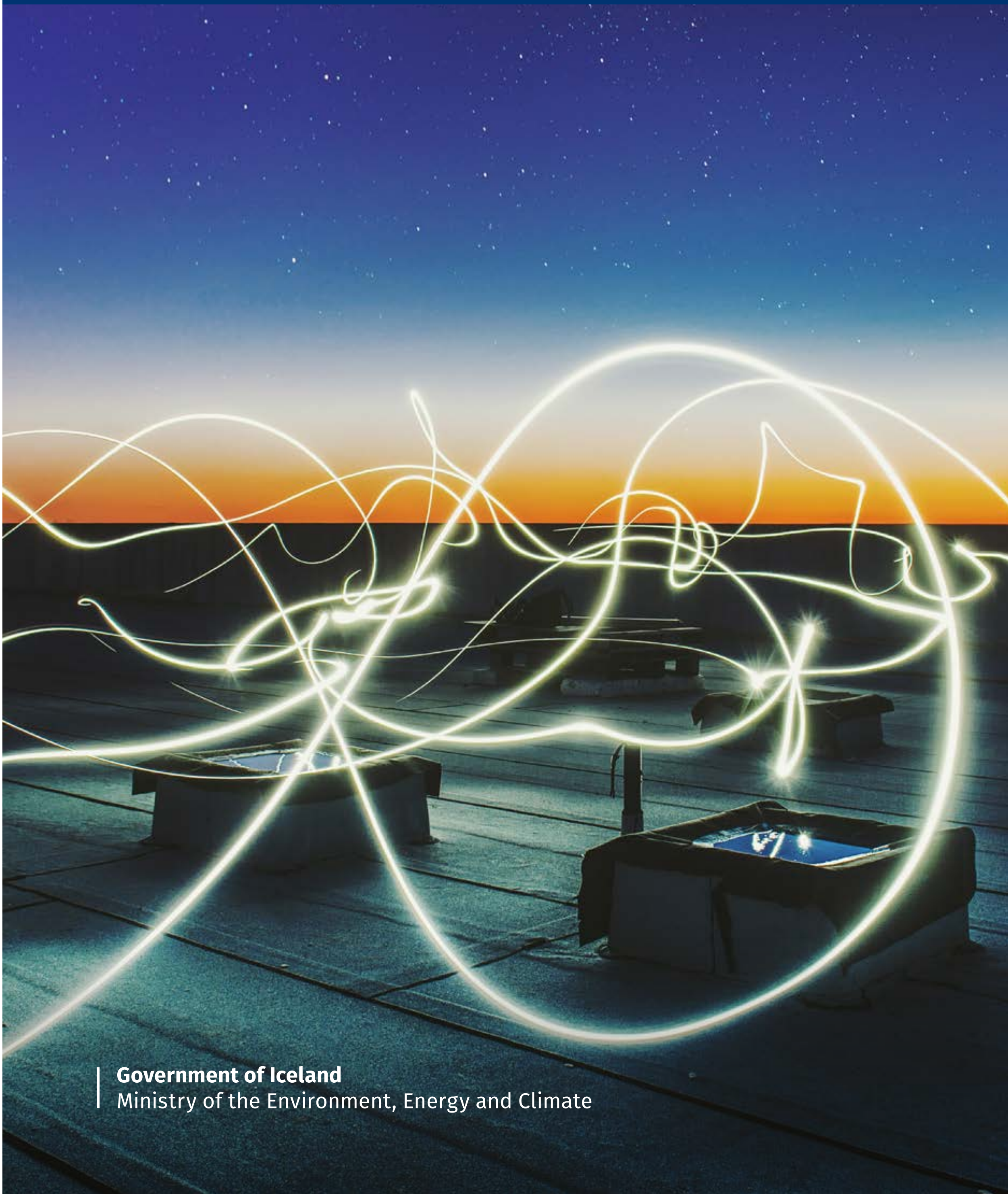
April 2024

Hydrogen and E-fuels Roadmap for Iceland



Government of Iceland
Ministry of the Environment, Energy and Climate

Hydrogen and E-fuels Roadmap for Iceland

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Executive summary

Energy concerns all Icelanders and is essential to their daily lives. Access to energy, i.e., heating, electricity, and fuel, is fundamental to the general quality of life in Iceland. In this context, the energy transition, or replacing fossil fuels with renewable energy, is necessary to combat the climate crisis. Therefore, the energy transition is crucial as the climate crisis is one of the most urgent challenges currently facing humankind.

The Icelandic Government has set ambitious targets for decarbonisation and sees the energy transition as one of the critical pillars in reaching these targets. By 2030, the Government aims to increase the share of renewable energy resources in the road transportation sector to 40% and maritime industry to 10% (as defined by the EU Renewable Energy Directive). The Government's policy aims to achieve carbon neutrality and fossil fuel-free Iceland by 2040.

The Icelandic Government developed this Roadmap to provide a clear context concerning the production, transport, and consumption of green hydrogen and e-fuels, outlining its vision and the necessary steps to reach a sustainable energy future.

Green hydrogen and related chemicals derived from hydrogen (e.g., e-ammonia, e-methanol, e-diesel, and e-kerosene) will significantly decarbonise the world economy as feedstock and fuel. It will play a key role in sectors heavily relying on fossil fuels, such as heavy-duty road transport, maritime and aviation sectors, and industries that are hard to decarbonise such as the fertiliser, steel, and refinery industries. In Iceland, hydrogen and e-fuels are the keys to decarbonising the transportation and maritime sectors.

This Roadmap addresses the decarbonisation of sectors with heavy fossil fuel use, both for Iceland's Effort Sharing Sectors (ESR), such as heavy-duty road transport, fishing, domestic navigation, and domestic aviation, as well as sectors that fall under the EU Emissions Trading System (ETS), which includes emissions from fossil fuels in international aviation and international navigation.

Emissions in Iceland from the ESR and ETS sectors (excluding "Land Use, Land-Use Change, and Forestry," or LULUCF) totalled 4,820 kt CO_2e in 2020. Road transport accounts for 17% of the GHG emissions, maritime application 11%, mainly from fuel use in fishing vessels, and domestic aviation 0.3%. International aviation accounts for 6%. International navigation accounts for 2%, but fuel purchases in this category occur mainly outside of Iceland.

In 2020, COVID-19 heavily impacted fuel use and emissions. In 2018, combined emissions from these sectors reached a historical peak at 6,362 kt CO_2e. Fuel use for international aviation was five times higher than in 2020, and the segment made up 20% of total emissions. Hence, it is worth noting that the status quo emissions and fuel data from 2020 are strongly affected by the transportation restrictions and deviate significantly from the trend leading up to that year. The official projected fuel use by the Icelandic Energy Authority considers the expected temporary impact of COVID-19 and the return to business as usual.

Addressing these emissions requires actions before 2030. This decade, the Icelandic Government will pursue the necessary steps to support the development of the infrastructure needed for Icelandic companies to use hydrogen fuelled trucks, to support the decarbonisation of the heavy-duty road segment parallel to the commercialisation of the required vehicles. This will be essential to reach a 40% renewable energy share in the road transport segment by 2030. E-fuels such as e-methanol, e-ammonia, and e-diesel are expected to decarbonise the maritime sector significantly. The Government will encourage further pilots focused on the maritime industry. Furthermore, the Government has drafted a recommendation stating that 20% of fuel usage in domestic aviation could come from renewable sources by 2030. Finally, pilots for e-kerosene production and blending quotas for aviation will be evaluated as well as the economics of import options supporting the aviation sector's decarbonisation.

By 2030, the annual hydrogen demand for domestic use in heavy-duty road transport, maritime applications, and domestic aviation could reach ten thousand metric tonnes per annum (10 ktpa), requiring 0.6 TWh for hydrogen and e-fuel production. Additionally, the electrification of road transport could require an additional 1.3 TWh of renewable power by 2030. Reaching a 10% share of renewable energy for fuels in international aviation by 2030 would require a speedy ramp-up of either own production capacities or securing imports. Theoretically, to reach a 10% renewable energy share supplied with domestic production of fuels by 2030, an additional 25 ktpa could be required, or another 1.3 TWh of renewables, bringing total requirements to 3.2 TWh. These equal ~17% of Iceland's current annual power generation.

To reach these 2030 ambitions, considerable investment in power generation, transmission capacities, and other infrastructure is required. The estimated total cumulative investment could range from ISK 160-275 billion to meet domestic goals for the ESR sectors by 2030. This includes power generation, electrolyser, hydrogen and e-fuel production, distribution, and downstream use. Additionally, assuming potential ETS volumes would be met with domestic renewable fuel production, an additional ISK 90-160 billion could be required across power generation, transmission, fuel production, and potential distribution infrastructure. These cumulative investments could range from ISK 160-440 billion, or, to put into perspective, 6-12% of Iceland's 2022 gross domestic production (GDP).

Beyond 2030, the focused development and ramp-up of hydrogen and e-fuels and associated infrastructure will continue to decarbonise road transport, maritime, and aviation sectors to ensure Iceland's 2040 goal of carbon neutrality and fossil fuel independence is met. Therefore, to put Iceland on a trajectory for the 2040 ambitions, investment in infrastructure and the energy system must start this decade.

A full stop of fossil fuel use in 2040 across road transport, domestic maritime, and aviation sectors could require ~7 TWh, equivalent to 30-35% of Iceland's annual renewable energy generation. If a complete conversion of fuel use in international aviation and international navigation were to be addressed with domestic production, an additional ~16 TWh could be required, bringing the total energy needed to ~23 TWh, more than the current annual energy generation in the country. The Government will continue to support research and innovation in sustainable aviation fuels production in Iceland. It will also evaluate the economic impact of imports and domestic production of fuels.

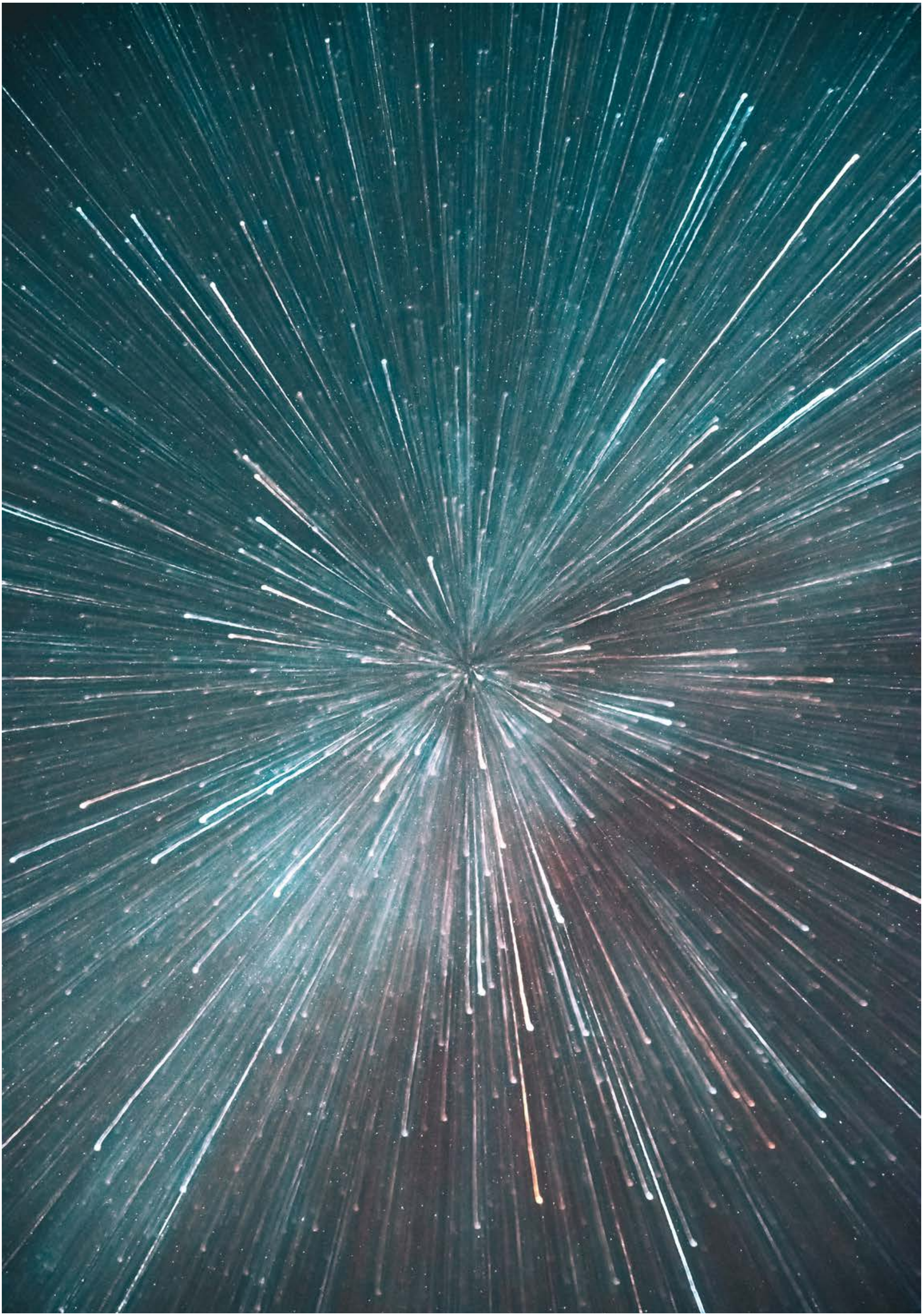
To achieve these ambitions successfully and sustainably, several regulatory, fiscal, and economic tools could support this mission, e.g., public de-risking instruments, a regulatory framework supporting green investments and penalising fossil-based policies, and financial incentives and subsidies.

Iceland is in an excellent position to produce green hydrogen and e-fuels by utilising its vast renewable energy resource potential. The competitive electricity prices, availability of green baseload energy supply, and 100% green electricity grid make it possible to produce the required green hydrogen sustainably at a competitive price. Along with domestic use, opportunities for green hydrogen and e-fuel exports will be assessed, as well as their impact on accelerating domestic adoption, developing new local industries, and reaching Iceland's decarbonisation goals.

List of abbreviations

CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
CUTE	Clean Urban Transport for Europe
DME	Dimethyl Ether
ECTOS	Ecological City Transport System
EOY	End of Year
ETS	Emissions Trading System
EU	European Union
EEA	European Economic Area
EV	Electric Vehicle
GHG	Greenhouse Gas
GW	Gigawatt
H2	Hydrogen
H2ME	Hydrogen Mobility Europe
HCV	Heavy-Commercial Vehicles
HDV	Heavy-Duty Vehicles
HRS	Hydrogen Refuelling Station
IEA	International Energy Agency
kt	Kilotonne (metric)
ktpa	Kilotonne per annum (metric)
kW	Kilowatt
kWh	Kilowatt-hour
LCV	Light-Commercial Vehicles

LULUCF	Land Use, Land-Use Change, and Forestry
MW	Megawatt
RES	Renewable Energy Shares
SAF	Sustainable Aviation Fuel
SMART H2	Sustainable Marine and Road Transport – Hydrogen in Iceland
TWh	Terawatt-hour
VAT	Value Added Tax
YOY	Year-Over-Year

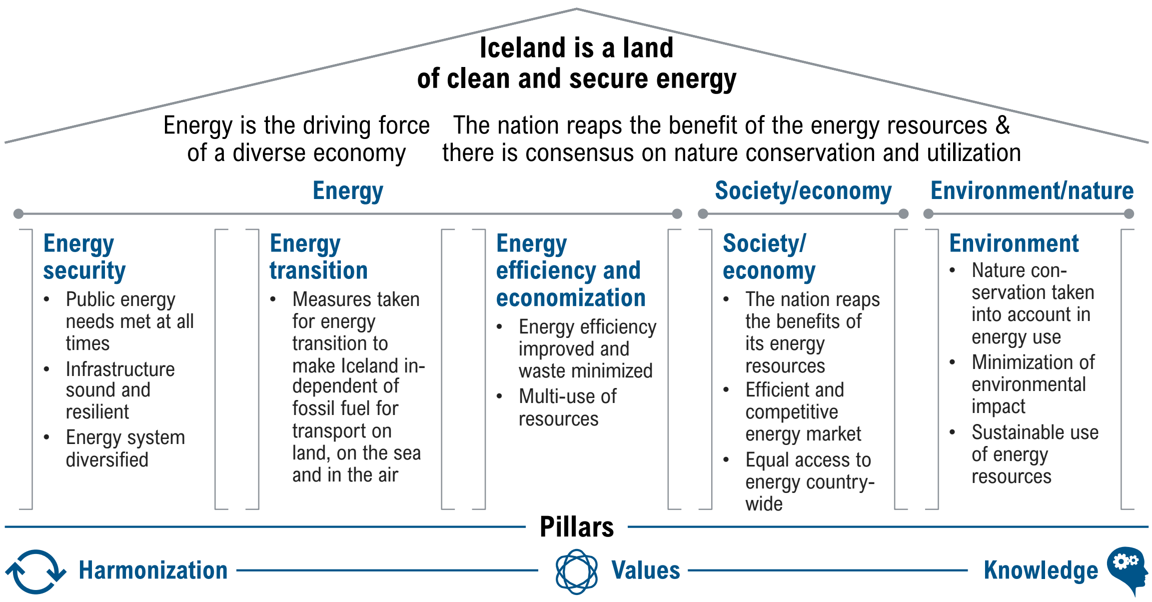


1. Goal: Iceland's decarbonisation and energy targets

Iceland is strongly committed to fighting the causes of climate change and is very well positioned to do so. About 85% of Iceland's primary energy supply is derived from domestically generated renewable energy sources. This is the highest share of renewable energy in any national total energy budget. However, the country aims to increase that share even further, focusing in recent years on setting ambitious decarbonisation targets underpinned by a clear energy policy and ensuring follow-up on required actions. These goals include improving energy efficiency and maximising the value of energy by utilising by-products from energy, industry, and waste management, wherever feasible.

In September 2020, the Icelandic Government published a long-term Energy Policy for 2050, encompassing a clear vision of a sustainable energy future. The long-term objective of the energy transition is Iceland's independence from fossil fuels and meeting all the country's energy needs using non-fossil sources by 2040.

The Energy Policy includes five guidelines with 12 objectives built on three pillars.



Source: The Icelandic Government (A Sustainable Energy Future – An Energy Policy to the year 2050), Roland Berger

Figure 1. Iceland's long-term Energy Policy for 2050 - Guidelines, objectives, and pillars.

As part of these efforts, the Icelandic Government published an Energy Policy Action Plan, including 48 actions to support the 12 objectives.

Action ***"A.4 Hydrogen/e-fuels"*** is focused on supporting research and development of hydrogen- and e-fuel production as part of the domestic energy transition, focusing on heavy-duty transportation and maritime applications. Additionally, the Government will explore infrastructure requirements for domestic hydrogen production and distribution, the future option of green hydrogen exports, and opportunities for international collaborations.

Furthermore, in October 2020, the Government put forth a new Climate Strategy, boosting efforts to reach the goals set out in the Paris Agreement, along with a Climate Action Plan focused on how to reach these ambitious goals.

As part of its Climate Action Plan 2020, Iceland:

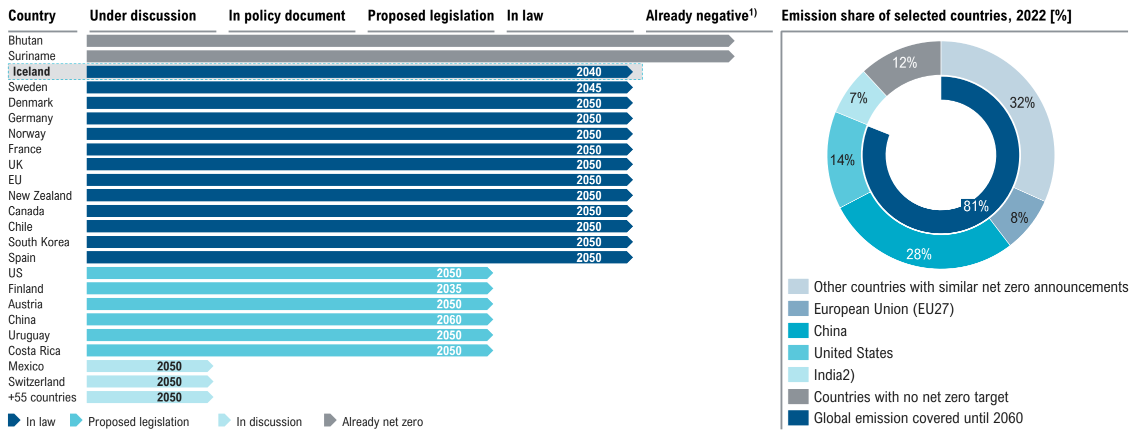
1. **Has set goals to reduce emissions by 40% by 2030 compared to 2005 levels in the EU effort sharing regulation (ESR) sectors,**
2. **Aims to achieve carbon neutrality by 2040, and**
3. **Plans to spend a minimum of ISK 46 billion[1] by the end of 2024 to reach these targets.**

Among the steps outlined in the plan is a ban on registering new petroleum and diesel vehicles after 2030. In June 2021, Iceland passed legislation that included the goal of becoming carbon neutral by 2040. The 2040 target is the earliest target of any country passed as law, displacing Sweden's 2045 target. Additionally, the Icelandic Government further enhanced its climate action ambition to target a 55% reduction of greenhouse gas emissions by 2030 compared to 1990. Furthermore, the country has set the goal to reach fossil fuels independence by 2040.

Over 130 countries, representing over 80% of global GHG emissions, have committed to net-zero emissions by 2060.[2] Global efforts need to be dramatically increased to reach the outlined goals in the Paris Agreement, and Iceland aims to be a role model for other nations to follow the same path.

[1] Includes direct investments and incentives (e.g., in the form of lower taxes).
[2] Climate Action Tracker (2022); Net Zero Tracker (2022).

Net-zero commitments by country



1) Only Bhutan and Suriname have already achieved carbon neutrality due to large offset with forestry activities; 2) Net zero emission until 2070

Source: IEA, Energy & climate intelligence unit, Roland Berger

Figure 2. Net-zero commitments by country.

Reaching these ambitious targets will be a monumental task that requires clear guidelines from the Government, substantial investments in new technologies, and public acceptance.

Iceland has undergone two energy transitions in the last century and is uniquely positioned to decarbonise the transport sector. As about 85% of households are heated with geothermal energy and almost 100% of the electricity production is generated from renewable sources, emissions mainly stem from the industrial, transport, waste management, maritime, and agricultural sectors.

The largest contributors to Iceland's current domestic GHG emissions profile are the metal industry, transportation, and fishing.

Emissions from the metal industry have increased over the last 30 years with the expansion of the aluminum industry in Iceland. Technological advances in the past decade have reduced emissions, but the sector still contributed 37% to GHG emissions (domestic emissions and emissions from international transport without considering emissions from LULUCF) 2020.

Notably, emissions from the metal industry fall under the EU-ETS accounting system, not Iceland's Effort Sharing Regulation targets. According to the EU, the ETS was implemented for international sectors to "ensure that the emissions reductions take place where it is cheapest to do so".[3] Iceland's fully renewable grid has attracted energy-intensive indus-

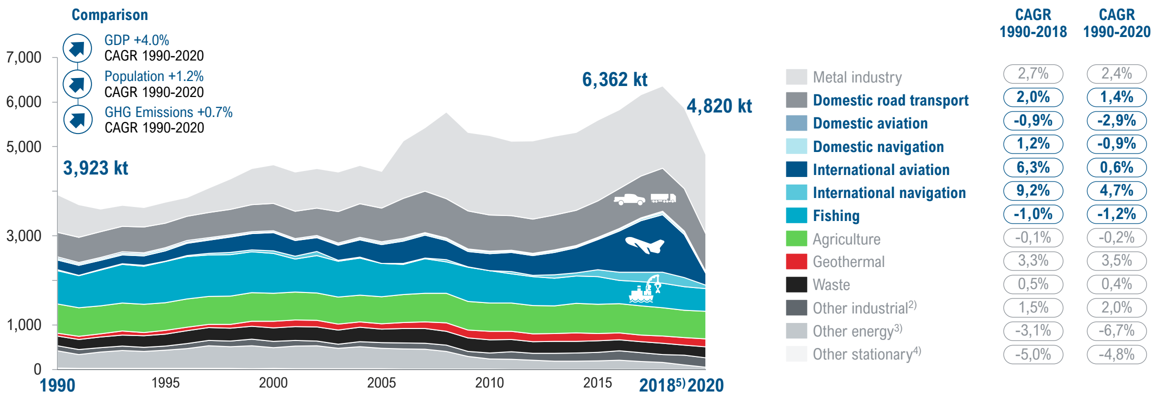
[3] European Union, https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3542 (July 2021).

tries that otherwise could have been placed in locations with more intensive emissions profiles. Emissions from the metal industry stem from the production processes, and hydrogen plays a limited role in Iceland's industry.

The other significant emissions contributor, transportation, has also increased in the last decade mainly due to increased tourism and currently contributes to 18% of GHG emissions. This sector relies almost entirely on the imports of fossil fuels.

The Icelandic Climate Action Plan 2020 outlines clear decarbonisation targets for the road transport, domestic navigation, and fishing sectors. The Climate Action Plan is supported by new energy policies outlined in the long-term Energy Policy for Iceland to 2050.

GHG emissions in Iceland by sector (excl. LULUCF[1])., 1990–2020 [kt CO_2e, %]



1) Land use, land use change and forestry (LULUCF); 2) Includes mineral-, chemical-, and other producing industries; 3) Includes energy-, manufacturing industries and fuel combustion from other sectors; 4) Includes some minor GHG emissions from other sectors such as commercial, institutional and residential buildings; 5) 2018 was the year with the highest fossil fuel use, that is the reason why it is highlighted here

Source: World bank, Iceland National Inventory Report, Statistics Iceland, Roland Berger

Figure 3. Iceland's domestic greenhouse gas emissions (1990-2020).[4]

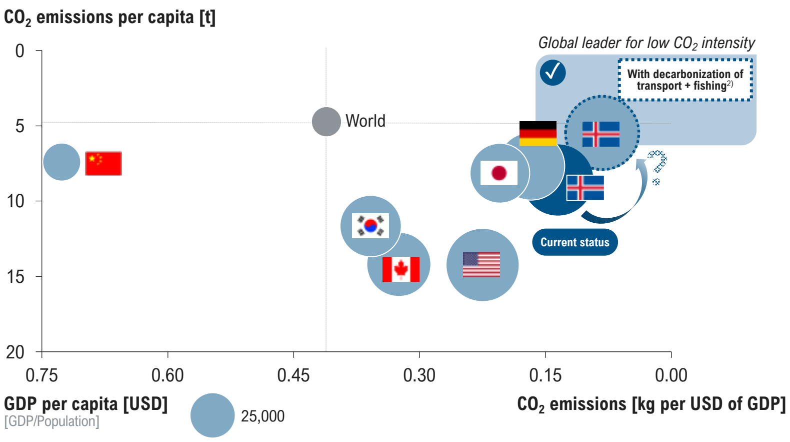
Thus, Transportation and fishing accounted for almost 30% of GHG emissions in 2020. In the road transportation and maritime sectors, hydrogen and e-fuels can play a decisive role in enabling decarbonisation.

When looking at direct domestic CO_2 emissions[5], Iceland is already in a leading peer group for low CO_2 intensity per capita but could decarbonise even further to become a global leader.

[4] Emissions from LULUCF were 9,010 kt CO_2e in 2020, mostly from drainage of wetlands in the latter half of the 20th century. It was largely ceased by 1990 (these emissions continue for a long time after drainage).

[5] When comparing CO_2 emissions only (no other gases), excluding LULUCF and international transportation.

Comparison of countries' CO_2 emissions intensity, 2020[1]



1) Only CO2 emissions shown (does not include other gases or CO2 equivalents), carbon dioxide emissions include all emissions from energy production (from coal, oil, gas and flaring) plus direct industrial emissions from cement and steel production. Land use change is not included; 2) Illustrative example showing what happens to Iceland's status if full decarbonization is achieved in the transport- and fishing sector

Source: World bank, Our World in Data, Destatis, Iceland National Inventory Report, Statistics Iceland, Global Carbon Project, UN, Roland Berger

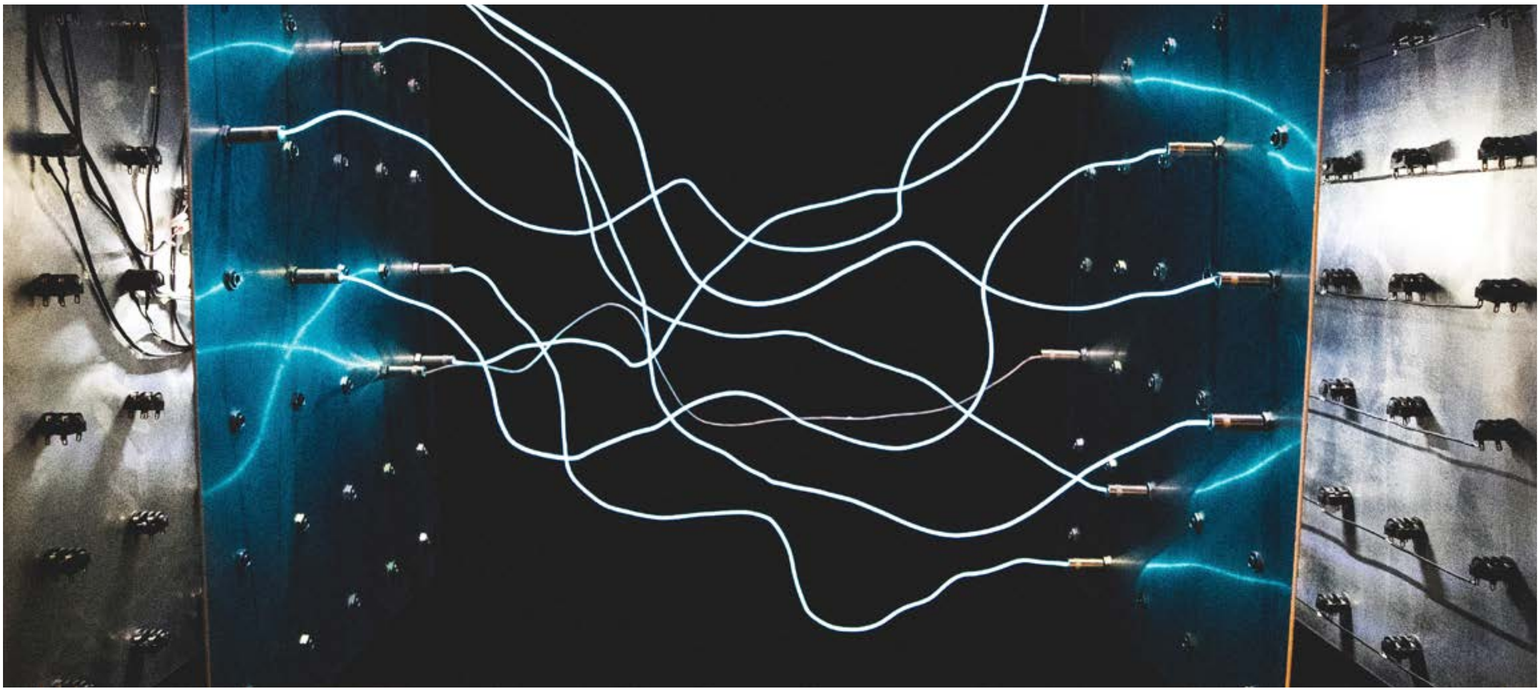
Figure 4. Comparison of different countries' CO_2 intensity (2020).

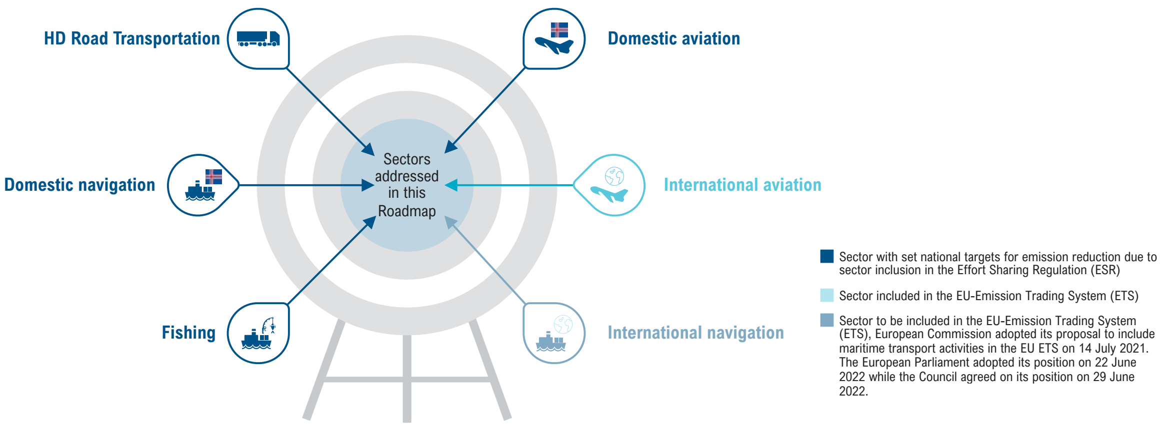
To meet the decarbonisation goals, fossil fuels need to be replaced by alternative options while ensuring Iceland's security of energy supply, affordability, and environmental compatibility.

Hydrogen and e-fuels will play a key role in enabling the energy transition as Iceland moves away from its dependence on fossil fuels.

- Hydrogen can be used directly as an energy source through fuel cells to power vehicles, boats, and airplanes.
- Hydrogen can be used to produce e-fuels, for example, e-methanol, e-ammonia, e-diesel, and e-kerosene, which can be feasible alternatives to fossil fuels in road, maritime, and aviation applications.

Although hydrogen might play a role in reducing emissions from some industrial processes in Iceland, reducing transport applications is the most significant opportunity for meaningful impact. Therefore, the Roadmap focuses on hydrogen's potential key role in decarbonising heavy-duty road transport, maritime (international, domestic navigation, and fishing), and international and domestic aviation.





Source: The Icelandic Government, Roland Berger

Figure 5. Sectors addressed in the roadmap.

1.1 Status quo: Emissions from road transport, maritime and aviation sectors

The total consumption of fossil fuels in Iceland was 588 kt[6] in 2020[7] and 893 kt in 2019. Fossil fuels consumption was mainly in road transport (48%), maritime (32%), and aviation (15%) sectors. Other sectors made up 5% of the consumption. These three sectors, road transportation, maritime, and aviation, are the primary sources of emissions from fossil fuels.

[6] Includes domestic use as well as fossil fuels use in international aviation and navigation.

[7] The fuel use and emissions numbers for 2020 deviate from the trend of recent years due to the impact of COVID-19. In 2019, total fossil fuel use was 893 kt, or 52% higher than in 2020.

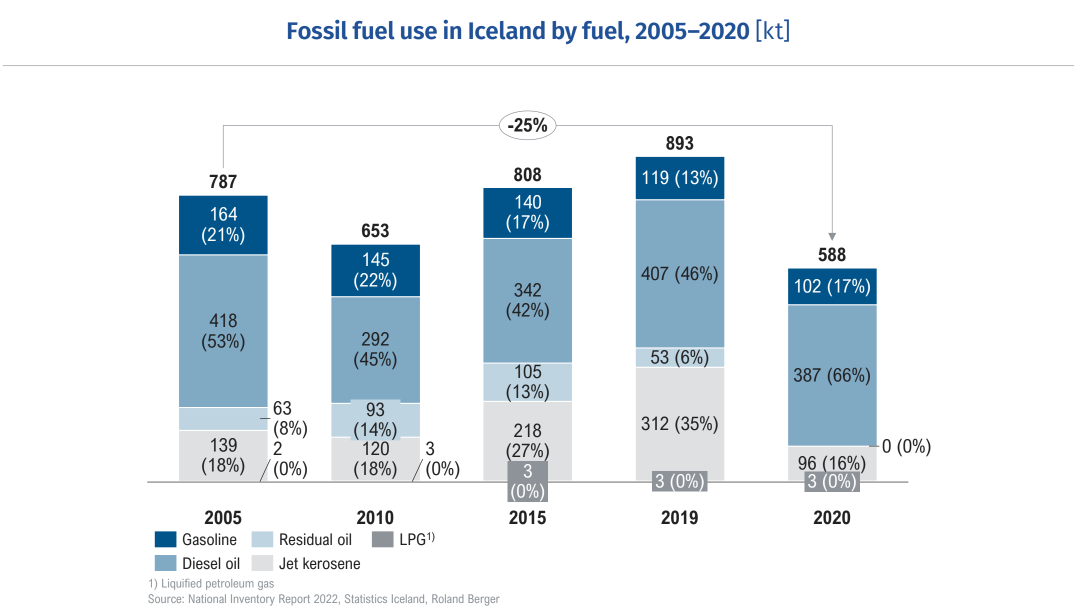


Figure 6. Iceland's fossil fuel use by fuel type (2005-2020) – Numbers differ slightly from sector breakdown due to the reporting source.

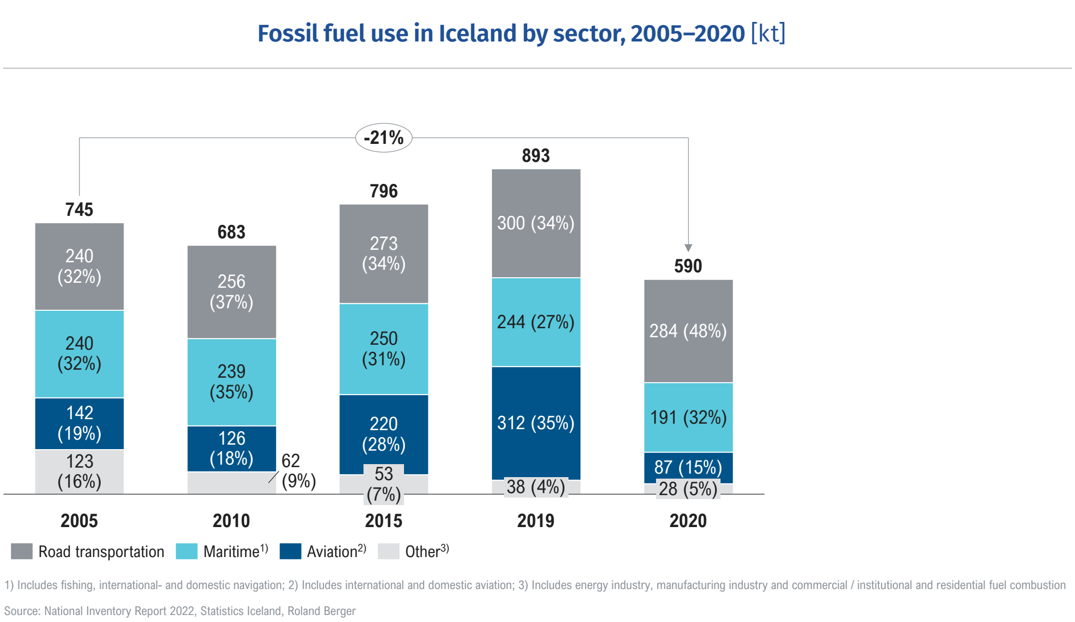


Figure 7. Iceland's fossil fuel use in road transport, fishing, navigation, and aviation (2005-2020) – Numbers differ slightly from fuel type breakdown due to the reporting source.

While domestic transport emissions[8] have risen from 617 kt CO_2e in 1990 to 863 kt CO_2e in 2020, fishing vessel emissions decreased over the same period from 746 kt CO_2e to 508 kt CO_2e, mainly driven by the renewal and consolidation of the fishing fleet. In both sectors, most emissions come from fossil fuels for propulsion purposes. Emissions and fossil fuel use from the aviation sector decreased significantly in 2020 due to the reduced air traffic caused by COVID-19. It is assumed that this will only be a temporary trend.

Road Transport

Emissions from road transport, 2005–2020 [kt CO_2e]

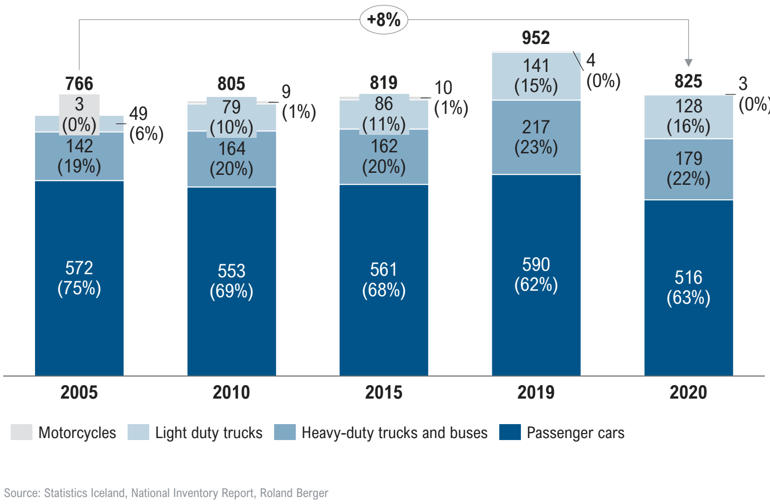


Figure 8. Iceland's road transport emissions (2005-2020).

The road transport sector emitted 825 kt CO_2e in 2020. Fuel consumption of diesel oil (199.9 million litres) was the main contributor, followed by gasoline consumption (122.1 million litres), biodiesel (14.8 million litres), and ethanol (14.0 million litres). Biomethane (1,440 t) and hydrogen (0.4 t) were negligible in fuel consumption in 2020 for the road transport sector.

Cars and motorcycles

The GHG emissions for cars and motorcycles have increased drastically in the last 30 years due to increased tourism, population growth, more cars per capita, increased

[8] Includes road transport, domestic aviation, and domestic navigation.

mileage, and larger vehicles. For that reason, cars are the number one contributor to road transport emissions, or 516 kt CO_2e in 2020.

Most of the cars registered in Iceland are powered by gasoline, followed by diesel. However, hybrid and electric vehicles (EVs) have recently seen high uptake rates. From 2015 to 2020, plug-in hybrid vehicles grew by 122% YOY, while EVs grew by 67% YOY. Personal cars make up the bulk of newly registered vehicles.

Iceland has been committed to decarbonising the road transport sector for over ten years. The goal of a 10% renewable energy share in total fuel consumption in road transport by 2020 was surpassed, reaching 11.4%. This number includes electricity, biodiesel, methane, and hydrogen. For comparison, in 2019, the share of renewable fuels was 9.5%. One reason for this growth is the strong uptake of new registrations of electric and hybrid vehicles. This marked a significant milestone for overall sustainability efforts. This success is also reflected in the share of plug-in electric vehicles in new car sales, which was the second highest in the world in 2020 at 45%.[9]

[9] Including plug-in hybrids and light vehicles, excluding commercial vehicles.

Light-duty vehicles

Light-duty vehicles contributed 128 kt of CO_2e to Iceland's total GHG emissions in 2020. Most of the light-duty vehicles registered in Iceland are powered by diesel, followed by gasoline, with alternative fuels currently playing a negligible role. The uptake rate for alternative fuels in this segment is far lower than for cars; however, this might change in the future with the new actions outlined in the Climate Action Plan.

Heavy-duty vehicles

Even though electrification is an excellent way to decarbonise some transport segments, other segments with more extensive and heavier vehicles or vessels, or those that require a more extended range, are far more challenging to electrify cost-efficiently. Alternative technologies, such as hydrogen fuel cells, can come into play for these segments.

While the number of vehicles in this sub-sector is much smaller, the GHG emitted is proportionately larger: roughly 179 kt of CO_2e in 2020. Almost all heavy-duty vehicles registered in Iceland are propelled by diesel, whereas gasoline and alternatives play a negligible role. For heavy-duty vehicles to achieve net-zero carbon emissions, hydrogen can be explored.

Navigation

Emissions from domestic and international navigation totalled 103 kt CO_2e in 2020. Domestic navigation contributed 25 kt CO_2e, and international navigation contributed 78 kt CO_2e. Fuel consumption totalled 38 million litres of diesel oil.

No residual fuel oil or alternative fuels, such as biodiesel, were used in international or domestic navigation in 2020.[10] Total emissions from the maritime sector are less than from road transport, but they are still substantial and need to be addressed not to endanger Iceland's climate action targets.

In contrast to road transport, where decarbonisation measures are far more transparent, there are multiple paths in the maritime sector to decarbonise; however, all of them are not yet entirely commercially viable, nor are some technologically feasible yet to decarbonise the entire fleet of ships in Iceland. The two most promising paths to leverage new hydrogen infrastructure are e-ammonia and e-methanol. Additionally, electrification is a promising pathway for vessels used for shorter trips.

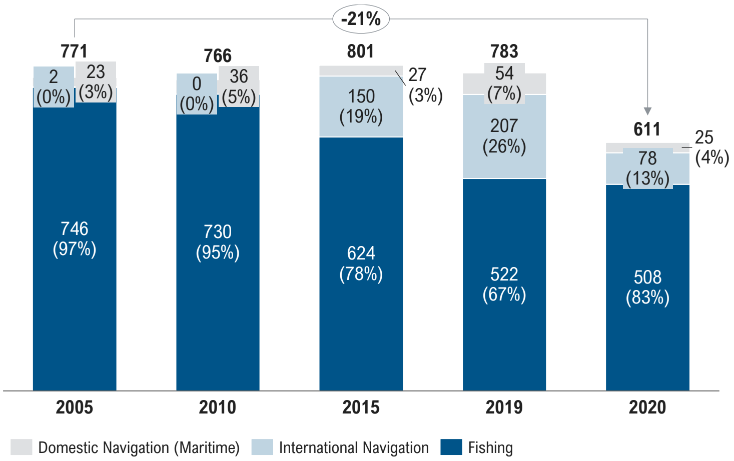
[10] According to the Iceland National Inventory Report 2022.

Fishing

The fishing sector in Iceland has a long tradition and is one of the country's largest economic sectors today. Historically, it has been one of the most significant contributors to greenhouse gas emissions. Over the last 20 years, emissions from fishing have decreased with the consolidation of the fishing fleet and newer ships.

In 2020, CO_2e emissions from fishing vessels increased to 508 kt, based on fuel consumption of 188.9 million litres of diesel oil and 85 thousand litres of biodiesel. No residual fuel oil was used.[11] As with recreational and transportation maritime vessels, the decarbonisation path with e-ammonia and e-methanol are two promising pathways for long-term decarbonisation that rely on hydrogen production.

Emissions from maritime applications, 2005–2020 [kt CO_2e]



Source: Statistics Iceland, National Inventory Report, Roland Berger

Figure 9. Emissions from maritime applications (2005-2020).

[11] According to the Iceland National Inventory Report 2022.

Aviation

International- and domestic aviation emitted 277 kt CO_2e in 2020, with international aviation contributing 264 kt CO_2e (95%) and domestic aviation 13 kt CO_2e (5%).

Before COVID-19, international aviation was by far the most significant contributor to emissions in the transport sector, with emissions increasing considerably over the last decade. In 1990, international aviation emissions only contributed 221 kt CO_2e. This number had quadrupled by 2019, with a growing number of flights driven by tourism and stop-overs.

Emissions from domestic- and international aviation, 2005–2020 [kt CO_2e]

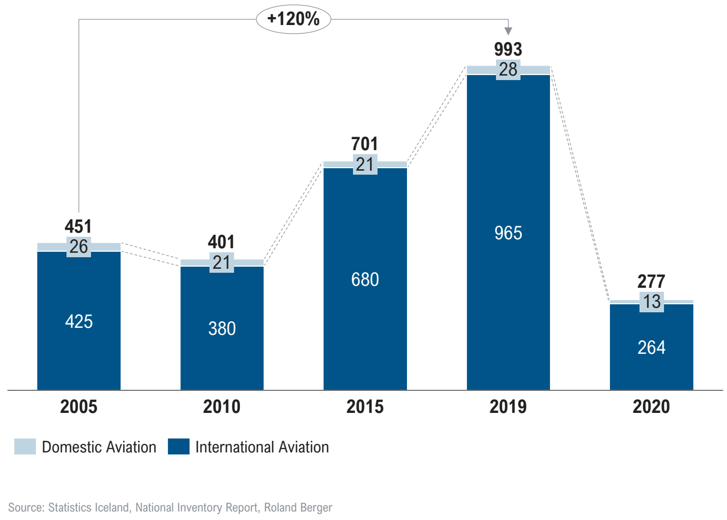
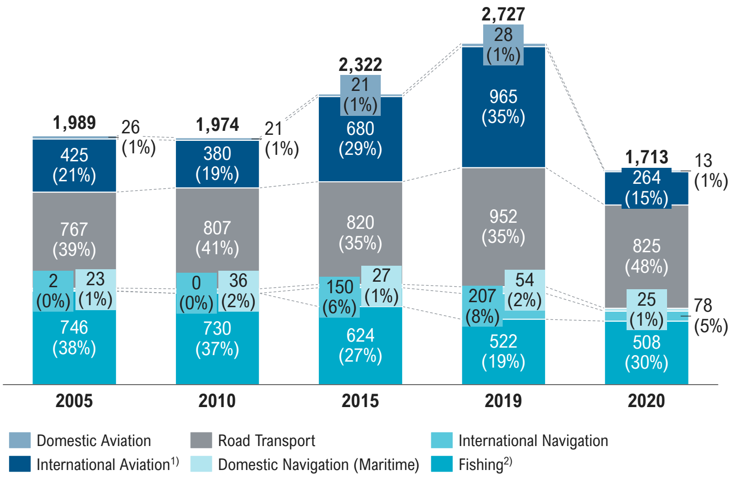


Figure 10. Aviation emissions in Iceland (2005-2020).

In 2020, domestic aviation used 5 million litres of jet kerosene, and international aviation used 101 million litres. For the international aviation sector, the Icelandic Energy Authority projects that energy consumption will rise sharply from 2020 to 2025 as the industry recovers from the COVID-19 impact, with moderate growth from 2025 onwards. For domestic aviation, a slight decline is projected.

Although Iceland has not independently defined renewable energy share goals for international aviation, it follows European regulations and targets as part of the European Economic Area (EEA). The sector imports a considerable volume of fuels annually, which offers a significant opportunity to reduce Iceland's dependence on fossil fuel imports and become a pioneer in the sustainable aviation fuel space.

Total emissions from transport split by mode, 2005–2020 [kt CO_2e]



1) Incl. Icelandair & WOW air (ceased operation as of 2019); 2) Excluding emissions from road transport refrigeration (usually HFCs and PFCs emissions)
Source: Statistics Iceland, National Inventory Report, Isavia, Roland Berger

Figure 11. Iceland's emissions from domestic and international transport (2005-2020).

1.2 Targets: Decarbonisation and energy targets for road transport, maritime, and aviation sectors

The updated Icelandic Climate Action Plan, introduced in 2020, includes 48 actions to reduce GHG emissions by more than one million tonnes of CO_2e by 2030 from 2005 levels. Specific goals were set for each sub-sector.[12]

[12] Iceland's 2020 Climate Action Plan (October 2020).

Road transport

Road transport aims to reduce emissions by 161 kt CO_2e from 2005 to 615 kt CO_2e in 2030. Ten actions set forth for both sectors in the Climate Action Plan support the goal.

Figure 12. Greenhouse gas emissions reduction goals for 2030 - Road transport.

According to the Climate Action Plan, there are ten actions that the Icelandic administration is setting forth regarding road transportation:

1. **Infrastructure for active mobility[13]**
2. **Incentives for active mobility**
3. **Encouraging public transport**
4. **Incentives for low- and zero emissions vehicles**
5. **Infrastructure for low- and zero emissions vehicles**
6. **Energy transition legislation and regulations**
7. **Ban on new registration of diesel and gasoline vehicles after 2030**
8. **Energy transition in heavy transport**
9. **Low emissions rental cars**
10. **Low emissions vehicles in Government and state enterprise**

[13] Active mobility covers, e.g., cyclic and walking. Thus, infrastructure for active mobility includes, e.g., biking and walking paths and bridges.

Navigation and fishing

The reduction goal for domestic maritime applications is 320 kt CO_2e from 2005 levels, reaching 449 kt CO_2e in 2030.

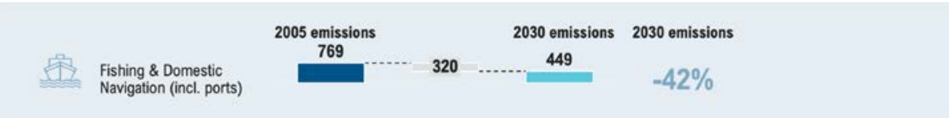


Figure 13. Greenhouse gas emissions reduction goals for 2030 - Fishing and domestic navigation.

Actions according the Climate Action Plan for ships and ports cover:

1. **Energy transition in fisheries**
2. **Electrical infrastructure in ports**
3. **Ban on use of heavy fuel oil**
4. **Energy transition of ferries**
5. **Energy transition of state-owned vessels**

Hydrogen and e-fuels could play a significant role in supporting many of these actions.

Aviation

Figure 14. Greenhouse gas emissions reduction goals for 2030 - Aviation and heavy industry.

The goal for the Icelandic aviation (domestic and international) and heavy industry sectors is to reduce greenhouse gas emissions by 43% by 2030 from 2005. Iceland participates in the EU-ETS for the aviation sector, which aims to reduce GHG emissions and prevent carbon leakage to other countries. However, some technologies can be used in addition to the action taken under the EU-ETS with the potential to reduce GHG emissions further and help Iceland on its path to carbon neutrality. One promising fuel technology that could have an immediate impact is e-kerosene, an e-fuel derivative produced with hydrogen and carbon. Other biobased fossil-free fuels (e.g., from agricultural waste or used cooking oil) could also be considered.

According to the Climate Action Plan, actions targeting the aviation sector include:

1. **Updated regulation under the Emissions Trading System[14]**
2. **Participation in international system for reducing aviation emissions**

In April 2023, the EU Parliament and the EU Council reached a political agreement on the ReFuelEU Aviation proposal.[15] The regulation[16] dated September 2023 mandates aviation fuel suppliers to ensure that all fuel made available to aircraft operators at EU airports contains a minimum share of SAF and synthetic fuels. The yearly minimum SAF shares are 2% starting in 2025, 6% in 2030, 20% in 2035, 34% in 2040, 42% in 2045, and 70% in 2050. A portion of the yearly SAF share is to be met with synthetic fuels, with an average of 1.2% over the period 2030-2031 (of which each year a minimum of 0.7%), average of 2% over the period 2032-2034 (of which a minimum of 1.2% in 2032 and 2033, and a minimum of 2% in 2034), a minimum of 5% in 2035, 10% in 2040, 15% in 2045, and 35% in 2050.

Renewable energy share goals

The Icelandic Parliament passed a resolution with Iceland's National Renewable Energy Action in 2017 with measures that aid the development of renewable energy in transport, maritime, and air operations. These targets include two crucial milestones by 2030:

1. **40% renewables share in road transport, and**
2. **10% renewables in maritime applications.**

Additionally, the Government is exploring targets for domestic aviation and has, in a draft from 2022, recommended a 20% target of renewable energy shares by 2030.[17]

[14] EU Emissions Trading System (EU ETS).
[15] Council of the European Union (October 9th, 2023)
[16] European Union (September 20th, 2023)
[17] Samradsgatt, Orkuskipti i Flugi (2022)

These targets follow the renewable energy share accounting standards, showing energy use as a proportion of the gross final energy consumption of the country. The RES figures include energy used in the following transportation subsegments:

1. **Heavy-duty road transport,**
2. **Domestic and international navigation and fishing, and**
3. **Domestic and international aviation.**

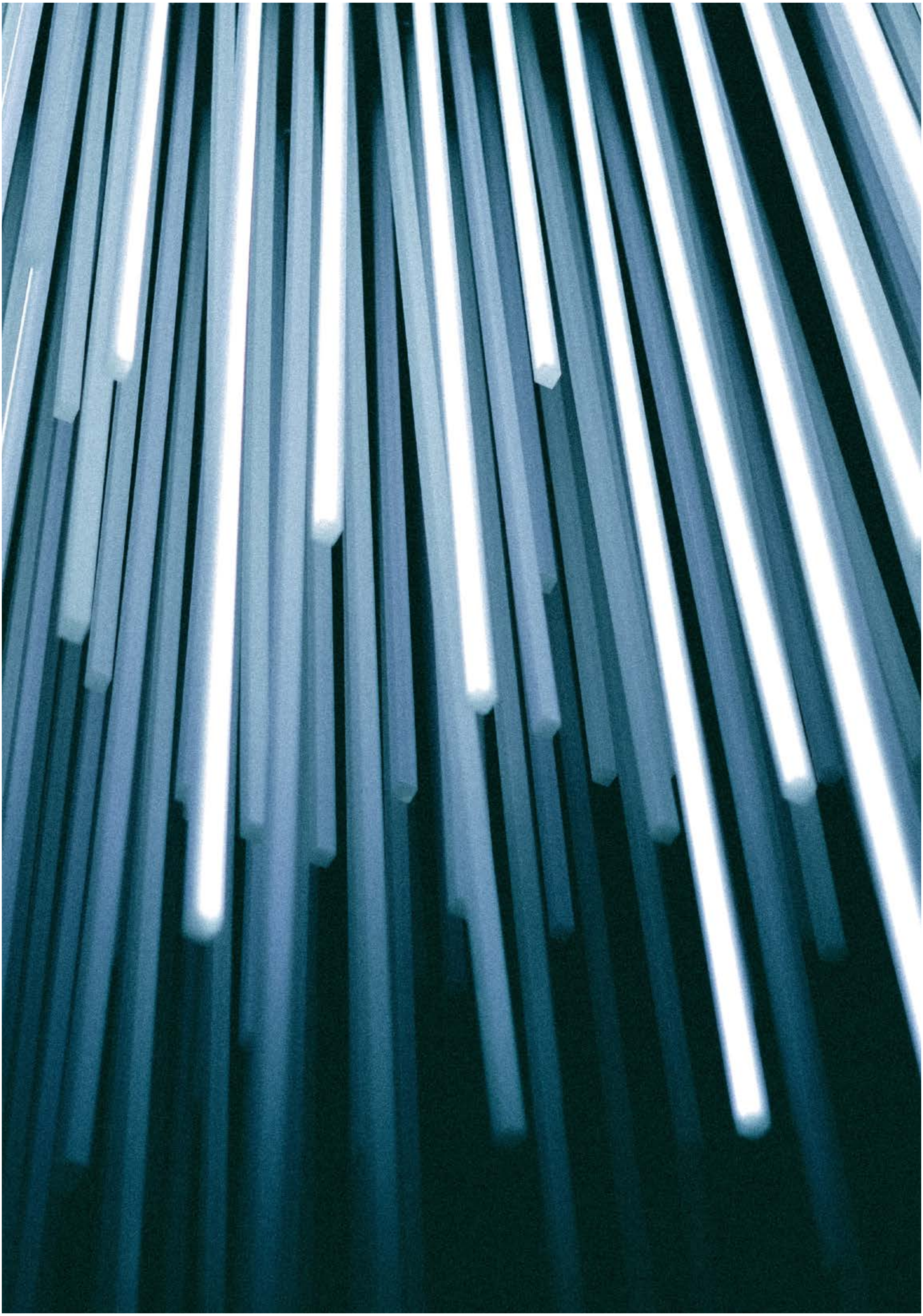
When calculating the gross final energy consumption, which is critical to measure whether the national targets, as well as the interim targets of the RED and the NREAP (National Renewable Energy Action Plan), are met, the share of energy consumed in aviation compared to the gross final energy consumption is at most 6.18% (community average).[18]

Renewable electricity counts four times its energy content towards the 14% renewable energy in transport target (set for the EU member states) when used in road vehicles.[19] Fuels used in the aviation and maritime sectors can opt-in to contribute to the 14% transport target but are not subject to an obligation. The contribution of non-food renewable fuels supplied to these sectors is 1.2 times their energy content. No multipliers are currently available for hydrogen.

The Government has also included in its policy documents that it aims for the country to become independent of fossil fuels by 2040. This means that to reach the 2040 goal of fossil fuels independence, Iceland aims to reach 100% renewable energy shares (RES number) in all three sectors of transportation (road transport, maritime, and aviation).

[18] When a Member State calculates national energy consumption, it can ignore any energy for aviation that exceeds 1.5 times the national average of energy related to aviation in the EU. The national average of emissions stemming from aviation was 4.12% in 2005, thus the maximum percentage of energy from aviation that must be included in national accounts was set to 1.5*4.2 = 6.18%. Malta and Cyprus must include only 4.12% (Norden – Sustainable jet fuel for aviation)

[19] EU – Renewable Energy – Recast to 2030 (RED II).



2. Vision: Potential of hydrogen in Iceland

Hydrogen is universally considered one of the essential energy vectors for decarbonisation, thus, combatting climate change in the upcoming decades. To reach net zero, the IEA estimates that hydrogen use will reach more than 200 m tonnes by 2030 – from 90 m tonnes in 2020 – of which over 50% would need renewable power via electrolysis. Green hydrogen enables decarbonisation of hard-to-abate sectors such as heavy-duty transport, where hydrogen can replace fossil fuel use, or in the fertiliser industry, where hydrogen is used as feedstock.

For Iceland, hydrogen and e-fuels (e.g., e-ammonia, e-methanol, and e-diesel) are expected to play a crucial role in decarbonising the transport sector, especially the segments where battery-electric solutions and thus direct electrification may be a less viable option. These segments include heavy-duty road transportation, maritime applications, fishing vessels, and navigation. The Icelandic Government has emphasised the efforts in its Energy Policy Action Plan to address these two sectors while exploring hydrogen's potential contribution to e-kerosene for domestic and international aviation in the following decades.

2.1 Past, current, and planned hydrogen projects and initiatives

Iceland's ambitions in hydrogen are rooted in a long history of hydrogen production and applications based on fuel cell technology projects carried out over the past 20 years. The country was a pioneer in the industry's early days and one of the first countries to pilot hydrogen fuel cell transport applications in the early 2000s.

The ECTOS project ("Ecological City Transport System"), partially funded by the EU, deployed three hydrogen fuel cell buses and a hydrogen production, storage, and hydrogen refuelling station (HRS) to test the technology's viability as well as infrastructure in a real-life environment of a city's public transport system. During the project, the buses drove more than 140,000 km and used more than 27,000 kg of hydrogen. The project, headed by Icelandic New Energy, operated from 2001 until 2005. As their performance exceeded expectations, the buses were later used in the European HYFleet: CUTE (Clean Urban Transport for Europe) project.

Building on the success of the ECTOS project, Icelandic New Energy pursued the testing of hydrogen fuel cell passenger vehicles under the SMART-H2 project ("Sustainable Marine and Road Transport – Hydrogen in Iceland"). They deployed 35 cars from 2007 to 2012 while leveraging the existing hydrogen production, storage, and HRS from ECTOS.

Additionally, the auxiliary power unit of a whale-watching ship was retrofitted with a fuel cell – the first of its kind in the world.

The projects were conducted early in the industry, which led to considerable knowledge creation within the country. Both ECTOS and SMART-H2 were accompanied by extensive technological and social research conducted by both Icelandic research institutions and international research bodies. Thus, Iceland became the centre of applied hydrogen research and contributed to further technological developments and global visibility of hydrogen fuel cell technologies. During the ECTOS project, several hundred media outlets visited the project, and more than ten documentaries were filmed, further contributing to the marketing of the technology and Iceland's progressive stance.

After signing the Paris Agreement in 2015, the Icelandic Government set further goals for decarbonisation of the road transport sector, and a renewed interest in hydrogen became a reality. Since 2018, "Íslenska Vetnisfélagið," formed by Orkan in cooperation with NEL Hydrogen and Hydrogen Mobility Europe (H2ME), has opened three HRS for passenger vehicles in Reykjavík and Reykjanesbær near Keflavík Airport. The hydrogen is supplied via trucks from the Hellisheiði geothermal power station production site, located 30-40 km southeast of Reykjavík. ON Power operates the 700 kW electrolyser and serves the 20-30 fuel cell vehicles currently operating in Iceland.

Following this renewed momentum for Icelandic hydrogen, new early-stage companies have entered the market in recent years, working across the whole hydrogen value chain, from production to transport to distribution. These companies are actively exploring opportunities for new business models, both for domestic use and as a potential export. Most of the current focus is on the rapid deployment of heavy-duty vehicles for road transport and the nationwide roll-out of hydrogen refuelling networks. Hydrogen and e-fuel production for maritime and aviation applications and export opportunities for green hydrogen and e-fuels are also being explored.

Furthermore, Iceland is the country where the world's first power-to-liquid methanol plant with large-scale electrolysis was built by Carbon Recycling International, with an electrolyser capacity of 6 MW. From 2012, the plant produced 4,000 tonnes of certified renewable methanol annually using CO_2 from the nearby geothermal power station at Svartsengi, located 50 km southwest of Reykjavík. The methanol was sold to international off-takers.

Other early-stage hydrogen projects include:

- A pre-feasibility study for a new e-fuels facility at the Grundartangi ferrosilicon plant. The plant could produce green hydrogen from electrolysis and utilise CO_2 emissions from the production process to produce green methanol. Carbon Recycling International, Landsvirkjun, Elkem, and Þróunarfélag Grundartanga jointly conduct the study.

- A planned green hydrogen production with a multi-MW electrolyser capacity, enabling the operation of heavy-duty hydrogen trucks and other hydrogen use cases within a hydrogen valley concept. Landsvirkjun is exploring the project in collaboration with Linde and other stakeholders, and site planning is underway.
- A project being explored to develop a “Green Port” in Finnafjörður, located in Northeast Iceland. Key role could include production of green hydrogen and e-fuels.
- In July 2021 and September 2022, Icelandair signed Letters of Intent with Universal Hydrogen and Heart Aerospace to explore the possibilities of electric- and hydrogen-powered aircraft for domestic routes. Icelandair aims to operate emissions-free on domestic routes by the end of this decade.
- In August 2021, a partnership between HS Orka and Hydrogen Ventures Limited (H2V) was announced to develop a production plant at the Reykjanes geothermal power station for green methanol using green hydrogen to power the maritime sector, as well as domestic and commercial vehicles such as cars, vans, and trucks. The power consumption is estimated at 60 MW from geothermal energy to produce green methanol and use most of the carbon dioxide released from HS Orka’s operations. The estimated investment is around EUR 150 million, equivalent to over ISK 20 billion.
- In October 2021, the municipality of Fjarðabyggð, Landsvirkjun, and Copenhagen Infrastructure Partners (CIP) partnered to explore the opening of a hydrogen production facility at the Green Energy Park in Reyðarfjörður under the name “Orkugarður Austurlands”. The amount of ammonia produced is planned to be 200 kt per year with an electrolyser capacity of 250 MW. Letters of Intent have been signed with several off-takers and power suppliers (e.g., Skeljungur, Municipality of Fjarðabyggð, Síldarvinnslan, Atmonia and Arctic Hydro). The project is planned to be operational by 2028 or 2029.
- In November 2021, Green Fuel and Topsoe announced they would join forces to identify technologies to produce green ammonia in Iceland. Green Fuel plans a hydrogen and ammonia production facility at the Bakki industrial site near Húsavík in Northeast Iceland. The total estimated size is 100 MW for green ammonia for export and domestic maritime use. Green Fuel plans to produce ammonia that could power a third of the Icelandic fishing fleet. The amount of produced ammonia is planned to be 105 kt per year or 300 tonnes daily.
- In April 2022, Landsvirkjun and the German investment company, PCC SE, collaborated to analyse the possibility of capturing and utilising carbon emissions from PCC’s silicon metal plant in Northeast Iceland. Carbon emissions would produce green methanol using green hydrogen that can replace fossil fuels in ships and industry.

- In May 2022, Landsvirkjun and Verne Global, a provider of sustainable data centre solutions for high-intensity computing, announced a partnership in which Verne Global will test and deploy hydrogen fuel cells to provide reliable and sustainable backup power for its Icelandic data centre campus.
- In July 2022, Vetnis Iceland announced it had entered into a financing agreement with Prime Capital AG. The company is developing green hydrogen infrastructure in Iceland, focusing on heavy-duty road transport.
- In September 2022, Landsvirkjun and the shipping company Eimskip signed a Letter of Intent to jointly conduct market conditions and technology development analysis regarding using hydrogen or e-fuels in the transportation sector to replace fossil fuels. In detail, they focus on Eimskip's energy transition for its shipping and ground transport fleet. Depending on the outcome of this analysis, the two companies will evaluate potential future procurement and sales of hydrogen or e-fuels produced by Landsvirkjun or its partners.
- In March 2023, IdunnH2 and Icelandair signed a Memorandum of Understanding that IdunnH2 would supply the airline with up to 45 kt annually of SAF produced from green hydrogen. The facility is planned to be located near Keflavík Airport and will use up to 300 MW of renewable energy with a capacity of 65 kt annually of SAF. A feasibility study has been conducted, and the facility is planned to be operational by the end of 2027.
- Carbon Iceland is planning a green fuel facility with a capacity of 110-330 kt annually of e-methanol, DME, and other products suitable for maritime applications, aviation, and heavy equipment. Grundartangi and Bakki industrial sites are being explored as sites for the facility, and the company expects production to commence by the end of 2026.
- Qair Iceland is developing a large-scale hydrogen electrolysis project at Grundartangi, Iceland. The site has already been secured, and the legally required environmental assessment has commenced. Qair intends to power the facility with energy from nearby wind parks, which the company has been developing since 2018. Qair is also developing a pilot hydrogen infrastructure project (refuelling stations and production) in a joint venture with Orkan IS ehf.
- Several recent research papers and initiatives led by the Icelandic Government, the University of Iceland, and other stakeholders focused on the feasibility of hydrogen- and e-fuel production and adoption.

In 2020, the European Commission adopted a new dedicated strategy on hydrogen for Europe. Several European countries have adopted their national systems, and interest in the hydrogen sector has increased. Governments have started exploring supply opportunities as many European countries will remain net hydrogen importers in the future due to limited domestic green production capacities.

Landsvirkjun and the Port of Rotterdam concluded a pre-feasibility study in June 2021 on hydrogen production in Iceland and subsequent export. The study finds that it could be financially attractive and technically feasible to export hydrogen or e-fuels before 2030.[20]

Given this experience, early trials, and technology demonstrations, Iceland is ideally placed to develop a domestic hydrogen sector, and the Icelandic Government will provide the necessary framework for industry to seize this opportunity.

2.2 Hydrogen potential for road transport, maritime, and aviation sectors

To reach the goals set by the Icelandic Government, adopting alternative renewable energy sources is required across all modes of transportation. The global commercial viability of hydrogen and alternative technologies varies across each sector.

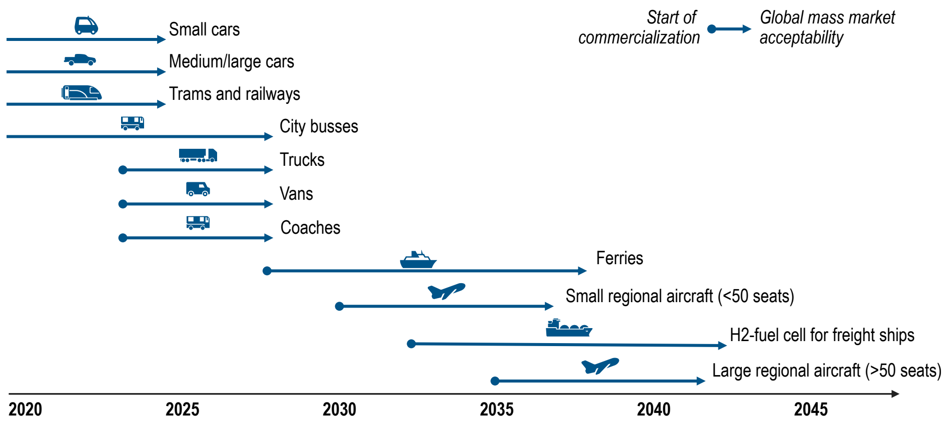
In the case of heavy-duty road transport, hydrogen-based alternatives are starting to become commercially available, with several pilots running globally and expected mass-market acceptability this decade.

For maritime applications, hydrogen and e-fuel technologies for ships and vessels are still at an early stage compared to road transport. Several hydrogen and e-fuel prototypes and pilots are currently being carried out. Still, the timeframe for global mass market acceptability for larger ships is expected to be later than that of road transport. For larger maritime applications, most industries currently focus on blending renewable fuels as the main lever for decarbonisation in the short term. Renewable fuels include e-fuels, which are a viable option for blending.

Alternative solutions in the aviation industry are still being developed, and technological maturity generally follows road transport and maritime applications, especially in international aviation. Countries are taking steps to address aviation emissions as blending quotas are implemented in Europe. E-kerosene made from green hydrogen is one of the options that is being considered, along with other SAF options.

[20] https://www.portofrotterdam.com/en/news-and-press-releases/study-shows-shipping-green-hydrogen-from-iceland-to-rotterdam-to-be

Decarbonised hydrogen end uses across transportation sectors



Source: Hydrogen Council; Roland Berger

Figure 15. Commercialisation timelines for hydrogen and e-fuels end-uses (forecasted).

The plans the Icelandic Government has put forth are technologically neutral, and they will consider the efficiency and effectiveness of all available technologies to reach the Icelandic emissions targets. Hydrogen and e-fuels are expected to play a prominent role in road, maritime, and aviation decarbonisation and, in that regard, merit the Government´s attention.

2.3 Expected hydrogen demand for road transport, maritime, and aviation sectors

Iceland's road transport, maritime and aviation sectors consumed 537 kt of fossil fuels in 2020. This includes 92 kt of gasoline, 359 kt of diesel, and 87 kt of jet kerosene.

These sectors drive the expected domestic hydrogen and e-fuel demand in Iceland.

A theoretical conversion of fossil fuels to hydrogen at 2020 levels for heavy-duty road transport, maritime, and aviation sectors results in a substitution volume of roughly 149 kt of hydrogen annually.[21] It is important to note that fuel use in 2020 was lower than in recent years due to the pandemic, and if 2019 is used as a benchmark, this figure becomes 378 kt of hydrogen per year. The expected hydrogen demand is based on the official

[21] Reference: Roland Berger analysis. Example assumes hydrogen fuel cells for heavy-duty transport and buses, ammonia for maritime, and e-kerosene for aviation, but the Roadmap remains technology neutral.

sectoral fuel use projections from the Icelandic Energy Authority. It considers that 2020 was not a representative year of emissions and fuel use.

Assuming an ambitious but viable uptake in the next decade, hydrogen could be necessary to reach the renewable energy share goals for 2030 in these three sectors. Adoption rates will be influenced by technology availability, market demand, and economics.

For non-ETS sectors, assuming hydrogen and e-fuels would make up 20% of primary energy used for heavy-duty road transport, up to 10% in domestic maritime, and 20% in domestic aviation, total hydrogen demand could reach ~10 ktpa by 2030, which could displace 30-40 ktpa of fossil fuel use for non-ETS sectors. This could require 71 MW of electrolyser capacity by 2030.

Additionally, reaching a 10% share of renewable energy for fuels in international aviation and international navigation by 2030 would require a speedy ramp-up of either own production capacities or securing imports. Theoretically, to reach a 10% renewable energy share satisfied with domestic production of fuels by 2030, an additional 26 ktpa of hydrogen and 155 MW of electrolyser capacity could be required, bringing the total demand to 35 ktpa and the total electrolyser capacity needed to 237 MW.

Similarly, by 2040, annual hydrogen demand for non-ETS sectors could reach 60 ktpa, equivalent to 430 MW of electrolyser capacity. If a complete conversion of fuel use in international aviation and international navigation were to be addressed with domestic production, an additional 304 ktpa could be required, bringing the total hydrogen demand to 364 ktpa, equivalent to 2,429 MW of total electrolyser capacity.

Expected fuel use, 2030–2040 [ktpa fossil fuel]

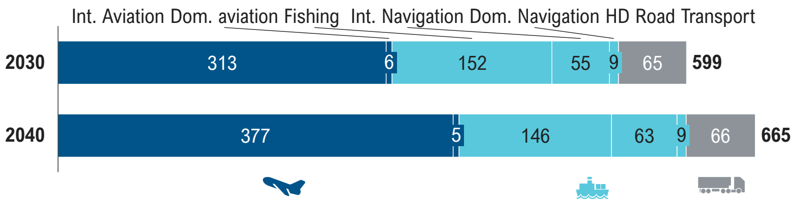
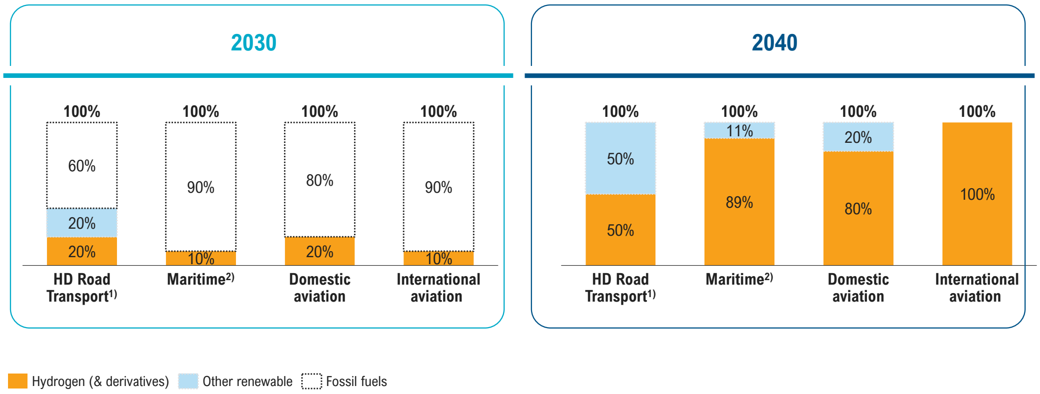


Figure 16. Expected fuel use for heavy-duty road transport, maritime applications, and aviation (2030-2040) – Note that this excludes any expected fuel use for light-duty and medium-duty vehicles.

Penetration rates by sector, 2030 and 2040 [% of primary energy use]

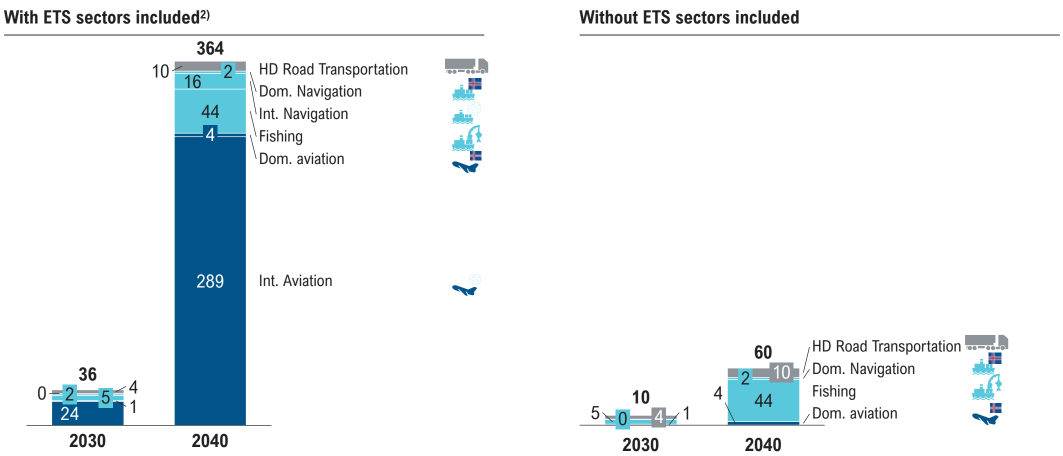


1) Including buses; 2) Assumptions for hydrogen and e-fuels in maritime include fishing (10% by 2030, 90% by 2040), international navigation (10% by 2030, 90% by 2040) and domestic navigation (5% by 2030, 70% by 2040). The penetration rate for maritime is the weighted average of the penetration rate of the individual sectors

Source: Statistics Iceland, Icelandic Government, Desk research, Expert interviews, Roland Berger

Figure 17. Scenario assumptions by segment (2030-2040).[22]

Hydrogen demand forecast with and without considering ETS sectors, 2030–2040 [kt][1]



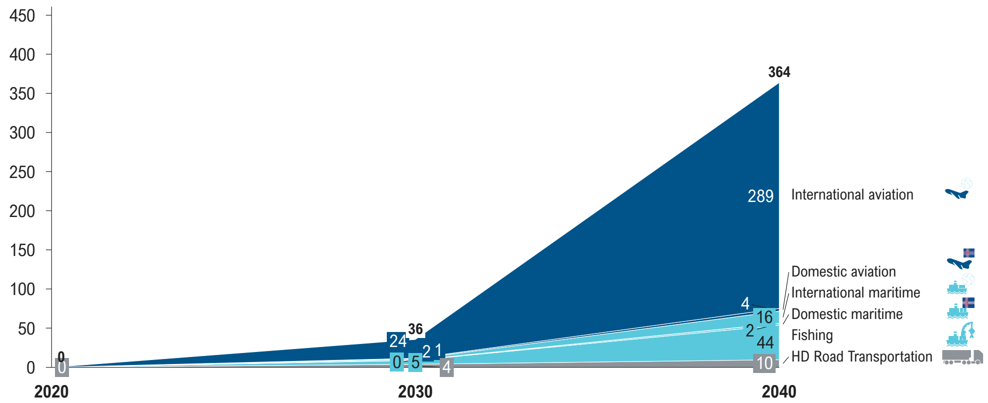
1) 91% is assumed as capacity factor for electrolyzer and 52 kWh/kg required energy for the road and aviation sector and 59 kWh/kg for the maritime sector; 2) International maritime and aviation

Source: Roland Berger

Figure 18. Expected yearly hydrogen demand with and without considering EU ETS sectors (2030-2040).

[22] Detailed overview of assumptions can be found in the Appendix.

Hydrogen demand forecast, 2020–2040 [kt][1]



1) 91% is assumed as capacity factor for electrolyzer and 52 kWh/kg required energy for the road and aviation sector and 59 kWh/kg for the maritime sector

Source: Roland Berger

Figure 19. Estimated hydrogen demand by sector assuming fossil fuel independence in all segments by 2040 (2020-2040).

Heavy-duty trucks and buses

Emissions from heavy-duty trucks and buses[23] were 179 kt CO_2e in 2020, or 22% of total greenhouse gas emissions from the road transport sector in Iceland.

Total diesel and gasoline consumption in heavy-duty transportation and buses was estimated at 70 million litres in 2020. That volume roughly equals the 17 kt of hydrogen required for the complete conversion of these vehicles.

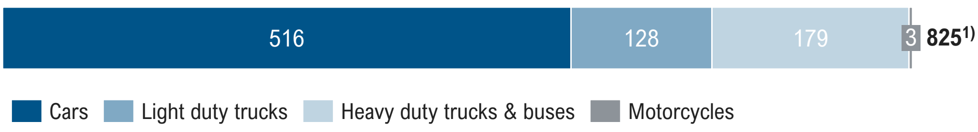
The Icelandic Government has set a goal of 40% renewable share of road transportation. For heavy-duty trucks and buses, most of that share fits well with hydrogen vehicles. Assuming hydrogen makes up 20% of the renewable energy share goal in heavy-duty road trucks and buses by 2030, the total hydrogen demand is expected to reach up to 4 kt by 2030.

From 2030 to 2040, the sector for renewable fuels in heavy-duty trucks and buses is expected to mature. A fast ramp-up during that period could result in an annual hydrogen demand that will, at a minimum, double, reaching at least 7 kt by 2040.

[23] Defined by the Icelandic Transportation Authority as Vehicle Categories M2, M3, N2, N3.

Emissions split & overview of fuel usage of different forms of road transport, 2020

Emissions from road transport, 2020 [kt CO_2e]



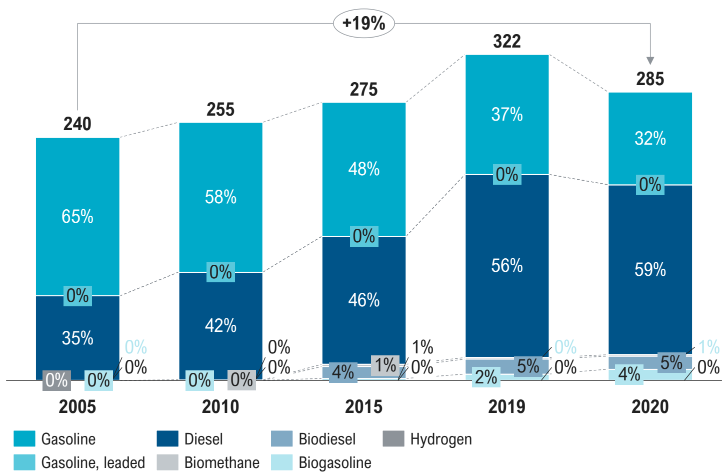
Vehicle Classification[3]	Vehicles <2.5 t[4]	Vehicles 2.5 to 6 t	Vehicles >6 t
Number of total vehicles	**228,056**	**74,023**	**9,508**
Gasoline powered vehicles	159,322	13,236	104
Diesel powered vehicles	55,548	57,736	9,355
Other vehicles (BEVs[5] etc.)	13,186	3,051	49

1) Difference to different rounding; 2) Calculated as kt CO_2e/kt of fuel consumption; 3) Data from 2019 as no more recent data published; 4) Vehicle own weight (without payload); 5) BEV = Battery-powered electric vehicle

Source: Statistics Iceland, National Inventory Report, Roland Berger

Figure 20. Road transport emissions in Iceland.

Fuel use in road applications, 2005-2020 [kt]



Source: Statistics Iceland, National Inventory Report, Roland Berger

Figure 21. Fuel use in road transportation (2005-2020).

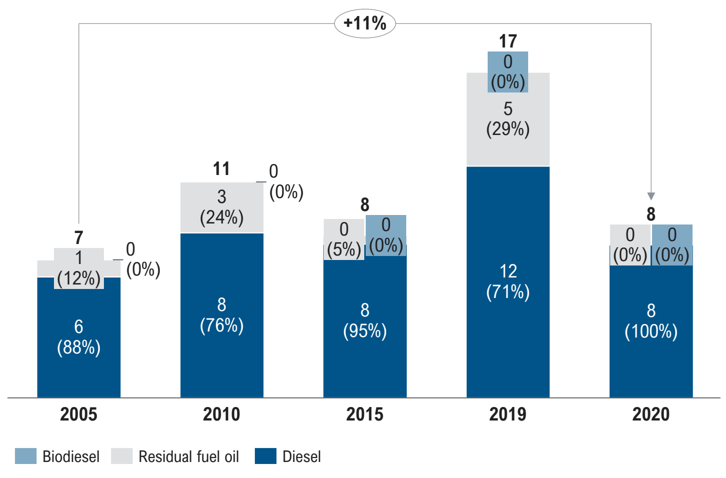
Maritime applications

Maritime applications[24] emitted 611 kt CO_2e in 2020, with fishing vessels contributing 508 kt CO_2e (83%), domestic navigation 25 kt CO_2e (4%) and international navigation 78 kt CO_2e (13%).

Total fuel use for maritime applications was 190 million litres or 167 kt in 2020. The fishing industry consumed over 80% of the fuel use for maritime applications.

When considering international navigation, it is essential to note that most fuel used is purchased outside Iceland. It is estimated that roughly 70-90 kt of additional energy is purchased annually outside of Iceland for use by these vessels.[25] When considering the total fuel use of the international shipping companies servicing the country, most of it is not counted in the local consumption. This needs to be considered further when assessing the energy transition of shipping companies servicing Iceland.

Fuel use in maritime applications – Domestic navigation, 2005–2020 [kt]

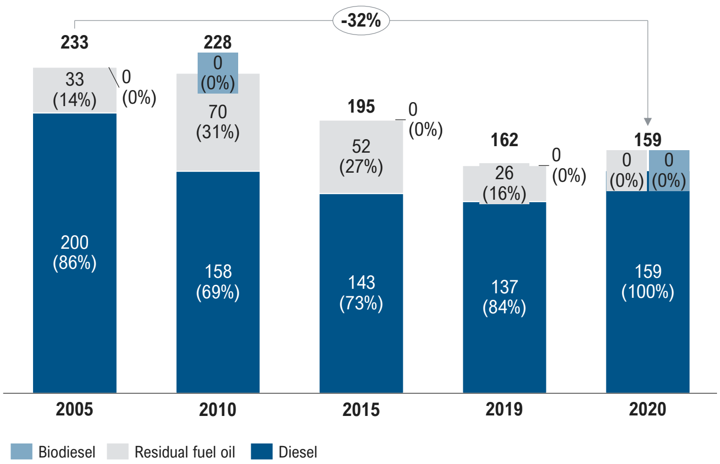


Source: Statistics Iceland, National Inventory Report, Roland Berger

Figure 22. Maritime fuel use in Iceland – Domestic navigation (2005-2020).

[24] Excluding international navigation, as that fuel use does currently not count towards the country's renewable energy shares according to the EU Renewable Energy Directive.
[25] Efla ("Raforkuþörf vegna orkuskipta í skipum") – https://www.efla.is/blogg/fagid/raforkuthorf-vegna-orkuskipta-i-skipum

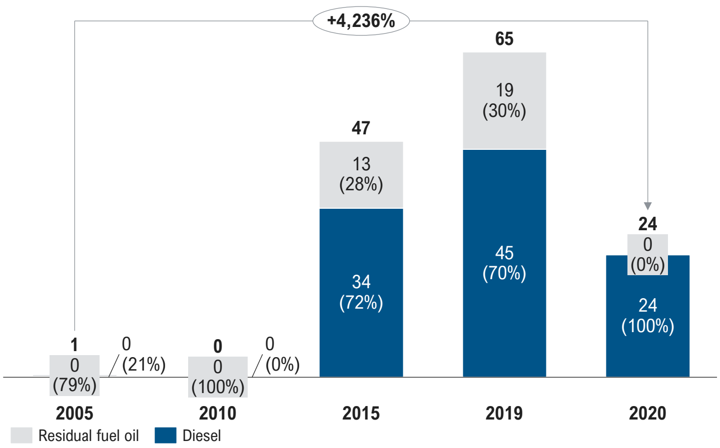
Fuel use in maritime applications – Fishing, 2005–2020 [kt]



Source: Statistics Iceland, National Inventory Report, Roland Berger

Figure 23. Maritime fuel use in Iceland – Fishing sector (2005-2020).

Fuel use in maritime applications – International navigation, 2005–2020 [kt]



Source: Statistics Iceland, National Inventory Report, Roland Berger

Figure 24. Maritime fuel use in Iceland – International navigation (2005-2020).

In 2020, registered fishing vessels in Iceland were 1,561, of which 46 were trawlers, 695 were decked vessels, and 820 were undecked vessels. Most of the fuel use is by trawlers and larger decked vessels. Due to the nature of these vessels, their routes and time spent at sea make them a fitting option for liquid e-fuels such as methanol, ammonia, or e-diesel.

Less than 10%[26] of the fuel consumption by fishing vessels is estimated to be by vessels where batteries are currently the preferred option, leaving at least 90% of the fuel use in fishing requiring an alternative solution. This is equivalent to 170 million litres of fossil fuels that could be converted to hydrogen and e-fuels.

For domestic navigation, an estimated 30% of the fuel use is by vessels where battery-electric solutions might be a well-fitting alternative. This leaves 70%, equivalent to 6.5 million litres of fossil fuels that could be a well-fitting alternative to be converted to hydrogen and e-fuels.

Iceland's goal for the renewable energy share in maritime applications is 10% by 2030. E-fuels, such as ammonia, methanol, and e-diesel derived from e-crude, along with other carriers, such as biofuels, are alternatives to fossil fuels in these sectors and could play an important role. A pilot project for biofuel from rapeseed oil for maritime applications has already been conducted by the Icelandic Transport Authority (Samgöngustofa). For several years, Orkey, located in Akureyri, has also produced biodiesel for maritime fuel blending at a pilot scale.

Assuming e-fuels make up a 10% share in fishing, a 5% share in domestic navigation,[27] and a 10% in international navigation, hydrogen demand could reach roughly 7 kt by 2030, where fishing vessels make up over 75% of demand. Energy demand for fishing and navigation will stay relatively flat until 2030.

From 2030 to 2040, the demand for alternative fuels for maritime applications will grow exponentially with the maturing market. Pending technology advancement and adoption rates, yearly demand for hydrogen to produce e-fuels for maritime applications could increase up to 10 times, reaching 62 kt by 2040.

[26] DNV analysis for the Ministry of Innovation and Industries (June 2021).

[27] Ammonia used as example for hydrogen volume conversion to e-fuels, methanol would require roughly additional 5% of hydrogen. Other e-fuels such as e-diesel could also be explored.

Aviation

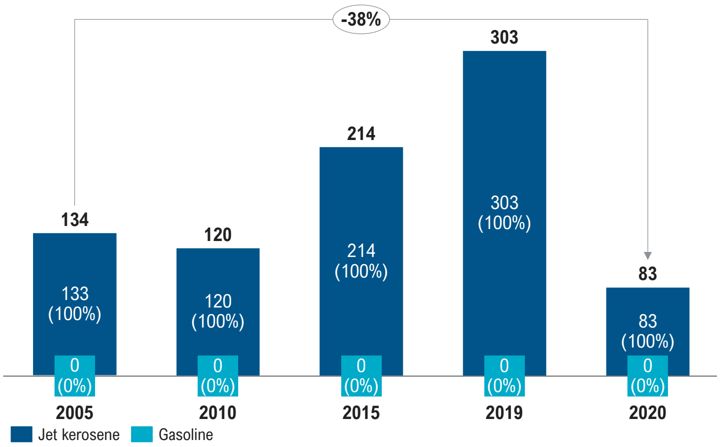
Total jet kerosene use for aviation was 87 kt in 2020, of which 83 kt was used for international aviation and 4 kt for domestic aviation. The pandemic heavily impacted the industry. To put this into perspective, in 2019, fuel use in the aviation sector totalled 312 kt, of which 303 kt was used by international and 8 kt by domestic aviation.

The Icelandic Government will explore the opportunity for Iceland to become a global leader in the energy transition for aviation, focusing on domestically produced sustainable aviation fuels. While Iceland has not adopted country-specific renewable energy share targets for aviation, the Government is closely observing developments in neighboring countries.[28]

A complete conversion of the e-kerosene needed in the international and domestic aviation sector by 2030 would require up to 244 kt of hydrogen.[29] If 10% of the international and 20% of the domestic fuel consumption for aviation were met with e-kerosene, hydrogen, or other e-fuels by 2030, demand could reach up to 25 kt.

Looking towards 2040, market demand for sustainable aviation fuels could increase sharply if technological advancements emerge. The Government will continue to monitor developments in the EU regarding aviation emissions and adapt accordingly. The feasibility of domestic e-kerosene production should be explored alongside the potential for imports as the industry develops over the next two decades.

Fuel use in aviation applications – International aviation, 2005–2020 [kt]



Source: Statistics Iceland, National Inventory Report, Roland Berger

Figure 25. Aviation fuel use in Iceland – International aviation (2005-2020).

[28] Examples: Norway has mandated a 0.5% blend of sustainable aviation fuels, with the goal of increasing it to 30% by 2030. Sweden introduced a greenhouse gas reduction mandate for aviation fuels in 2021, reducing emissions of sold fuel by 0.8% in 2021 and gradually increasing it to 27% by 2030. Germany approved an e-kerosene quota in May 2021 of 2% by 2030. This is in addition to the European aviation mandates under the ReFuelEU package.

[29] Assuming 0.75 kg of hydrogen required for kg of e-kerosene through a Fischer-Tropsch production process.

Fuel use in aviation applications – Domestic aviation, 2005–2020 [kt]

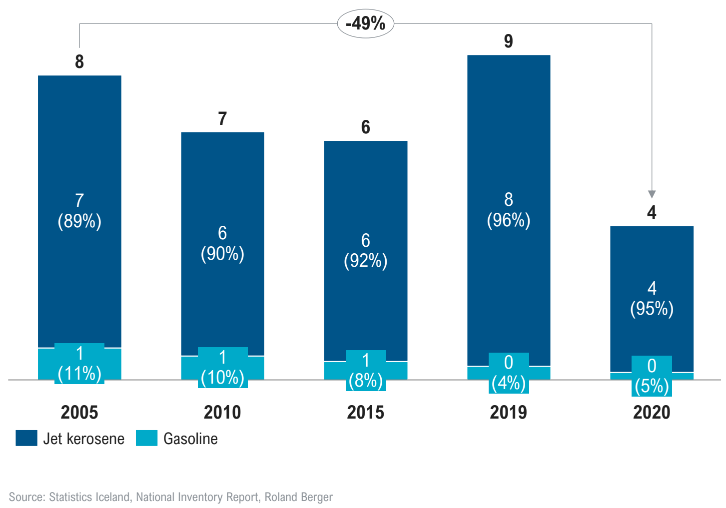


Figure 26. Aviation fuel use in Iceland – Domestic aviation (2005-2020).

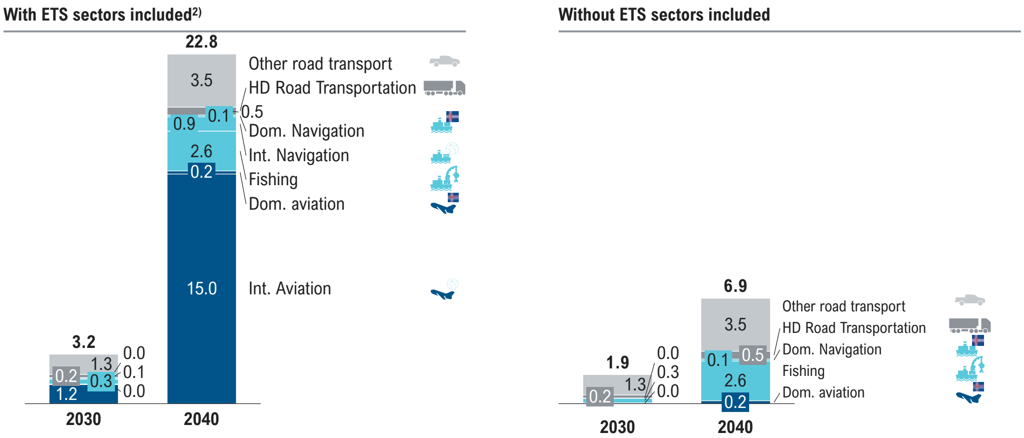
Electricity and power requirements

By 2030, the electricity requirements to produce hydrogen and e-fuels for non-ETS sectors (i.e., heavy-duty road transport, fishing, domestic navigation, and domestic aviation), along with the additional electrification of vehicles, could reach ~1.9 TWh.[30] If ETS sectors are included, the additional electricity requirements could be 1.3 TWh, bringing the total to 3.2 TWh by 2030.

As the industry ramps up from 2030 onwards, the electricity requirements are expected to grow considerably. For the non-ETS sector, including the electrification of road transportation, the total electricity requirements are expected to reach ~6.9 TWh. If ETS sectors were included in full domestic production, the total electricity requirements could reach ~22.8 TWh.

[30] Assuming 52 kWh/kg of hydrogen required for electrolysis.

Required energy for a full energy transition, 2030–2040 [TWh][1]

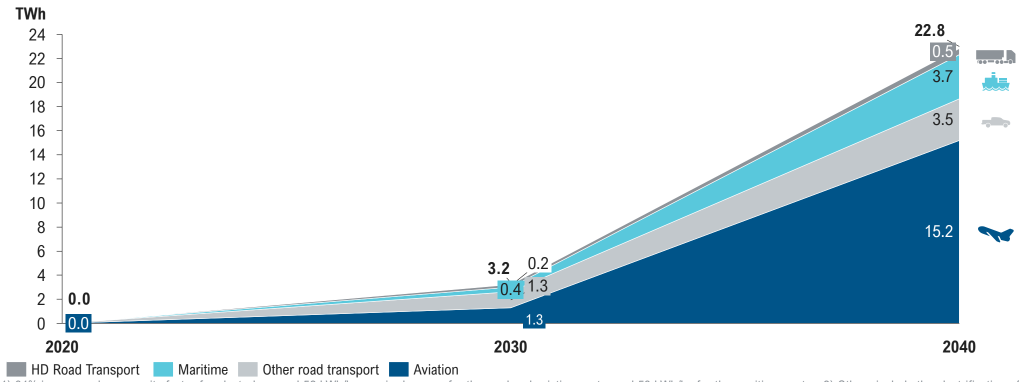


1) 91% is assumed as capacity factor for electrolyzer, 80% for the power plant and 52 kWh/kg required energy for the road and aviation sector and 59 kWh/kg for the maritime sector; 2) Others include the electrification of passenger cars, light- and medium-duty vehicles as well as the share of heavy-duty vehicles which can not be fueled with alternative hydrogen-based fuels; 2) International maritime and aviation

Source: Roland Berger

Figure 27. Required energy for a full energy transition with and without ETS sectors (2030-2040).

Required energy for a full energy transition, 2020–2040 [TWh][1]



1) 91% is assumed as capacity factor for electrolyzer and 52 kWh/kg required energy for the road and aviation sector and 59 kWh/kg for the maritime sector; 2) Others include the electrification of passenger cars, light- and medium-duty vehicles as well as the share of heavy-duty vehicles which can not be fuelled with alternative hydrogen-based fuels

Source: Roland Berger

Figure 28. Energy for a complete energy transition and electrolyser and power station capacity.

Iceland generated 19.1 TWh of electricity in 2020. The current total power capacity is 2.9 GW, of which 73% is from hydropower stations and 26% from geothermal stations. Other sources, such as wind, make up less than 1% of installed capacity but present a significant opportunity for further development.

Electricity generation, 2005–2020 [TWh]

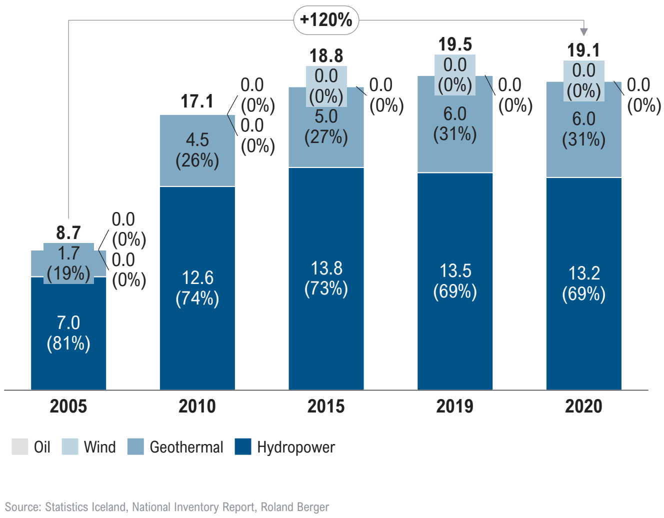


Figure 29. Iceland's electricity generation (2005-2020).

Since energy-intensive industries consume most of the energy generated in Iceland and the country is an island power system, the system experiences an energy surplus for some years. It is estimated that an average of 1-2 TWh of surplus energy[31] could be harnessed yearly with strategic investment in the energy system. Using this energy such as to produce hydrogen and e-fuels, could increase the overall utilisation of the system and reduce energy waste. The system is hydropower dominated, and the reservoir inflow varies between years. As this is intermittent energy, availability highly depends on the time of year and can vary significantly between years.

A portion of the surplus energy may also be needed to react to unexpected changes in supply or generation in the system. Future availability will also depend on factors such as aluminum prices and demand for flexible loads. Therefore, the risk of surplus energy being unavailable must be studied carefully.

[31] The Icelandic Energy Authority (Report from June 2016) and Landsvirkjun (2021).

Another factor that increases energy demand and decreases energy availability is increased power use due to direct electrification (e.g., electric vehicles) and other industries (e.g., data centres and aquaculture). In the past few years, Iceland has experienced considerable growth in EVs, which is expected to continue as the country aims to reach its decarbonisation goals. The availability of nonutilised renewable resources is still considerably high in Iceland. Areas with high wind speeds are abundant, and new options for hydro and geothermal power stations are still being explored, albeit subject to Governmental policies.

As hydropower and geothermal power stations enter potential ramp-ups in costs compared to already utilised resources, and with the continued competitiveness of wind power technology, further exploration into wind power utilisation in Iceland will be critical if this Roadmap is to materialise.

The required additional power capacity amount must be explored further regarding the available surplus and the 2030 goals. Given the current situation of the Icelandic energy industry, new power stations must be built if domestic production of hydrogen and e-fuels is to be utilised to reach the 2040 goals.

The availability of renewable energy is vital for this Roadmap.

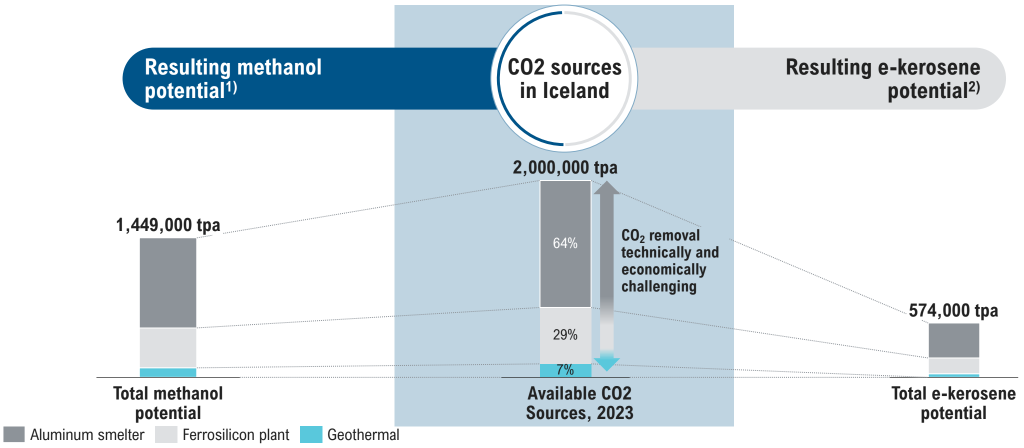
Carbon feedstock

In some cases, e-fuel production requires CO_2 sources for feedstock. This is the case for methanol and any e-crude derivative (e.g., e-kerosene as an alternative for jet fuel or e-diesel for maritime or road transport).

In Iceland, available CO_2 point sources total ~2,000 kt per year, where 1,300 kt is emitted from aluminum smelters, 580 kt from ferrosilicon plants, and 140 kt from geothermal power stations.

Assuming all the available CO_2 sources would be used for e-fuel production, the total possible output from local sources would be equivalent to approximately 1.45 m tonnes of methanol or 0.57 m tonnes of e-kerosene. While there are still technological and commercial limits to capturing and cleaning CO_2, especially for aluminum smelters, the Government will carefully observe and support the technological development related to capturing existing CO_2.

Current CO_2 sources in Iceland and potential for methanol and e-kerosene production, 2023



1) Assuming 90% recovery rate for all CO2 sources; 2) Assuming 90% recovery rate for all CO2 sources; based on Fischer-Tropsch route and 75% e-kerosene yield in final product mix, includes full CO2 demand to reach respective production volume; CO2: e-kerosene = c. 3.5:1; CO2: methanol = 1.4:1

Source: Landsvirkjun, Roland Berger

Figure 30. Current CO_2 sources in Iceland and potential for methanol and e-kerosene production.

From a volume perspective, the local CO_2 sources from industry and geothermal could be a limiting factor for the potential domestic production of e-fuels, both maritime and aviation applications, and further research is required. Looking toward the 2040 target, when the output of e-fuels is expected to ramp up, additional domestic carbon sources are needed to reach volume goals.

Alternative options for CO_2 sources could include direct air capture or imports of CO_2. Current costs for direct air capture are generally higher than for direct use from industry, but these costs could come down as the technology is developed. Iceland has conducive preconditions for direct air capture. Large volumes of water and access to thermal energy are available in many areas.

The Government will carefully observe and support the technological development related to sourcing CO_2 to reach its decarbonisation goals. This includes further analysis of the CO_2 supply chain and an assessment of the technological and commercial readiness.

In 2023, the EU issued two Delegated Acts, establishing criteria for renewable hydrogen and approved sources of CO2 for the production of renewable fuels of non-biological origin (RFNBO). As outlined in the Delegated Regulation (EU 2023/1185), CO2 from geological sources naturally released is always considered qualifying. However, CO2 from industrial point sources (as listed in Annex I of the EU ETS directive) will qualify for RFNBO production until 2041.[32])

[32] COMMISSION DELEGATED REGULATION (EU) 2023/1185 of 10 February 2023.

2.4 Economic opportunities and strategic perspective on hydrogen production in Iceland

Iceland is uniquely positioned to produce green hydrogen and use it to decarbonise domestic emissions to reach its climate goals. Over 99.9% of Iceland's energy generation is from renewable sources, and it has one of the greenest electricity grids globally. It has vast renewable resources of hydro and geothermal energy that can provide competitive baseload electricity for hydrogen production, as well as significant potential for electricity production from wind – with similar total load hours to the most attractive European offshore wind parks – to expand capacities further.

The 100% renewable energy profile of the Icelandic electricity grid could serve as a basis for the country's rapid decarbonisation of the transport sector in the upcoming decades and makes it particularly attractive as a location for competitively viable green hydrogen production since one of the significant cost drivers of hydrogen is the electricity price. This unique context could drive an even faster adoption of hydrogen and e-fuel technologies in Iceland than elsewhere in Europe.

The global scale-up of the hydrogen economy will also give rise to a substantial economic potential. Iceland can benefit from its domestic conditions that put the country in an excellent position to participate constructively in the future hydrogen and e-fuel economy. The Icelandic Government seeks to contribute to a sustainable economic growth by developing the sector. Opportunities for domestic hydrogen and hydrogen-based fuels production and subsequent deployment will be developed. The additional potential arising from energy exports to countries with limited renewable resources will be explored in the European Union and beyond. Iceland has already gained substantial experience with pilot and demonstration projects of the technology over the past decades. It is now prepared to scale up existing activities and pursue concrete project development opportunities as a subsequent next step.

Green hydrogen and e-fuels also provide an opportunity to create jobs for highly skilled workers across the entire value chain, ranging from production to storage and transport, as well as distribution infrastructure and use of the new fuels. Fostering local knowledge and know-how creation by collaborating with Icelandic research institutions will also be explored. Ultimately, the goal is to be able to train and educate highly skilled technicians and researchers locally. This could be done by establishing a central research and training hub to support hydrogen development in the country in the form of a campus combining efforts from various Icelandic research and educational institutions with the potential involvement of industry players.

Expanding Iceland's own hydrogen and e-fuel capabilities, including production capacity, will ultimately increase Iceland's security of energy supply and make the country more independent from energy imports in the long term. The Government's long-term strategy is to become fossil fuel-independent by 2040. In this decade, the necessary groundwork to achieve this goal and become a self-sustainable producer of hydrogen and e-fuels must be laid. This includes the planning of the required resilient infrastructure. Producing renewable fuels domestically would also reduce Iceland's exposure to fluctuating supply and corresponding price fluctuations from fossil fuels.

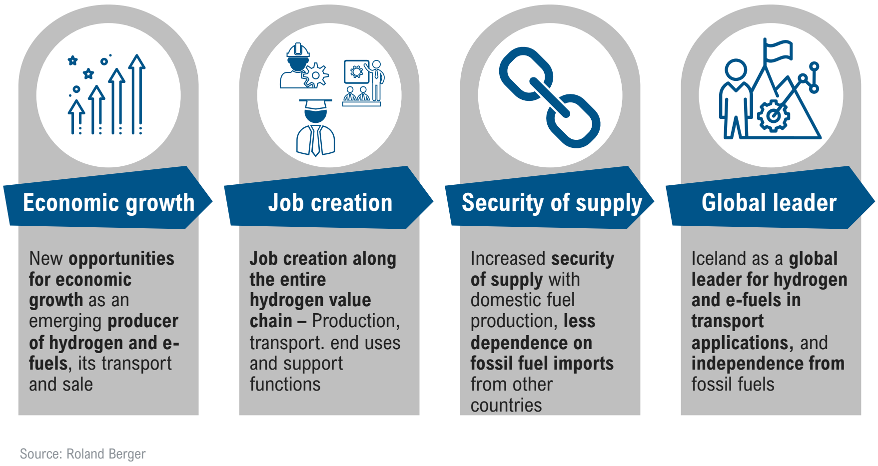


Figure 31. Strategic opportunities for Iceland.

2.5 Potential for green hydrogen exports

Global hydrogen and e-fuel demand is expected to take off in the coming decades as transportation, industrial use, and energy applications will increasingly be decarbonised. The IEA expects global hydrogen demand to reach more than 200 m tonnes by 2030 from less than 90 m tonnes in 2020. By 2050, the hydrogen demand is expected to surpass 500 m tonnes.[33]

The EU projects European hydrogen demand to increase from more than 8 m tonnes in 2020 to 20 m tonnes by 2030 and up to 95 m tonnes by 2050.[34] Simultaneously, the almost 8 m tonnes of hydrogen currently used annually and produced from natural gas must be replaced with low-carbon hydrogen. Therefore, to satisfy the increasing demand, the EU has set the following targets:

[33] IEA (2021): "Net-zero by 2050 – A roadmap for the global energy sector".
[34] IEA (2021): Global Hydrogen Review 2021; Hydrogen Council (2021): Hydrogen for Net Zero.

1. **10 million tonnes of annual domestic renewable H2 production by 2030**
2. **10 million tonnes of annual renewable H2 imports from third countries by 2030**[35]

The domestically produced volumes of 10 million tonnes annually will require an electrolysis capacity ramp-up of at least 65-100 GW by 2030.[36]

Hydrogen demand in Europe, 2022–2030 [%; million tonnes]

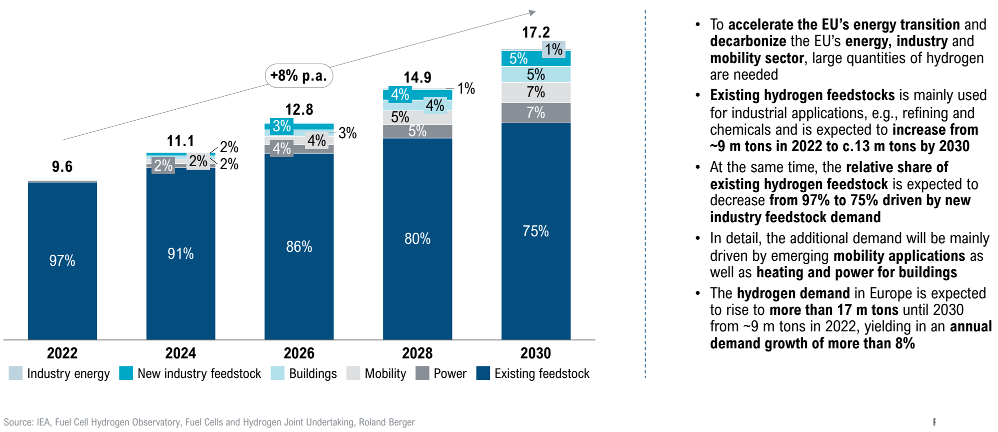


Figure 32. Forecast of the European hydrogen demand 2020 – 2030 [million tonnes].

Europe's import demand could be an additional economic opportunity for Iceland. The local conditions in Iceland, the availability of competitively priced renewable electricity, and economic, financial, and political stability have put the country on the radar of many project developers and governments needing clean energy supply. Iceland has received significant interest as a potential location for large-scale hydrogen and e-fuels production for subsequent export. The European Union is expected to remain a net importer of hydrogen in the foreseeable future.

[35] EU (2022): Hydrogen accelerator.

[36] Roland Berger (2022).

Estimates of hydrogen imports until 2050 [million tonnes]

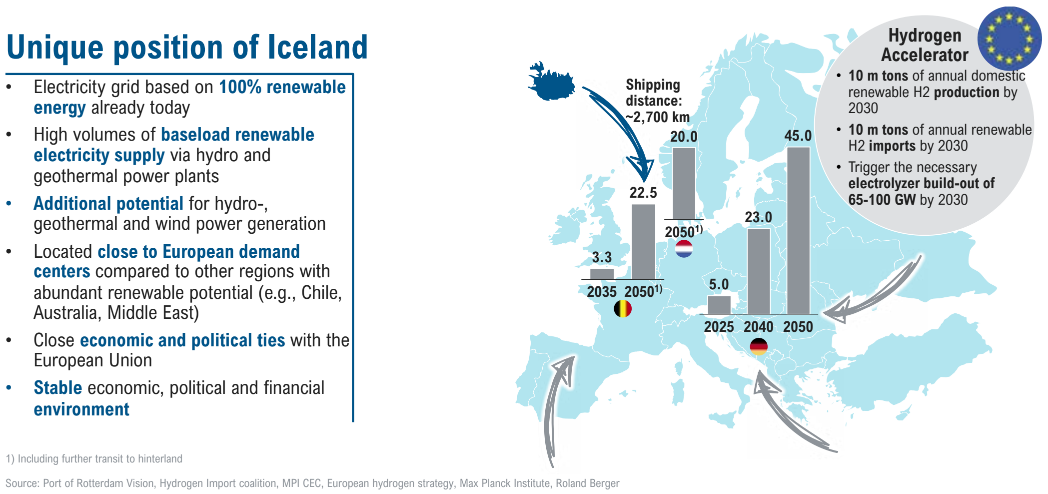


Figure 33. Estimates of European hydrogen imports until 2050 (million tonnes).

Icelandic companies have also been exploring export opportunities. A pre-feasibility study undertaken by Landsvirkjun, the National Power Company of Iceland, and the Port of Rotterdam released in June 2021 assumes that hydrogen exports from Iceland will be financially and technically viable and "realistic before 2030". The study estimates that 2 to 4 TWh, or 200 to 500 MW of electrolyser capacity, could be deployed in Iceland in the second half of this decade.[37] The study does not consider the additional capacity required for the domestic energy transition, as it was only focused on exports.

A large-scale hydrogen or e-fuel project of similar size could simultaneously satisfy domestic demand and offer potential for export. The Icelandic Government seeks to explore the opportunities arising from larger-scale projects with an export component due to several reasons:

1. **Economies of scale in larger-scale projects drive down hydrogen production costs significantly which can further contribute to the attractiveness and economic competitiveness of hydrogen and e-fuels to reach domestic decarbonisation goals.**

2. **Securing international off-take commitments through large-scale export projects can mitigate initial upstream investment risk and ensure the availability of hydrogen**

[37] https://www.portofrotterdam.com/en/news-and-press-releases/study-shows-shipping-green-hydrogen-from-iceland-to-rotterdam-to-be

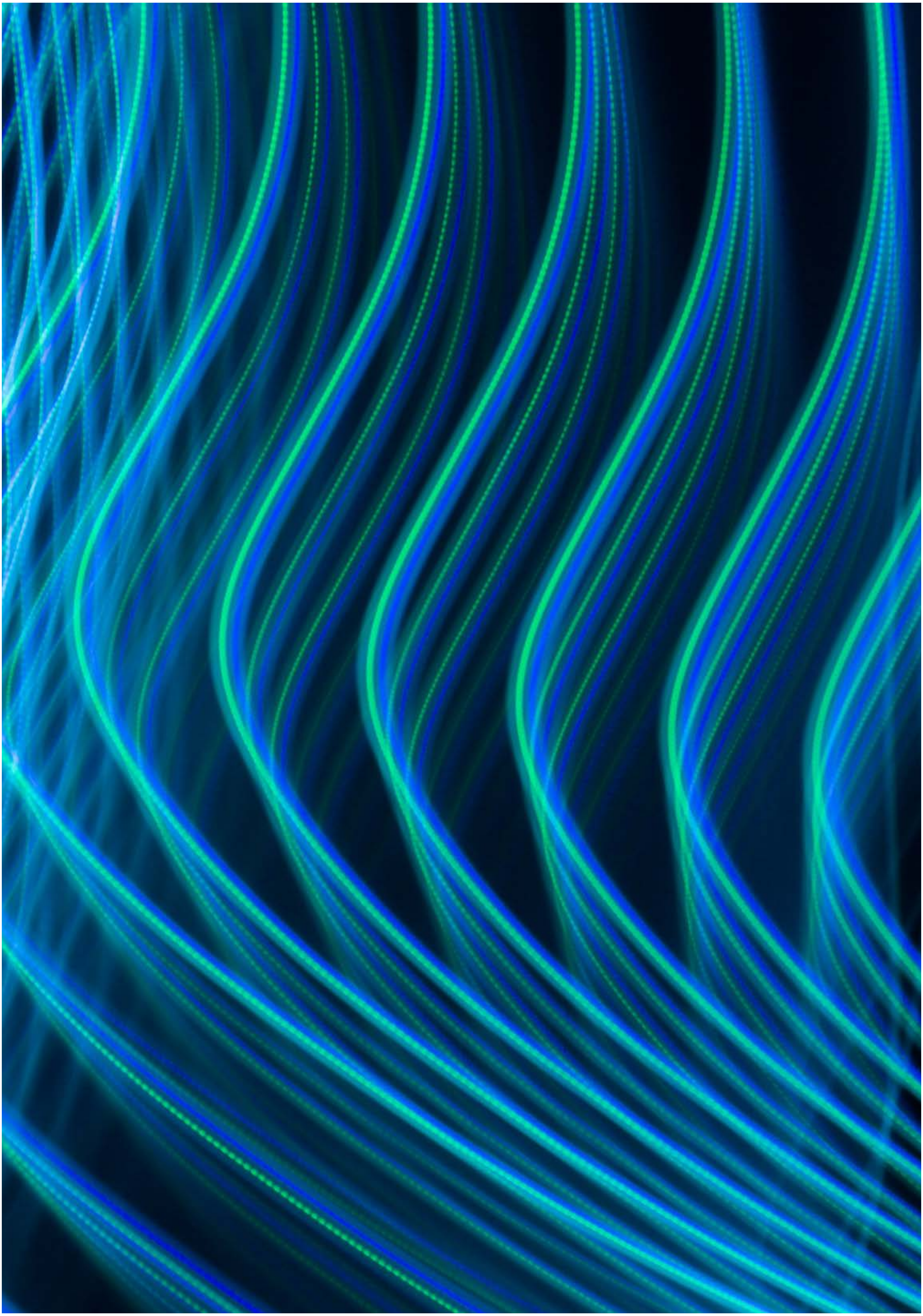
supply before the full development of domestic demand and associated infrastructure has occurred.

3. **Domestic demand can grow alongside an export project by moving away from previous "pilot character" projects. Thus, downstream investments into new technology for domestic end-users are further de-risked.**

4. **Expanding hydrogen and e-fuel production in Iceland to supply international off-takers could further increase economic benefits and foster economic growth in the upcoming decades. It could become a prominent new export sector and a pillar of the local economy.**

The power generation needed to scale up a hydrogen and e-fuel economy in Iceland to decarbonise the transport sector is, of course, contingent on the availability of renewable energy sources. The Icelandic Government is committed to the third energy transition required to fulfil Iceland's ambitious climate goals.

Iceland will explore how best to support the export path as an additional driver for decarbonisation, value and job creation in Iceland and further evaluate the associated cost and benefits.



3. Roll-out: Plan, milestones for 2030 and outlook for 2040

3.1 Roll-out plan and phases

Based on assessing the technological and commercial readiness of hydrogen and e-fuels, the Icelandic Government has put together the following roll-out plan for 2030 to support its vision for the Icelandic Energy Policy and the hydrogen economy to ensure its goals are reached. This roll-out plan will be supplemented and clarified in more detail in a forthcoming energy transition plan issued by the Government. The energy transition plan is subject to further internal ministerial consultation and budgetary process. The aim is to finalise and introduce the energy transition plan in 2024.

2020-2030: Building blocks – Reaching 2030 goals

Hydrogen is expected to play a substantial role in heavy-duty transportation, focusing on reaching the 2030 goal of 40% renewable share for road transport. E-fuels are expected to play a role in the maritime sector, with the decade focused on developing pilots and blending to reach the Government's 10% renewable energy share goal by 2030. E-kerosene pilots will be evaluated for international aviation, and alternative fuels for domestic aviation will be explored further. Most of the infrastructure investment will be focused on reaching decarbonisation goals for road transportation, maritime industries, and domestic aviation.

The phase up to 2030 is critical as it lays the foundations for further decarbonisation in the following decades. Thus, the relevant infrastructure preparations and investments along the hydrogen value chain must be undertaken by 2030. During this decade, these decisive decisions must be taken.

Further feasibility studies need to be conducted to create clarity about locations, sizes, and fuel types.

The Government will evaluate the feasibility and impact of additional hydrogen and e-fuels production for export on its ability to reach the decarbonisation targets, whether through increased economics, faster adoption rates, or other factors.

The Government recognises that everything between now and 2030 is essential and acts as a preparatory step for a much steeper scaling phase to 2040.

2030-2040: Focused development – E-fuels for maritime and aviation sectors

In the following decade, hydrogen demand is expected to further increase in all three sectors. To reach the goal of fossil fuel independence by 2040, the maritime and aviation industries will play an increasingly significant role. Hydrogen for heavy-duty road transport is expected to mature along with a systematic development of e-fuel capacity, such as e-methanol, e-ammonia, e-diesel, e-kerosene, or other carriers. Carrier choice in the maritime sector will depend on market conditions, technology development, and ship design, and maritime and aviation pilots are expected to be scaled up.

Reaching 2030 milestones: Hydrogen Valleys

Regionally integrated hydrogen ecosystems, so-called “Hydrogen Valleys,” are increasingly used as frameworks to develop the hydrogen economy. With their integrated approach, Hydrogen Valleys paved the way for the setup of the first regional 'mini hydrogen economies' by combining supply and demand, often with long-term off-take agreements by joint stakeholder cooperation, thus contributing to market development. As a result, the project's investments get de-risked, and the concept's viability increases.

Over the past years, the concept has emerged as a firmly established term in the European funding and collaboration landscape. Hydrogen Valleys have formed the first regional "hydrogen economies" as bottom-up steppingstones in developing a national hydrogen economy. The Hydrogen Valley approach typically comprises a multi-million EUR investment, financially supported by governments.

For the industry's scale-up to 2030, Iceland will consider the established Hydrogen Valley approach by matching supply and demand in medium to large-scale projects and potentially interlinking different end-use sectors to leverage specific infrastructures for emerging applications.

Stream 1: Hydrogen Valley Iceland for road transport decarbonisation (2024 and onwards)

By 2030, the infrastructure required to switch from conventional heavy-duty trucks and buses to hydrogen technology must be developed. This includes the necessary hydrogen production capacity and the HRS road-transport network, comprising 10-30 stations along the main routes after full development. Developing the necessary infrastructure will signal to domestic users of hydrogen trucks and Original Equipment Manufacturers that Iceland is committed to making heavy-duty transport decarbonisation a reality.

Stream 2: Hydrogen Valley Iceland for maritime decarbonisation (2026 and onwards)

The next phase will – along with scaling up the activities of stream 1 – include leveraging infrastructure development for decarbonising maritime applications. This includes assessing whether the hydrogen supply can be increased to serve fuel cell vessels or produce e-fuels for blending or direct use in new or retrofitted vessels. As a first step,

it is envisaged to convert the state-owned fleet to run on hydrogen or e-fuels by 2030. Correspondingly, the necessary refueling infrastructure will be rolled out for new vessels to be immediately supplied once in operation.

The Icelandic Government supports the Hydrogen Valley approach as a joint effort of all relevant Icelandic and international stakeholders. For both streams, the Icelandic Government will explore how to make support available to incentivise and de-risk private sector investments, as will be further stipulated in the Energy Transition Plan on implementation of the Roadmap.

3.2 Policy and incentive frameworks required for Roadmap realisation

High volumes of renewable power and electrolyser capacity are required to meet the Government's climate goals for fossil fuel independence. The Icelandic Government will explore policy and incentive frameworks to support its vision and implementation. Developing the hydrogen and e-fuel economy is part of the overall actions Iceland will undertake in the following decades.

The following overview displays the policies and measures which are already in place. Ten of them are related to the electrification or fuel change of the car fleet, three have to do with promoting public transport, cycling, or walking, three are on the electrification of ferries, and the final one has to do with mitigating emissions from aviation.

Policy and measure	Instrument type	Status[37]	Description
Participation in an international scheme for mitigating emissions from aviation (ETS and CORSIA)	Economic, Regulatory	Implemented	Iceland will participate in CORSIA which is meant to reduce GHG emissions from aviation
Incentives for low- and zero emissions vehicles	Economic, Fiscal, Regulatory	Implemented	Tax incentives will be continued and expanded as necessary to increase low-and zero emissions vehicle use in Iceland
Infrastructure for low- and zero emissions vehicles	Economic, Fiscal, Regulatory	Implemented	Infrastructure will be increased for low- and zero emissions vehicles. Investment grants have been allocated for high power recharging points widely around the country, near tourist accommodation, among other incentives
Legislation and regulations for clean energy transition	Regulatory	Implemented	Diverse measures have recently been taken in this regard, including a requirement that all new buildings supply EV charging stations, and regulations facilitating setting up EV charging stations in apartment buildings
Ban on new registration of diesel and gasoline vehicles after 2030	Regulatory	Implemented	Registration of new diesel and gasoline vehicles will be banned after 2030 with some exceptions
Infrastructure for active mobility	Fiscal	Implemented	Tax incentives will be adopted to encourage active mobility, such as cycling and walking
Encouraging public transport	Economic, Regulatory	Implemented	Public transport will be encouraged with a better public transport system in the capital area. Public transport between population centres in regional Iceland will be supported
Low emissions vehicles in government and state enterprises	Economic, Regulatory	Implemented	Government agencies will be obliged to buy low emissions and electric vehicles when renewing their vehicle fleet
Energy transition of ferries	Fiscal	Implemented	Ferries that are a regular part of the transport system will be required to use fossil free fuel
Incentives for active mobility	Economic, Information	Implemented	Tax incentives will be adopted to encourage active mobility, such as cycling and walking
Energy transition in heavy transport	Fiscal	Adopted (not implemented)	A task force that aims towards accelerating energy transition in heavy vehicle transport has been formed
Incentives for low emissions rental cars	Economic, Fiscal	Adopted (not implemented)	The action aims at increasing the availability of low emissions and electric rental cars. Tax incentives will be provided on revenue from renting out low emissions rental cars

Policy and measure	Instrument type	Status[38]	Description
Energy transition of state-owned vessels	Fiscal	Adopted (not implemented)	The action aims to reduce the use of fossil fuel in state owned vessels other than ferries
Full depreciation of vehicle in year 1	Fiscal, Economic	Implemented	Full depreciation in the year of purchase down to the residual value, on vehicles powered by methane, methanol, electricity or hydrogen
Additional depreciation adder (+25%) in year 1	Economic, Fiscal	Implemented	In year of purchase, next to the full depreciation an additional 25% of the depreciation amount is granted
No excise duty	Economic, Fiscal	Implemented	No excise duties have to be paid for electric vehicles

Figure 35. Implemented and adopted transportation policies and measures.[37]

Specifically, with a focus on road transport, several incentives are in place for hydrogen and e-fuel transportation options, including:

1. **No VAT on general revenue up to ISK 6.5 m yearly (to EOY 2023)**
2. **No VAT on revenue from renting out vehicles (to EOY 2023)**
3. **No excise duty**
4. **Full depreciation of vehicle in year 1 (to EOY 2023)**
5. **Additional depreciation adder (+25%) in year 1 (to EOY 2025)**
6. **Minimum vehicle tax irrespective of vehicle size**

Most of the current incentives in place focus on the road transportation segment. Within the road transportation segment, the incentives have a varying degree of impact on the subsegments. Nr. 1 (VAT exceptions) does not impact commercial vehicles, as corporations are generally exempt from VAT. Similarly, for Nr. 3 (excise duties), vehicles like large buses, goods trucks, off-road vehicles, and cars exclusively used for motorsport and rescue operations are generally exempt from excise duties. Combined, they generally only work as new incentives for zero-emissions heavy-duty trucks.

[38] Policy implementation is generally defined as a series of activities undertaken by Government and relating parties to achieve the goals and objectives articulated in policy statements. In contrast to that, policy adoption refers to the phase of the policy process in which policies are accepted by Government bodies for future implementation; however, action has not been taken yet.

An exception is the incentive, which allows an additional 25% depreciation in year one, also valid for domestic maritime transportation. In its current form, it does not impact the fishing segment.

So far, no incentives have been implemented to target the direct production of e-fuels.

In Figure 35 below, various examples along the value chain are displayed. Specifically, the value chain steps “Tendering,” “Production,” “Distribution, storage, sales,” and “End use applications” were addressed. The Government might assess a “Contract Governance” mechanism for the tendering process. It ensures a reliable permitting process from the very beginning. Further instruments range from direct incentives via a price or CAPEX subsidy to other de-risking tools like a “Contract for Differences”. This is essential to ensure an offtake for capacity roll-out, especially from 2030 onwards. Another potential instrument might be a bonus/penalty system, which leads to a systematic redirection in favor of green technologies. Many of which will require legal amendments. Each selected tool has different characteristics that potentially enable the management of the identified key risks.

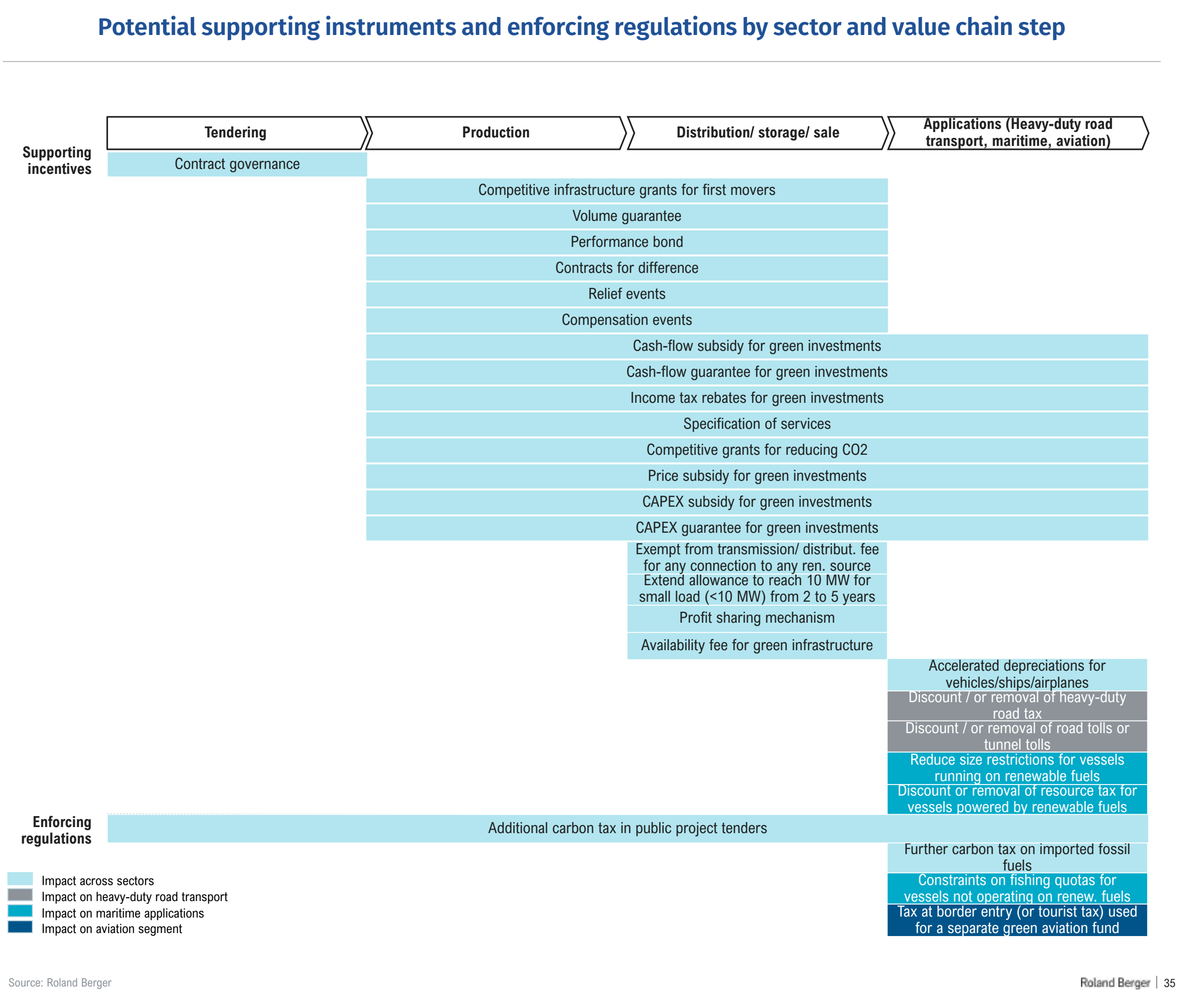


Figure 35. Examples of incentives and de-risking tools to explore.

The Government will evaluate the individual options in detail to assess which instrument might suit a particular situation. Moreover, the Government must ensure that the policies do not distort the competitive position of Icelandic companies vis-à-vis other countries, nor that the policies lead to carbon leakage. Especially in the context of the aviation sector, this might be significant. Iceland, located in the North Atlantic Ocean, is unique since the distances between Iceland and European destinations are generally greater than between other European countries.

Typically applied instruments in the context of the hydrogen ramp-up are:

Tool	Description	Key factors	Application examples from Europe
Contracts for differences	A contract for differences is a form of revenue support in which the public guarantees to compensate (in form of a cash payment) the private operators for the difference between the (average) sales price and a predefined "target" sales price (i.e., strike price) for a certain product produced, in return for the operation by the private operators.	In addition to the actual volume of the product sold and the difference between strike price and the actual sales price, the amount paid by the public to the private operators depends on the public's funding willingness and other factors such as (EU state aid-related) regulatory requirements.	The German Government will support the use of electrolyser by launching a program entitled "Carbon Contracts for Differences". The program is funded with EUR 3 billion until 2024.
Cash-flow guarantee	A cash-flow guarantee is a guarantee provided by the public to the private operators to offset (at least certain parts of) the annual negative EBITDA from operations, if existent, in return for the operation by the respective private operators.	The actual cash amount paid depends on the materialisation of a negative EBITDA, the public's funding willingness and additional factors, such as (EU state aid-related) regulatory requirements and contractually defined aspects including certain costs.	The H2 Global initiative, launched by the German Government, guaranteed a private hydrogen market player, e.g., a hydrogen refuelling station operator to reimburse certain cost expenditures in the case of a negative EBITDA in return for the operation of the station.
CAPEX subsidy	A CAPEX subsidy is a cash payment by the public to the private operators which is paid in return for the construction (and fulfilment of contractually agreed construction requirements) by the respective operators. A CAPEX subsidy can be paid upfront or on an annual basis.	The actual cash amount paid by the public to the private operators depends on the public's funding willingness as well as additional factors, such as (EU state aid-related) regulatory requirements and contractually defined aspects.	The German Government promotes the acquisition of LCV and HCV running on alternative fuels and the associated refuelling and charging infrastructure; 80% of the additional investment expenditure per vehicle is subsidised (add. expenditure to purchase a comparable vehicle powered by alternative fuels instead of a vehicle with a conventional drive system) and 80% of infrastructure investment (max. EUR 15 m subsidy per applicant and year).

The Government will assess their applicability and how to tailor them to incentivise the investments needed to reach Iceland's ambitious 2040 goals.

3.3 Investment requirements for roll-out to 2030

Investment will be required across the whole hydrogen value chain, from production to end-use, to ensure the successful development of an Icelandic hydrogen and e-fuel economy.

To implement this Roadmap, the general availability of electricity will need to be considered, including new renewable power generation and upgrades to the transmission system, along with electrolyser and equipment for conversion for storage and transport. Any additional equipment required for e-fuel production, such as process equipment or carbon capture and cleaning, must also be considered.

For distribution, additional hydrogen transportation capacity will be required to transport the hydrogen from production facilities to refuelling stations.

For road transport, the availability of HRS is a crucial enabler for adoption. Indication from industry has shown that having 10-30 stations in the country might be sufficient for heavy-duty road trucks and buses.

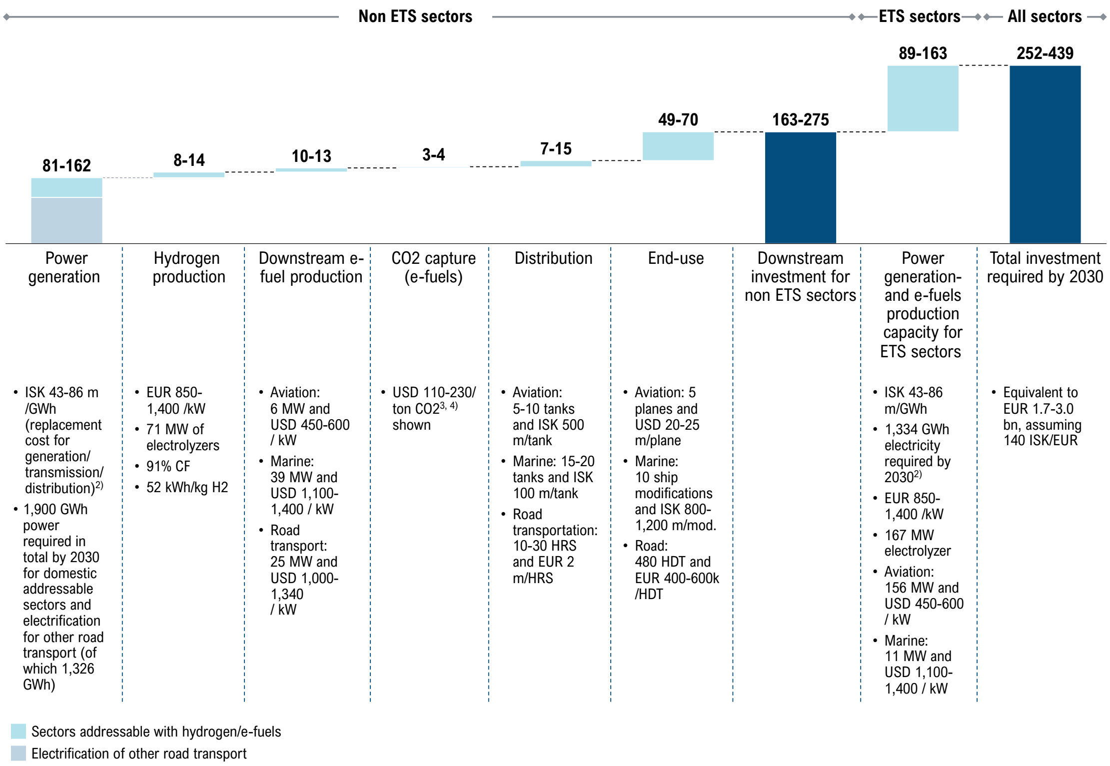
Further investment in refuelling stations, storage for e-fuels, and containment at harbors, ports, and airports may be required for the maritime and aviation sectors. Further design of the system will depend on multiple factors, such as the operating pressures of the vehicles, technological decisions on e-fuel types, and more.

A high-level analysis shows that by 2030, the estimated total investment required to reach these 2030 ambitions could range from ISK 160-275 billion for domestic use, with an additional ISK 90-160 billion assuming domestic production of e-fuels for the ETS sectors. In total, these investments range from ISK 160-440 billion.[39] For comparison, in 2021, Iceland's estimated GDP and total Government revenues were ISK 3,797 billion[40] and ISK 1,230 billion, respectively[41]. Therefore, the cumulative investment required by 2030 could be 6-12% of GDP in 2022.

The Icelandic Government will assess suitable options to support these required investments financially. Furthermore, the Government will explore opportunities to monetise green investments and cooperate with the private sector to leverage private financing of energy transition projects in the country.

[39] Figures are based on 2021 analysis and presented in 2021 ISK real-terms.
[40] January, 2024 - https://hagstofa.is/talnaefni/efnahagur/thjodhagsreikningar/landsframleidsla/
[41] Fjarsysla Rikisins (January, 2024 – https://rikisreikningur.is/).

Potential investment requirements along the value chain for 2023 goals [ISK bn][1]



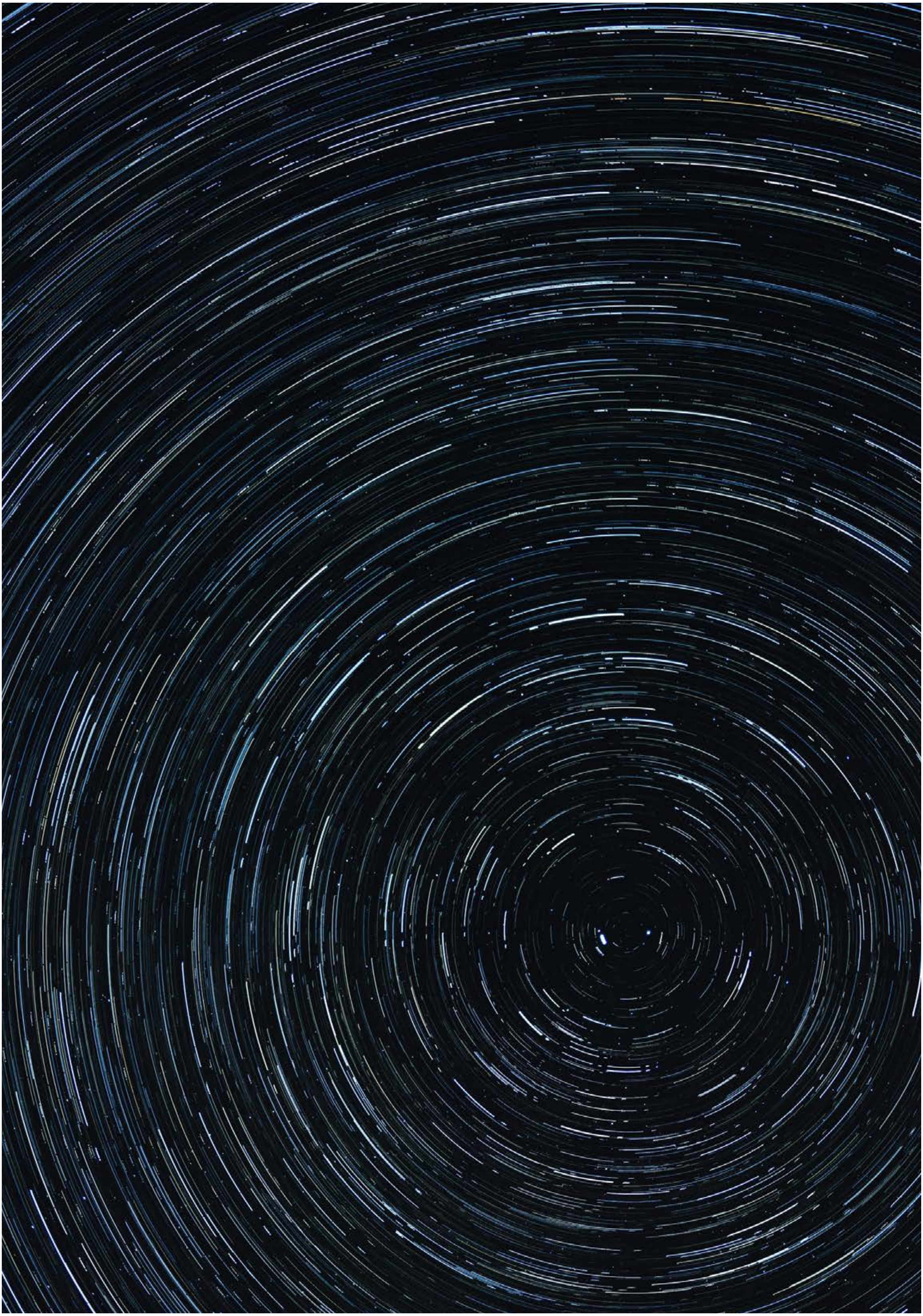
1) Excludes other potential areas such as transport, shipping of e-crude for refining, logistic costs etc., also excludes potential charging infrastructure for electric vehicles;[42] 2) Cost range for power generation: 300-600 m ISK/MW (source: Samtok Idnadarins), assuming capacity factor of 80%, equivalent required power plant capacity is 270 MW; 3) Indicative cost assumptions based on capture from aluminum (upper boundary) and geothermal (lower boundary); 4) Excl. storage and compression for methanol production

Source: Roland Berger

Figure 36. Potential investment requirements until 2030.

Overall, this infrastructure will require a significant investment.

[42] Figures are based on 2021 analysis and presented in 2021 ISK real-terms.

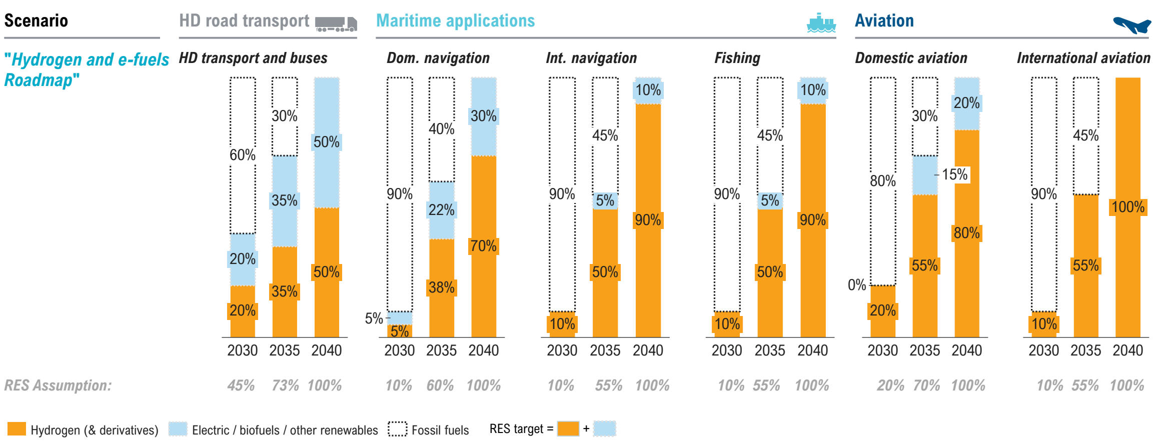


4. Appendix

Scenario assumptions for hydrogen uptake by sector

Below are assumptions on uptake percentages for hydrogen, e-fuels, and other renewable fuels by year for each subsegment (heavy-duty road transport, maritime applications, and aviation in Iceland).

Hydrogen and renewable fuel penetration rates – Assumptions



Source: Statistics Iceland, Desk research, Expert interviews, Roland Berger

Figure 37. Overview penetration rates.

Previous Roadmap draft version

A draft of the Roadmap from 2021 was used for reference to assess energy requirements for the complete energy transition in the Green Book, published by the Government in March 2022. The results below reflect energy requirements for estimated hydrogen and e-fuel demand for heavy-duty road transport, maritime applications (excluding international navigation), and aviation. Note that energy requirements for EVs are excluded from the assessment.

The key difference in assumptions between the 2021 Draft and the 2024 Roadmap are:

1. **Fossil fuel independence was assumed in 2050 in 2021 Draft, as opposed to 2040 in 2024.**
2. **International Navigation is included in 2024, not the 2021 Draft.**
3. **International Aviation assumption in 2024 is 0.75 kg H2 / kg e-kerosene, but 0.94 kg H2 / kg e-kerosene in the 2021 Draft.**
4. **The updated fuel use forecast from the National Energy Authority was used in 2024, but an older version was used for the 2021 Draft.**
5. **Assessment of energy requirements for electric vehicles is included in 2024, but the 2021 Draft excludes that assessment.**

Potential renewable energy demand for hydrogen production [TWh/year][1]

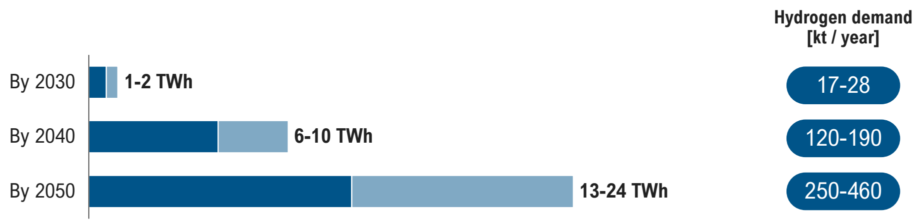


Figure 38. Assessment of energy required for a complete energy transition, from Hydrogen and E-fuels Roadmap for Iceland, 2021 Draft.

Government of Iceland
Ministry of the Environment, Energy and Climate