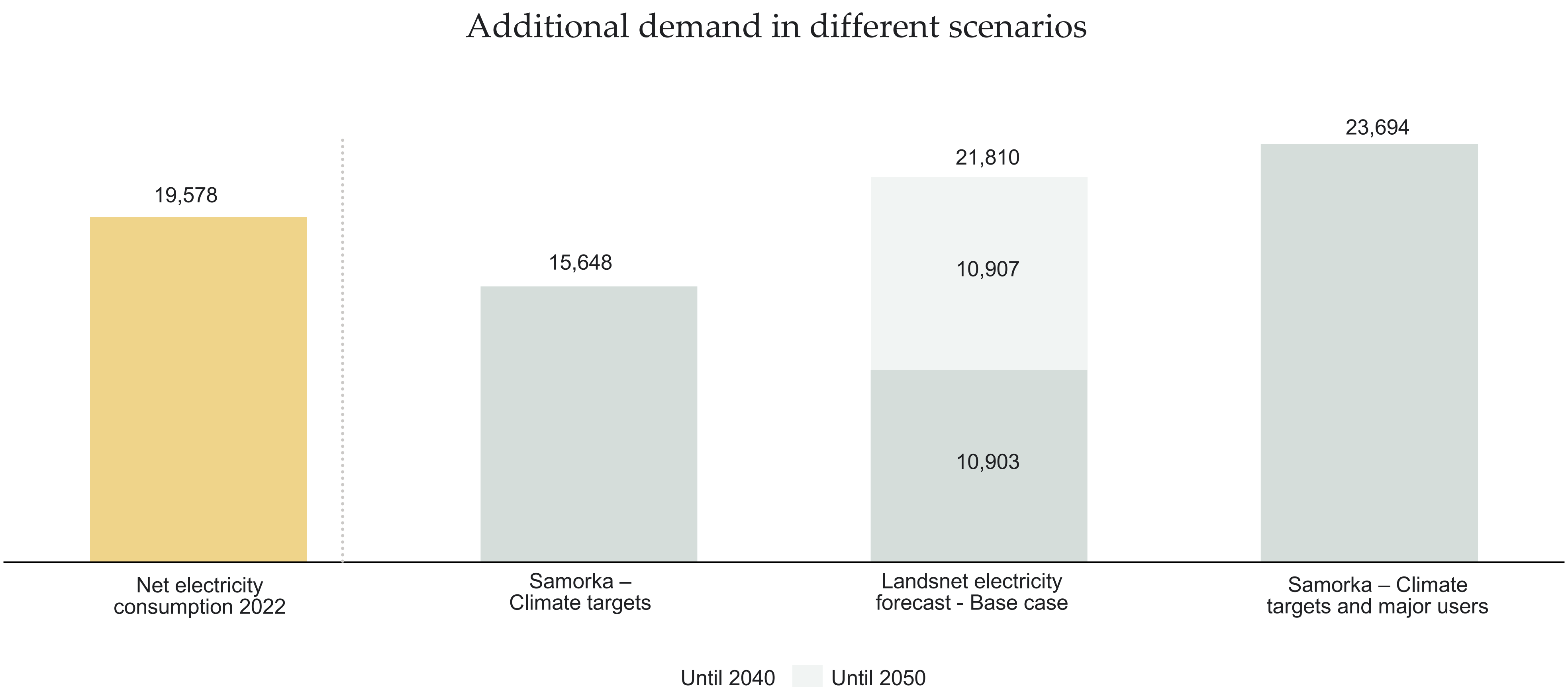
Additional electricity need in different forecast scenarios compared to current consumption
GWh



Source: Orkustofnun, Consumption dataset (net consumption in 2022); Orkustofnun: Electricity Forecast 2022-2050 – April 2023 (OS scenarios)

Scenarios of increased electricity demand if Iceland's climate goals are to be achieved show an even greater increase, some even doubling the current use

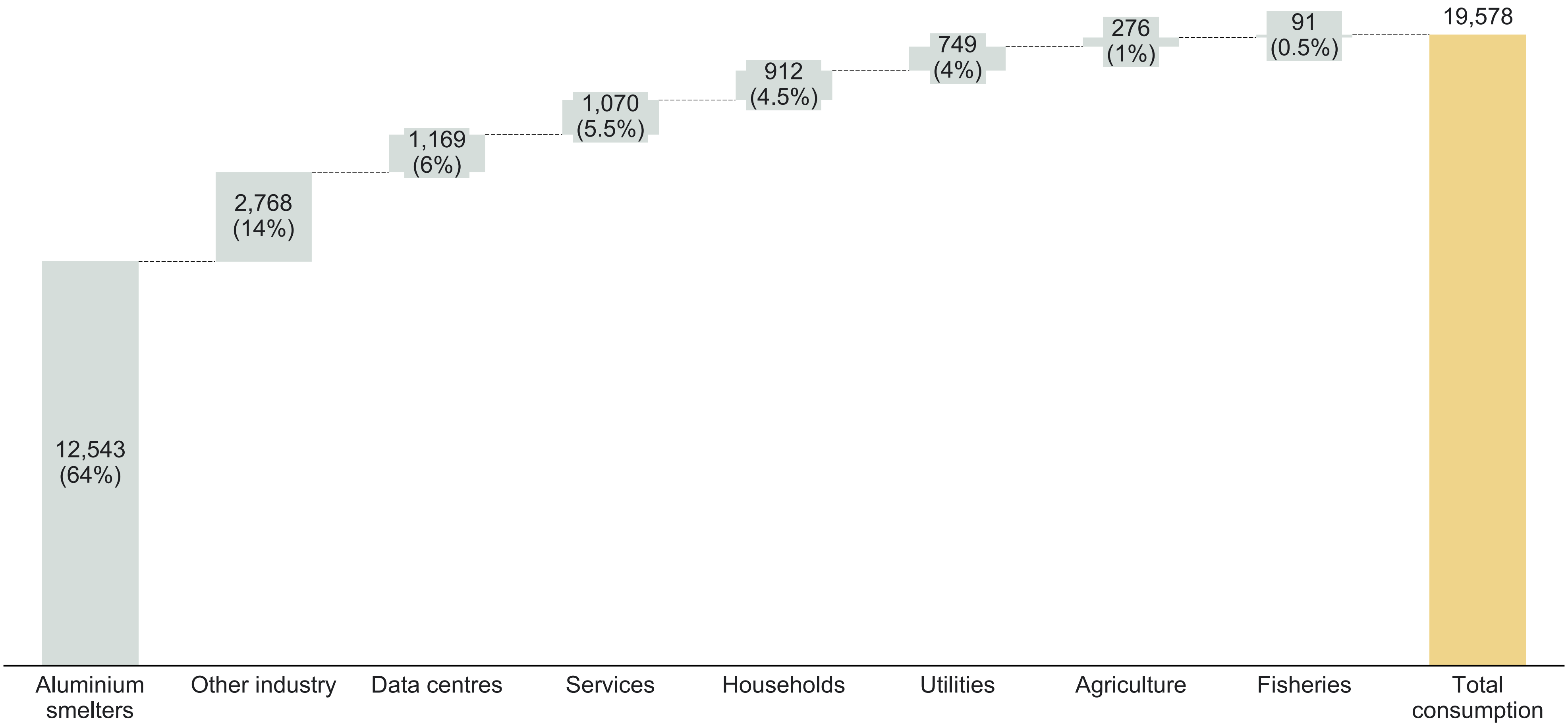
Additional electricity need in different forecast scenarios compared to current consumption
GWh



Source: Orkustofnun, Consumption dataset (net consumption in 2022); Electrification of Society: Landsnet's forecast on the development of demand and supply of electricity 2023-2060 (Landsnet scenario); Umhverfis-, orku- og loftslagsráðuneytið: Status and challenges in energy matters with reference to the government's climate goals and priorities – March 2022 (other scenarios).

Aluminium makes up about 64% of the total electricity demand. Other industries, services, households, and data centres make up the bulk of the rest

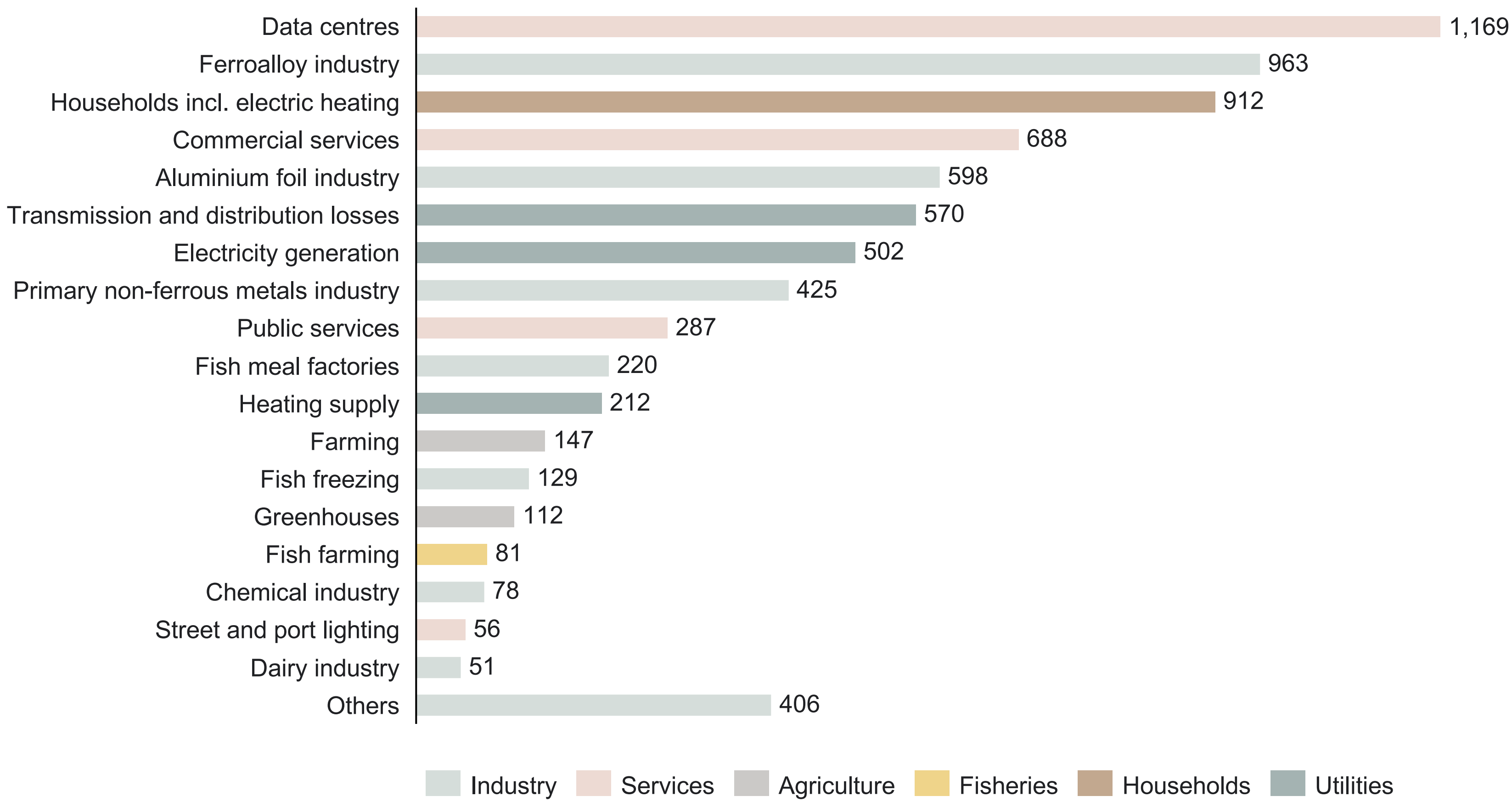
Total (net) electricity consumption by sector in 2022
GWh



Source: Orkustofnun, Consumption dataset

Excluding aluminium smelting, the ten largest subsectors consume about 6,300 GWh (about 83% of remaining total gross electricity consumption)

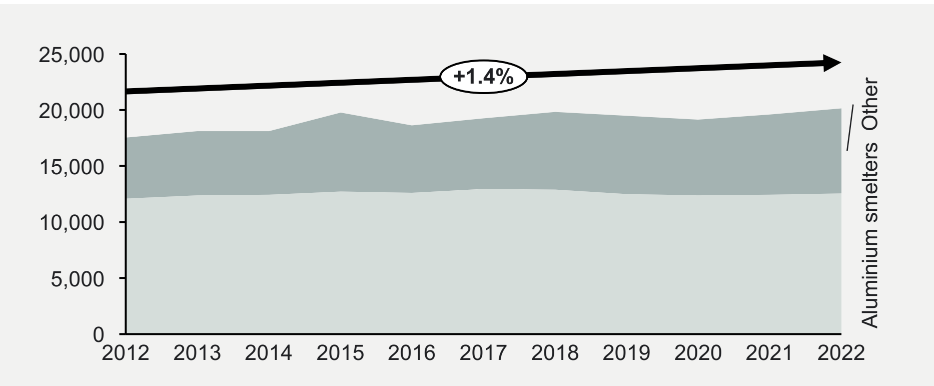
Gross electricity consumption (includes grid losses) in 2022
GWh



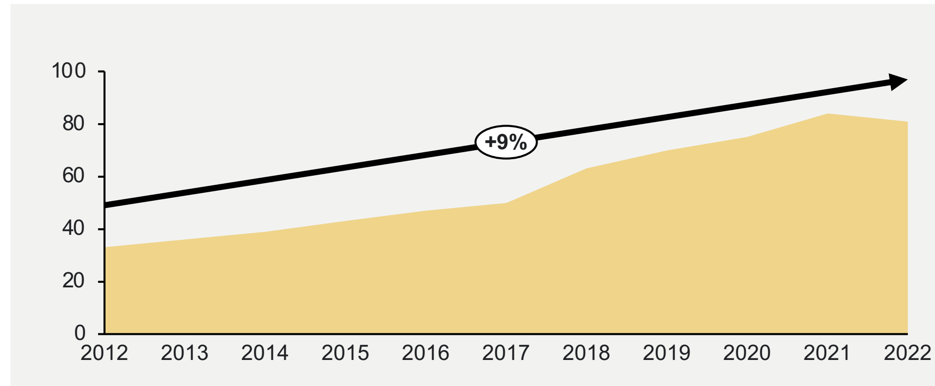
Source: Orkustofnun, Consumption dataset
Note: Heating supply also includes electric heating supply

Electricity generation has increased by 14.8% in the past 10 years. Consumption from aluminium smelting has increased only slightly, but other sectors have experienced significant growth

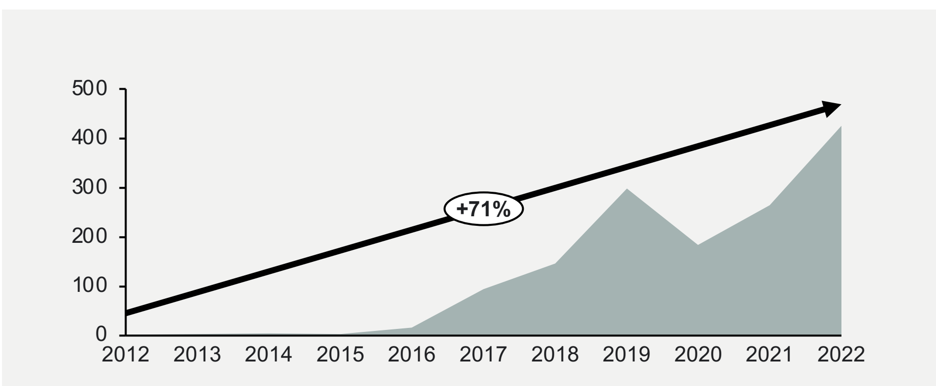
Aluminium
GWh; CAGR



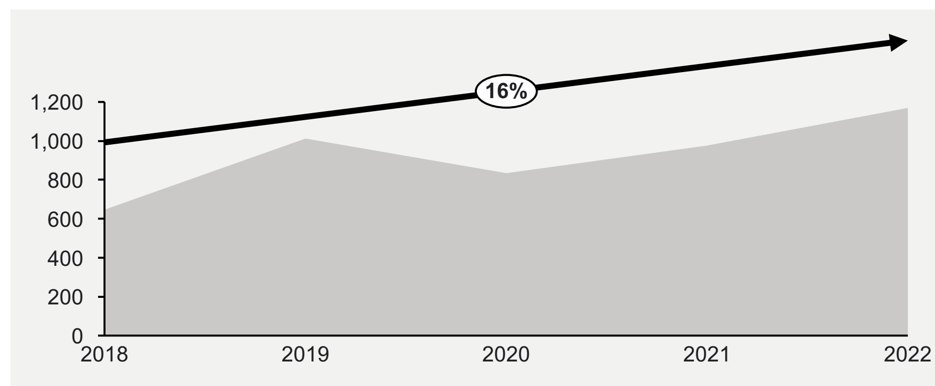
Fish farming
GWh; CAGR



Primary non-ferrous metal industry
GWh; CAGR



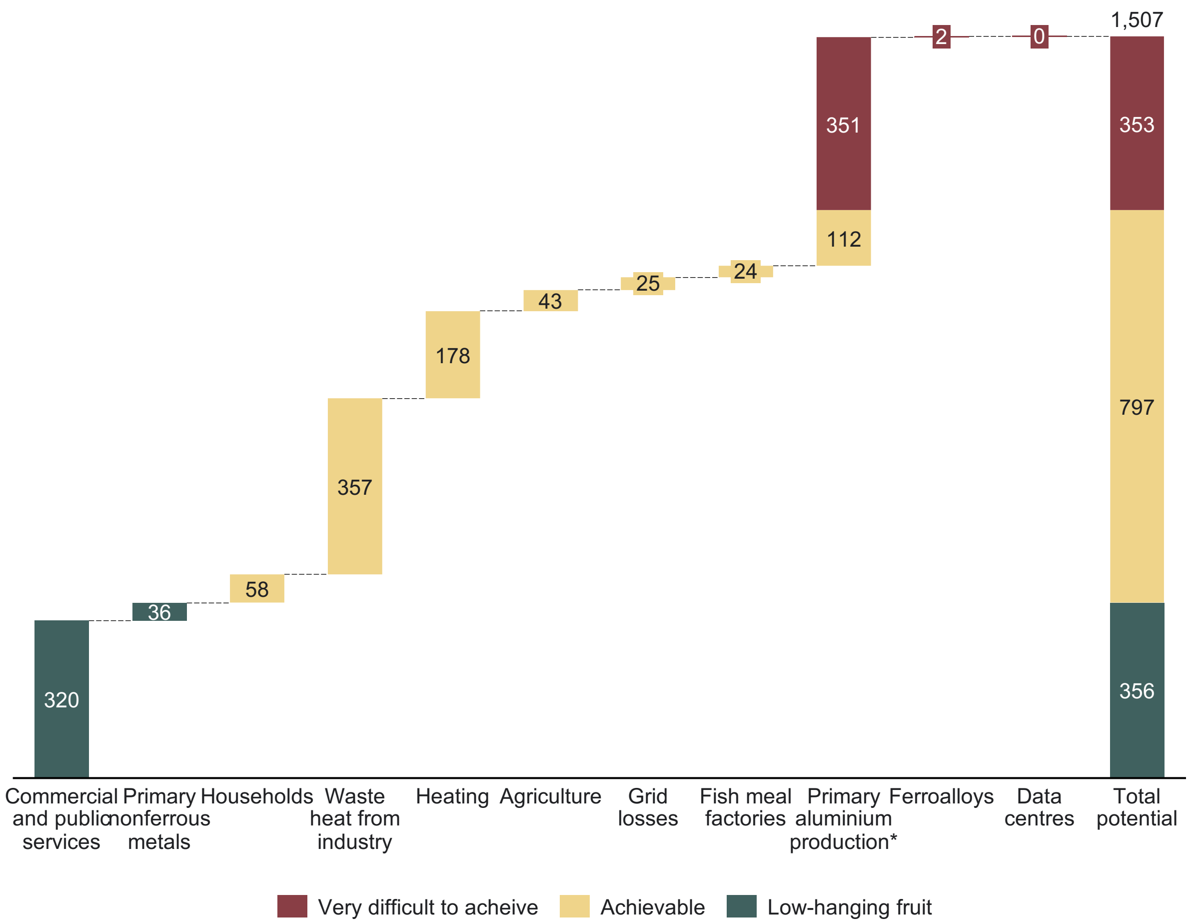
Data centres
GWh; CAGR



Source: Orkustofnun, Consumption dataset

Reduction potential

We have identified possible efficiency measures with a full potential to reduce electricity demand by about 1,507 GWh per year. For some sectors, the potential is harder to realise in terms of technical and economic feasibility



Savings of 1,507 GWh correspond to approximately 8% of the total consumption in 2022.

The largest identified potentials are in the utilisation of industrial waste heat and commercial and public services. For aluminium there is also a potential saving, albeit one that is much more difficult to achieve.

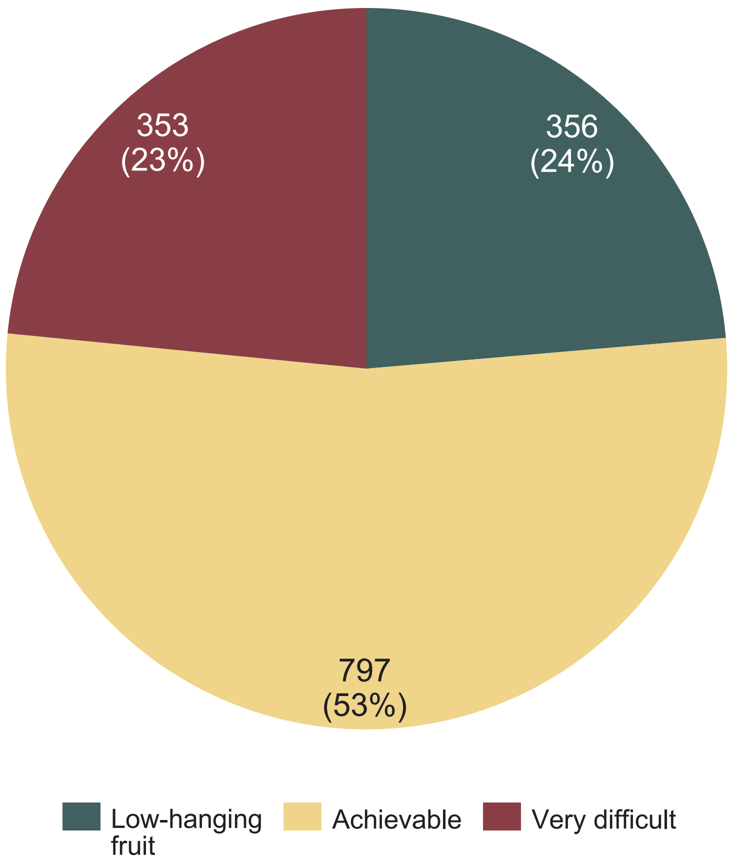
For comparison, a currently untapped electricity generation potential of roughly 100 GWh/year in the northeast could be realised by increasing the transmission capacity of the grid, without increasing the risk of depleting reservoirs and resorting to curtailments.

The assessment of ease to achieve is quite crude and assigns a single colour to most sectors. In reality, each sector will have a range of possible efficiency measures, which all have different ease-to-achieve scores. It has not been possible to reach that level of detail in this analysis, and further research should be conducted to provide this detail.

*The values reported here are the mid-point of the ranges given in the sector deep-dives.

23% of the identified potential is considered very difficult to achieve, while the remainder could be realised in the next decade

Breakdown of potential savings by ease to achieve
GWh



Qualifying the savings potential – a traffic light system

Very difficult: Theoretical savings potential that would require a complete substitution of production technology or a significant change in production scale or is otherwise considered too expensive and/or technically challenging to implement. This potential is likely only realisable in the long term (>10 years).

Achievable: Potential savings which would require investments that, although significant, are considered profitable and/or are already planned. This classification also includes sectors where many small measures would be required to achieve the full savings potential, which decreases the likelihood that the full potential will be realised. This potential can be realised in the short to medium term (5-10 years).

Low-hanging fruit: Potential savings that would involve relatively minor investments and/or changes in operation and would face no significant economic, regulatory or technical hurdles. This potential is available in the short term (1-5 years).

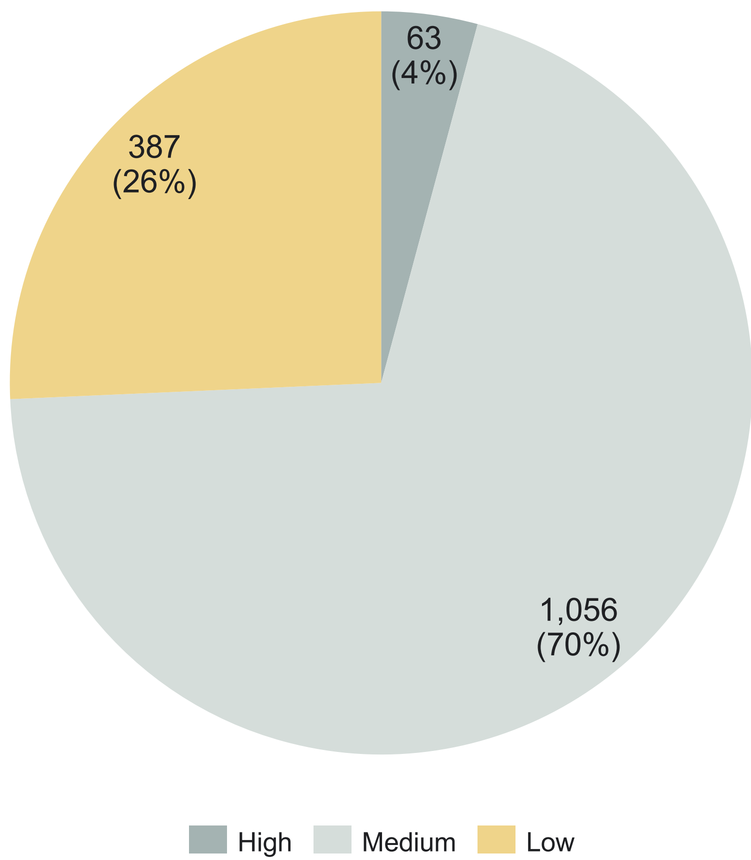
Different measures are typically used to reap potential savings in different sectors, with varying levels of complexity

The data currently available for Iceland does not allow us to determine whether the typical measures listed below are the ones required to achieve the potential savings identified in this report.

Sector	Typical efficiency measures	Ease to achieve in Iceland
Commercial and public services	Switching to LED lighting, improving efficiency of appliances, building renovations	
Primary non-ferrous metals	Increasing efficiency in smelter operation	
Households	Switching to LED lighting, improving efficiency of appliances, behavioural change	
Waste heat from industry	Utilising the potential for generating electricity from industrial waste heat	
Heating	Individual heat pumps in households and large (sea) heat pumps in areas not served by district heating	
Agriculture	Improving efficiency in pumping, ventilation, lighting and cooling	
Grid losses	Upgrading transmission and distribution networks	
Fish meal factories	Lowering cooking temperature, improving drying and evaporation processes	
Primary aluminium production	Optimising electrode design and disposition, improving process control tools	
Ferroalloys	Increasing efficiency in smelter operation	
Data centres	Improving efficiency in servers and cooling systems, increasing virtualisation	

The lack of robust data for many sectors is the biggest roadblock to a deeper understanding of the savings potential. Only 4% of the potential is deemed to have high methodological confidence

Breakdown of potential savings by confidence level
GWh



The level of confidence of our estimates is based on the availability and quality of data

There is a general lack of detailed, bottom-up data on the electricity efficiency of different sectors. This is the kind of data that would be necessary for a deeper analysis based on the current state of the physical capital stock and operations. We have instead relied on sector-level data on output and electricity to calculate electricity efficiency. We have assigned three confidence levels to our estimates, based on the availability and quality of the data.

- **Low:** There are important data gaps that had to be filled with estimates and/or extrapolations. This level also applies to sectors with a diverse set of outputs making a sector-wide comparison impossible and for which more detailed data is not available.
- **Medium:** Although there is sufficient data available overall, either multiple sources of varying quality are needed to assemble a complete dataset, potentially giving rise to methodological issues, or data must be transformed before being presented.
- **High:** Sufficient sector-wide data available either from a single source or from a combination of highly reliable sources with compatible datasets, giving rise to no methodological issues.

We have identified significant data gaps that prevent a deeper analysis of electricity efficiency in Iceland

Data gap	Description	Affected sectors
Lack of disaggregated data on electricity consumption	There is a general lack of bottom-up data mapping the electricity consumption of specific equipment and processes within each sector of the economy. There are international benchmarks and data sources at this level of disaggregation which would provide meaningful comparisons if similar data were available for Iceland.	All
Lack of public data on waste heat recovery potential	Through sector interviews, a significant potential for the recovery of waste heat from industry has been identified. There are, however, no public studies or public information that go in detail with these potentials.	All industrial sectors
Incomplete coverage of individual metering for electric heating consumption	Not all households with electric heating have a separate meter for their heating. Although a small gap, this weakens the understanding of electricity use for heating, its correlation with electricity scarcity and the overall system benefits of transitioning to heat pumps or district (geothermal) heating.	Households
Industrial companies disclose total energy consumed; not per process	For large industrial users, electricity consumption is published as total consumption and therefore not linked to specific processes in the company. This makes it more difficult to compare to other companies and countries where the production process might look different.	All industrial sectors, in particular aluminium
Electricity consumption in buildings	Without energy labels for buildings it is difficult to assess the energy standard of buildings and therefore the savings potential	Households and services

To advance the energy efficiency discussion in Iceland, there is a need to collect bottom-up data from all sectors of the economy

Recommended areas for improvement:

Collect energy consumption data at a more disaggregated level

Having access to more granular consumption data facilitates analyses and comparisons within Iceland, as well as between Iceland and international industry players or benchmarks.

The most relevant level for this type of analysis is that of end uses (e.g. general end uses like lighting and space heating or cooling, and industrial end uses such as drying, suction, distillation, etc.).

Data at this level brings insights into specific end-use consumption and therefore also how specific different energy efficiency measures could be applied to reduce consumption.

One possible structure for the collection of these data is that used by Denmark, where base statistics on energy consumption by sector and energy carrier are published yearly and a deep analysis at the end use level is done every few years (2 have been done so far, in 2015 and 2022; see box to the right for more details on the latest study).

Consolidate all energy data in one comprehensive, coherent database

Consolidating all energy data in one single database with clear variable definitions and comparable units of measurement increases transparency and provides a powerful foundation for further analysis of the energy sector in Iceland.

What has been done elsewhere – case of Denmark

The Danish Energy Agency published in 2022 a comprehensive study mapping energy consumption and savings potentials across 42 sectors of the Danish economy, 21 end uses, and 16 energy carriers.

The study was made possible by the existence of publicly available, disaggregated data from Statistics Denmark. Two databases were combined in the analysis:

- One database containing detailed energy accounting by application and energy carrier
- Denmark's industry census, which has detailed data on the energy use of all companies with at least 20 employees

The end uses for which data is available are at the process level and include, for example, lighting, drying, distillation, heating/cooking, pumping, and compressed air.

The estimation of energy savings and electrification is based on technical and economic data collected in 60 case studies. These data are then extrapolated to determine the total potentials.

The full study is available in Danish on the Danish Energy Agency's website: https://ens.dk/service/fremskrivninger-analyser-modeller/analyser/analyser-af-dansk-erhvervslivs-energiforhold

Sector deep dives

A sector-by-sector analysis identifies where the savings potential lies and assesses how difficult it is to realise

The following pages present a deep dive into the savings potential in individual sectors of the Icelandic economy.

They comprise

- **Sector overview:** A description of the sector is provided, which includes its composition in Iceland, its share of the country's electricity consumption and the main drivers of electricity consumption in the sector.
- **Savings potential:** The savings potential in each sector is assessed based on relevant comparisons to either established industry benchmarks or comparable countries or regions. In the sectors for which a benchmark is used, the precise definition of the selected benchmark can be found in the methodology section. These comparisons are imperfect. Benchmarks are often set for a class of products and do not take differences in product specifications in these classes into account, which may affect electricity consumption (for example the exact purity of silicon metal or the casting of different aluminium products such as ingots and billets). Our estimates in this report are intended to provide an order of magnitude of the savings potential across Icelandic sectors with some margin for error and should not be treated as precise estimates.
- **Confidence level:** The savings potential identified in each sector is classified according to confidence levels based on a qualitative assessment. The main determinants in this assessment are the availability and quality of data.
- **Ease to achieve:** The savings potential in each sector is also classified according to how easily it could be realised. This classification is also based on a qualitative assessment. More details about the meaning of each category can be found in the breakdown of the savings potential according to ease to achieve presented on the previous page.

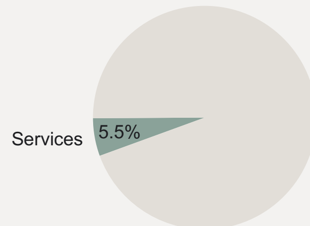
SECTOR OVERVIEW –

COMMERCIAL AND PUBLIC SERVICES

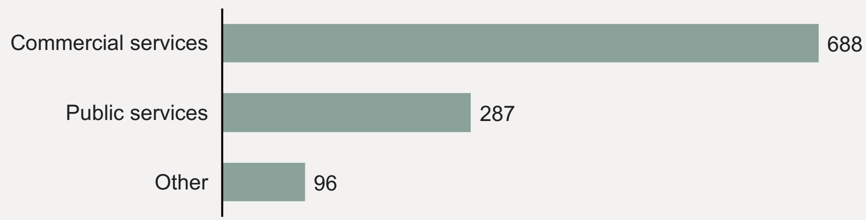
Sector description

The commercial and public service sectors include a vast amount of different activities, including government and public institutions, financial services, wholesale and retail, real estate etc.

Electricity consumption in Iceland in 2022 (%)



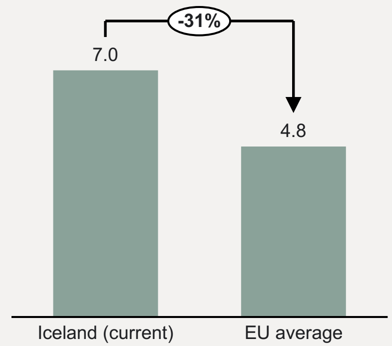
Electricity consumption in the sector – 2022 (GWh)



Main drivers of electricity consumption
Worldwide, electricity consumption in the service sector is largely related to lighting and operation of buildings as well as ventilation and cooling in retail stores. Generally, consumption is split into three categories: lighting, electrical appliances (computers, printers etc.) and processes (ovens in bakeries, washing machines in laundries etc.). In Iceland, ventilation i offices is mostly done by opening windows. In retail stores, it is done mainly by circulating cold water through heating elements.

Savings potential

Electricity efficiency in 2020 (MWh/employee)



Savings potential

320 GWh/year

Confidence	Ease to achieve
Low	Low-hanging fruit

Assessment of potential efficiency gains

- Assessing the efficiency potential of the service sector is not trivial, as this covers several different consumption drivers and activities.
- Comparisons to other countries also yield challenges, as the structure of the service sectors varies across countries. Electricity consumption per employee varies, e.g. from around 3 MWh/employee in the UK to more than 6 MWh/employee in Sweden and 12 MWh/employee in Norway, with an EU average of about 5 MWh/employee.[1]
- A major efficiency driver is lighting. Efficiency potentials depend to a large extent on how swift the adoption of especially LED light sources has been in Iceland. As an example; in Denmark in 2015, efficiency potentials of lighting were estimated at 68%, whereas this was reduced to only 18% in 2022 due to a massive uptake of more efficient sources.
- If Iceland were to reduce electricity consumption per employee to the EU average, it would reduce consumption by 31%.

Notes:

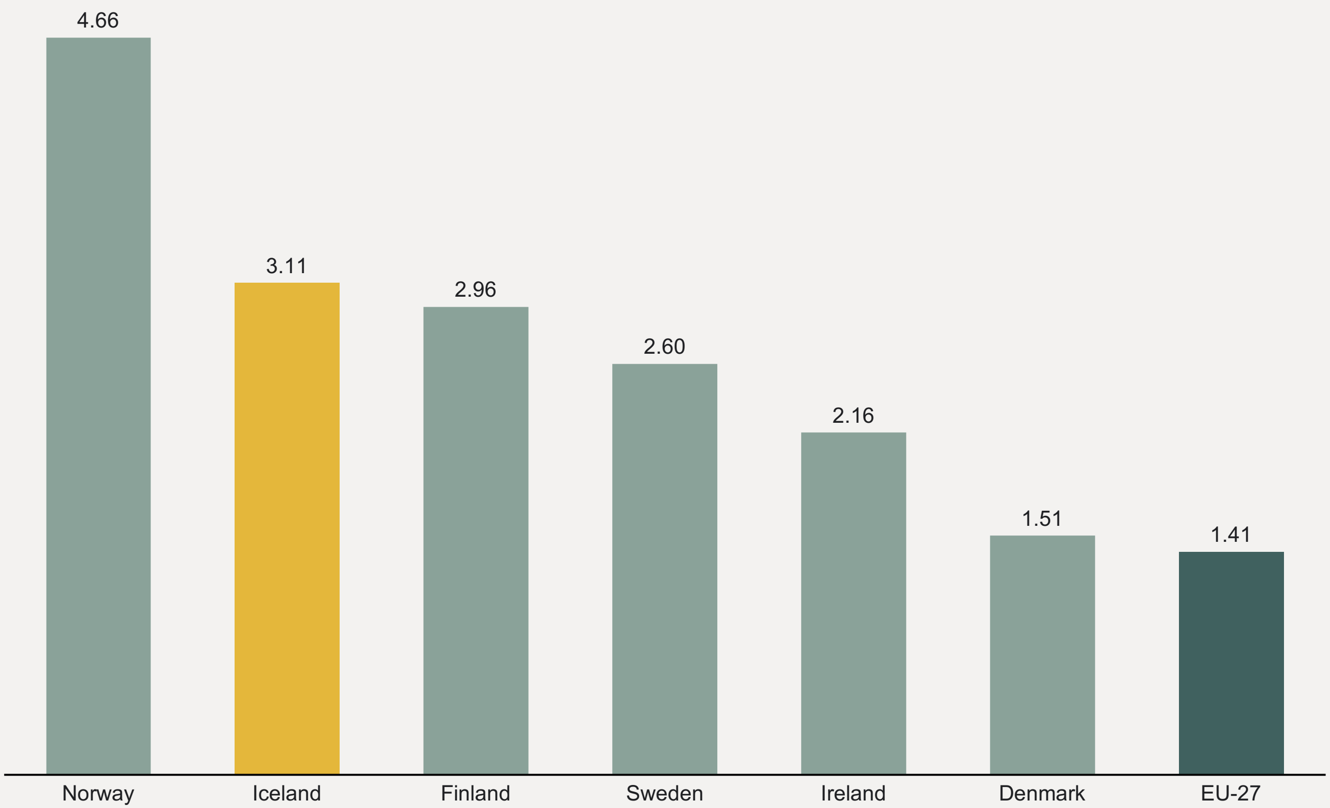
Sources:
[1] https://www.odyssee-mure.eu/publications/efficiency-by-sector/services/services-eu.pdf
[2] Energistyrelsen (2022) – Kortlægning af energiforbrug og opgørelse af energisparepotentialer i produktionserhvervene

SECTOR OVERVIEW –

COMMERCIAL AND PUBLIC SERVICES

Icelandic performance in a global context

Electricity consumption for services, excl. data centres
MWh per capita



Methodological note

Data for electricity consumption in the service sector has been modified to exclude the consumption of data centres, which is treated separately in this report.

The numbers presented here for countries other than Iceland are based on data published by the European Commission for the year 2021, from which we have subtracted the electricity consumption of data centres as reported in industry reports from individual countries (see sources).

The Icelandic number is based on data published by Orkustofnun for the year 2022 and is also exclusive of data centre consumption.

Sources: Orkustofnun, Consumption dataset; Datacenter-forum, https://www.datacenter-forum.com/datacenter-forum/norway-new-requirements-for-waste-heat-from-data-centers#:~:text=In%20recent%20years%2C%20many%20new,year%20was%20about%20135%20TWh; Motiva, https://www.motiva.fi/files/5321/Energy-efficient_Data_Centre.pdf; RI.SE, https://www.diva-portal.org/smash/get/diva2:1742192/FULLTEXT01.pdf; Social Justice Ireland, https://www.socialjustice.ie/article/electricity-consumption-data-centres-increased-32-2021; Itavis, https://itavis.dk/en/tanker-ideer/itavis-leverer-100-gron-datacenter-drift; EU Commission, https://commission.europa.eu/news/green-and-digital-study-shows-technical-and-policy-options-limit-surge-energy-consumption-cloud-and-2020-11-09_en

SECTOR OVERVIEW –
HOUSEHOLDS (EXCL. HEATING)

Sector description

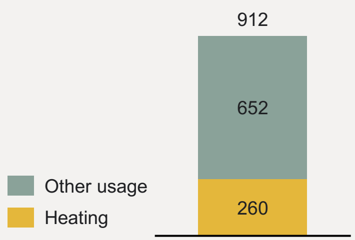
The population of Iceland was about 386,000 in 2022, living in 150,000 households. The number of households is expected to increase by 15,000 in 2027 and 37,000 in 2032.

Total electricity consumption in households increased by an average of 0.8% per year from 2012-2021, while population growth averaged 1.7% per year in the same period.

Distribution between heating and other purposes

Based on our own calculations, we assume that 260 GWh is used for electric heating, while 652 GWh is used for other uses such as cooking, lighting and appliances.

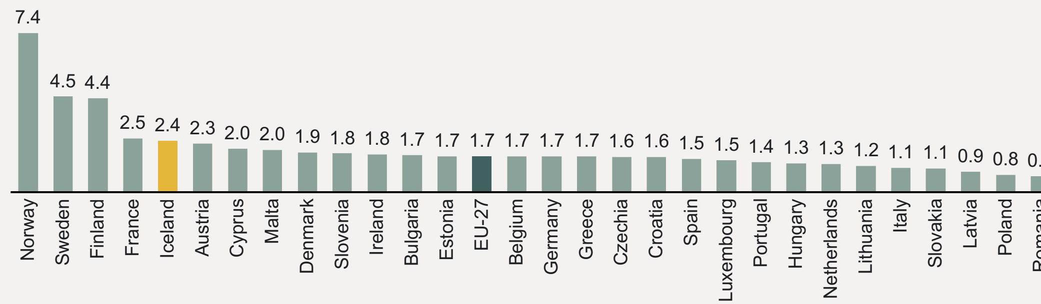
GWh, 2022



Household sector electricity consumption compared to Europe

Compared to Europe, Iceland's households are among the top user of electricity only surpassed by Norway, Sweden, Finland and France. These three countries have a larger share of direct electric heating. Electric heating is also an important driver of Iceland having a high use. We separate heating from non-heating below.

MWh per capita, 2021

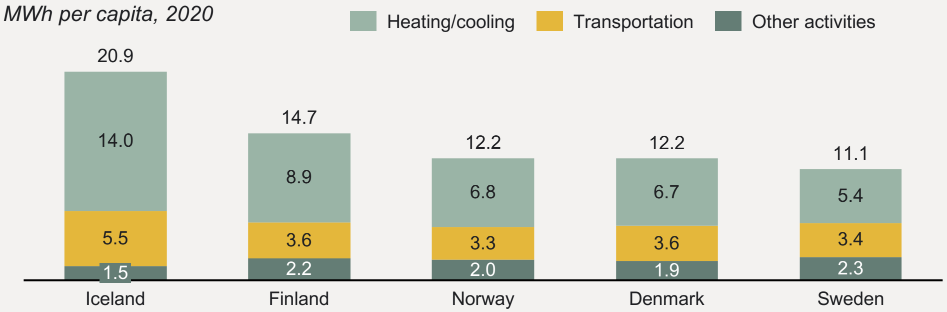


Source: Eurostat (NRG_CB_E and DEMO_PJAN)

Energy consumption of households in the Nordics

Looking at energy (not just electricity), Iceland has a much larger consumption per capita than the other Nordic countries (42-88% higher). This is mainly driven by a much larger heating consumption per capita than the other Nordic countries, which to a very large extent is non-electric energy (however, electricity is used directly as well as indirectly in the Icelandic hot water production, as elaborated below).

MWh per capita, 2020

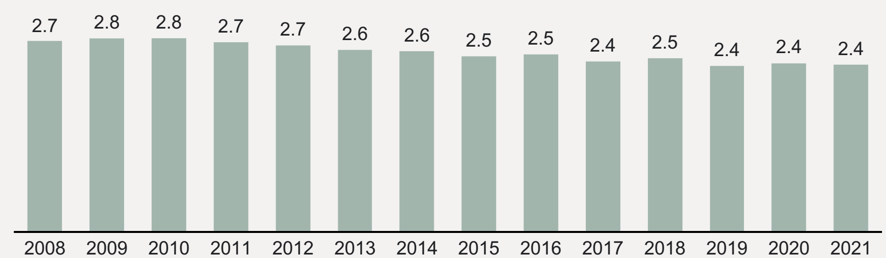


Source: Eurostat, ENV_AC_PEFA04

Household sector electricity consumption per capita over time in Iceland

Household electricity consumption per capita has been increasing up until 2009 where it peaked and has been declining until 2019. The reduction is primarily a result of the adoption of more energy-efficient light bulbs as well as more energy-efficient household appliances. In 2020, consumption started to increase again, which can mainly be attributed to an increase in the uptake of electric vehicles.

MWh per capita



Source: Eurostat (NRG_CB_E and DEMO_PJAN)

SECTOR OVERVIEW –

HOUSEHOLDS (EXCL. HEATING)

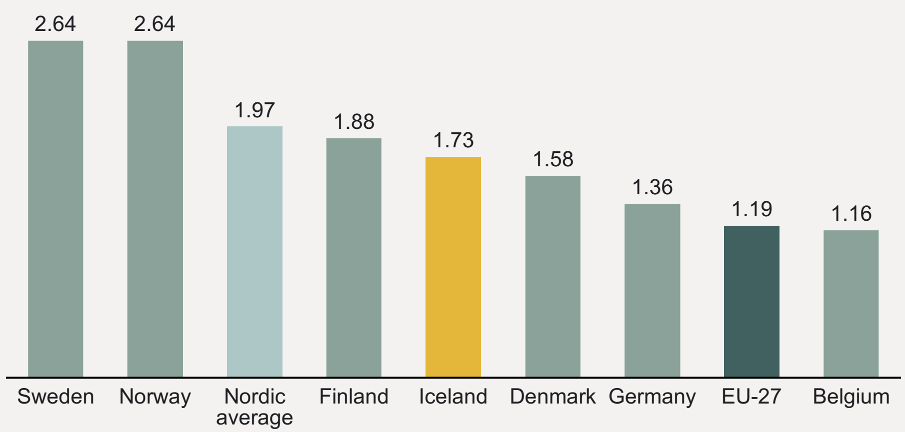
Sector description

Total electricity consumption for non-heating purposes by households is estimated at around 664 GWh in 2020. This includes lighting and electrical appliances in particular. In the EU, about 58% of household (non-heating) electricity is consumed by lighting and electrical appliances, about 13% by cooking and about 12-13% by water and space heating, respectively.

However, these numbers vary substantially, also between households where small homes typically use less electricity than large homes.

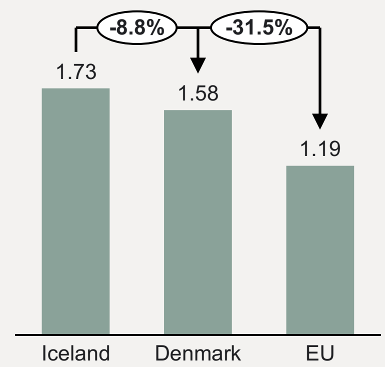
Consumption for cooking, lighting, electrical appliances etc. compared to the Nordics (MWh per capita)

When looking only at non-heating purposes, Iceland is still far below Sweden and Norway (around 30%) and slightly below Finland. Consumption per capita in Denmark is about 8.8% lower.



Savings potential

Electricity efficiency in 2022 (MWh/capita)



58 GWh/year

if same efficiency as Denmark.

Confidence	Ease to achieve
Medium	Achievable

Assessment of potential efficiency gains

- Electricity consumption in households for non-heating purposes varies substantially across countries. At the low end of the EU are countries like Germany, at 1.36 MWh per capita, and at the high end are countries like Finland and Sweden at 1.88 and 2.64 MWh per capita respectively. The EU average is 1.19 MWh per capita. Iceland stands close to the high end, with around 1.73 MWh per capita.
- Part of the difference is linked to the volume and quality of appliances as well as behaviour, whereas another part is linked to country geographies such as the yearly number of daylight hours.
- There is insufficient data available on the switch to LED lighting in Icelandic households, but international experience suggests that savings from this measure could be significant. In Denmark, for example, it has been estimated that continuing the roll-out of LEDs could reduce electricity consumption in households by as much as 18% compared to current roll-out.

Source: Eurostat (table NRG_D_HHQ) and own calculations

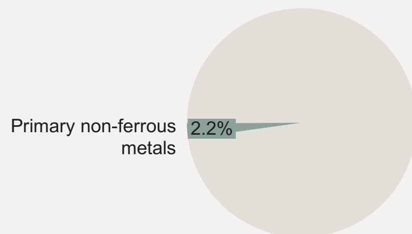
SECTOR OVERVIEW –

PRIMARY NON-FERROUS METALS

Sector description

In Iceland, the primary non-ferrous metal industry is represented by a single company, PCC Bakki, which operates a silicon metal factory in Húsavik.

Electricity consumption in Iceland in 2022 (%)



Source: Orkustofnun, Consumption dataset

Electricity consumption in the sector – 2022 (GWh)

Source: Orkustofnun, Consumption dataset and PCC Bakki's annual report

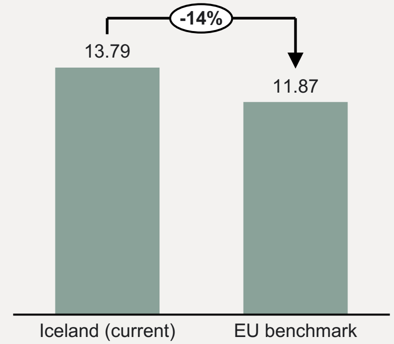
Main drivers of electricity consumption

- In Iceland, submerged electric arc furnaces where silicon metal is produced correspond to over 90% of the power usage in the sector.

Source: EFLA

Savings potential

Electricity efficiency in 2021 (MWh/tonne)



Sources: PCC Bakki annual report 2020 (Iceland); Support study of energy efficiency benchmarks in the context of the revised ETS state aid guidelines (EU benchmark)

Savings potential

36 GWh/year

in potential savings if the same output was produced with all Icelandic production operating at the current EU benchmark for energy efficiency in the industry.

Confidence	Ease to achieve
High	Low-hanging fruit

*"Electricity consumption efficiency benchmark is defined as the product-specific electricity consumption per tonne of output achieved by the most electricity-efficient method of production for the product considered, taking into consideration the production processes in all countries currently covered by the EU ETS […]." – Support study for the preparation of energy efficiency benchmarks in the context of the Revised ETS State Aid Guidelines

Assessment of potential efficiency gains

- The silicon smelter in Bakki is operating somewhat above the benchmark set by the EU.
- The smelter is relatively new, with the first furnace entering into operation in 2018[1]. Conversations with the company indicate that significant efficiency improvements have been made in 2022, which will be reflected in their upcoming environment report.
- The plant is still operating considerably below its permitted capacity of 66,000 tonnes of silicon metal/year (production was just below 19,000 tonnes in 2021)[2]. As it scales up, it is likely that its energy intensity will fall. In spite of these efficiency gains, its total consumption will rise as production increases.

[1] PCC Bakki website's description of the commissioning of their plant, available at pcc.is/the-plant-technology/our-silicon-metal-plant/
[2] PCC Bakki's green accounting report 2021, submitted to the Icelandic Environmental Authority (Umhverfistofnun)

Notes: The benchmark is set for all silicon metal except for that which contains no less than 99.99% silicon by weight. PCC Bakki's products can reach 99% silicon by weight, which is within the range specified for the benchmark. There is, however, a significant difference between this benchmark and the one set for silicon metal at or above 99.99% purity (11.87 MWh/tonne versus 60 MWh/tonne), which may suggest that the electricity intensity rises non-linearly with the purity of the metal and could depend on the mix of products produced by each individual smelter.

SECTOR OVERVIEW –

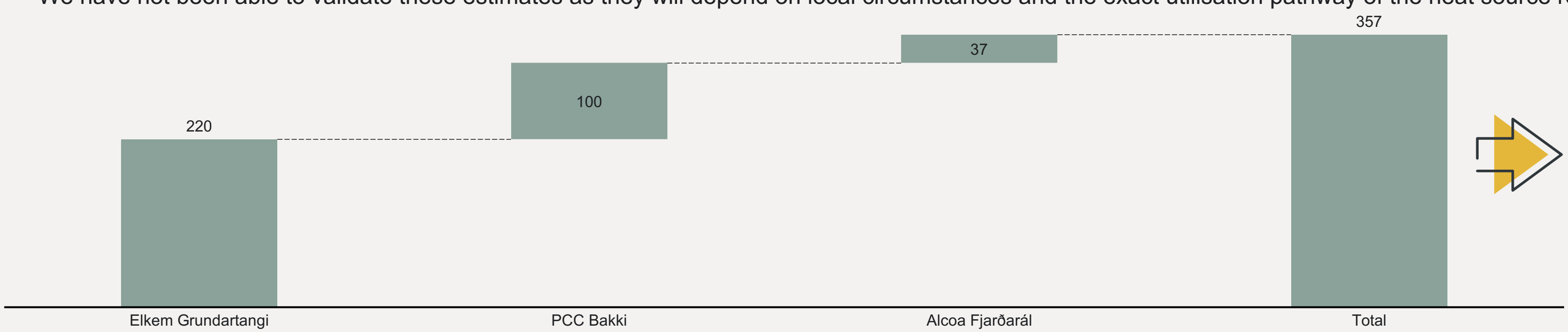
WASTE HEAT FROM INDUSTRY

Sector description

- Industrial facilities typically generate substantial amounts of waste heat as part of their processes. By reusing the waste heat for other purposes, energy can be saved.
- Waste heat can be thought of for different applications, including generating steam for the same industrial processes it came from, being utilised for district heating in the local district heating system or used for generating electricity through a turbine. In this section, we only consider the electricity generating potential from waste heat e.g. through directly fuelling electricity generators or by being fed into the district heat system thereby replacing electric boilers in some regions.
- There seems to be no strong incentives to utilise industrial waste heat.

Savings potential (GWh)

- Based on dialogues with different industry stakeholders, a savings potential of about 350 GWh has been assessed – even up to 500 GWh at best from just three industrial facilities. For Elkem and PCC, we have been told that, as a rule of thumb, about 25-30% of the consumed power could be reutilised by using the energy in the off-gas for generating new electricity.
- The utilisation of this potential will depend on how the waste heat can be recuperated and reused. In some specific geographical circumstances, it might replace large electric boilers in the district heating system; and in other circumstances, it might be used directly to generate electricity to be fed into the grid. This will depend on the local circumstances and should be further analysed. The estimates derived here should be treated in addition to the estimates we derive in the industrial sectors, as the benchmarks we compare to – to our knowledge – do not include recovered waste heat.
- We have not been able to validate these estimates as they will depend on local circumstances and the exact utilisation pathway of the heat source relevant at that location



357 GWh/year

Confidence	Ease to achieve
Medium	Achievable

* Industry interviews conducted by either Implement or Orkustofnun

HEATING SECTOR

Sector description

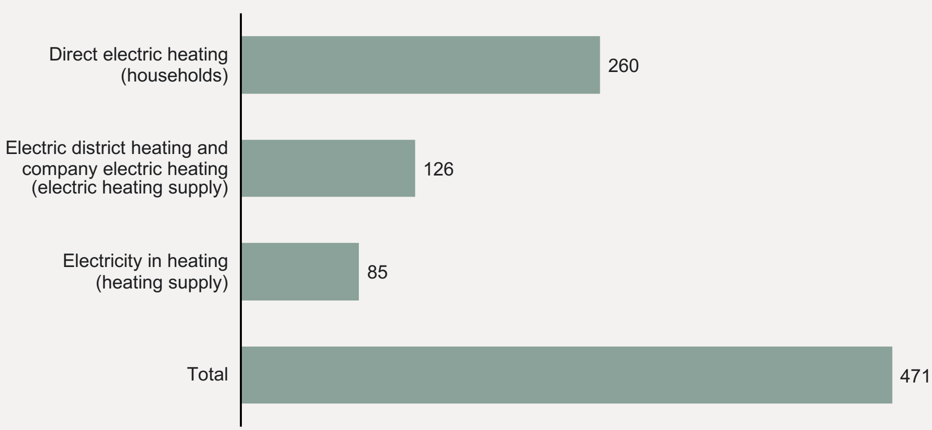
Electricity is used to generate heat through different channels:

- Direct electric heating through electric panels and/or heat pumps in households.
- Electric boilers and large heat pumps used in the district heating system as a supplement to geothermal resources as well as pumping hot water into the system. Also includes direct electric heating in companies.
- Pumps and other electric equipment used to power the production of non-electric heat, e.g. pumping geothermal hot water out of reservoirs.

In this section, we consider electricity used for all heating purposes, including households, services and public institutions.

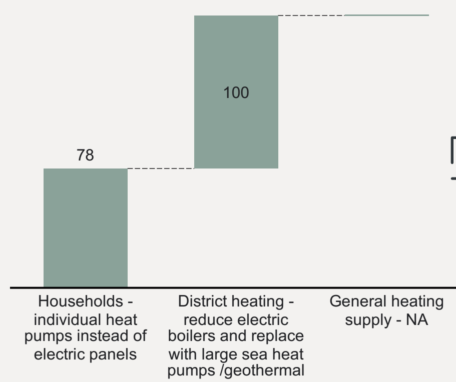
Electricity consumption for heating in Iceland (GWh)

In total, we estimate that around 460 GWh are used for heating purposes in Iceland. This is relatively even spread out between direct electric heating in households, electric district heating and electricity for powering other sources of district heating



Savings potential

Electricity reduction potential (GWh)



178 GWh/year

Confidence	Ease to achieve
Medium	Achievable

Assessment of potential efficiency gains

- Replacing direct electric heating in households with individual heat pumps is estimated to save around 78 GWh. While heat pumps are typically economic, they involve large upfront costs and are also associated with behavioural barriers that can reduce uptake speed. We assume that all households with direct electric heating can install a heat pump and save about 30% of their electricity consumption.* Both electricity used directly for heating and the capital costs of switching to heat pumps are currently subsidised in Iceland.
- Some heating utilities are using electric boilers to generate hot water in the district heating system, for example in Vestfirðir, Seyðisfjörður and Vestmannaeyjar. Measures to replace such boilers with e.g. sea heat pumps and additional geothermal heat could reduce consumption by around 100 GWh per year according to estimates (based on Orkustofnun estimates).
- It was not possible to assess whether there is also a potential for reducing electricity consumed in the general heating supply such as improving the pumping of steam from geothermal wells.
- There could be a potential for saving energy by utilising the used hot water from households that is currently just being discharged. This would mainly lead to thermal energy savings, perhaps with a slight increase in electricity consumption due to increased use of heat pumps.

* Atlason, R.S., Oddsson, G.V. & Unnthorsson, R.(2017) Heat pumps in subarctic areas: current status and benefits of use in Iceland

SECTOR OVERVIEW –

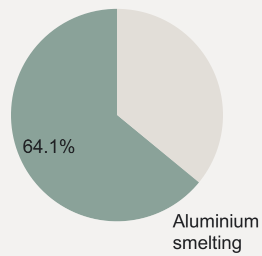
PRIMARY ALUMINIUM PRODUCTION

Sector description

Aluminium smelters produce primary aluminium from raw materials such as bauxite or other aluminium-rich ores. In Iceland, there are three aluminium smelters, owned by Norðurál, Rio Tinto, and Alcoa. Together, they produce around 860,000 tonnes of aluminium per year.

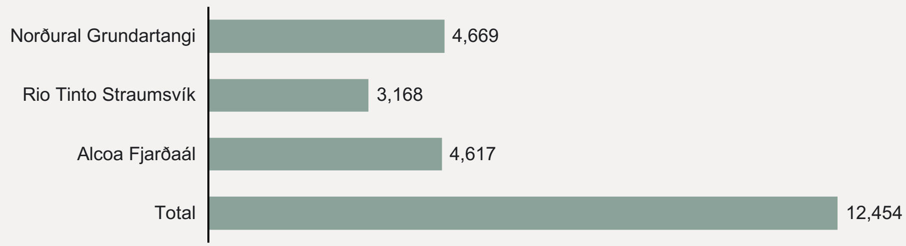
The companies produce different final products of different quality and value. Due to these differences, we focus solely on the smelting process to ensure comparability.

Electricity consumption in Iceland in 2022 (%)



Source: Orkustofnun, Consumption dataset

Electricity consumption in the sector – 2021 (GWh)



Source: Annual reports of Icelandic smelters

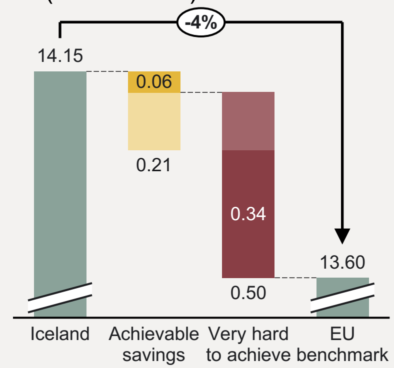
Main drivers of electricity consumption

- The aluminium smelting process involves the use of a strong electrical current, which, in Iceland, represents ~95% of the electricity consumption in the sector.

Source: EFLA

Savings potential in the smelting process

Electricity efficiency of the smelting process in 2021(MWh/tonne)



Savings potential

47-177 GWh/year

286-416 GWh/year

in achievable savings if the same output was produced with all Icelandic production operating at the current EU benchmark for energy efficiency in the industry.

Confidence	Ease to achieve
Medium	Achievable/very difficult

Sources: Annual reports of Icelandic smelters (Iceland); Support study of energy efficiency benchmarks in the context of the revised ETS state aid guidelines (EU benchmark). Due to differences in the processing of aluminium in the cast houses, we have only considered the electricity used in the electrolysis process.

Assessment of potential efficiency gains

- The operation of Icelandic smelters, on average, is not far from the industry benchmark. Electricity is a major component of the operating costs of smelters, which already provides strong incentives to implement efficiency-improving measures.
- Due to significant differences in the processes that happen in the cast house after the aluminium is smelted, including differing degrees of electrification and the inclusion of scrap in varying proportions, we focus exclusively on the smelting (electrolysis) process.
- Our methodology suggest two different potentials. One potential which industry experts have deemed achievable, and one potential which is deemed much harder to achieve, based on the comparison with an EU benchmark. The full realisation of the latter would likely require a full refurbishment or substitution of current smelters.

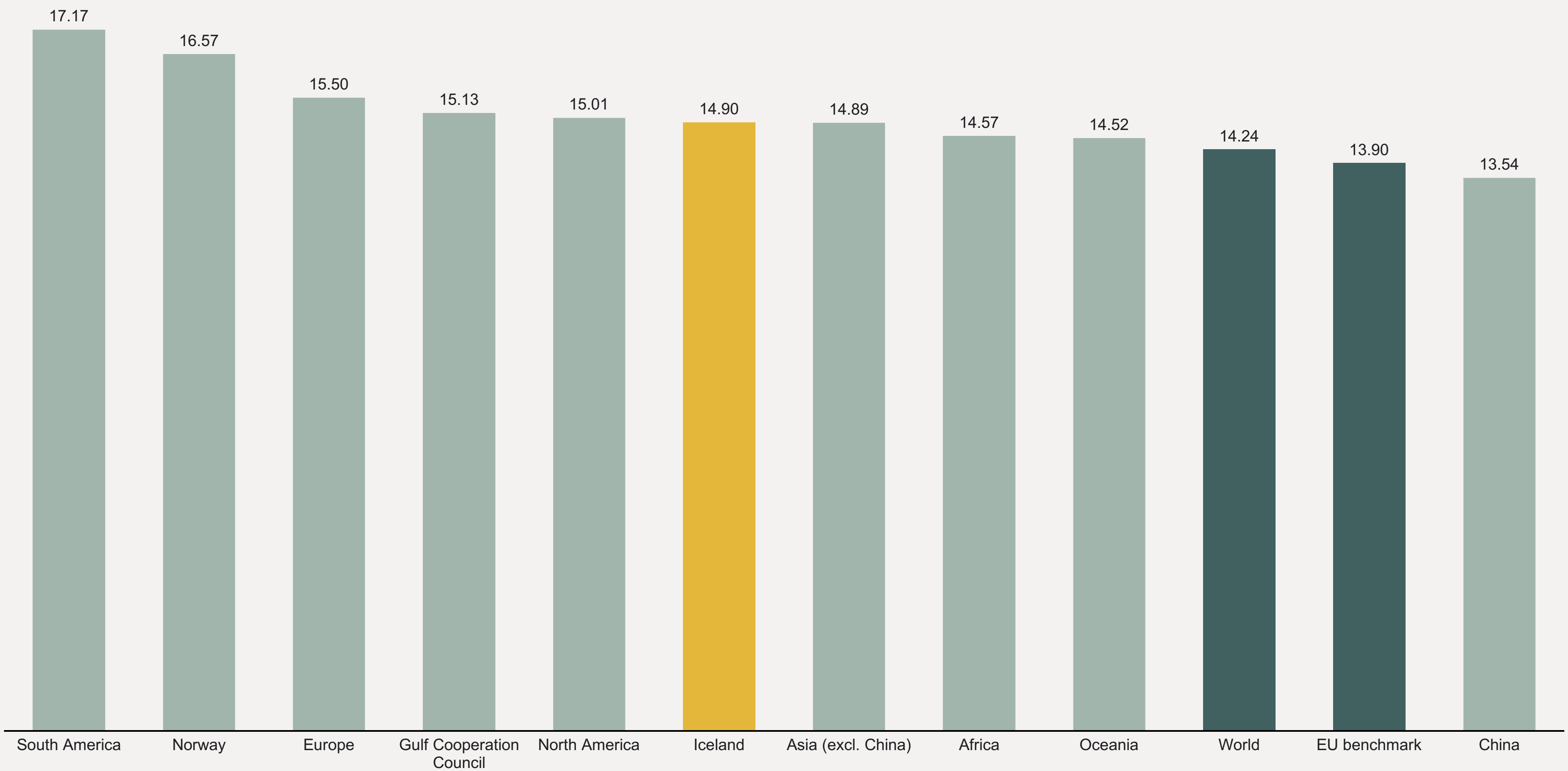
Notes: Smelters in Iceland produce several different aluminium products such as ingots and billets. The electricity used in the casting of these products (which occurs after the aluminium is smelted) is included in the reported numbers. This complicates the direct comparison of energy efficiency between companies manufacturing different mixes of aluminium products, as more energy is put into producing more valuable goods. We have addressed this, by only including electricity used in the smelting process.

SECTOR OVERVIEW –

PRIMARY ALUMINIUM PRODUCTION

Icelandic performance in a global context

Electricity intensity of aluminium smelting, 2020
MWh per tonne aluminium



Sources: Annual reports of Icelandic smelters (individual smelters and Iceland); International Aluminium (all other regions); Support study of energy efficiency benchmarks in the context of the revised ETS state aid guidelines (EU benchmark).

SECTOR OVERVIEW – AGRICULTURE

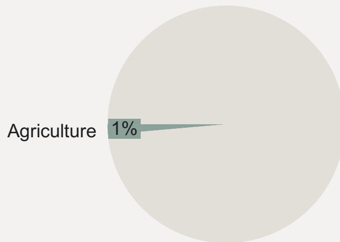
Sector description

Agricultural produce plays an important role for Icelandic food security. Moreover, it is also the mainstay of livelihood and employment in the rural areas of the country.

The most important categories in terms of production value:

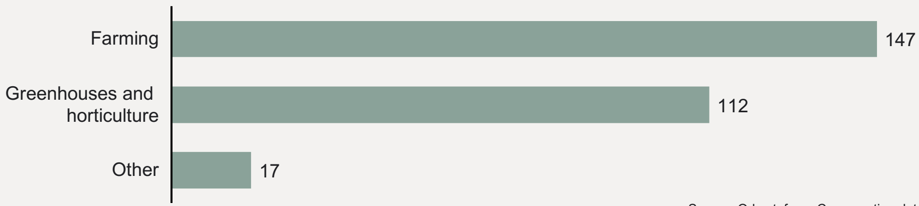
- Milk and milk products (the largest category)
- Horticulture
- Sheep farming
- Cattle breeding and poultry farming

Electricity consumption in Iceland in 2022 (%)



Source: Orkustofnun, Consumption dataset

Electricity consumption in the sector (GWh)



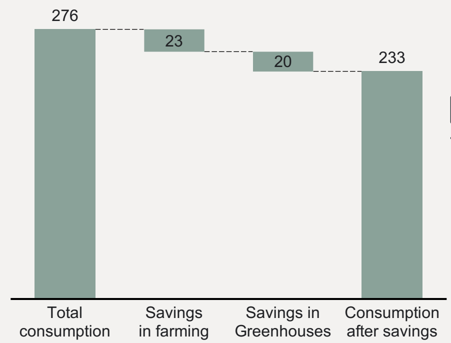
Source: Orkustofnun, Consumption dataset

Main drivers of electricity consumption

- The farming category includes all electricity consumption from farming activities and households where farming is the main income stream and can include pumping, e.g. for irrigation, ventilation of animal stables and cooling for milk production as well as lighting and heating.
- Iceland has roughly 25 ha of greenhouses, mainly located in the southern part. The greenhouses are usually heated using geothermal heating but rely on electric light for growth as well as electricity for pumping.

Savings potential

Electricity consumption (GWh)



Savings potential

43 GWh/year

in potential savings.

Confidence	Ease to achieve
Low	Achievable

Assessment of potential efficiency gains

- **Farming**

Activity	Share of electricity consumption	Savings potential (%)	Savings potential (GWh)
Pumping	22%	25%	
Ventilation	13%	28%	
Lighting	13%	22%	
Boiling/heating	12%	13%	
Cooling/freezing	9%	26%	
Total		16%	23

- **Greenhouses**

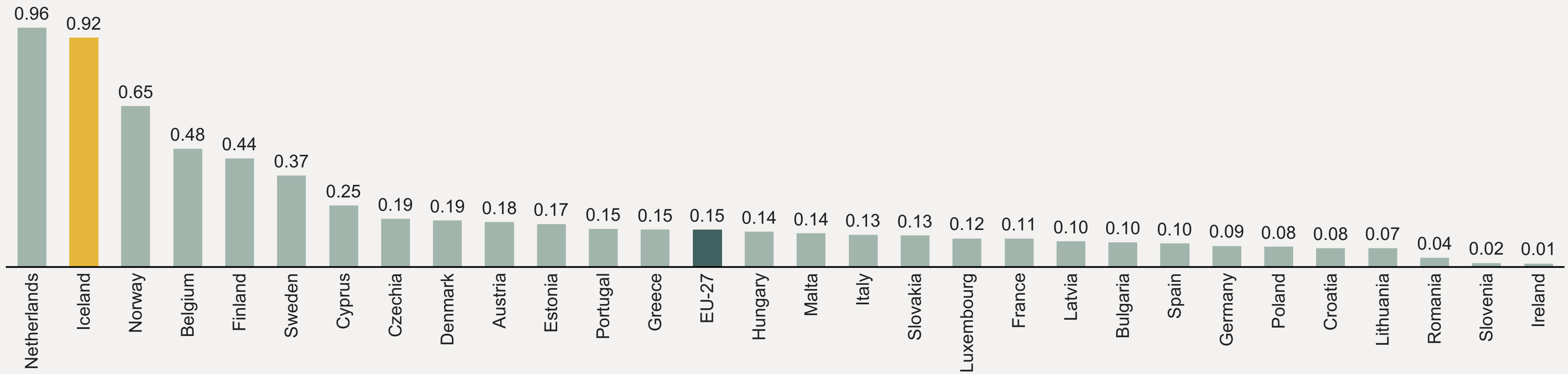
Activity	Share of electricity consumption	Savings potential (%)	Savings potential (GWh)
Lighting	57%	25%	
Pumping	15%	25%	
Total		18%	20

Notes: The assumptions of the drivers of electricity consumption and the savings potential are derived from a thorough Danish study. Consequently, the underlying assumption of these estimates is that greenhouses and other farming activities are structurally similar to those in Denmark. The share of electricity consumption, especially in farming, is likely to be different in Iceland. The savings potential will also depend on the state and efficiency of the equipment in Iceland.

Source: Energistyrelsen (2022) – Kortlægning af energiforbrug og opgørelse af energisparepotentialer i produktionserhvervene

Icelandic performance in a global context

Electricity consumption per value of agricultural production, 2020
MWh per $1000



Sources: FAOSTAT (Value of Agricultural Production), Eurostat (ENV_AC_PEFASU)

Electricity efficiency for greenhouses
MWh per m2

Assessment and considerations

- Iceland does not have a very electricity-efficient production of agricultural products nor greenhouse operations.
- The main factors might be relatively poor conditions for agricultural efficiency such as soil conditions and a relatively high number of dark and cold days, giving rise to an increased need for electricity for lighting and growing purposes.
- There is a threshold of 100MWh of yearly electricity consumption for greenhouses to qualify for a subsidy to the purchase of electricity. This disincentivises energy savings initiatives, as they could result in the loss of economic support if they move the greenhouse below the threshold. Further, it could provide incentives for greenhouses that are just below the threshold to consume more in order to secure support.

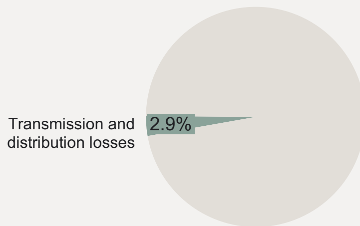
Sources: Bibbiani, C., Fantozzi, F., Gargari, C., Campiotti, C. A., Schettini, E., & Vox, G. (2016). Wood biomass as sustainable energy for greenhouses heating in Italy. Agriculture and agricultural science procedia, 8, 637-645; Orkustofnun, Consumption dataset

SECTOR OVERVIEW –
TRANSMISSION AND DISTRIBUTION LOSSES

Sector description

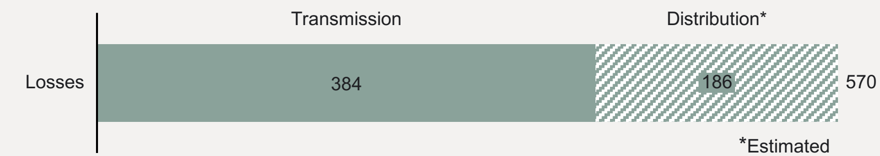
Energy losses occur throughout the entire transmission and distribution network. They comprise different types of losses such as core and resistive losses. Core losses relate to the power required to operate the grid and are independent of electricity flows. Resistive losses, on the other hand, relate to the resistance of the lines and grow exponentially with the flow of electricity.

Electricity consumption in Iceland in 2020 (%)



Source: Orkustofnun, Consumption dataset

Electricity consumption in the sector – 2022 (GWh)



Source: Landsnet

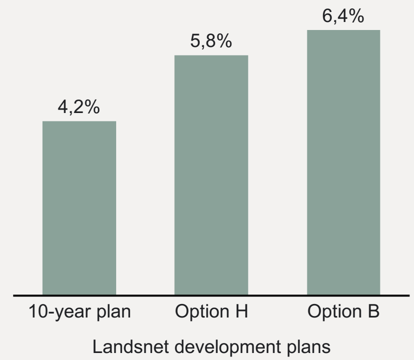
Main drivers of electricity consumption

Worldwide, the majority of grid losses can be classified as:

- Resistive losses in transmission and distribution lines.
- Core and resistive losses in substations and transformer stations.

Savings potential

Savings potential for different grid upgrade plans presented by Landsnet



16-25 GWh/year

in potential savings depending on the development plan adopted by Landsnet.

Confidence	Ease to achieve
High	Achievable

Source: Landsnet's system plan 2021-2030

Assessment of potential efficiency gains

- In 2021, Landsnet published its development plan for the Icelandic electricity transmission system for 2021-2030. The document considers three possible plans:
  1. **10-year plan:** This plan sees the strengthening of the connection from Hvalfjörður to the eastern region and the main transport system in the Westfjords.
  2. **Option H:** In addition to the upgrades included in the 10-year plan, option H also includes the further development of the main transport system and the highland connection.
  3. **Option B:** In addition to the upgrades included in the 10-year plan, option B also includes the further development of the main transport system as in option H and the strengthening of the settlement line south of Vatnajökull.
- There are indications that there could be a larger savings potential to be reaped with additional investments. The two main indicators are the relatively advanced age of the transmission lines and substations and the international comparison of total system losses in Iceland once the weight of heavy industrial consumers is properly accounted for. Both arguments are explored in more detail on the next page.

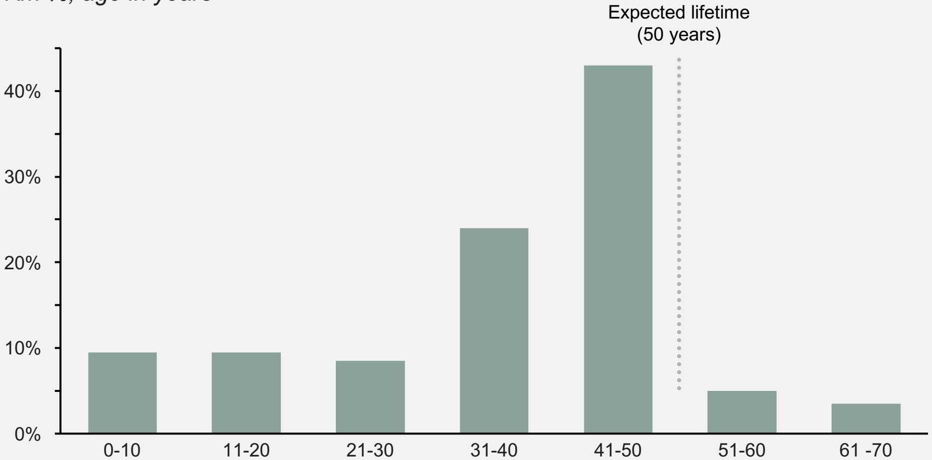
Notes: The savings in percentages presented in Landsnet's system plan are based on the monetary value of transmission losses and have been assumed to correspond directly to energy savings.

SECTOR OVERVIEW –

TRANSMISSION AND DISTRIBUTION LOSSES

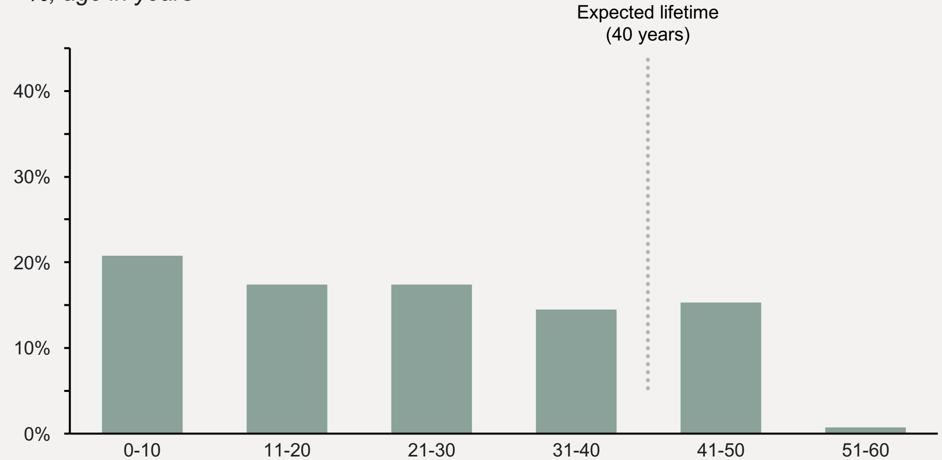
Age of Iceland's transmission system equipment

Age distribution of transmission lines
Km %; age in years

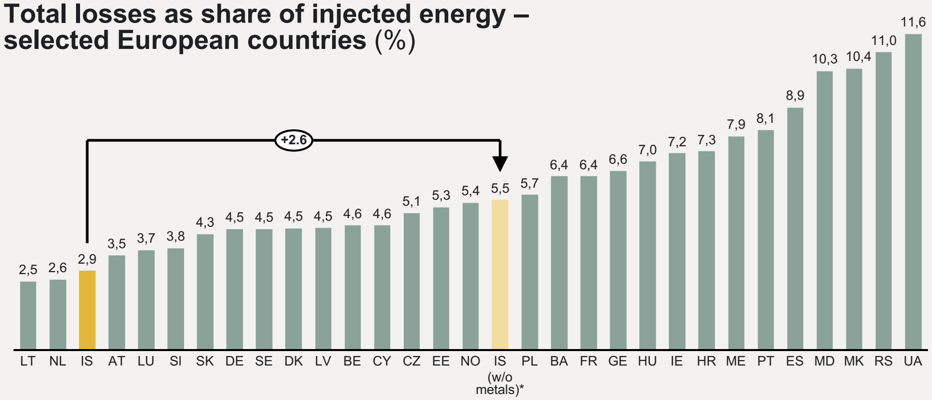


Source: Landsnet

Age distribution of substations/switchgear equipment
%; age in years



Total losses as share of injected energy – selected European countries (%)



Sources: Orkustofnun (Iceland), 2020; 2nd CEER Report on Power Losses (all others), 2018

Description of methodology for the adjusted loss ratio

- We conclude that the loss ratio of 2.9% does not accurately represent the efficiency of the grid in an international context. This is because a very large share of the electricity injected into the grid (>70%) is only being transported via the transmission grid to large electricity consumers, never making use of the distribution network. This substantial amount of electricity, which does not give rise to many grid losses, therefore skews the picture of the losses from the rest of the grid.
- In order to provide an alternative estimate, we exclude the electricity consumption of the metals industry (aluminium smelters, aluminium foil producers, silicon metal and ferrosilicon smelters) and the losses incurred in the transport of this electricity from the analysis. A detailed description of how this is done can be found in the methodology section.
- This adjusted methodology yields a loss ratio of 5.5%, which positions Iceland close to the median in Europe instead of among the best performers. Although the actual figure of 5.5% might not be completely accurate, it provides a context as to how very low total loss numbers can be reconciled with the reality of a relatively old grid infrastructure.

*For detailed calculations, please refer to the methodology section

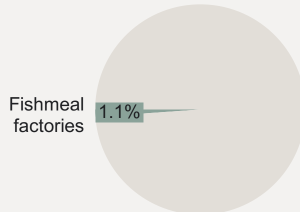
SECTOR OVERVIEW –

FISHMEAL FACTORIES

Sector description

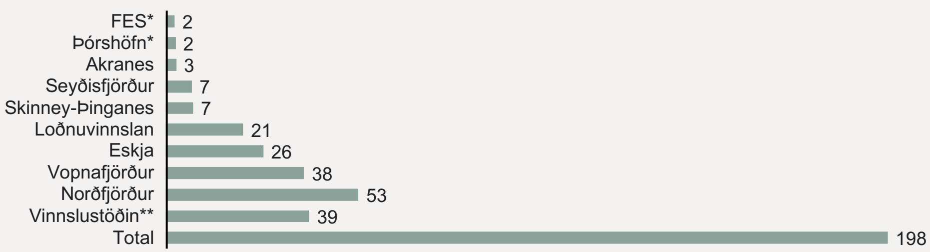
Fishmeal factories produce fishmeal and fish oil. Fishmeal is primarily used as animal feed and fertiliser, whereas fish oil is used in the production of foods and in several industrial processes. The sector is represented by ten factories in Iceland. The process is energy intensive and variable, as it depends on strongly fluctuating raw material (fish). Factories currently rely on curtailable power contracts and use oil as a backup energy source when there is not enough electricity being delivered for the required operations.

Electricity consumption in Iceland in 2022 (%)



Source: Orkustofnun, Consumption dataset

Electricity consumption in Iceland by fishmeal factory – 2020 (GWh)



*Factories primarily powered by oil

**Umhverfistofnun report not available for the year 2020. Value calculated as a residual from total consumed by the sector, as reported by Orkustofnun

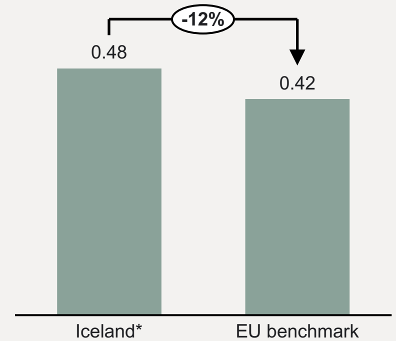
Source: Reports submitted by each company to the Icelandic Environmental Authority (Umhverfistofnun)

Main drivers of electricity consumption

The analysis of an Icelandic factory has identified air/steam dryers, evaporators, presses, and cookers, in that order, as the main drivers of electricity consumption. [1]

Savings potential

Electricity efficiency in 2020 (MWh/tonne)



*Excl. factories primarily powered by oil

Savings potential

24 GWh/year

in potential savings with all Icelandic production operating as best in class.

Confidence	Ease to achieve
Low	Achievable

Sources: Reports submitted by each company to the Icelandic Environmental Authority Iceland); Best Available Techniques (BAT) Reference Document for the Slaughterhouses, Animal By-products and/or Edible Co-products (EU) Industries

Assessment of potential efficiency gains

- The primary energy-related concern of the sector is to rely as little as possible on oil in order to reduce GHG emissions. Electrification is the easiest path, as all factories already run at least partially on electricity.
- This points to a likely increase in the use of electricity in the sector as the energy transition progresses, even if there are significant improvements in energy efficiency.
- Some low-hanging fruits exist. As an example, a recent study conducted at an Icelandic fishmeal factory has shown that electricity use can be reduced by about 1% simply by lowering the cooking temperature of the fish by 5ºC, which could also improve the quality of the final product.[1]
- A Danish study identifies significant medium-term efficiency gains for some of the most energy-intensive activities in the sector. In 10 years, the study estimates that electricity can be reduced by 26% for drying, 17% for evaporation and 13% for cooking, using the current Danish industry as a baseline. [2]

[1] Gudrun Svana Hilmarsdóttir, Ólafur Ögmundarson, Sigurjón Arason, María Gudjónsdóttir, Identification of environmental hotspots in fishmeal and fish oil production towards the optimization of energy-related processes, Journal of Cleaner Production, Volume 343, 2022
[2] Analyser af dansk erhvervslivs energiforhold (Energistyrelsen; 2022)

Notes: Since most, if not all, factories rely at least partially on oil to power their operations, their electricity efficiency numbers may mask the true energy efficiency of the production process itself. Further electrification of the sector's operations in Iceland would lead to a significant deterioration in the reported electricity intensity of factories currently relying heavily on oil.

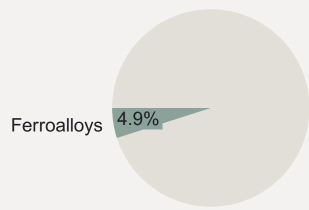
SECTOR OVERVIEW –

FERROALLOYS

Sector description

The ferroalloy industry produces metal alloys that contain iron. In Iceland, it is represented by a single plant in Grundartangi, owned and operated by Elkem ASA, which produces a specific ferroalloy, namely ferrosilicon.

Electricity consumption in Iceland in 2022 (%)



Source: Orkustofnun, Consumption dataset

Electricity consumption in the sector– 2022 (GWh)

Source: Orkustofnun

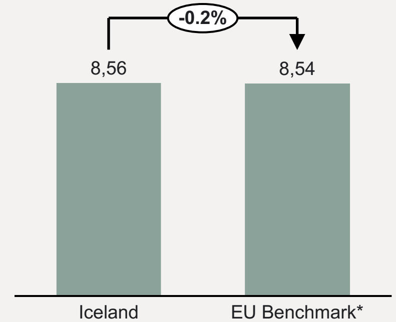
Main drivers of electricity consumption

- In Iceland, the electric arc furnaces where the ferrosilicon is produced consume over 90% of the electricity used in the sector.

Source: EFLA

Savings potential

Electricity efficiency in 2022 (MWh/tonne)



Savings potential

2 GWh/year

in potential savings if the same output was produced with all Icelandic production operating at the current EU benchmark for energy efficiency in the industry.

Confidence	Ease to achieve
High	Very difficult

Sources: Orkustofnun, Elkem annual report 2020 (Iceland); Support study of energy efficiency benchmarks in the context of the revised ETS state aid guidelines (EU benchmark)

Assessment of potential efficiency gains

- Ferrosilicon production in Iceland is operating very close to the EU benchmark set for the product.
- Elkem's plant is relatively old, with each of the three furnaces starting operations in 1979, 1980 and 1999.[1] Despite their age, they are, as indicated above, operating roughly at the EU benchmark, which suggests that most of the potential savings have already been realised and the remaining savings may be difficult and/or costly to achieve.

[1] Elkem website's description of their plant in Grundartangi, available at https://www.elkem.com/about-elkem/worldwide-presence/iceland/elkem-iceland

Notes: The ferrosilicon produced by Elkem contains 55-75% silicon, while the EU benchmark refers more generically to all ferrosilicon alloys containing at least 55% silicon.

SECTOR OVERVIEW – DATA CENTRES

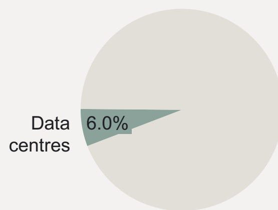
Sector description

The industry is represented by nine data centres in Iceland, operating mostly in the Reykjavík and Keflavík areas.

Iceland is a particularly attractive location for data centres, offering cheap, reliable and carbon-free energy, a stable legal and economic environment and a cold climate, which reduces the energy required for cooling.

Icelandic data centers are focused on computation and storage, but currently largest share of their energy consumption is used to perform other functions such as cryptomining.

Electricity consumption in Iceland in 2022 (%)



Source: Orkustofnun, Consumption dataset

Electricity consumption in the sector – 2022(GWh)

Source: Orkustofnun, Consumption dataset

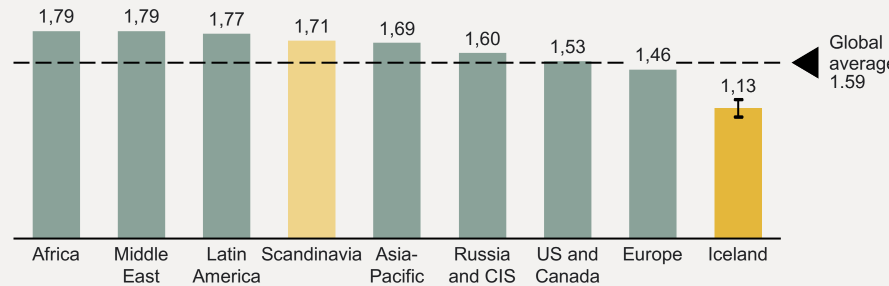
Main drivers of electricity consumption

Worldwide, consumption drivers in data centres can be divided into two categories:

- IT servers
- Cooling, power provision, and other auxiliary services

Savings potential by becoming "best in class"

PUE – Iceland vs regional averages



Sources: Data centers by Iceland, Borealis, atNorth (Iceland); JRC (Scandinavia); Uptime Institute (all others)

No significant potential identified

Confidence	Ease to achieve
Medium	-

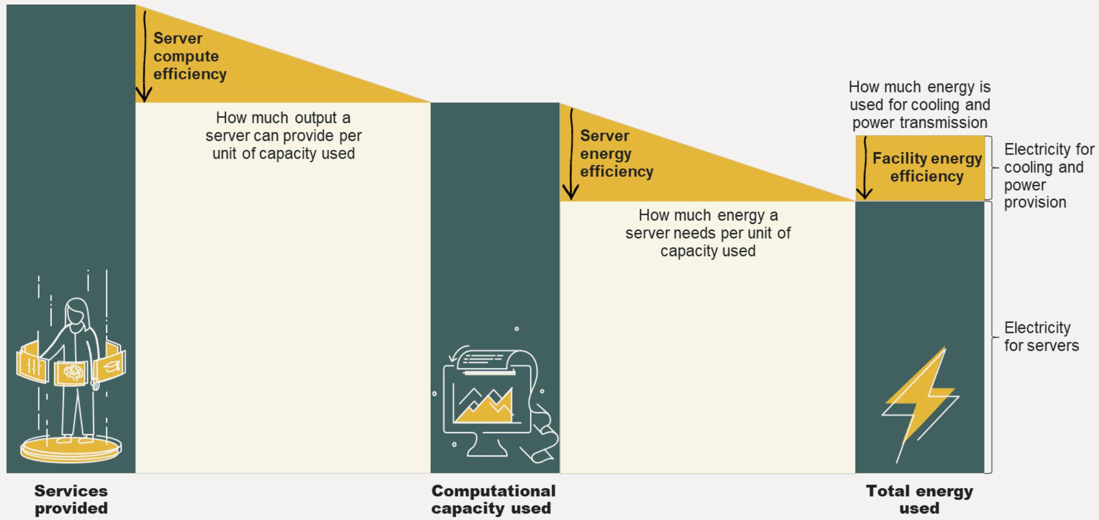
Assessment of potential efficiency gains

- Iceland already outperforms all regional averages in the main efficiency measure for data centres and power usage effectiveness (PUE). Hence, we do not see a significant potential for improvements.
- Some possible measures to investigate are: 1) the integration between servers' load and internal cooling systems and 2) revisiting whether standards for the required temperature in server rooms are excessively restrictive.
- Currently, there are no widely accepted measures for server energy efficiency, despite the fact that servers are the main consumers of power in the sector.
- Historically, energy efficiency gains in the data centre industry have occurred in parallel with rapid growth in the sector and have rarely led to actual savings in overall electricity use.

Notes: PUE is an imperfect measure of energy efficiency, which does not take into account the efficiency of the servers themselves and instead focuses on the efficiency of the data centre facilities. Nonetheless, it remains, for the moment, the most widely used metric of data centre energy efficiency.

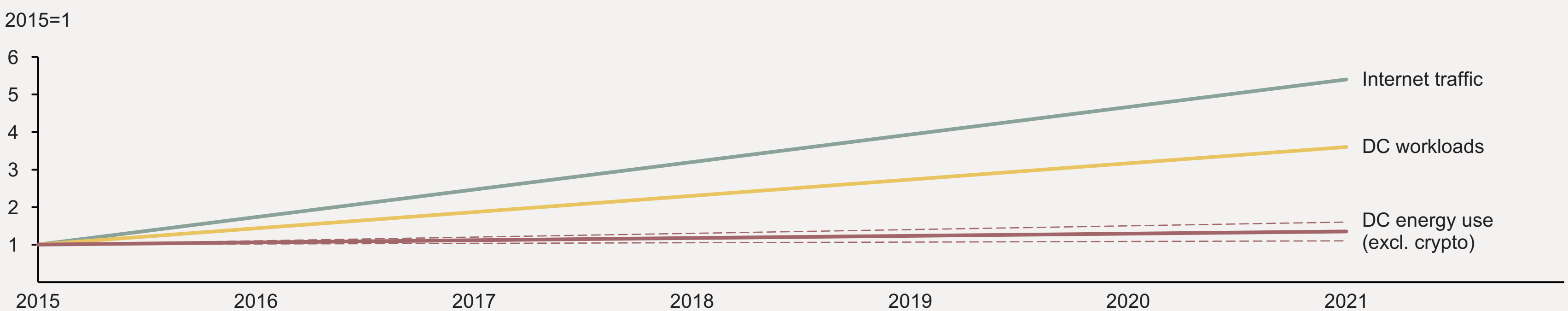
DATA CENTRES

There are three different types of efficiencies related to energy use in data centres



Source: Implement illustration

Efficiency gains have mostly served to offset a vertiginous increase in internet traffic and data centre workloads since 2015 (global numbers)



Source: IEA

Detailed methodology

HOUSEHOLDS

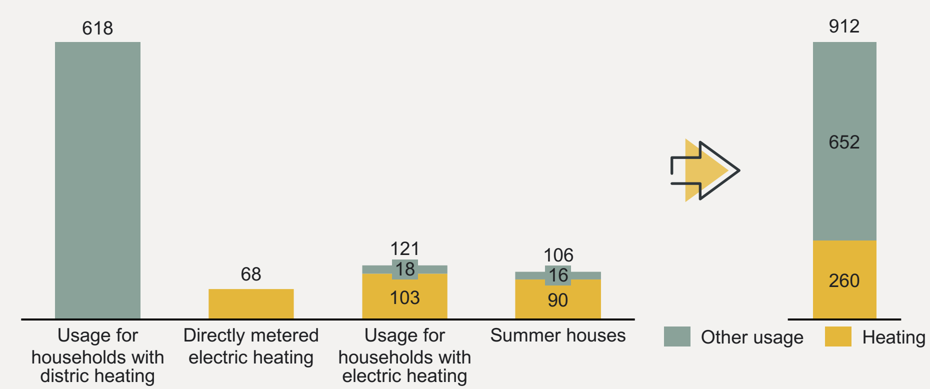
Potential savings – calculation methodology

Current electricity consumption × (Icelandic efficiency − Benchmark efficiency) ÷ Icelandic efficiency = Savings potential

Distribution between heat and other purposes

The electricity consumption of households with electric heating that are not individually metered cannot be accurately attributed to heat or other usage (cooking, lighting and appliances). Based on a dialogue with Orkustofnun, it is assumed that 85% of these households' consumption is used for heating. Consequently, we find that about 663 GWh are used for household ordinary consumption and 249 GWh for heating.

Calculation of type of electricity use in households, 2022
GWh



Non-heating potential savings – calculation methodology

- Based on the calculated electricity consumption for household usage other than heating, the reduction potential is found by comparing it with other Nordic countries.
- Eurostat provides detailed data on non-heating household consumption for EU countries from which the efficiency of selected countries is calculated by estimating the consumption per capita.
- The savings potential is then calculated by assuming that Iceland has the potential to same potential to reduce non-heating consumption in households as the one found for Denmark.

Heating potential savings – calculation methodology

- The reduction potential of switching from electric heating to heat pumps is calculated as the product of electricity used for heating and the reduction potential in percentages. The later number is based on the empirical study:
- Atlason, R.S., Oddsson, G.V. & Unnthorsson, R. (2017) Heat pumps in subarctic areas: current status and benefits of use in Iceland.

METHODOLOGY –

PRIMARY NON-FERROUS METALS

Potential savings – calculation methodology

Current electricity consumption − (Benchmark × Current production) = Savings

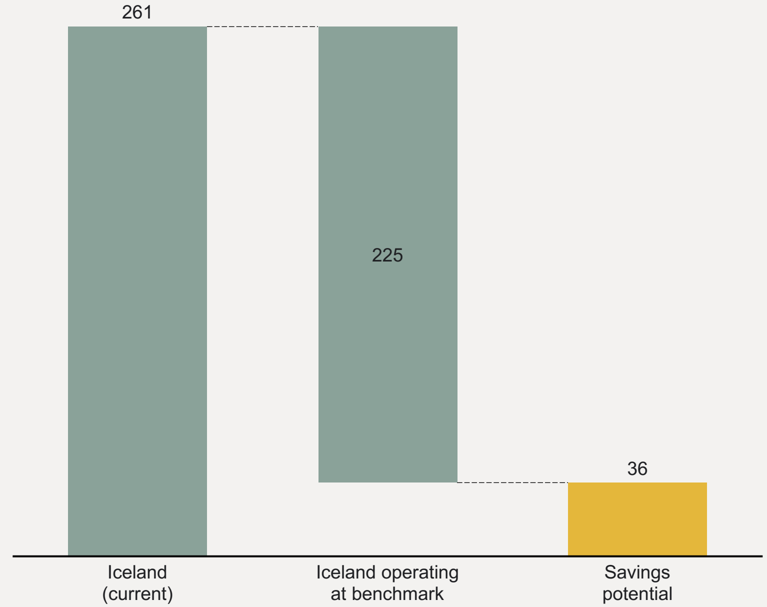
The calculation of the savings potential in the sector was based on the comparison between the current operation of the industry in Iceland and an industry benchmark. The benchmark was taken from the “Support study for the preparation of energy efficiency benchmarks in the context of the Revised ETS State Aid Guidelines”, a study ordered by the European Commission and prepared by ICF and Fraunhofer ISI.

The study defines the benchmark as follows: “Electricity consumption efficiency benchmark is defined as the product-specific electricity consumption per tonne of output achieved by the most electricity-efficient method of production for the product considered, taking into consideration the production processes in all countries currently covered by the EU ETS […].”

To establish the savings potential in the sector, we have followed three steps:

1. Identified the appropriate benchmark.
2. Multiplied the benchmark efficiency by the production of the industry in Iceland.
3. Subtracted the product from the reported consumption of electricity by the sector in Iceland.

Calculation of potential savings in primary non-ferrous metals
GWh



METHODOLOGY –

TRANSMISSION AND DISTRIBUTION LOSSES

Adjusted system losses – calculation methodology

$$\text{Current electricity consumption for metals} \times \text{Transmission losses (\%)} \div \left(1 - \text{Transmission losses (\%)} \right) = \text{Losses for metals}$$

$$\left(\text{Total losses} - \text{Losses for metals} \right) \div \left(\text{Total consumption} - \text{Consumption for metals} \right) = \text{Losses without metals (\%)}$$

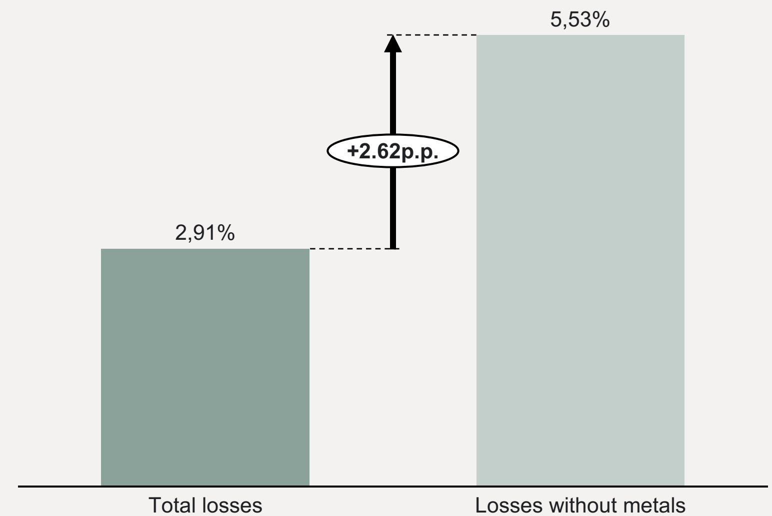
To offer a more accurate picture of the efficiency of the transmission and distribution grids in Iceland, we have excluded the metals industry from the calculation in accordance with the formulas above.

This includes the three Icelandic aluminium smelters as well as the factories which produce aluminium foil, silicon metal and ferrosilicon. All of these industrial plants are directly connected to the transmission grid and are located in relative proximity to their energy sources. The calculation was carried out in two steps:

1. Estimated the losses incurred in the transmission of electricity for the metals industry using the percentage of transmission losses in the overall system.
2. Subtracted the losses calculated above from the total losses and divided the result by the total consumption minus consumption by the metals industry to obtain the losses without metals.

The relative proximity of the industrial facilities in question to their sources of energy suggests that the relative losses incurred in the transport of the electricity used by these large consumers might be lower than those incurred by the rest of the system. This indicates that our calculations, which exclude losses as large as those observed in the overall transmission system, are a fairly conservative estimate.

Calculation of potential savings in transmission and distribution



METHODOLOGY –

PRIMARY ALUMINIUM PRODUCTION

Potential savings – calculation methodology

Current electricity for the smelting process consumption − (Benchmark for the smelting process × Current production) = Total savings

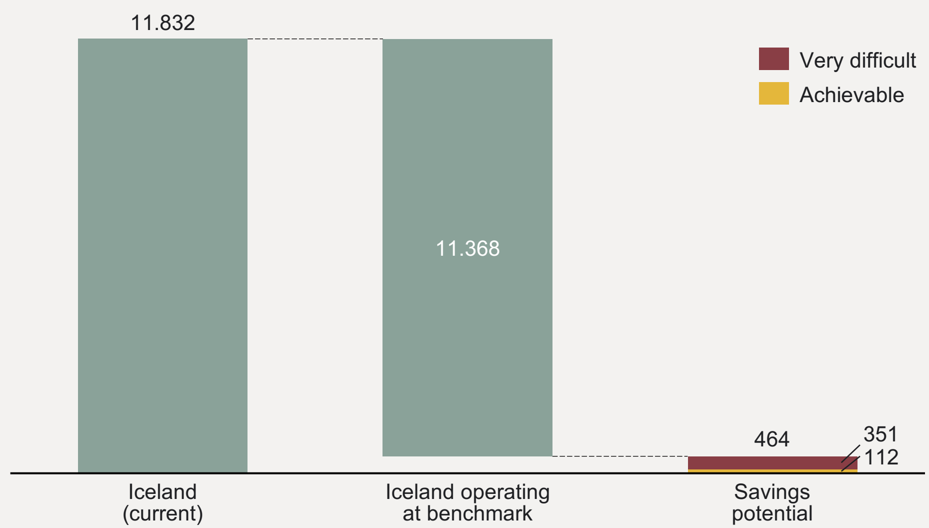
The calculation of the total technical savings potential in the sector was based on the comparison between the current operation of the industry in Iceland and an industry benchmark. The benchmark was taken from the “Support study for the preparation of energy efficiency benchmarks in the context of the Revised ETS State Aid Guidelines”, a study ordered by the European Commission and prepared by ICF and Fraunhofer ISI.

The study defines the benchmark as follows: “Electricity consumption efficiency benchmark is defined as the product-specific electricity consumption per tonne of output achieved by the most electricity-efficient method of production for the product considered, taking into consideration the production processes in all countries currently covered by the EU ETS […].” In the case of aluminium, the benchmark is broken down into the smelting process (electrolysis), anode production and the cast house. Due to significant differences such as the level of electrification in the cast house, which is typically higher in Iceland than in most other countries, differences in the value added to different aluminium products and the incorporation of scrap into the process to varying degrees, we focus exclusively on the smelting process itself to ensure comparability.

The savings potential in the sector was calculated in four steps:

1. Identifying the appropriate benchmark for the smelting process.
2. Multiplying the benchmark efficiency by the production of the industry in Iceland.
3. Subtracting the product from the consumption of electricity for the smelting process in Iceland, estimated using data provided by EFLA.
4. Qualifying the identified potential and classifying it into different ease to achieve categories based on industry expert interviews and our own analysis. The numbers shown here reflect the mid-point of a range estimated for each category.

Calculation of potential savings in aluminium smelting
GWh



METHODOLOGY –
FISHMEAL FACTORIES

Potential savings – calculation methodology

(Current electricity intensity − Benchmark) ÷ Current electricity intensity × Current electricity consumption = Savings

Potential savings in % = (Current electricity intensity − Benchmark) ÷ Current electricity intensity

The calculation of the savings potential in the sector was based on the comparison between the current operation of the industry in Iceland and an industry benchmark. The benchmark was taken from the final draft of the document "Best Available Techniques (BAT) Reference Document for the Slaughterhouses, Animal By-products and/or Edible Co-products Industries", a report authored by the Joint Research Centre of the European Commission.

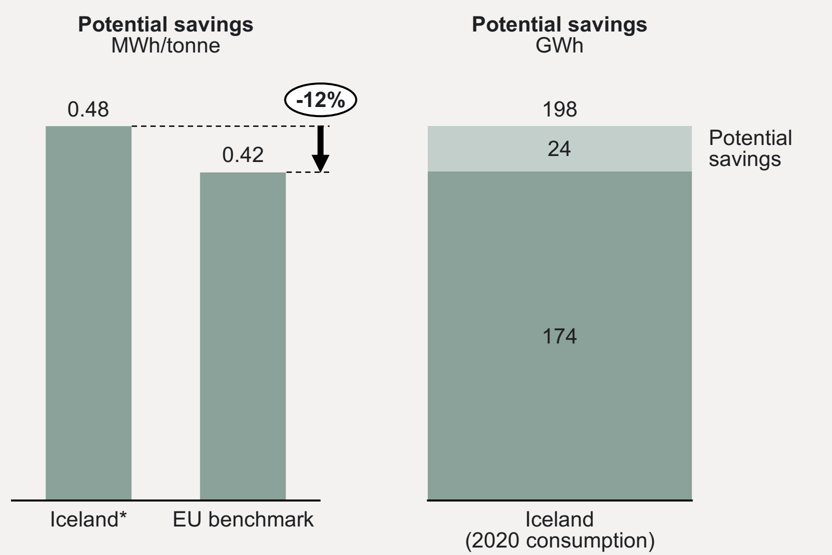
The benchmark corresponds to the "BAT-associated environmental performance levels (BAT-AEPLs) for specific net energy consumption in installations processing animal by-products and/or edible coproducts". Following the methodology used in the "Support study for the preparation of energy efficiency benchmarks in the context of the Revised ETS State Aid Guidelines" to set certain benchmarks, we have taken the lowest value in the range presented for the production of fishmeal.

To establish the savings potential in the sector, we have followed four steps:

1. Identified the appropriate benchmark.
2. Subtracted the benchmark from the current electricity intensity.
3. Divided the difference by the current electricity intensity to determine the potential savings in percentages.
4. Multiplied the potential savings in percentages by the industry's electricity consumption in Iceland to determine the total savings potential.

This methodology was chosen as a result of the data availability of the sector.

Calculation of potential savings in fishmeal factories



*Excl. factories primarily powered by oil

FERROALLOYS

Potential savings – calculation methodology

Current electricity consumption − (Benchmark × Current production) = Savings

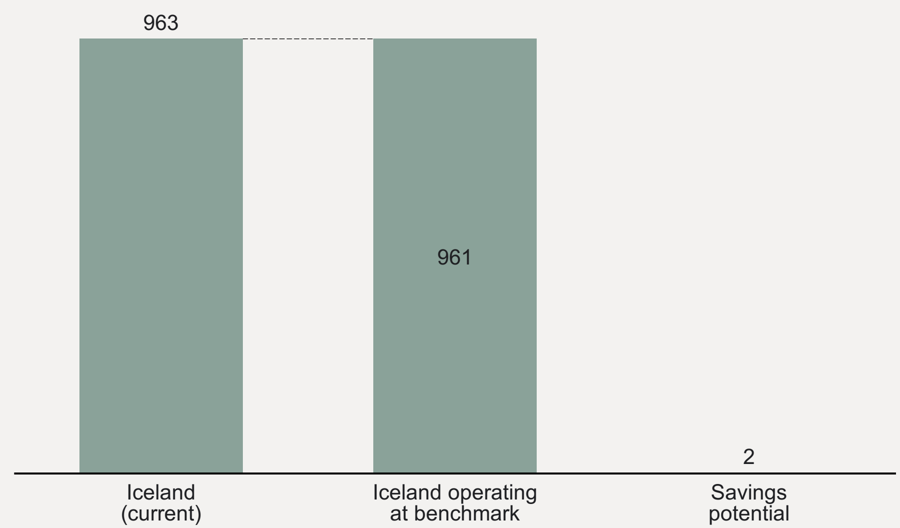
The calculation of the savings potential in the sector was based on the comparison between the current operation of the industry in Iceland and an industry benchmark. The benchmark was taken from the “Support study for the preparation of energy efficiency benchmarks in the context of the Revised ETS State Aid Guidelines”, a study ordered by the European Commission and prepared by ICF and Fraunhofer ISI.

The study defines the benchmark as follows: “Electricity consumption efficiency benchmark is defined as the product-specific electricity consumption per tonne of output achieved by the most electricity-efficient method of production for the product considered, taking into consideration the production processes in all countries currently covered by the EU ETS […].”

To establish the savings potential in the sector, we have followed three steps:

1. Identified the appropriate benchmark.
2. Multiplied the benchmark efficiency by the production of the industry in Iceland.
3. Subtracted the product from the reported consumption of electricity by the sector in Iceland.

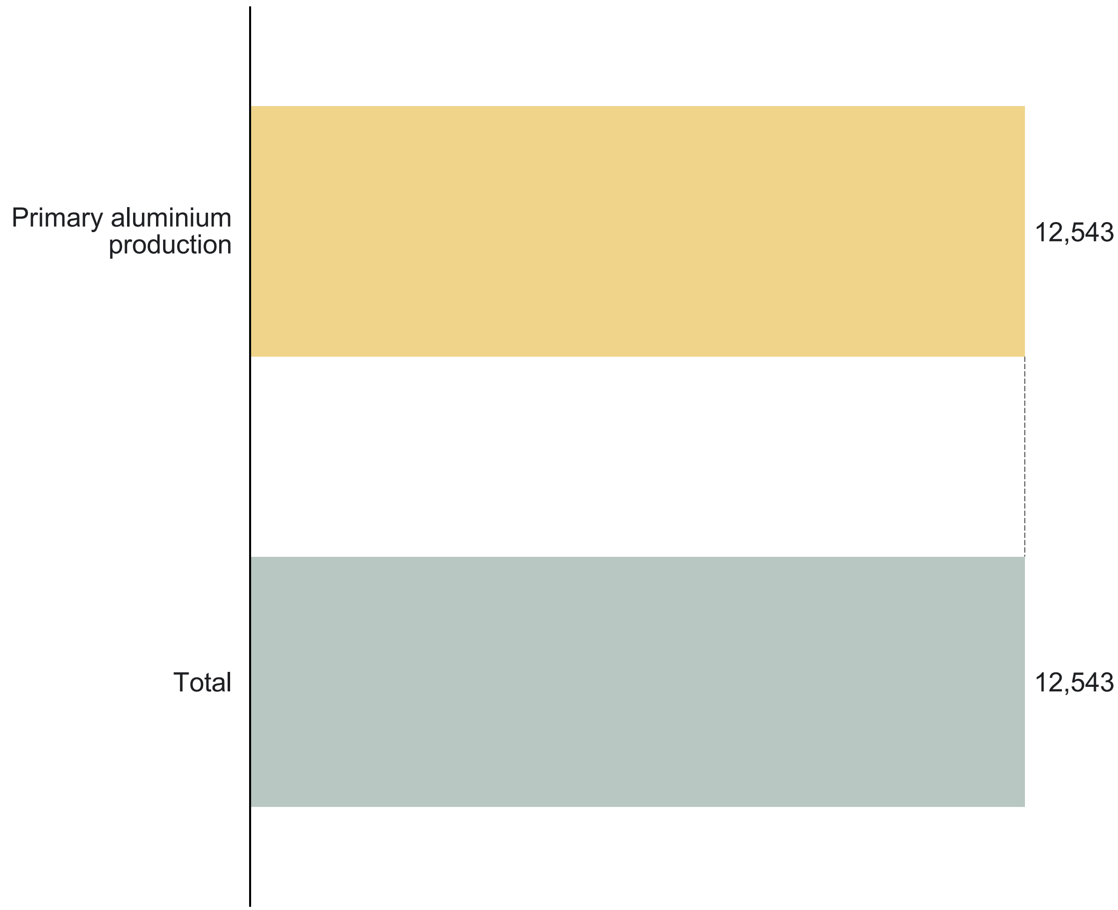
Calculation of potential savings in ferroalloys
GWh



Detailed energy splits

Primary aluminium production

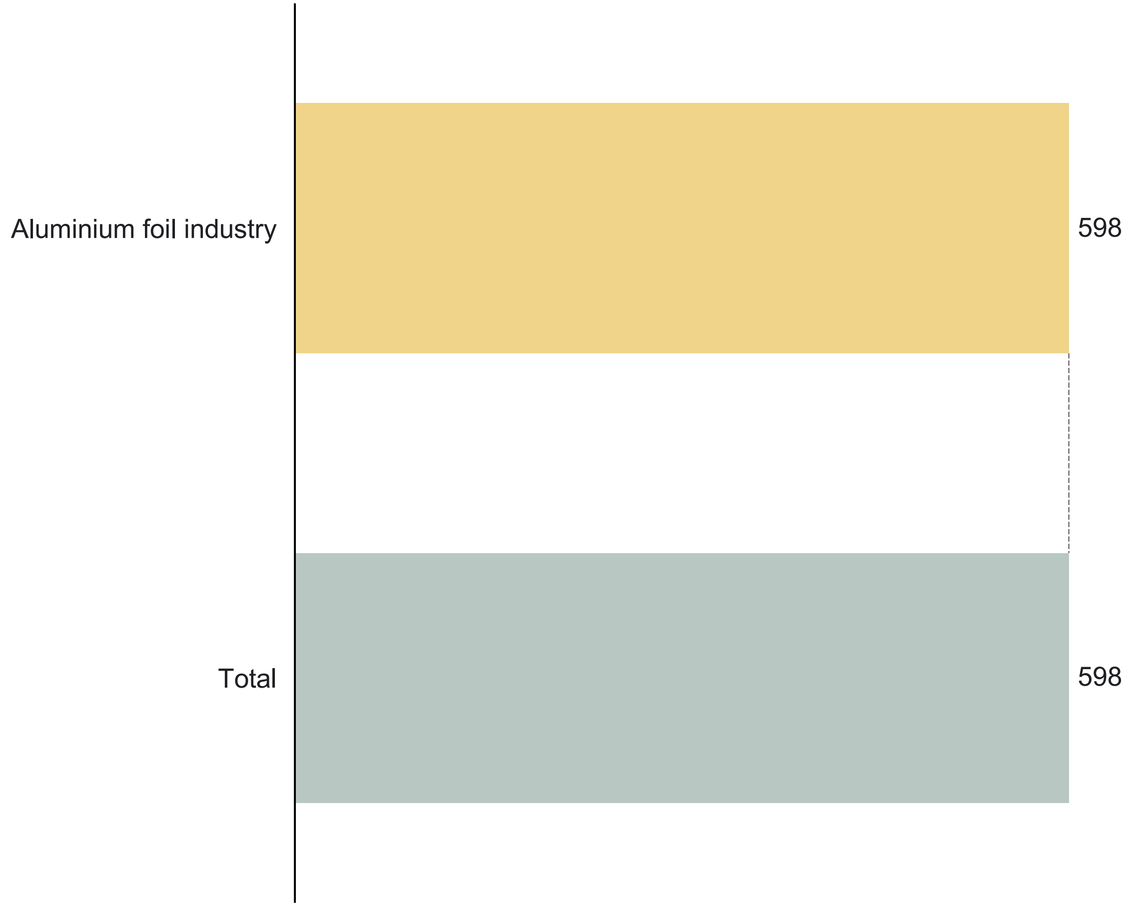
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Aluminium foil

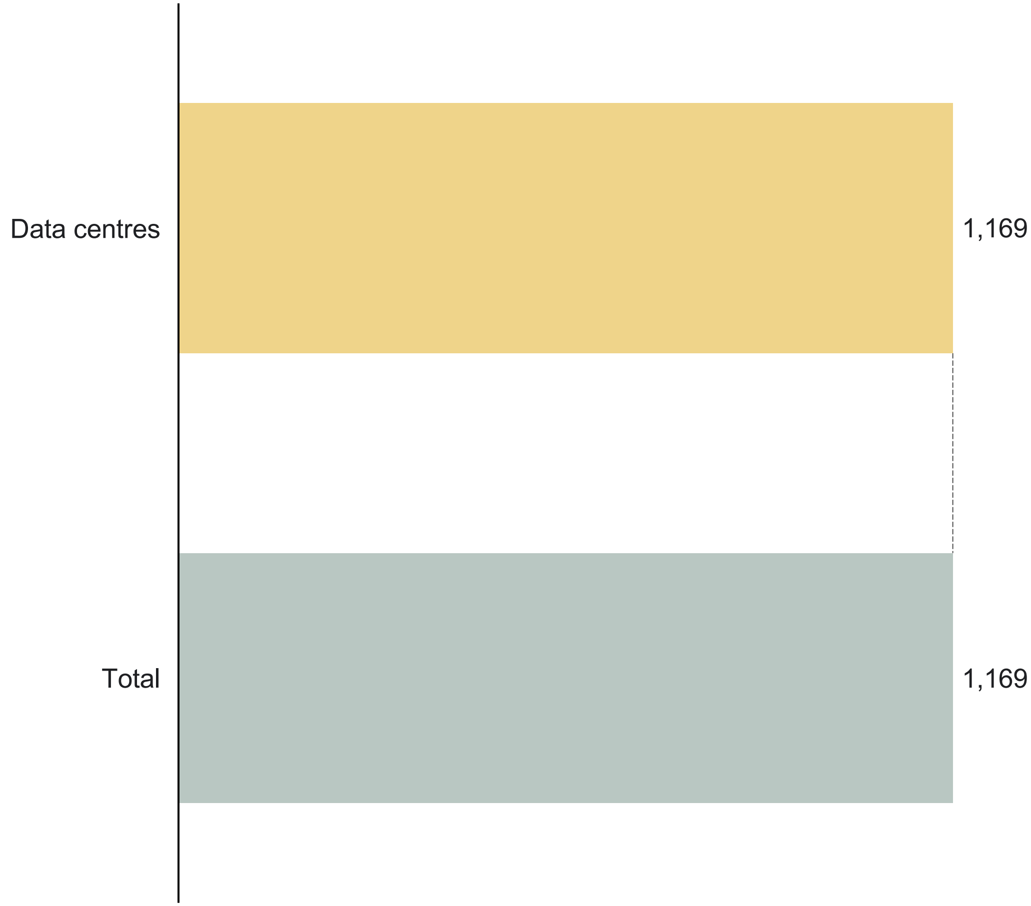
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Data centres

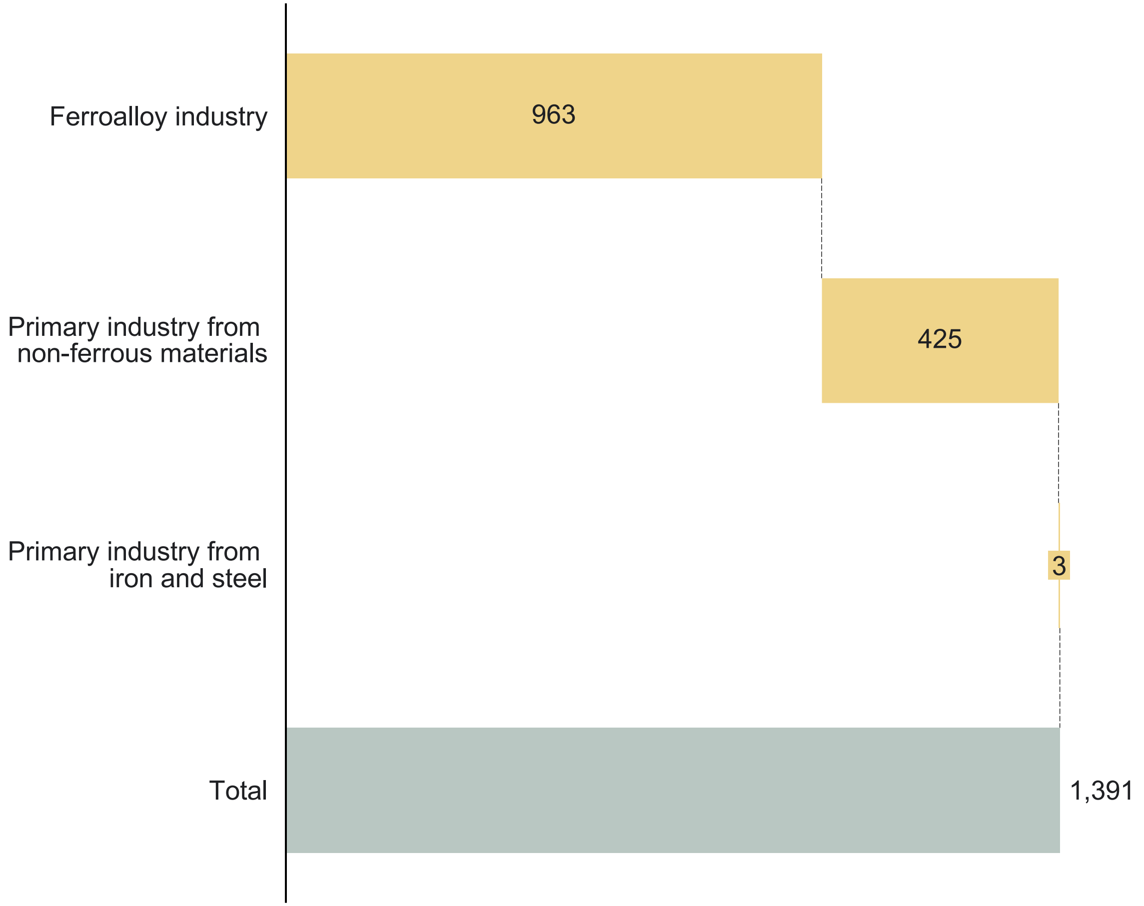
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Other metal industries

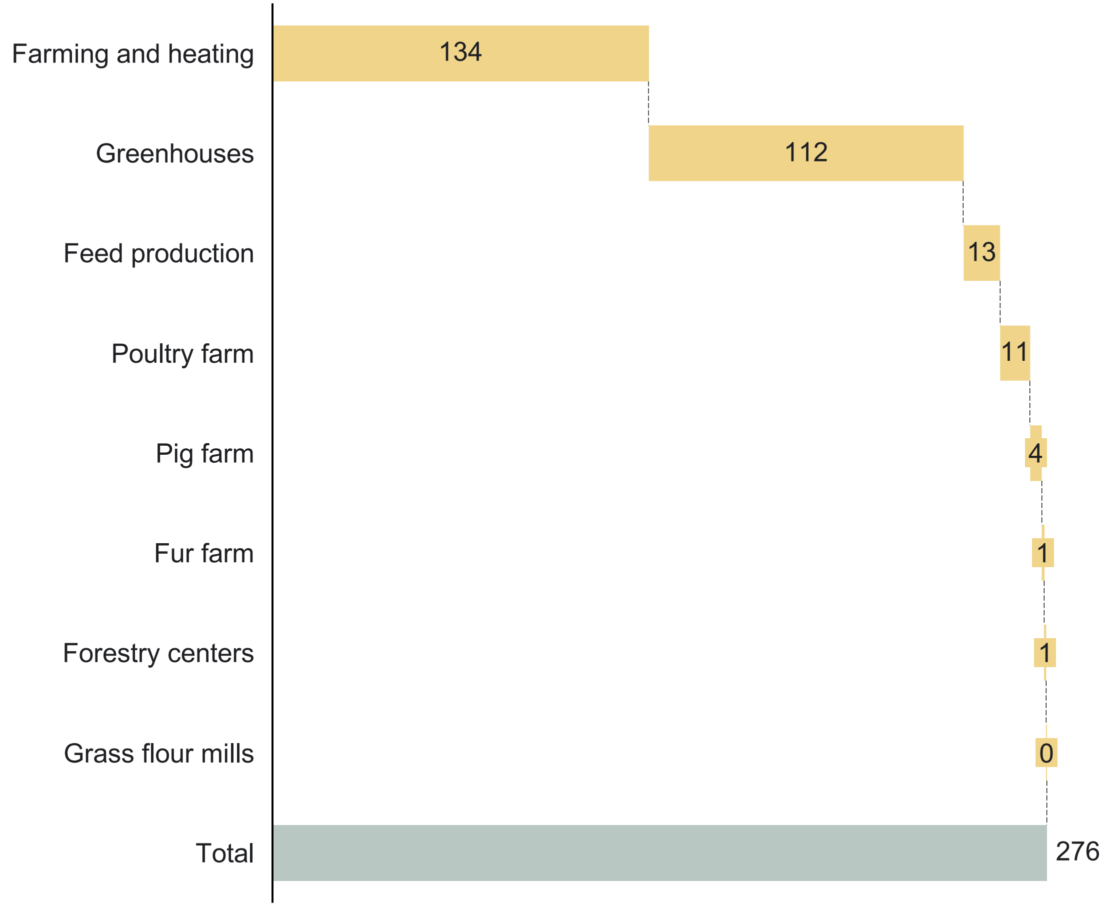
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Agriculture

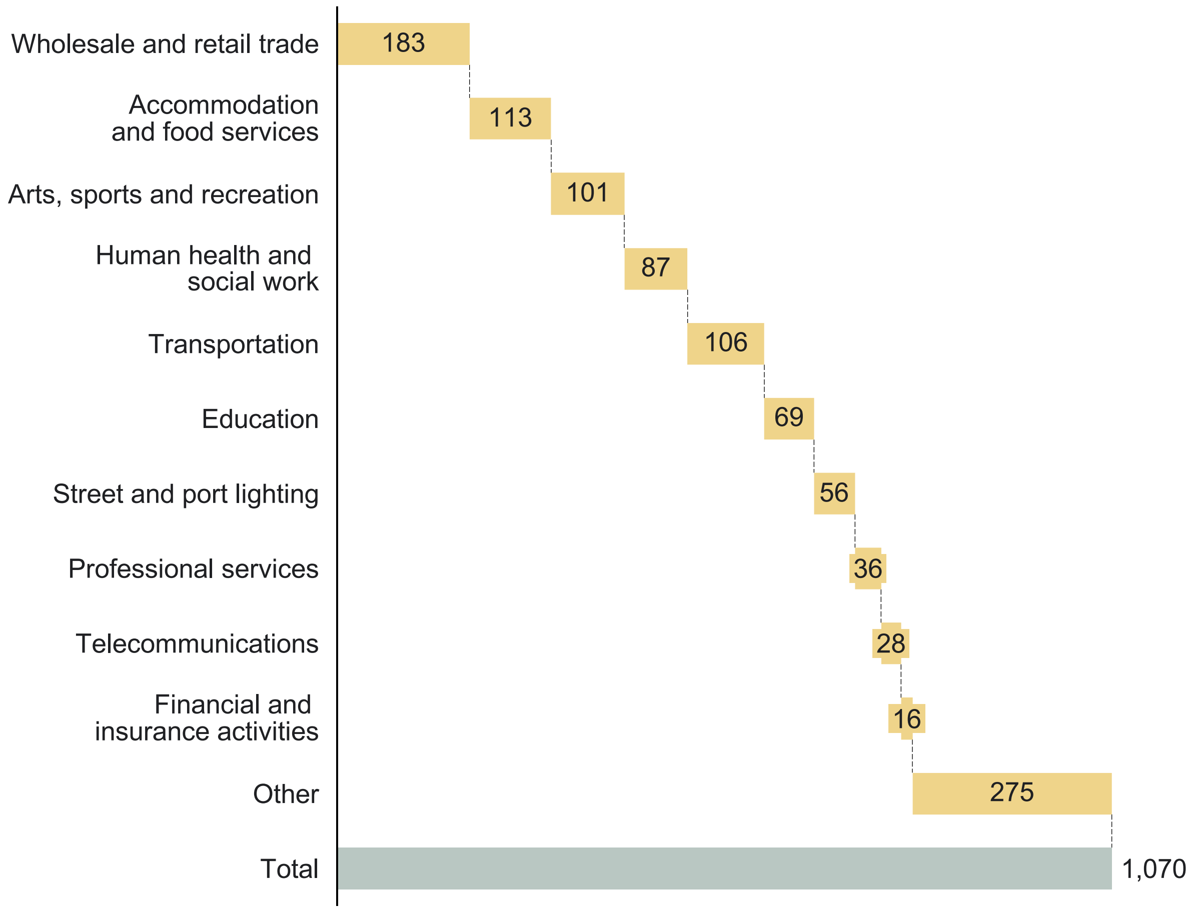
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Commercial and public services

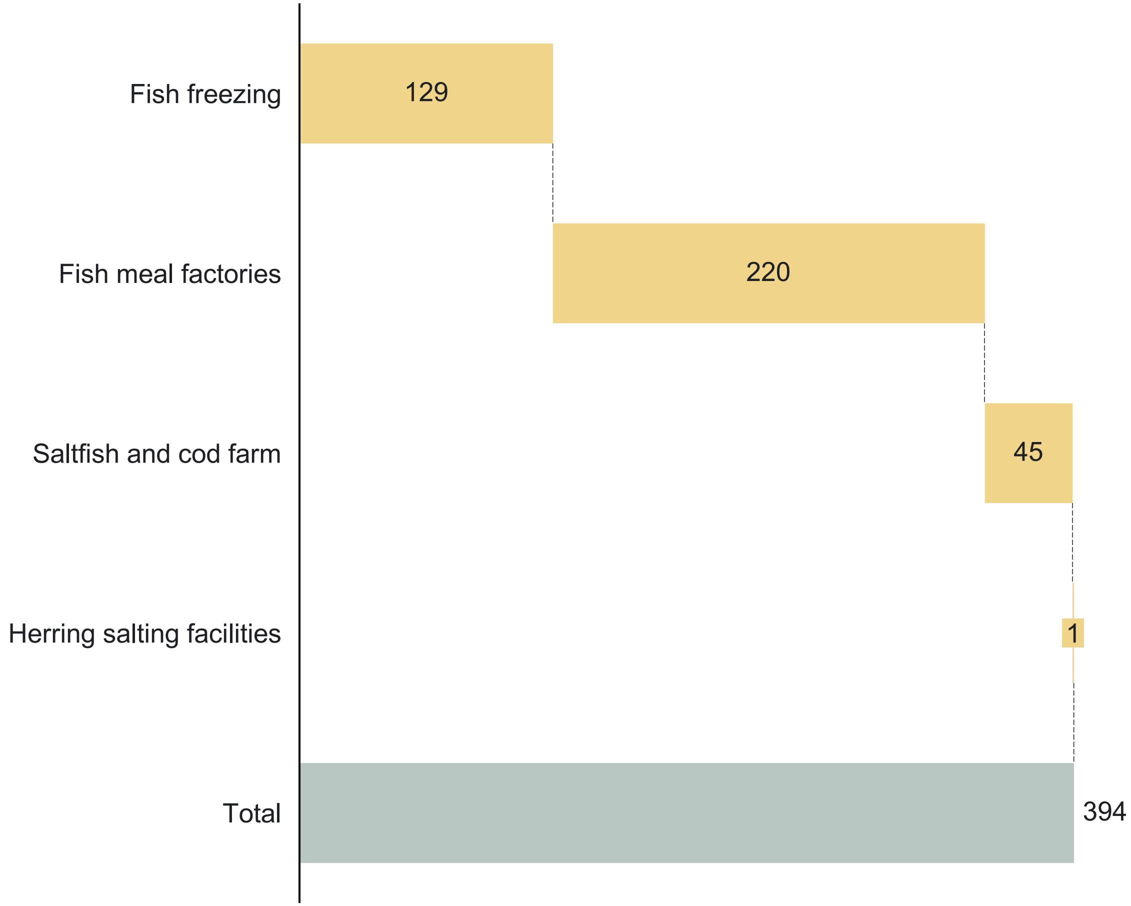
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Fish processing industry

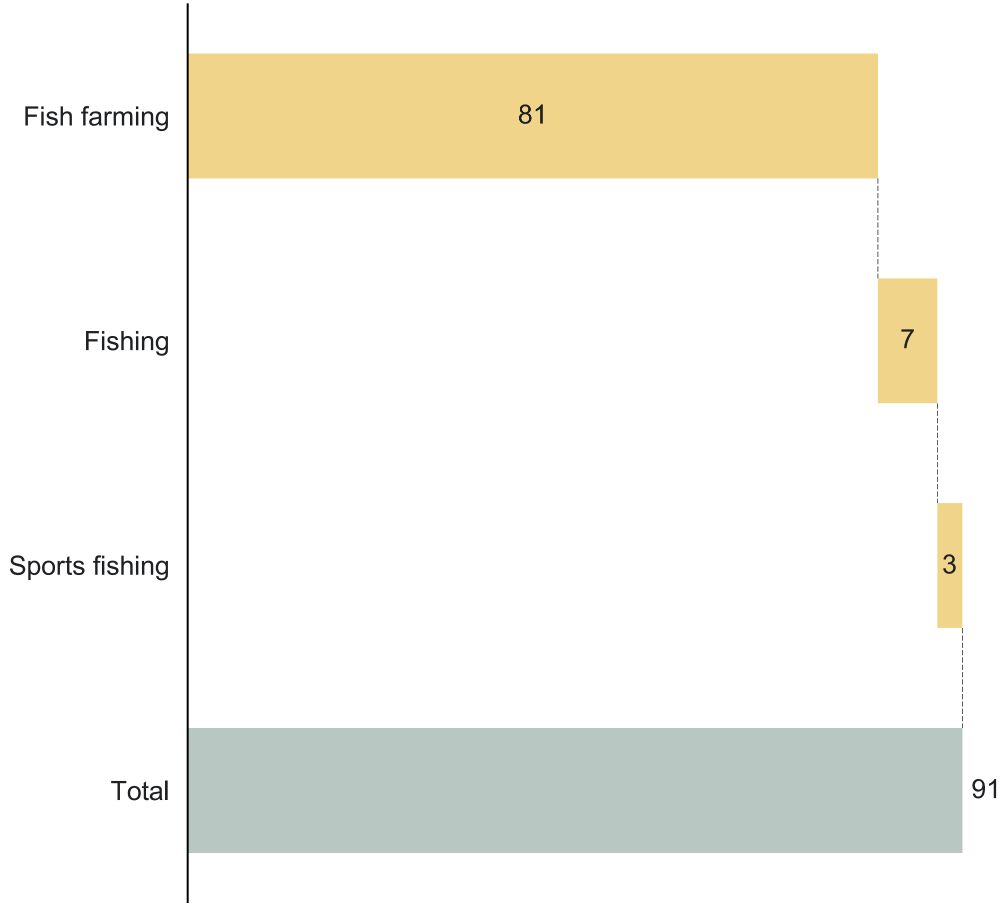
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Fisheries

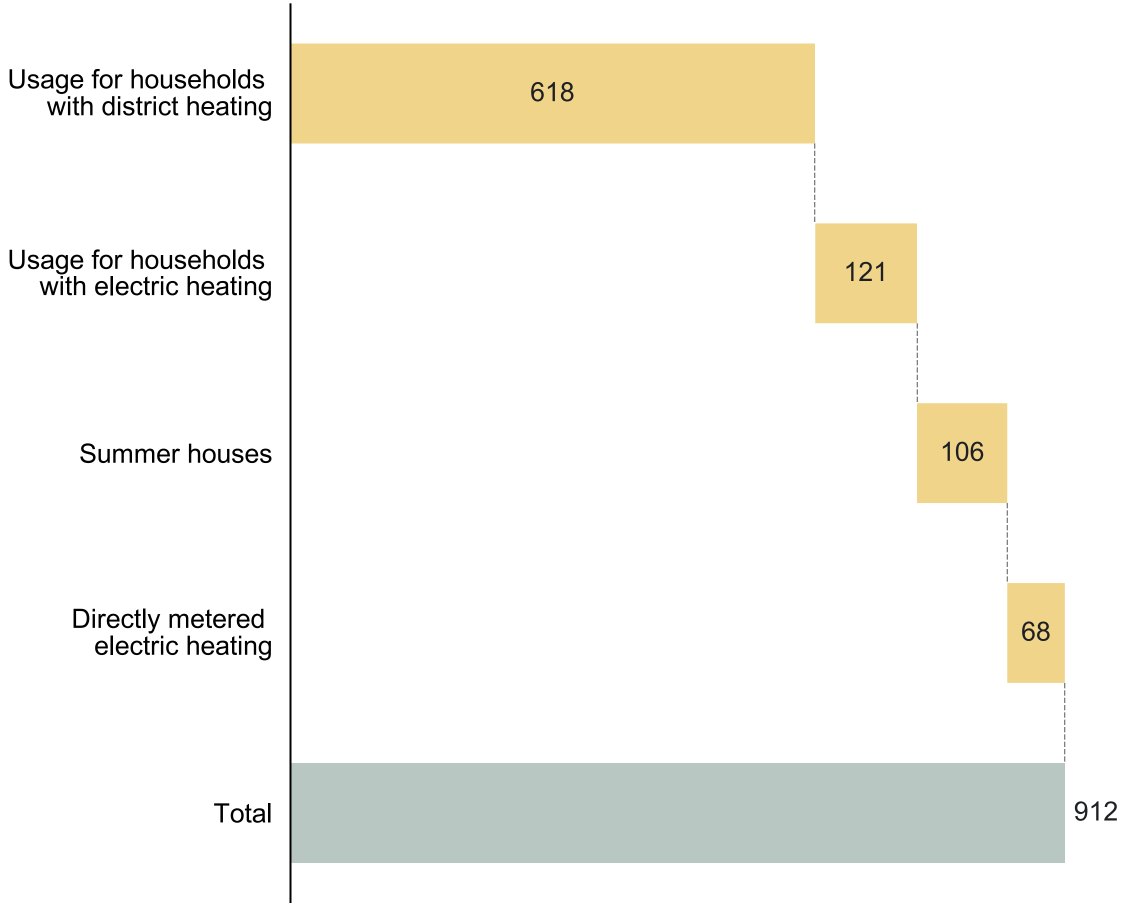
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Households

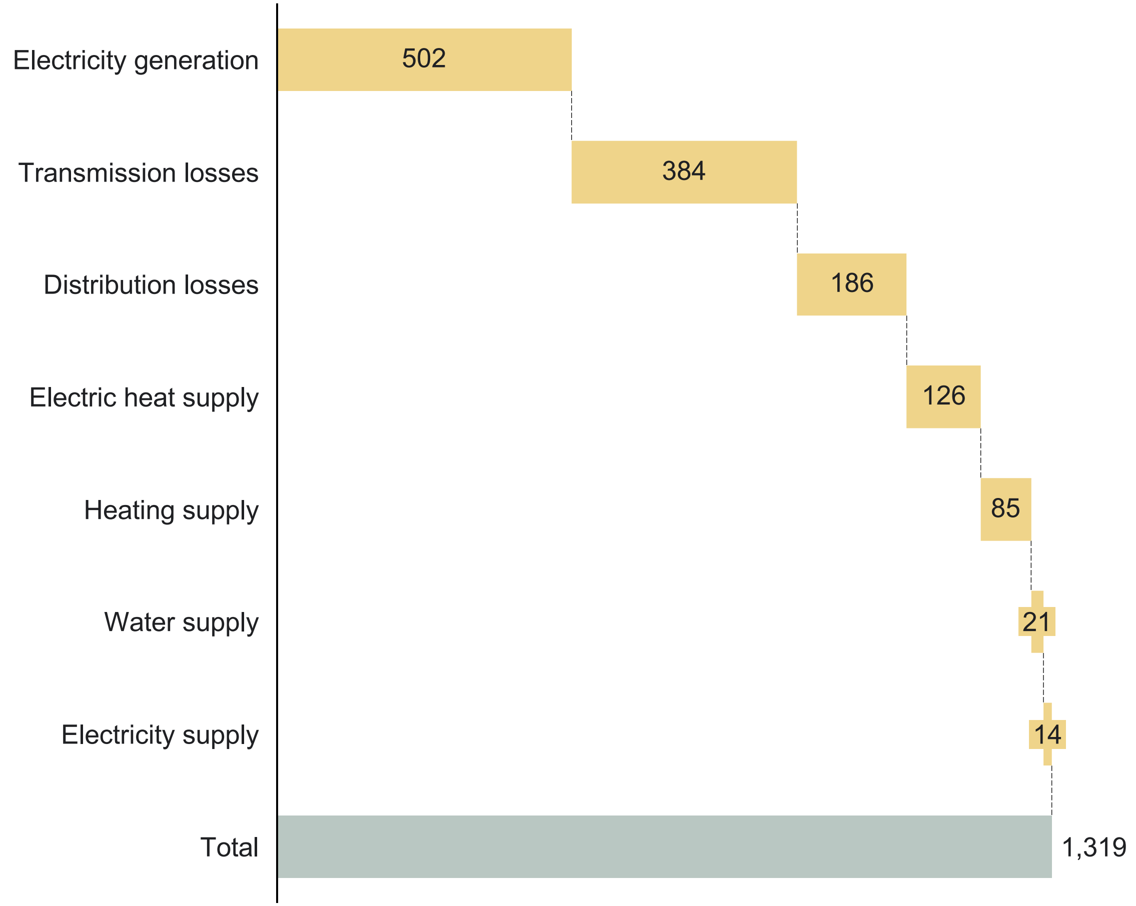
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Utilities and losses in the system

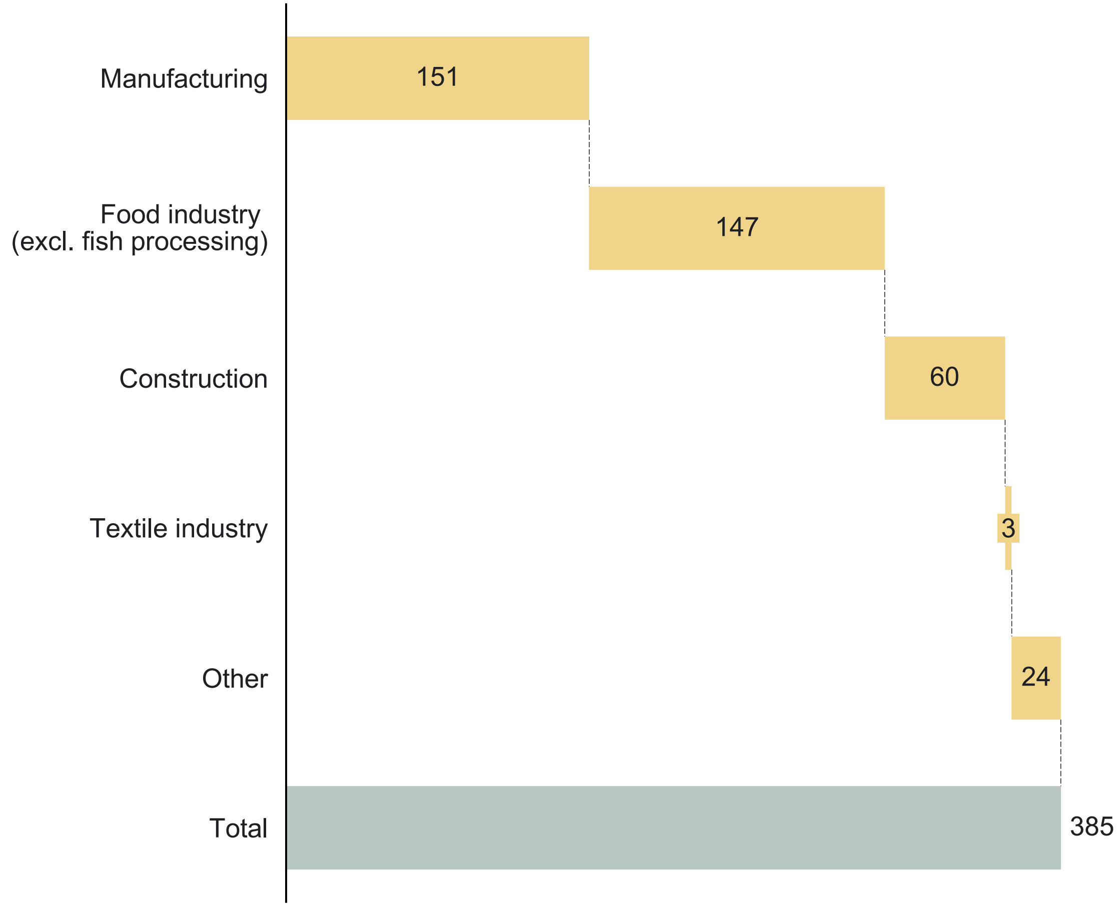
Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset

Other industries

Electricity consumption, 2022
GWh



Source: Orkustofnun, Consumption dataset