July 2024
Landsnet

Iceland energy outlook for sustainable aviation fuel

COWI Iceland ehf.
Urdarhvarfi 6
203 Kopavogur

Tel.: +354 422 3000
www.cowi.com

Iceland energy outlook for sustainable aviation fuel

Project No.	Document no.
A275042	A275042-103 Report_Iceland Energy Outlook SAF

Version	Date of issue	Description	Prepared	Checked	Approved
1.0	15.07.2024		KATRR, KNHD, OLEK, IRISK	KNHD	GPST

Table of Contents

Summary

Landsnet is currently working on further development of Landsnet's Energy Forecast, which was published for the first-time in 2023. As part of that development, Landsnet has reached out to COWI to get a better understanding on how the demand for sustainable aviation fuel (SAF) could develop in the future.

The objective of the Iceland Energy Outlook for SAF report is to:

1. Explore how the demand for SAF could develop in Iceland towards 2050.

2. To illustrate relevant supply side aspects in terms of Iceland's CO_2 and RES available for SAF production.

The outlook report focuses on international aviation, which dominates the aviation fuel demand in Iceland[1]. The supply side aspects are illustrated looking at 2035, representing a near-term, and 2050, as the long-term perspective.

Four scenarios are set up to explore how the demand for SAF could develop (see Figure 0-1). The scenarios are created by varying factors that will have a large influence on the SAF demand and are at the same time uncertain. As such, the scenarios are made by assuming:

- Different levels of aviation demand: Iceland's future demand for international aviation towards 2050; depending on the sector development and behavioural aspects.

- Different ambition levels in implementing SAF in aviation in Iceland: Whether aligning with the min. SAF shares in EUs ReFuelEU aviation act; or aiming for 100 % SAF towards 2050 in line with the national target of phasing out fossil fuels by 2050.

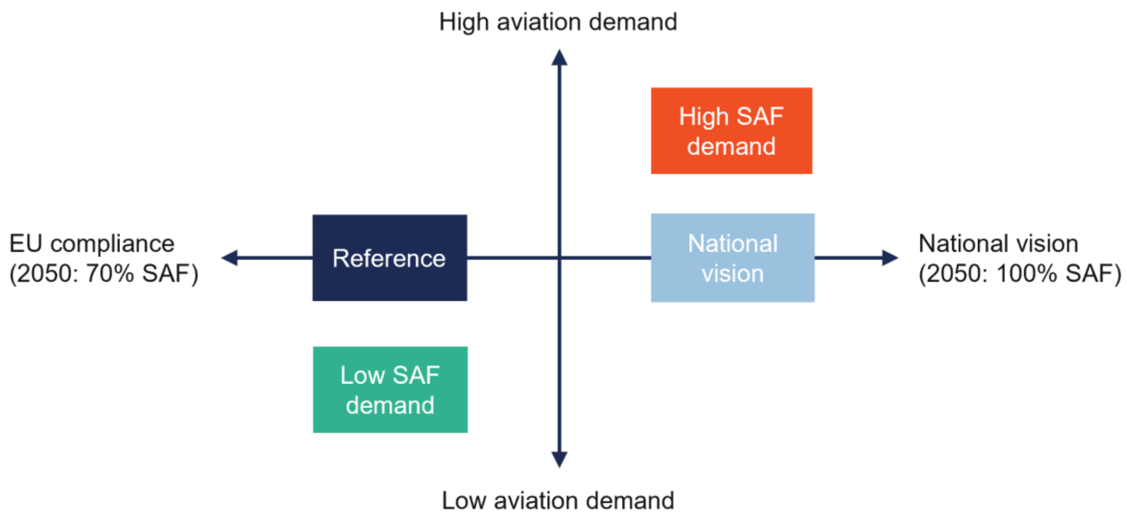


Figure 0-1. Conceptual illustration of the scenarios set up.

[1] The fuel demand for international aviation in Iceland has been 95-98% of the total aviation fuel demand in Iceland since 2010 (domestic aviation covers the remaining 2-5%).

The future SAF demands estimated for the four different scenarios are given in Figure 0-2. The e-SAF for the given scenarios includes only e-SAF, excluding other fuels that can be used to reach the e-SAF target according to the ReFuelEU regulation.

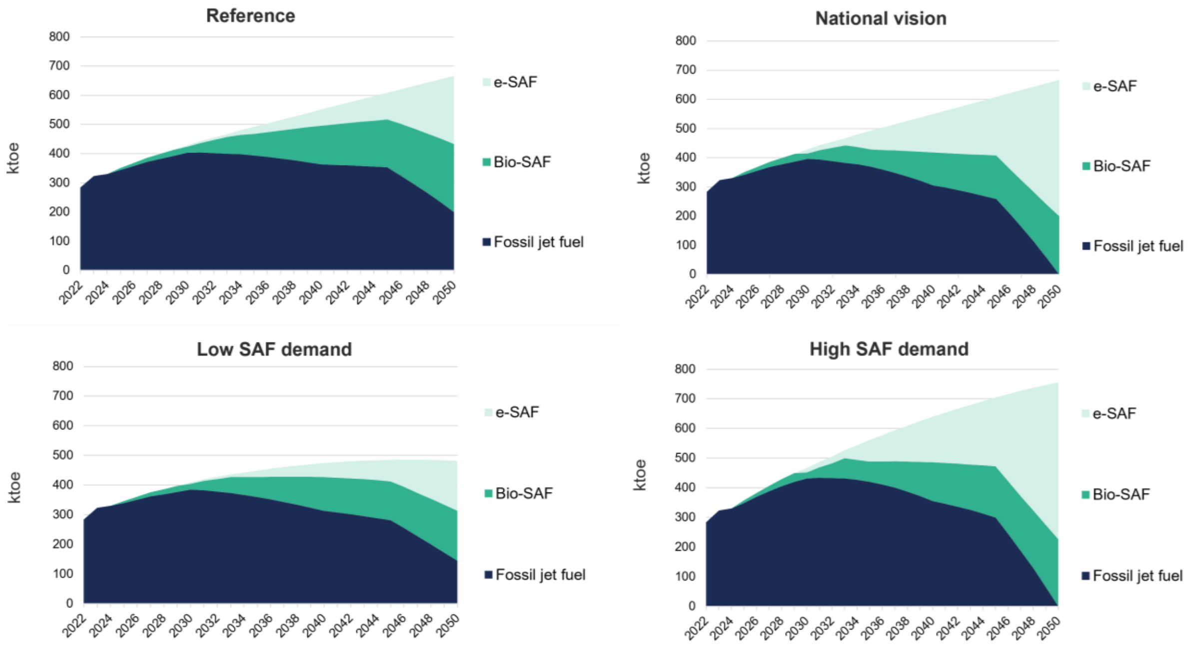


Figure 0-2. Final energy demand for Iceland's international aviation in the four scenarios.

The results illustrate that Iceland's demand for e-SAF and bio-SAF towards 2050 will significantly depend on both the development in total aviation demand, the ambition level in terms of phasing out fossil aviation fuels, and to which extent the SAF demand is met by e-SAF vs. bio-SAF. The scenario differences become larger towards 2050 where the difference in both aviation demands and SAF shares are largest.

The results point to that in 2035 1) the forecasted electricity generation from renewable energy sources (RES) in Iceland is sufficient to cover the estimated electricity demand incl. SAF production in the scenarios 2) and that the technical CO_2 potential in Iceland is sufficient to cover the CO_2 input needed for SAF production, also in case of meeting the SAF demand purely by domestic SAF-production.

However, in 2050, the supply side aspects become more challenging. As such, the estimated electricity demand in 2050 is significantly higher than the currently forecasted RES generation regardless of the scenario. This is due to the large electricity consumption that would be needed for e-SAF production (in case of domestic supply), and the significant increase in electricity demand in the other sectors as part of the planned energy transition. This illustrates that significant expansion of RES will be required in Iceland, if the future SAF in the scenarios are to be covered by domestic SAF production. As such, the scenarios indicate that if RES generation is not increased further than given in the forecast, the SAF demand in 2050 would have to be met purely by import.

Moreover, in 2050, the domestic biogenic CO_2 point sources[2] are insufficient to cover the estimated CO_2 demands for e-SAF production, regardless of the scenario. As a result, even if RES generation

[2] After 2041, for the e-SAF to be considered RFNBO in alignment with the ReFuelEU aviation regulation, the CO_2 source needs to be biogenic.

capacity is expanded sufficiently, a significant amount of CO_2 would have to be based on other sources, if pursuing to meet the SAF-demand domestically. These alternative CO_2 sources cover: CO_2 import or Direct Air Capture (DAC) or Direct Ocean Capture (DOC). Alternatively, part of the SAF demand could be covered by importing SAF.

1 Introduction

Iceland has abundant renewable energy resources, specifically geothermal and hydroelectric power, but also significant potential for wind power. These sources provide most of the country's electricity and primary energy, as shown in Figure 1-1.

Geothermal energy plays a significant role in Iceland's energy mix, both in electricity generation and district heating. However, although Iceland has limited fossil fuel consumption, almost all transport in Iceland is powered by fossil fuels. This includes vehicles, machines, maritime and aviation. The share of fossil fuels (oil) in the country's primary energy consumption is almost as high as the share of hydropower.

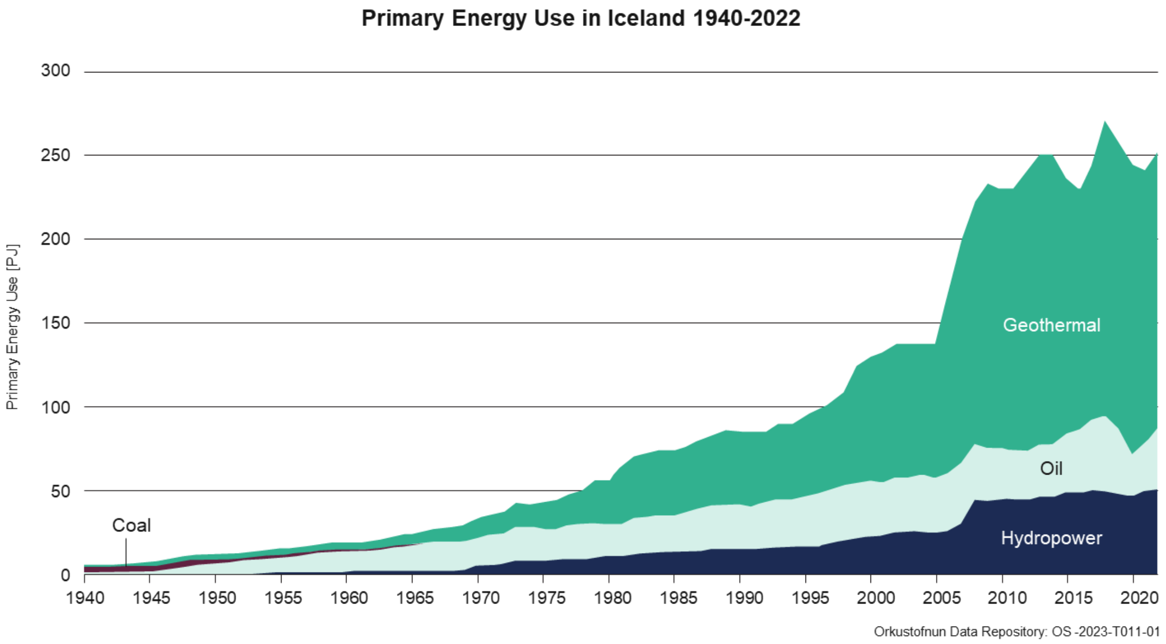


Figure 1-1. The development of the primary energy use in Iceland from 1940-2022. [1]

In Iceland the electricity production is almost exclusively with renewable energy sources (RES) as Figure 1-2 demonstrates.

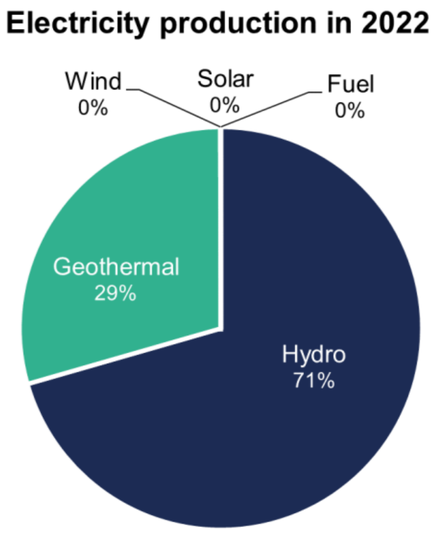


Figure 1-2. Electricity production in 2022 in Iceland.

The electricity demand in 2022 distributed on uses are displayed in Figure 1-3. The energy transition is included in general use, which is mainly in transport on land. Based on fuel consumption data, no energy transition has begun in the aviation sector in Iceland yet, neither in domestic nor international. [2]

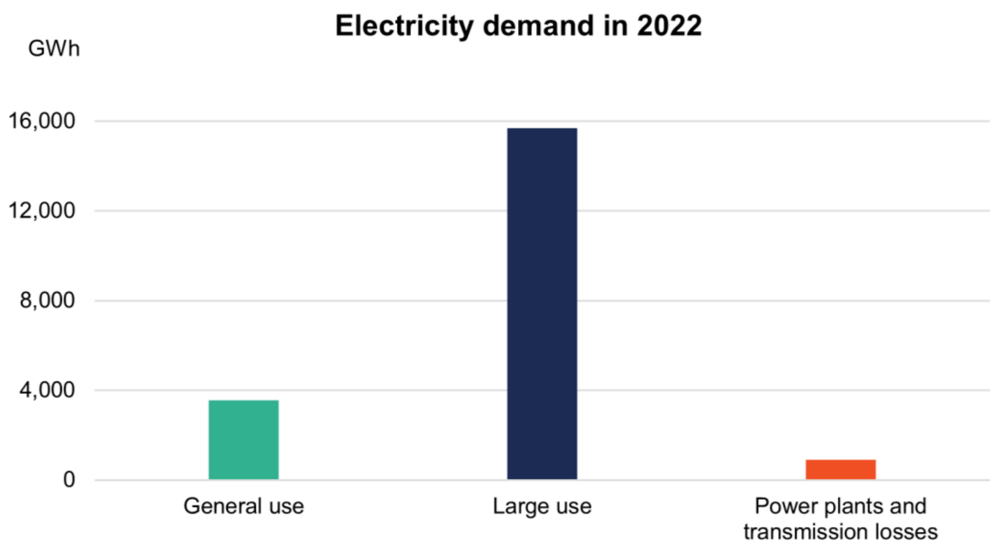


Figure 1-3. Electricity demand in 2022 distributed on uses.

Based on the Energy Outlook published by Landsnet last year, the electricity demand in Iceland is estimated to double with a full energy transition in 2050. The outlook estimates that the energy transition in transport on land, machines and domestic aviation will be achieved in 2040, estimated as 27% of the total energy demand of the energy transition, see Figure 1-4. For the energy transition in international aviation and maritime is expected to be achieved in 2050, in line with the Energy Policy for Iceland from 2020.

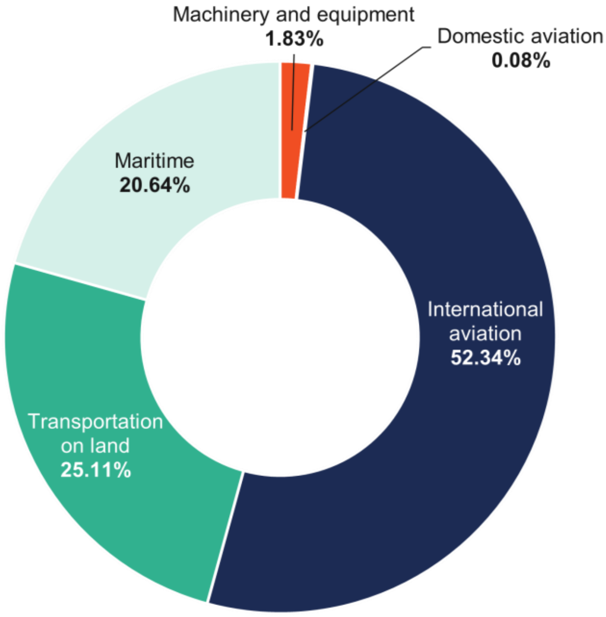


Figure 1-4. The share of estimated energy demand required for energy transition in 2050. [3]

Landsnet is currently working on further development and update of the Energy Outlook, which was published for the first-time last year. As part of that development, Landsnet has reached out to COWI to get a better understanding on how the demand for sustainable aviation fuel (SAF) could develop in the coming years. International aviation is the biggest sector in the energy transition in Iceland, estimated around 52% in last year's outlook, and thus has a large impact on Landsnet's forecast and the electricity required for the transition. In comparison, the domestic aviation demand covers a diminishing share of the expected energy transition (0,08 %) and is therefore neglected in the outlook report.

Since 2010, the fuel demand for international aviation in Iceland has been 95-98% of the total aviation fuel demand in Iceland, whereas domestic aviation covers the remaining 2-5%. [4]

1.1 National targets and EU regulations

This section gives an overview of relevant national energy & climate targets and EU regulations.

1.1.1 National targets

Iceland has an ambitious target of becoming carbon neutral by 2040. This target has been implemented into the Climate law no. 70/2012 [5]. According to answers from the Minister of the Environment, Energy and Climate on the target of carbon neutrality by 2040, it is highlighted that definitions and methodologies for measuring performance are still being developed. Moreover, that emissions from international aviation and international shipping are generally excluded from the obligations of individual countries. At the level of the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), countries agree on actions to ensure that these emissions are systematically reduced. Emissions from international aviation and shipping are therefore not considered towards the goal of carbon neutrality [6].

The Government's Energy Policy 2020 includes a future vision for Iceland to become independent of fossil fuels in 2050, for energy transition on land, sea, and air. This would include the aviation sector as well, if technically feasible [7]. These ambitions are also a part of the SDG7 Energy Compact [8]. The vision sets a direction but is not implemented in the Climate law and is thus not legally binding.

Targets for a renewable energy share in transport by 2030 of at least 40% on land and 10% for maritime have also been set. [9] Moreover, a draft for policy and action plan for energy transition in aviation suggested 20% renewable energy share for domestic aviation by 2030. [10]

Iceland has not defined specific renewable energy goals for international aviation. However, Iceland generally incorporates European regulations and targets as part of the European Economic Area (EEA).

1.1.2 European climate law, EU ETS, and CORSIA

The European Climate Law makes it a legal obligation for EU as a whole to reach climate neutrality by 2050. As a crucial step towards this goal, the EU has set a target of reducing emissions by at least 55% by 2030, compared to 1990 levels [11].

The EU's climate policy is based on three pieces of legislation:

1. the Emissions Trading System (EU ETS), which is included in the EEA Agreement,
2. the Effort Sharing Regulation for emissions that fall outside the EU ETS, and
3. the Land Use, Land Use Change and Forestry (LULUCF) Regulation.

While Iceland is not an EU member state, it has committed to many of the EU's climate and energy regulation, including the ones mentioned above.

Specifically for the aviation sector, emissions in the EU are covered by two instruments, i.e. the EU ETS and ReFuelEU Aviation. Moreover, the international aviation sector is globally regulated by the International Civil Aviation Organization (ICAO), which agreed in 2022 on a long-term aspirational goal of net-zero CO_2 emissions from aviation by 2050.

The EU ETS currently covers fuel emissions for all flights both departing and arriving in the European Economic Area (EEA) (intra-EEA flights) as well as flights to Switzerland and the UK. The EEA covers all EU member states as well as Iceland, Liechtenstein, and Norway. All airlines operating in Europe – regardless of whether these are European or not – are required to monitor, report, and verify their emissions and surrender allowances against these emissions. In this regard, airlines receive a certain number of tradeable allowances covering a specific level of emissions from their flights per year. [12]

A reform of the EU ETS was carried out and completed in 2023. The updated ambition for the EU ETS sectors is to bring (domestic) emissions down by 62% by 2030 compared to 2005 levels. Furthermore, a reduction of free allowances is also included in the reform, meaning that airlines will get 25% fewer free allowances in 2024 and 50% fewer in 2025 before a complete phase-out from 2026. At the same time, the reform makes available 20 million allowances for aircraft operators to offset from 2024 to 2030 the higher cost of SAF production. It should be noted that Iceland managed to negotiate a separate agreement with the European Commission for an extension of free aviation allowances until 2026. Regarding commercial aviation, the EU ETS will continue to apply effective carbon pricing for intra-EEA flights and departing flights to the United Kingdom and to Switzerland.

In addition, legislation is in place to apply the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) established by ICAO, as appropriate, to EU-based aircraft operators for flights to and from other third countries participating in CORSIA. [13] From the start of 2027, carbon pricing will also be applied to emissions from flights involving third countries which do not participate in CORSIA. [14] Iceland has committed to participating in CORSIA.

1.1.3 ReFuelEU aviation regulation

The ReFuelEU aviation regulation was adopted in October 2023 and oficially became law in January 2024. [15] The regulation states that aviation fuel suppliers shall ensure that all aviation fuel made available to aircraft operators at each Union airport contains minimum shares of SAF, including the minimum shares of synthetic aviation fuel as laid down in the regulation. This is regardless of the final destination of the aircraft. As such, it covers both domestic and international aviation. Since Iceland is not a part of the EU, the regulation has not yet been adopted into Icelandic law. The regulation is currently under examination for inclusion in the EEA agreement, and if accepted would make it an obligation to make SAF available at Icelandic airports [16]. Furthermore, given Iceland's strategic position as a significant aviation hub, it is also expected that the SAF blending mandates will be aligned in order to avoid operational disruptions and maintain competitive parity with EU airports.

The minimum share of SAF distributed will increase, starting with 2% in 2025 and progressively rising to 70% in 2050.

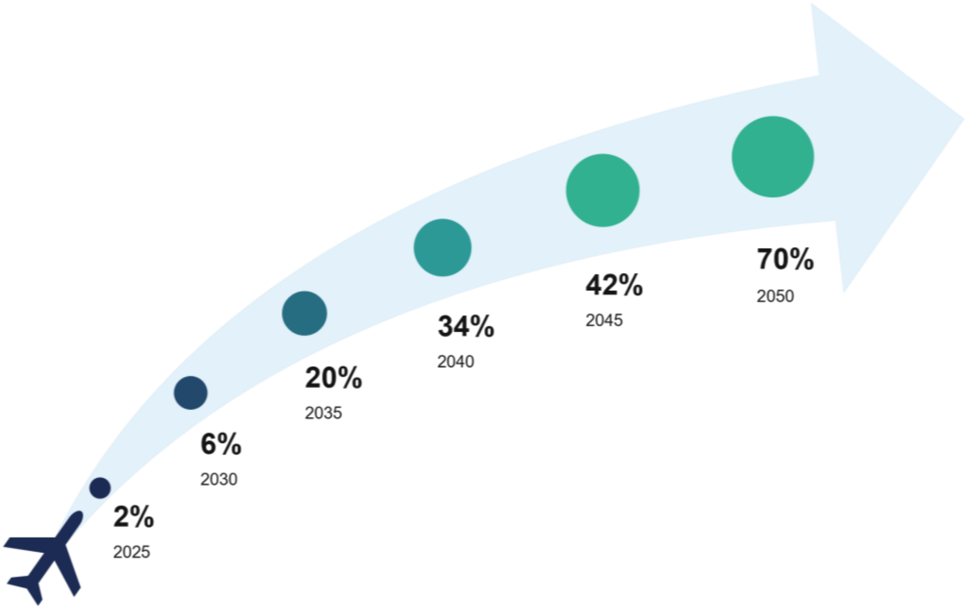


Figure 1-5. Minimum share of supply of SAF for 2025-2050 according to the ReFuelEU act.

The scope of eligible SAF includes:

- Certified aviation biofuels,
- Synthetic aviation fuels, i.e. aviation fuels that are 'renewable fuels of non-biological origin' (RFNBO), according to the definitions in the revised Renewable Energy Directive (EU) 2018/2001 [17].
- Recycled carbon aviation fuels, i.e. aviation fuels that are 'recycled carbon fuels' according to the definitions in the revised Renewable Energy Directive and complying with sustainability and emissions saving criteria set out in the directive.

Moreover, it should be noted that according to art. 4(1) of the regulation, other types of fuels can also be used to reach the minimum shares in the respective part of the ReFuelEU regulation, including:

a) **renewable hydrogen** used in aviation, i.e. hydrogen that qualifies as a 'renewable fuel of non-biological origin' according to RED.

b) **low-carbon aviation fuels:** this category contains both synthetic low-carbon aviation fuels and low-carbon hydrogen for aviation, produced from non-fossil and non-renewable sources (i.e. nuclear power) and meeting a lifecycle emission saving threshold of 70%.

In addition to the more overarching SAF blending requirement, the regulation also mandates a minimum sub-share of synthetic aviation fuels (or e-SAF), starting from 1.2% in 2030, rising progressively to 35% in 2050 (shares of total aviation fuel), see Figure 1-6.

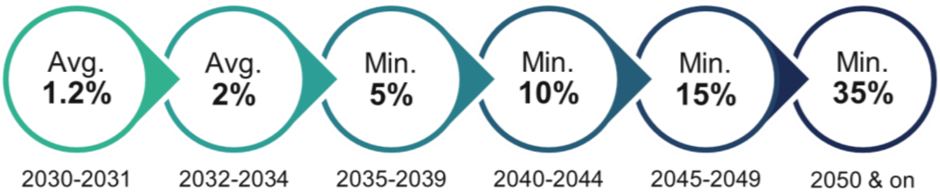


Figure 1-6. Synthetic aviation fuel share requirement according to the ReFuelEU aviation regulation (as shares of total aviation fuel)

These sub-targets of e-SAF can be met with using e-SAF, or by using renewable hydrogen or low-carbon aviation fuels [15]. Table 1-1 summarizes which fuel types can be used to meet the minimum fuel shares given in the ReFuelEU aviation regulation.

Table 1-1. Overview of fuel types that can be used to fulfil the min. SAF shares stated in the ReFuelEU aviation regulation.

	Fuels that can be used to achieve the target
Min. shares of synthetic aviation fuel (e-SAF)	• e-SAF • renewable hydrogen • low-carbon aviation fuels
Min. shares of total SAF	• certified aviation biofuels • e-SAF • renewable hydrogen • low-carbon aviation fuels • recycled carbon aviation fuels

Renewable fuels of non-biological origin

As mentioned above, synthetic aviation fuels (e-SAF in short) are aviation fuels that qualify as *renewable fuels of non-biological origin* (RFNBOs). RFNBOs are defined in RED [17], art. 2(36) as 'liquid and gaseous fuels the energy content of which is derived from renewable sources other than biomasses. RFNBOs nearly exclusively derive their energy content from renewable hydrogen produced from electrolysis, powered by renewable electricity. In order to qualify as a RFNBO, the produced fuel needs to have a minimum 70% GHG-emission saving compared to fossil fuels, which is equivalent to 28.2g CO_2eq/MJ. Specific, additional rules are described for the production of RFNBOs in two delegated acts to RED which became law in June 2023 [18] [19]. The first delegated act [18] describes the rules for accounting electricity for RFNBO production as fully renewable, while the second one [19] contains the GHG-emission saving methodology as well as a list of eligible CO_2 sources to be used in RFNBO production.

Regarding the latter, according to the second delegated act [19], besides biogenic CO_2, it is possible to use industrial (i.e. fossil) CO_2 for RFNBO production up to and including 2040. This is provided that the carbon is captured by an activity included in the EU-ETS sector and an appropriate carbon pricing mechanism is in place. For aviation fuel this will mean that:

- **Until 2040**: it will be possible to use both biogenic and industrial CO_2 for the production of e-SAF. This is of course provided that CO_2 eligibility criteria and other relevant criteria for RFNBOs as outlined in the delegated regulation are met. This fuel can both be used to live up to the sub-targets for e-SAF and to minimum SAF requirements.

- **From 2041**: only e-SAF produced with biogenic CO_2 or other compliant CO_2 sources (including CO_2 captured from the air or captured CO_2 stemming from a geological source and released naturally) will be considered as RFNBO. However, aviation fuel produced using fossil CO_2 could potentially still qualify as e-SAF, provided that the 70% GHG-emission target is met and that the fuel originates from non-fossil and non-renewable sources (i.e. nuclear power) – and therefore, contribute to both the minimum SAF requirements and the e-SAF sub-targets. For the case of Iceland this would require building up nuclear power capacity, which is not the plan according to the Master Plan. Additionally, living up to 70% requirements would most likely be very challenging, if the CO_2 emitted during fuel combustion it is not captured (and stored) – which is hardly realistic considering the final use of the fuel in aviation. Therefore, from 2041 and onwards, using fossil CO_2 for SAF production may not be possible as part of achieving the regulation's minimum SAF and e-SAF requirements.

Based on the above, when considering available CO_2 sources for SAF production in Iceland, fossil CO_2 sources are only considered for up to and including year 2040. targets.

1.2 SAF in Iceland

The regulatory environment with regards to SAF has been reviewed in the previous section and the definitions related to SAF clarified. In this section, a short introduction is given to the status, development perspectives, and challenges when it comes to the use of SAF in Iceland.

The biggest challenges in reducing emissions from aviation are technological developments related to new energy carriers and access to sustainable jet fuel at an affordable price for airlines. In addition to meeting a set of sustainability criteria, SAF processes need approval by organizations such as ASTM International. As of July 2023, 11 conversion processes for SAF production have been approved [20]. It is worth mentioning that currently, the aviation industry only permits maximum 50% blending of certified SAF with traditional fossil jet fuel. Even though, based on regulations and targets for reducing emissions from aviation, this is something that must be expected to change. The most commercially available pathways for SAF identified by Topsoe are provided in the Figure 1-7.

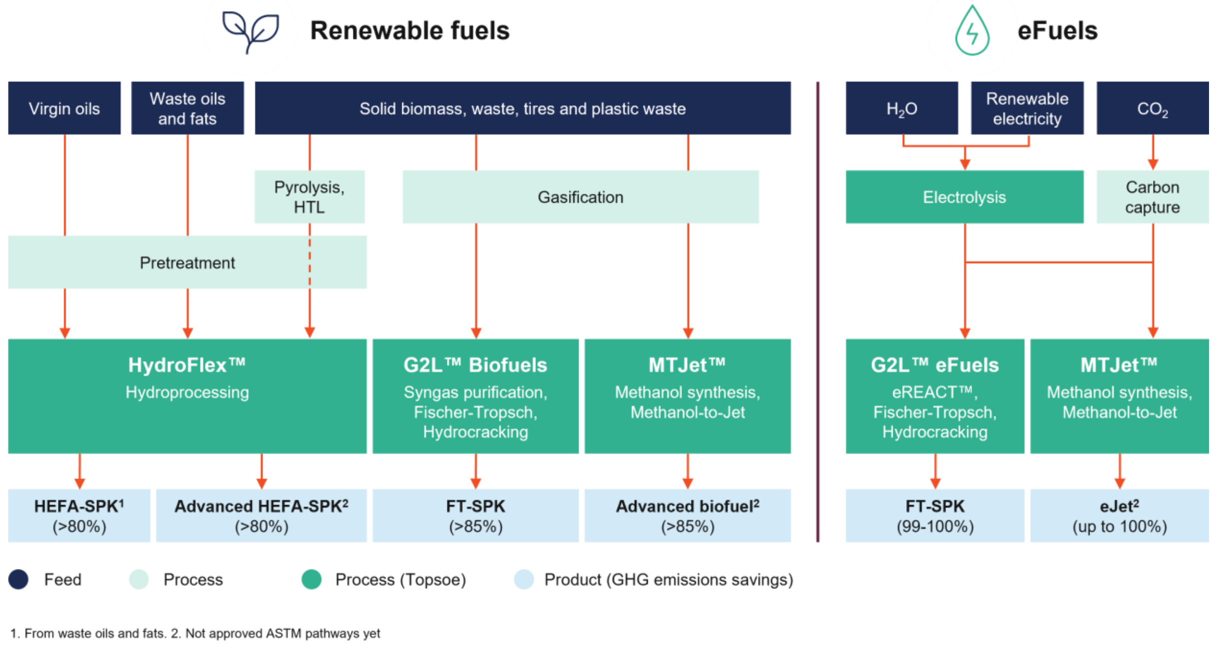


Figure 1-7. The main pathways for producing SAF. [21]

Currently, the production of SAF worldwide falls significantly short of the industry's projected future demands, and its purchase price is generally two to five times higher compared to conventional jet fuel.

In Iceland, SAF is currently inaccessible, and there is uncertainty surrounding the known projects aimed at SAF development and production in the country. Additionally, these projects do not ensure an adequate supply to meet the total aviation fuel demand in Icelandic airports, except for a limited duration. The aviation industry is growing globally, resulting in intense competition for the limited supply of sustainable fuel. [22]

Despite the lack of published data and absence of governmental decisions such as regulations and cause of action, SAF has been gaining significant momentum in Iceland. Some of the data encountered during the preparation of this report are summarized below:

- Landsnet and Orkustofnun, and previously Samorka, have made forecasts for the future SAF demand. [3]
- Icelandair is developing a forecast for SAF, focusing on 2030 and 2050, which will be published soon. [23]
- Isavia had a report on “Energy Sources for the Future” prepared for aviation in Keflavík airport. [22]
- The Government of Iceland has drafted a policy on energy transition in aviation in Iceland in order to be at the forefront of environmental issues related to aviation and operations (not published). [10]
- The Ministry of the Environment, Energy and Climate has been working on a report on energy transition in aviation, to be published soon.
- A guide to hydrogen and e-fuel development in Iceland was published earlier this year by the Ministry of the Environment, Energy and Climate. [9]

Based on the draft policy, the idea was that when applicable technology has been developed for production of SAF, incentives for energy transition for aviation will be implemented and promote the use of domestic renewable energy sources.

Lastly, one of the actions for energy transition for flights in Iceland is to investigate how to support the production and utilization of renewable energy sources. This will be considered in three ways, direct support incentive, through the tax system and via obligations on mixing SAF with fossil fuel [10].

The aviation industry shows a strong interest and desire for energy transition. However, one of the major hurdles is the high investment costs associated with upgrading fleets and adopting new technologies. To encourage energy transition in aviation and facilitate the development of new energy carriers or SAF production, there is not an established incentive or support system in place. Such a system can assist airlines in making the significant decisions and financial commitments required for these advancements [10].

The following sections provide insight into the situation in Iceland and the potential for bio-SAF and e-SAF in Iceland is briefly explored.

1.2.1 Bio-SAF

Currently, there are no significant amounts of unused biomass readily available in Iceland for bio-SAF production. Based on a study conducted by Samgöngustofa in 2018, there is, however, significant unused and available agricultural land in Iceland (i.e. land below 200 m excluding land already used for agricultural farming and difficult farmlands such as bays and rocky and wetlands). The study finds that growing rapeseed in the unused agricultural lands and producing biodiesel could technically power the entire shipping industry in Iceland and more. [24] However, the study does not consider to which extent it is economically feasible to realise this technical potential.

In the context of SAF, the question is to which extent, this type of biomass resource is allowed to be used for producing certified aviation biofuels, as part of achieving the minimum SAF targets in the ReFuelEU act. According to the Renewable Energy Directive 2018/2001, biofuels, bioliquids and biomass fuels should always be produced in a sustainable manner. Moreover, the GHG-emission saving requirements for biofuels to be used in the transport sector is 65% GHG-emission saving compared to fossil fuel. It is out of scope for this project to assess whether bio-SAF production based on biomass resources produced on the unused land in Iceland can qualify as certified aviation biofuels under the ReFuelEU Act. This could be interesting to investigate in further work.

In the current situation where there are no significant amounts of biomass in Iceland available for SAF production, certified aviation biofuel would largely have to be imported. This also reflected in e.g. Isavia’s study, where bio-SAF is assumed imported. [22]

1.2.2 Electricity and hydrogen fuelled aircrafts

The technological development of new generations of engines that run on electricity or hydrogen[3] could create opportunities for aviation in Iceland. Electricity in Iceland is mainly produced from renewable energy and therefore there are ideal conditions for electric aircrafts, as well as hydrogen powered aircrafts where the hydrogen is produced via electrolysis of water.

However, the electrification of aviation comes with certain challenges. Currently, the development of electric and hydrogen aircrafts is in its early stages, and their range is relatively limited. [25] Moreover, due to the geographical position of Iceland, the international flight distances are long and

[3] Either in fuel cells powering electric motors or by combustion in adapted gas turbine engines.

based on the technology readiness level, hydrogen and electric aircrafts still have a long way to go to be suitable for international aviation in Iceland. However, there are expectations of domestic flight becoming fossil fuel independent, with hydrogen and electric aircrafts, in the near future. [25] In a recent study from Isavia, hydrogen is forecasted to have a significant share from 2035-2050, based on Airbus development of hydrogen fuelled aircrafts that could cover much of the flight from Iceland to Europe. This technology is planned for 2035. [22] This is however considered a rather optimistic forecast considering the technological challenges and when comparing with other studies. E.g. in IEAs net zero roadmap for 2050, electricity and hydrogen fuelled aircrafts together account for just around 2% of the global aviation fuel consumption in 2050 [26]. As further justification, Icelandair, that currently has a market share of around 50% in international aviation in Iceland, has communicated that they are only considering electric and hydrogen powered aircrafts for domestic flights at this point (i.e. not for international flights).

1.2.3 E-SAF

Hydrogen can also be used to produce e-SAF for domestic or international aviation in the coming decades. Iceland should explore the feasibility of domestic e-SAF production together with the possibility of imports, in parallel with how the industry develops over the next two decades.

Currently, there is no production of SAF in Iceland, but ambitious plans have been made by IðunnH_2 to produce e-SAF fuel in 2028. In March 2023, IðunnH_2 and Icelandair signed a Memorandum of Understanding that IðunnH_2 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 2028. [27]

1.3 Scenarios

This study focuses on international aviation and aims to explore how the demand for SAF could develop in the future and which implications it could have for the supply side. In the process of identifying the most relevant scenarios, discussions on different possibilities have been carried out with Landsnet.

The scenarios are created, by varying factors that will have a large influence on the SAF demand and are at the same time uncertain. From this perspective, the most important factors to vary in the scenarios are found to be:

- Aviation demand: Iceland's future demand for international aviation towards 2050, depending on sector growth and behaviour among consumers and companies. A low, medium, and high-level aviation demand is assumed.
- SAF share: The SAF shares in Iceland's international aviation towards 2050; depending on the ambition level in terms of phasing out fossil aviation fuels. It is assumed that Iceland will align with the minimum SAF shares given in the ReFuelEU aviation regulation. As a highest ambition level, a full phase out of fossil aviation fuels in 2050 is assumed in line with the national vision.

Based on variations of these two factors, four scenarios have been set up (see Figure 1-8). As shown, the scenarios illustrate an outcome space covering variations within aviation demand and SAF share.

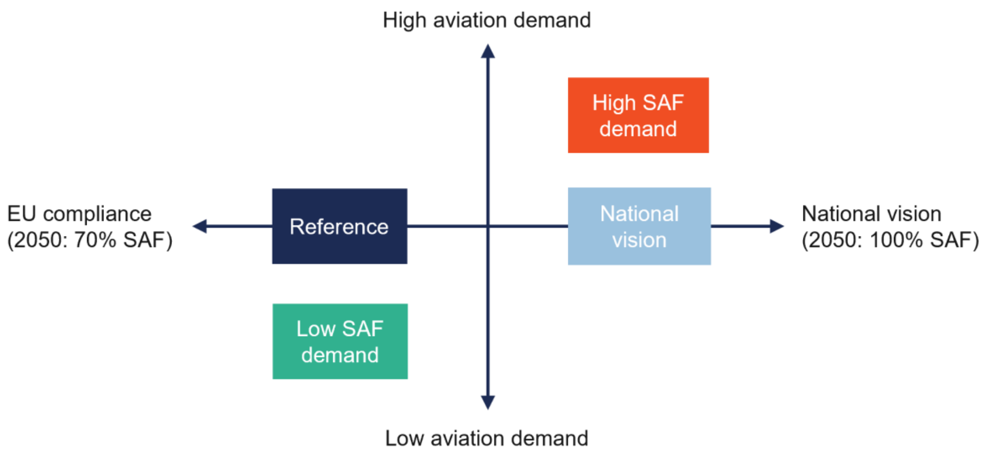


Figure 1-8. Illustration of the scenario setup.

The scenarios, further described in Table 1-2, were carefully selected to ensure clear results and a coherent storyline for the Energy Outlook.

Table 1-2. Short description of the scenarios.

Scenario	Aviation demand*	SAF share
Reference	Baseline projection based on Isavia's mid passenger forecast for international aviation.	Future SAF shares are corresponding to the minimum levels in the ReFuelEU aviation regulation (even though the regulation has not been adopted yet): • All aviation fuel made available to aircraft operators in EU airports must contain minimum SAF shares of 2% in 2025 increasing progressively to 70% in 2050. • E-SAF must cover 1.2% of the total aviation fuel supply by 2030-2031 increasing gradually to 35% in 2050 (see Figure 1-5 and Figure 1-6).
National vision	Same as for the Reference scenario.	Based on Iceland's vision of becoming independent on fossil fuel by 2050 (given in Iceland's Energy Policy 2020), a higher SAF share is targeted than required in the ReFuelEU aviation regulation. As such, 100% SAF aviation is assumed achieved by 2050.
Low SAF demand	Lower demand for international aviation based on Isavia's low passenger forecast for international aviation. This can represent climate conscious behaviour among consumers & companies and a more conservative aviation sector growth.	Same as in the Reference scenario.
High SAF demand	High growth in the international aviation sector in Iceland based on Isavia's high passenger forecast.	Same as in the National vision scenario.

*The method behind the demand forecasts is explained further in section 2.1.

The scenarios are treated equally, i.e. no scenario is appointed as the central or most likely scenario.

Hydrogen and electricity are not assumed viable options for international flights to and from Iceland due to the long distances involved. Therefore, use of hydrogen and electricity for international aviation have been assumed zero towards 2050 in the model and the e-SAF for the given scenarios includes only e-SAF, not including other fuels that can be used to reach the synthetic aviation fuel target, as listed in Table 1-1.

The share of SAF is divided between e-SAF and bio-SAF. Bio-SAF is assumed to account for the majority of SAF produced in the short term (2035); since it is more mature than e-SAF technologies. In the coming years, the most probable case is that SAF will be imported to meet the minimum requirements in the ReFuelEU regulation, as pointed out by Icelandair. Moreover, in the short term the SAF share is assumed relatively low, as the SAF technologies are still maturing, and increased efficiencies and cost reductions expected in the longer term.

The method applied for the SAF share in 2035 and the division between e-SAF and bio-SAF is specified in Table 1-3.

Table 1-3. Method used for SAF share and split between the different fuel types.

Scenario	SAF share
Reference & Low SAF demand	ReFuelEU regulation used as basis for the SAF share and division between e-SAF and bio-SAF, see Figure 1-5 and Figure 1-6. Fossil jet fuel estimated as residual. • The SAF shares for the years in between the target years of the ReFuelEU regulation are based on linear interpolation. • Overall, this results in a piecewise linear trend illustrating the progressive increase in the minimum SAF shares over the period.
National vision & High SAF demand	The overall SAF share has been estimated slightly larger than regulations require, i.e. 25% in 2035 (vs. 20% as given in the ReFuelEU aviation regulation). E-SAF share in 2035 has been estimated, taking into account the planned production of SAF from IðunnH2, see section 1.2. Bio-SAF is assumed to be less significant share of the SAF produced in the long term as e-SAF technologies are expected to mature and the global biomass resources are limited. • The SAF shares over the period are consistently assumed higher than in the Reference scenario throughout the whole period; and at the same time assumed to follow the same type of piecewise linear trend.

Putting the SAF share in 2035 into perspective, a linear regression towards 100% SAF in 2050 corresponds to 41% SAF in 2035, which is substantially higher than in the National vision & High SAF demand scenario (25%). Moreover, based on a study prepared for Isavia in 2023, a baseline scenario of around 22% SAF in 2035 was forecasted. [22]

In Figure 1-9 and Figure 1-10, the SAF share and distribution on type of jet fuel is shown to provide an overview for the focus years.

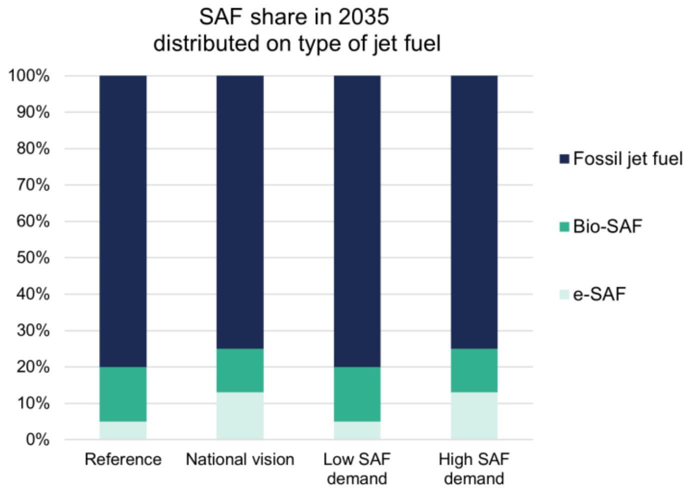


Figure 1-9. SAF share in 2035 for each scenario distributed on type of fuel.

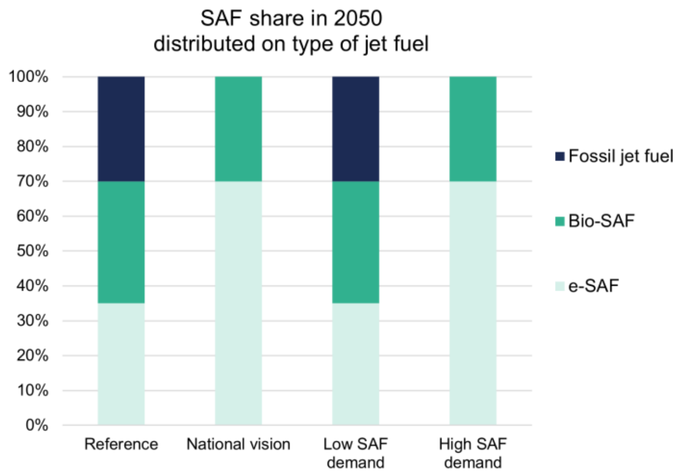


Figure 1-10. SAF share in 2050 for each scenario distributed on type of fuel.

Although the focus of the scenarios results was for the years 2035 and 2050 the SAF shares in the Reference scenario[4] are assumed to align with the minimum total SAF shares given for 2025, 2030, 2035, 2040, 2045, and 2050 in the ReFuelEU aviation regulation. Correspondingly, the Reference scenario is aligned with the average/minimum e-SAF shares given in the ReFuelEU aviation regulation for the different year intervals over the period.

[4] And the Low SAF scenario, where SAF shares are assumed the same as in the Reference scenario.

2 Methodology

The scenarios are modelled using a simple calculation model developed in excel. The model covers:

- Projection of aviation fuel demands distributed on fuel types (main focus).
- Illustration of supply side aspects (supplemental results, less detailed).
  - Electricity balance: Projected total electricity demand (for international aviation and other sectors) vs. forecasted RES generation in Iceland.
  - CO_2 balance: Projected demand for CO_2 as input to SAF production vs. CO_2 sources available in Iceland.

The demands are modelled on an annual basis towards 2050; while the supply aspects are illustrated for the years 2035 and 2050, representing a near-term and long-term case. For comparison, historical data is also considered.

Results are handled on annual national aggregated level, and variations in demand and supply over the year are not modelled. The calculation model is based on what-if-assumptions and not economic optimization. Other sectors than aviation are handled in a simple manner; based directly on Landsnet's Energy Outlook from 2023, supplemented by own assumptions.

As the model is tailored to illustrate an outcome space for how the SAF demand in Iceland can develop, it is not a full system model covering energy flows, costs, and emissions etc. for all sectors and technologies.

The calculation model has been handed over to Landsnet as part of the project deliverables.

The following sections give a short further description on how the different elements are estimated.

2.1 Aviation demand projection

Different methods for forecasting the future demand for international aviation have been investigated:

- Use of Isavia's forecast on number of passengers and the correlation between passengers and fuel demand for aviation.
- Growth rates for international aviation in Europe published by the International Civil Aviation Organization (ICAO) [28].
- Iceland's projection of Gross Domestic Product (GDP) and the correlation between GDP and fuel demand aviation.

It is found that the best forecasting method is to use Isavia's passenger forecast (low, mid, and high) as a basis. This is based on the following considerations:

- Looking at historical data (2004-2023), a strong correlation (R^2 = 0.92, see Figure 2-1) has been identified between the number of passengers for international aviation and fuel demand for international aviation.

- The passenger forecasts from Isavia take special conditions for the Icelandic aviation sector into account, as they consider Icelandair and Play airlines fleet forecasts as well as overall forecasts from Boeing and Airbus. [22]

- The growth rates from ICAO for Europe do not represent the country specific conditions for Iceland, which is e.g. indicated by larger relative GDP increase in Iceland compared to a European average.

- A satisfactory correlation has not been found between Iceland's historical GDP development and Iceland's historical fuel demand for international aviation[5] (R^2 = 0.57). This is likely due to the large increase from 2010 in the number of tourists visiting Iceland (see Figure 2-2), which cannot be explained by a GDP increase (in the Icelandic GPD).

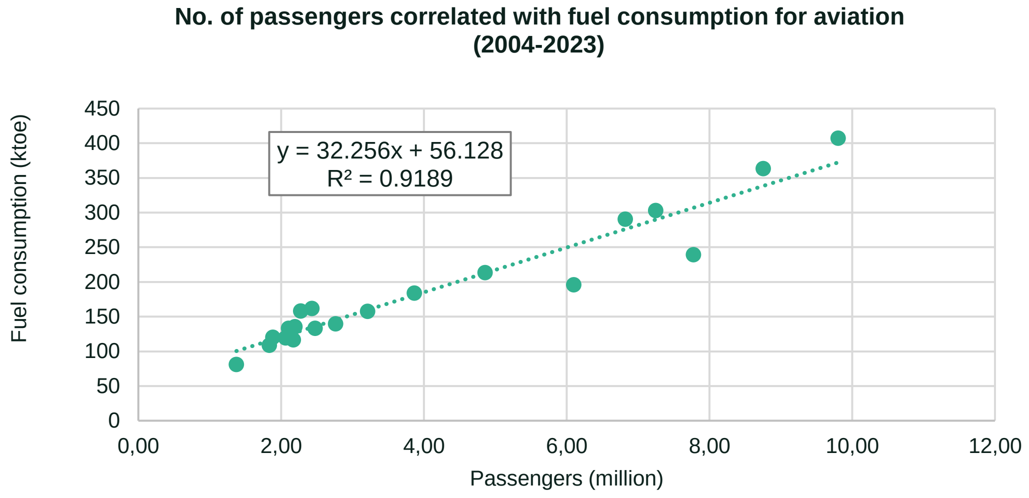


Figure 2-1 Correlation between number of passengers for international aviation and fuel demand for international aviation; over the period 2004-2023[6].

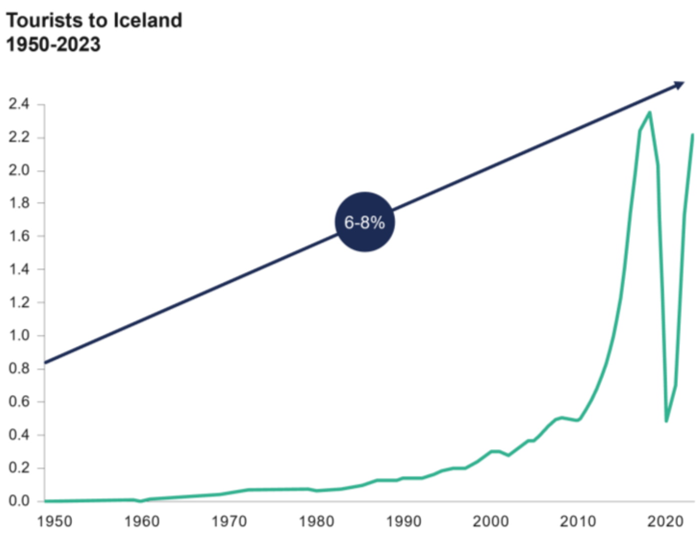


Figure 2-2. Historical development in number of tourists visiting Iceland (green curve) [29].

[5] For the period 1995-2023, where non-representative years due to the Covid pandemic, 2019-2021, have been excluded.

[6] Number of passengers for international flights from Keflavík Airport based on [30] and fuel demand for international aviation for 2010-2019 based on data from [3] and from 2020-2023 from [2].

Isavia's passenger forecasts low, mid, and high forecasts 2024-2033 are used as basis for estimating different development of future aviation demand. The method applied is specified in Table 2-1.

Table 2-1. Method used develop different projections of Iceland's future demands for international aviation.

International aviation demand	Scenario application	Method
Mid	Reference & National vision	Mid passenger forecast 2024-2033 [30] used as basis in combination with the correlation identified with aviation fuel demand. For 2034-2050: Passenger forecast based on linear trend in the end of the passenger forecast period, i.e. 2031-2033, is applied to resemble a continuation of the latest trend.
Low	Low SAF demand	Low passenger forecast 2024-2033 [30] used as basis in combination with the correlation identified with aviation fuel demand. For 2034-2050: Passenger forecast based on partly polynomial trend for 2024-2033 and partly linear trend for 2031-2033.
High	High SAF demand	High passenger forecast 2024-2033 [30] used as basis in combination with the correlation identified with aviation fuel demand. For 2034-2050: Passenger forecast based on partly polynomial trend for 2024-2033 and partly linear trend for 2031-2033.

The resulting projections of Iceland's international aviation demand are illustrated in Figure 2-3.

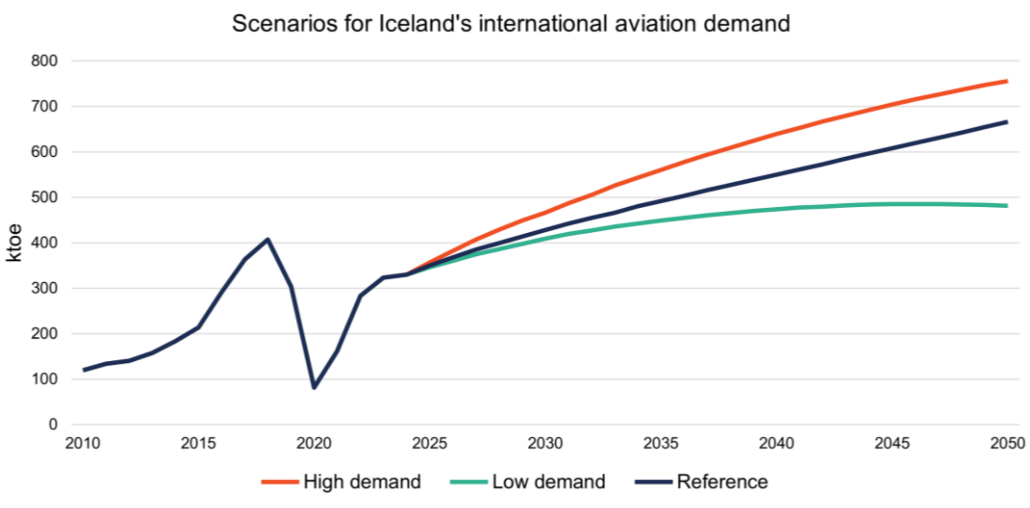


Figure 2-3. The scenarios developed for Iceland's international aviation.

As outlined in Table 2-1, a partly polynomial trend is applied for the low- and high-level projections of the aviation demand (based on the passenger forecast for 2024-2033). This method is applied to best capture the nature of the given scenarios.

As such, the Low SAF demand scenario towards 2050 reflects a situation with increasing climate conscious behaviour among citizens and companies; and a more moderate aviation sector development. By applying a partial polynomial trend, it is reflected that the aviation demand increase gradually phases out and stagnates in the long term. As a result, the aviation demand is approximately 10%, 15%, and 30% and lower in 2035, 2040 and 2050, respectively, compared to the Reference scenario.

The partial polynomial trend applied in the High SAF demand scenario reflects the fact that it is limited how much the aviation demand can continue to increase in the long term, even in a high demand scenario. E.g. the development can be constrained by the capacity of the airport infrastructure and the pace at which new aircrafts are built, and by limitations of the demand increase.

In Figure 2-4, the Reference scenario is compared to other forecasts.

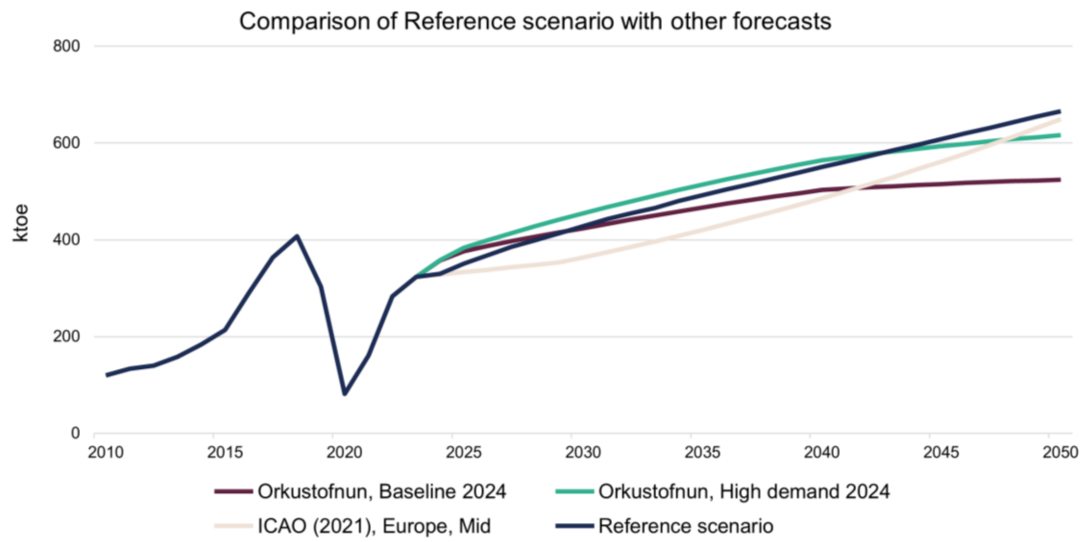


Figure 2-4. Comparison of the Reference scenario with other forecasts.

The Reference scenario and Orkustofnun's baseline case show similar values until 2035 when the Reference scenario shows forecasted increase while the baseline case is saturated. The Orkustofnun high demand case show slightly higher values until 2044. The ICAO trendline on the other hand shows exponential growth. The Reference scenario includes elements from each of the other scenarios. It resembles the trend from the years preceding Covid and introduces a slight decline in annual growth, but not to the extent included in the Orkustofnun scenarios. It shows a higher development and reaches a level comparable to ICAO’s projection. However, the increasing annual growth rate foreseen by ICAO does not seem realistic for Iceland due to capacity limitation in Keflavik airport. It is nevertheless representing the international economic growth (in both Iceland and the rest of the world), which will lead a continuous increasing air transport demand. The Reference scenario therefore includes some of this continuous growth in demand assuming that airport capacity will be adjusted and thus that more of the increasing demand can be accommodated.

The methodology behind the SAF demand involves applying the SAF share and distribution between fuel types for the aviation demand and fuel usage correlation.

2.2 Electricity demand and electricity generated from RES

The electricity consumption needed to produce the forecasted SAF demand have been estimated based on conversion factors from technology catalogue for green fuels published by the Danish Energy Agency (DEA) [31] [32].

For the e-SAF production, the technology data applied in this estimation are based on hydrogen production is reacted with CO_2 to produce syngas, which produces aviation fuel via the Fischer-Tropsch process. Although other processes such as methanol-to-jet fuel are currently being explored, the technology readiness level is lower for the power to methanol part. Moreover, according to Topsoe, the methanol-to-jet pathway has not been approved by the ASTM yet [21].

For the bio-SAF production, electricity consumption is assumed negligible as in general the gasification process does not require electricity. This is also reflected in the technology data for liquid fuels from gasification using the Fischer Tropsch process [32]. Electrical consumption might be involved in some of the preparing stages etc. depending on conditions.

As stated in [31], the power to jet fuel is still a technology in the research, development, and deployment stage. There are some improvements expected e.g. for the electrolysers and there is potential to improve yields and reduce costs with more experience and scaling up. However, there is still significant uncertainty regarding the performance of the processes. Linear interpolation is used to forecast the period between the technology developmental stages (2030, 2040 and 2050) given in [32].

For the electricity required for e-SAF production, transmission grid losses are set to 2,2% based on data from Landsnet. Distribution grid losses have been neglected since e-SAF are in most cases expected to be connected to the transmission grid level as larger consumers.

For simplicity and since the focus of this outlook is on exploring possible developments in Iceland's international aviation demand, the electricity demand for other sectors than aviation is assumed the same across all scenarios. This electricity demand is based on Landsnet's forecast, assuming full energy transition in 2050 (excl. international aviation to avoid double counting). [3]

The forecasted electricity generation from RES are also based on Landsnet's Energy Outlook 2023. The forecast relies on Landsnet's assessment of viable power plant options in the third and fourth phases of the Master Plan for Nature Protection and Energy Utilization, as well as small power plants with an installed capacity of less than 10 MW. The installed capacity in the geothermal power plants is assumed to increase by 600 MW until the year 2038. Moreover, it is assumed that four wind farms will be installed until the year 2035, with an installed capacity of 400 MW. In the same period, new hydro power plants with a total installed capacity of 500 MW are expected, but after 2035 only smaller power plants that fall outside the Master Plan are expected to be implemented.

2.3 CO_2 demand and point sources

As previously described in section 2.2, the e-SAF process considered is the Fischer-Tropsch process, where CO_2 is used in combination with hydrogen to produce syngas. The CO_2 demand for the forecasted SAF demand was estimated based on conversion factors from the Danish Energy Agency (DEA) [33].

In Iceland, no biomass-, waste-, or fossil fired power plants are available as CO_2 sources, since the electricity generation in Iceland is dominated by hydro- and geothermal. The CO_2 point sources mainly come from geothermal power plants and industrial sources such as aluminium- and ferro alloys production plants. There is also one waste biogas plant operating, GAJA, and some Waste to Energy and an aquaculture biogas plant in the planning.

The location of the main carbon point sources can be seen on the map of Iceland in Figure 2-5. Sources in the planning stage are indicated with yellow text.

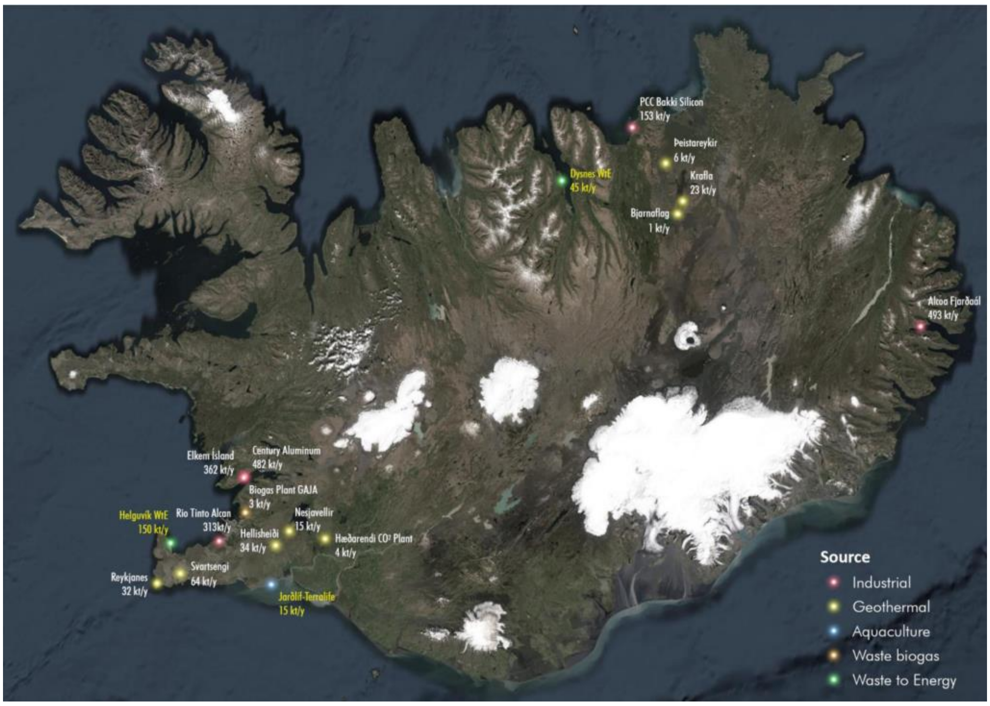


Figure 2-5. Map of the main CO_2 sources in Iceland. Sources in the planning stage are indicated with yellow text.

The data used to forecast the CO_2 point sources are based on COWI's knowledge and extrapolated data from Umhverfisstofnun [34]. Key assumptions made are listed below:

- Due to the requirement of using biogenic CO_2 for e-SAF production from 2041 an onwards (see section 1.1.3; and due to general relevance, e.g. for CO_2 emission calculations), the each of the CO_2 sources have been specified as biogenic or fossil.
  - Emissions from aluminium smelters are considered fossil CO_2 sources.
  - The ferroalloys plants use renewable biomass sources to some extent. The extrapolated data from Umhverfisstofnun only accounts for the fossil fuels, which are expected to decrease slightly. However, for simplicity and due to uncertainties on the share of biomass in the fuel mix; and the expected electrification within the industry as part of the energy transition; no biogenic CO_2 emissions from the ferroalloys plants are assumed.
- Most geothermal power plant owners are either operating or planning sour gas (H_2S, CO_2) separation and re-injection into the geothermal reservoir. Here only the power plants operated by ON power are excluded, due to their operation/planned re-injection of CO_2 (Carbfix).
- Potential future development of the aluminium process, eliminating carbon material from the process, are not considered.

3 Results

In this chapter, the results of the four scenarios are presented and discussed. The following are the main outputs calculated for the scenarios: Final energy demand for aviation and illustration of supply side aspects in terms of electricity and CO_2 balance. Finally, supplemental results are given on hydrogen generation and biomass demand for bio-SAF production.

3.1 SAF demand

The estimated final energy demand for international aviation distributed on fuel types is shown in Figure 3-1, Figure 3-2, Figure 3-3 and Figure 3-4. The different scenarios provide a spectrum of potential development of SAF demand in Iceland.

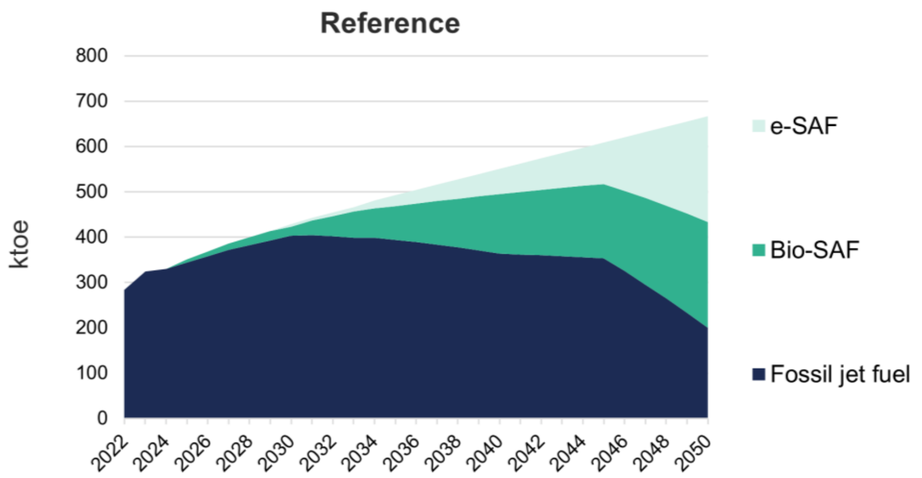


Figure 3-1. Final energy demand for international aviation for the Reference scenario, distributed on fuel types.

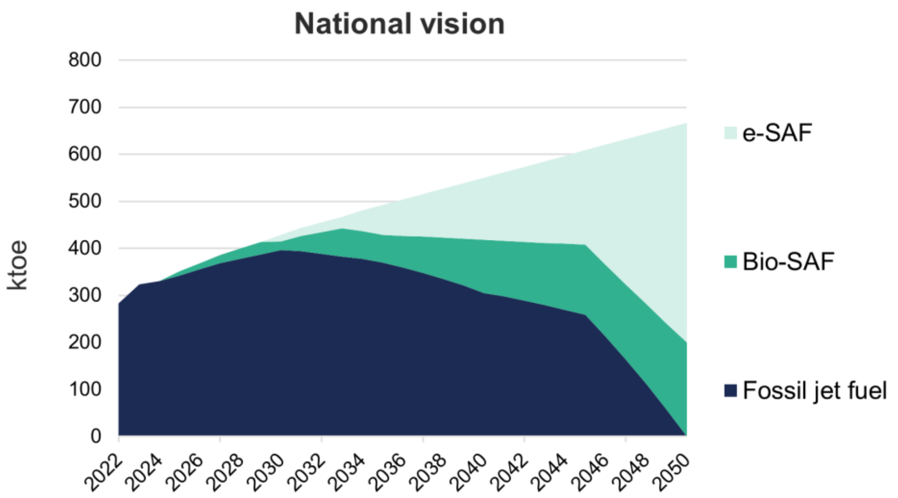


Figure 3-2. Final energy demand for international aviation for the National vision scenario, distributed on fuel types.

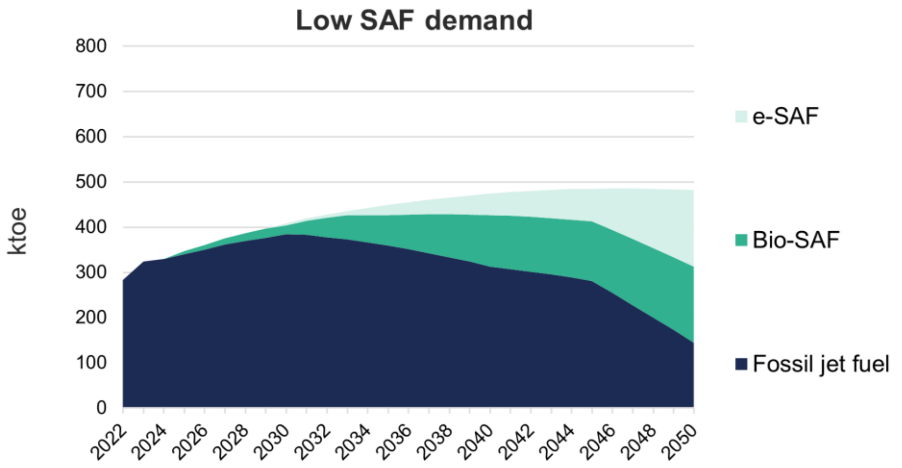


Figure 3-3. Final energy demand for international aviation for the Low SAF demand scenario, distributed on fuel types.

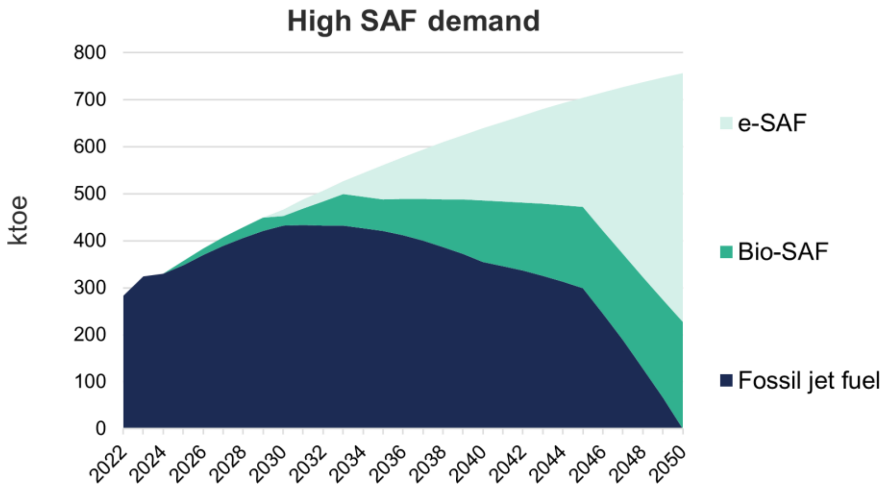


Figure 3-4. Final energy demand for international aviation for the High SAF demand scenario, distributed on fuel types.

The results illustrate that Iceland's demand for e-SAF and bio-SAF towards 2050 will significantly depend on both the development in total aviation demand, the ambition level in terms of phasing out fossil aviation fuels, and to which extent the SAF demand is met by e-SAF vs. bio-SAF.

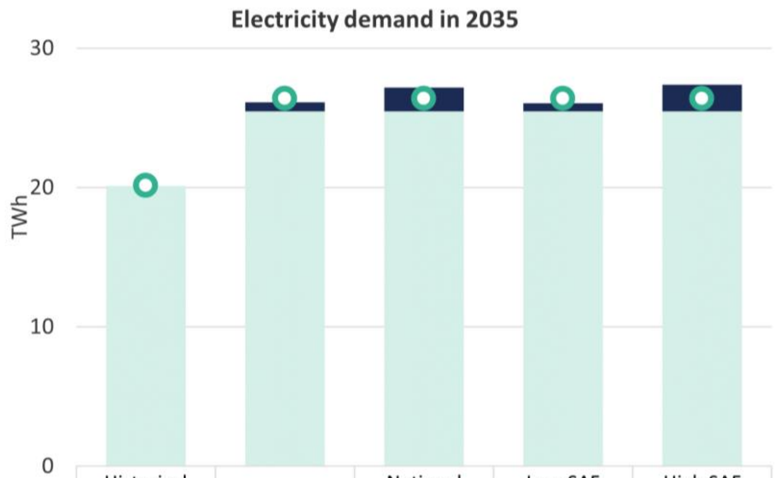
The graphs demonstrate that the differences between the scenarios are less visible in the short term, where the aviation demands and the SAF shares are lower. The scenario differences become larger towards 2050, due to larger differences in both aviation demands and SAF shares.

The e-SAF demand varies in the interval 22-73 ktoe in 2035 across scenarios and 233-529 ktoe in 2050. The lowest e-SAF demand is in the Low SAF scenario where both total aviation demand and e-SAF shares (and total SAF shares are lowest). The highest e-SAF demands are found in the High SAF demand scenarios, where both aviation demand and e-SAF shares are highest.

The bio-SAF demands vary 59-74 ktoe in 2035 and 169-233 ktoe in 2050. In 2050, the bio-SAF demand is highest for the Reference scenario, due to the higher bio-SAF share; even though total aviation demand is higher in the High SAF demand scenario. This illustrates that the future split on e-SAF and bio-SAF is an important factor when it comes to estimating the future SAF demands.

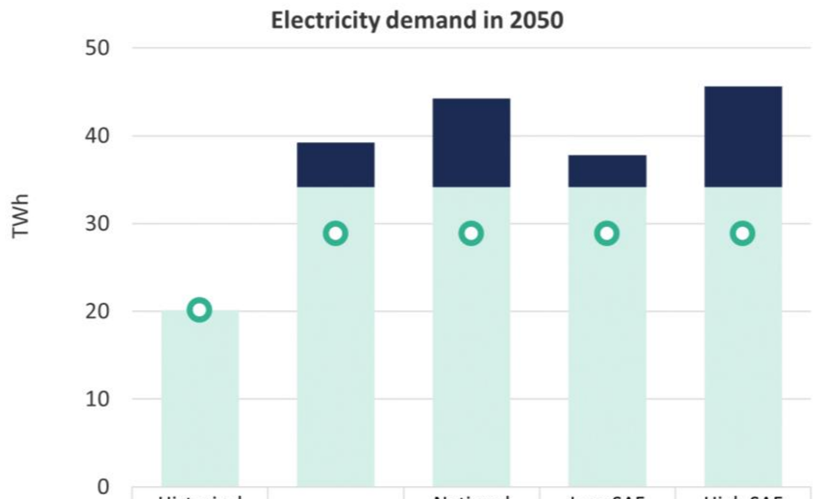
3.2 Electricity balance

The estimated total electricity demand in the different scenarios is compared with the forecasted renewable generation in Iceland. The electricity balance for 2035 and 2050 is given in Figure 3-5 and Figure 3-6 respectively. The electricity demand for other sectors and RES generation is based on Landsnet's forecast, assuming full energy transition in 2050. [3]



	Historical 2022	Reference	National vision	Low SAF demand	High SAF demand
Electricity for e-SAF production	0.0	0.7	1.7	0.6	1.9
Electricity demand for other sectors	20.1	25.5	25.5	25.5	25.5
RES generation historically and forecasted	20.1	26.4	26.4	26.4	26.4

Figure 3-5. The electricity balance for 2035.



	Historical 2022	Reference	National vision	Low SAF demand	High SAF demand
Electricity for e-SAF production	0.0	5.0	10.1	3.6	11.4
Electricity demand for other sectors	20.1	34.2	34.2	34.2	34.2
RES generation historically and forecasted	20.1	28.8	28.8	28.8	28.8

Figure 3-6. The electricity balance for 2050.

The graphs give indications to whether the currently forecasted renewable energy generation is sufficient to meet the electricity demand for the energy transition in international aviation and other sectors.

As shown, in 2035, the estimated electricity demand in the scenarios is on level with the forecasted generation from RES.

For 2050, the forecasted generation from RES does not meet the estimated electricity demand for any scenario. This illustrates that significant expansion of RES will be required in Iceland, if the future SAF in the scenarios are to be covered by domestic SAF production. As such, the scenarios indicate that if RES generation is not increased further than given in the forecast, the SAF demand in 2050 would have to be met purely by import.

Moreover, as shown, the currently forecasted RES production is not even enough to meet the electricity demand for other sectors after the expected energy transition.

Landsnet's 2023 RES forecast is quite conservative and only expects smaller power plants that fall outside the Master Plan to be implemented. It should be noted that the process of the Master Plan is continuous, and the fifth phase is currently in progress, which includes several wind farms and some hydro and geothermal projects that are not yet included here. It is expected that Landsnet's RES forecast will develop along with the development of the Master Plan.

The electricity demand for the e-SAF production for each scenario is also estimated over time in Figure 3-7.

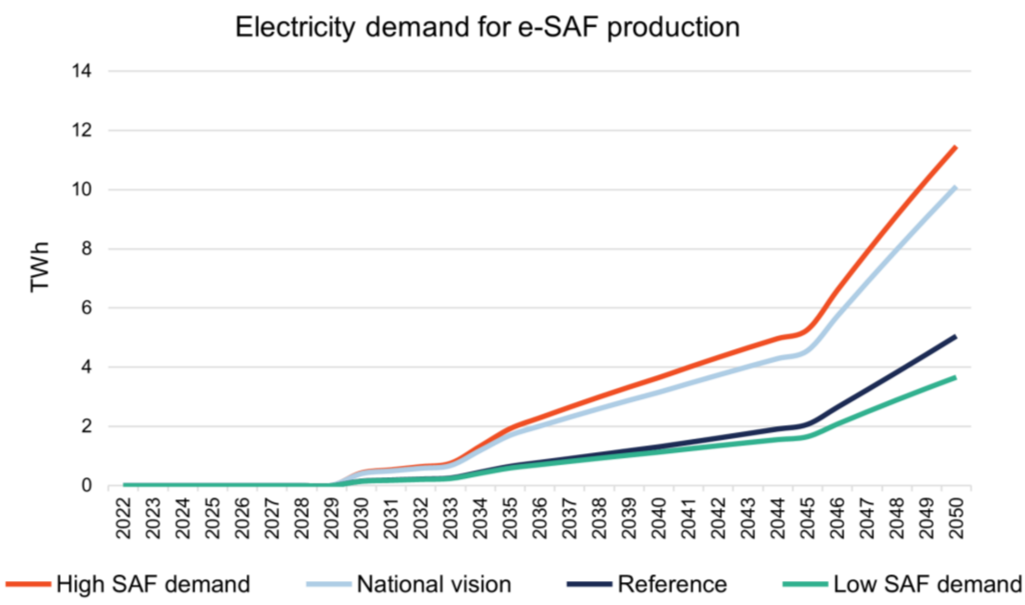


Figure 3-7. Electricity demand for e-SAF production over time.

The graph provides an overview of the required electricity for each scenario, whereas expected the High SAF demand has the highest electricity demand and the Low SAF demand has the lowest electricity demand over the entire period. Before 2035, the High SAF demand/National vision and Reference/Low SAF demand scenarios align, but then begin to diverge, indicating the variations between scenarios.

3.3 CO_2 balance

The supply constraints for CO_2 have been evaluated for 2035 and 2050 based on a simple overall perspective. Figure 3-8 shows the potential future CO_2 point sources by the type of emission source.

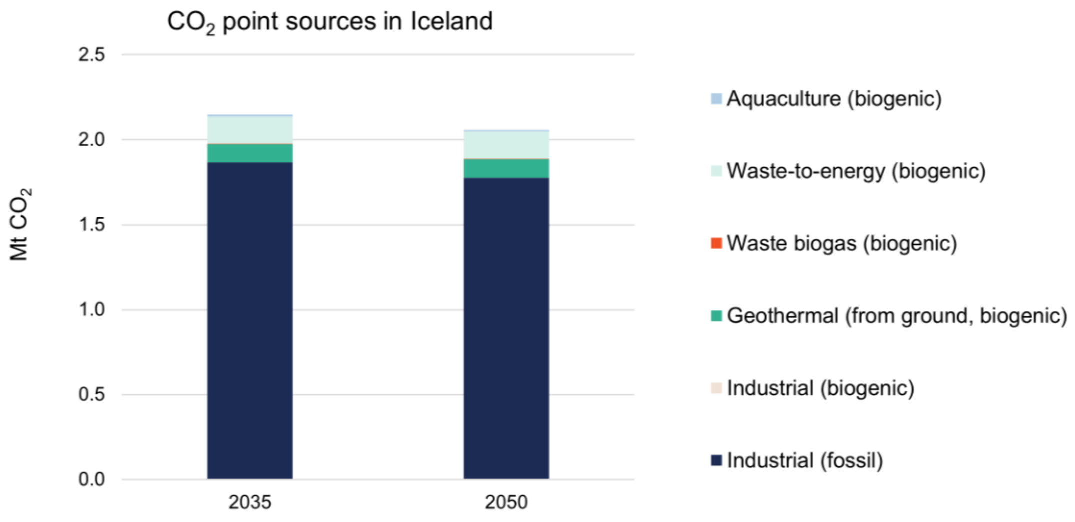


Figure 3-8. Potential future CO_2 sources in Iceland by source.

The industrial CO_2 sources decrease by a little based on data from Umhverfisstofnun on the estimated emission from ferroalloy plants, which are moving more towards biomass. [34]

In Figure 3-9 and Figure 3-10, the available and planned CO_2 point sources are compared to the CO_2 input needed for producing e-SAF in the scenarios.

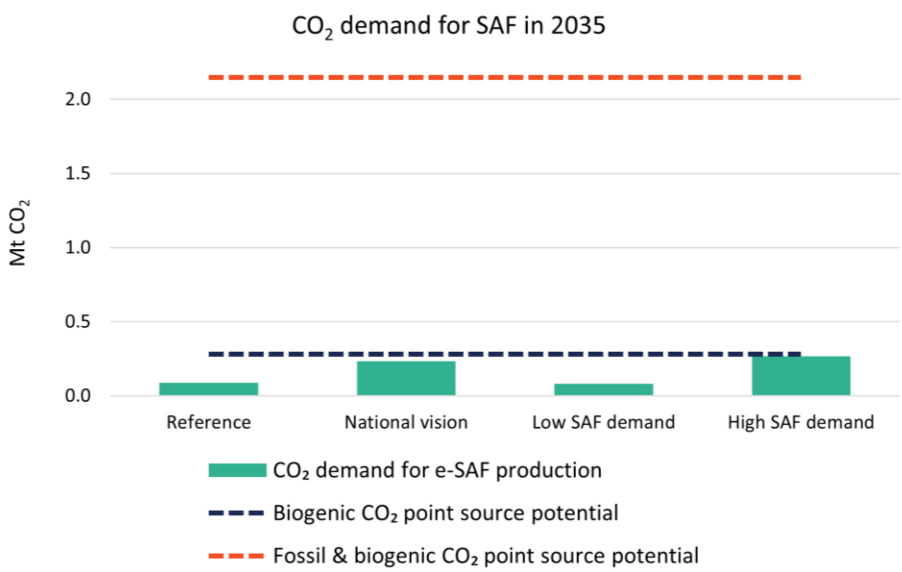


Figure 3-9. The CO_2 demand and point source potential in 2035.

As shown, the CO_2 point sources in Iceland are technically sufficient to cover the CO_2 input needed to produce the e-SAF amounts in the scenarios in 2035.regardless of the scenario. This is also the case if only using biogenic CO_2 sources[7].

As mentioned in section 1.1.3 and 2.3, based on the ReFuelEU aviation regulation, fossil CO_2 sources are only considered possible for use in the production of e-SAF until 2040. In this perspective, when comparing with the technical potential of fossil & biogenic CO_2 sources, the technical CO_2 potential is very large compared to the demand in the scenarios (see Figure 3-9).

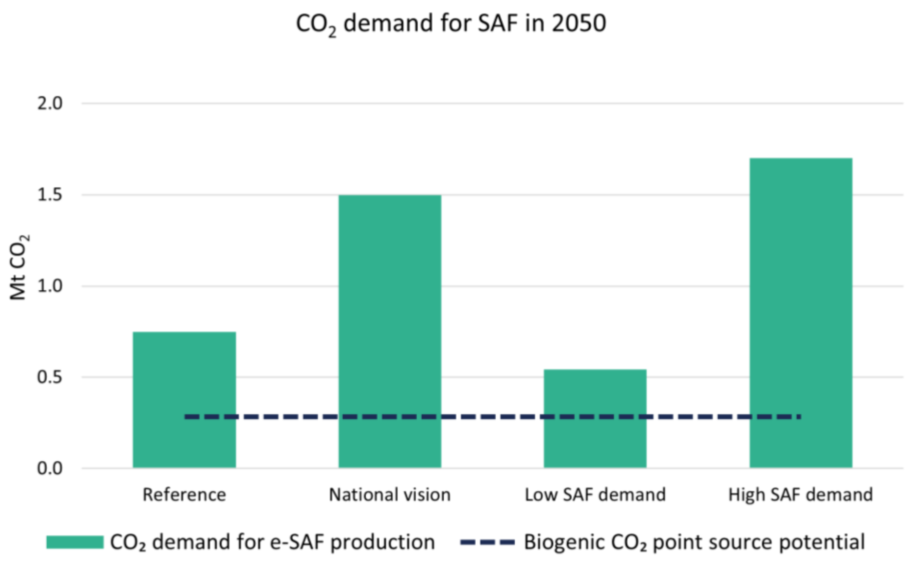


Figure 3-10. The CO_2 demand and point source potential in 2050.

As previously explained, after 2041 for the e-SAF to be considered RFNBO in the requirements of the ReFuelEU aviation regulation, the CO_2 source needs to be biogenic. Therefore, for the 2050 perspective, the CO_2 demand is compared with only the biogenic CO_2 point source potential.

Figure 3-10 shows that in 2050, the domestic biogenic CO_2 point sources are insufficient to cover the estimated CO_2 demands for e-SAF production, regardless of the scenario. This means that if Iceland want to pursue the estimated SAF amounts in international aviation, and cover this by domestic SAF production, a significant amount of CO_2 would have to be based on other sources: CO_2 import, Direct Air Capture (DAC) or Direct Ocean Capture (DOC). Alternatively, part of the SAF demand could be covered by importing SAF.

Although the results from Figure 3-9 indicate that sufficient domestic CO_2 is technically available, it should be kept in mind that the capture of CO_2 might be difficult in practice and economically challenging for some of the point sources. For example, the CO_2 from the aluminium smelters is both technically and economically challenging, as the CO_2 concentration is near 1 mol% and the pressure low and temperature approximately 60-80°C. Moreover, currently IðunnH_2 is presuming import of CO_2 for the e-SAF process, as gathering the scattered CO_2 sources, and purifying various sources with different impurities would most likely be more costly [27].

[7] Provided that all the estimated biogenic CO_2 sources in Iceland are allocated to e-SAF production.

3.4 Hydrogen and biomass

Calculations for hydrogen and biomass demand for fulfilling the required e-SAF and bio-SAF demand respectively, were carried out using assumptions, based on conversion factors from technology catalogues published by the Danish Energy Agency (DEA) [33].

The required hydrogen for the production of e-SAF is assumed through the same process as described in sections 2.2 and 2.3. In 2035, the hydrogen required is similar for all scenarios, 1-4 PJ. In 2050, the range is a bit wider from approximately 10 PJ for Low SAF demand to approx. 30 PJ for the High SAF demand scenarios.

In 2035, the biomass required is similar for all scenarios, 16-20 PJ of biomass input. In 2050, the range is a bit wider from approx. 40 PJ for Low SAF demand to approx. 55 PJ for the Reference and High SAF demand scenarios.

References

[1] Orkustofnun, "OS-2023-T011-01: Primary Energy Use in Iceland 1940-2022 [data file].," 2023. Available: https://orkustofnun.is/upplysingar/talnaefni/orka.

[2] Orkustofnun, "OS-2024-6-3: Orkuspá 2023-2050 niðurstöður," 2024. Available: https://orkustofnun.is/upplysingar/talnaefni/eldsneyti.

[3] Landsnet, "Raforkuspá Landsnets: Spá Landsnets um þróun eftirspurnar og framboðs á raforku 2023-2060," 2023. Available: https://landsnet.is/library?itemid=1b9f4026-dbf0-4bc2-a496-60bb2bd99088.

[4] Orkustofnun, "OS-2023-T006-02: Development of fuel sales by sector in Iceland (2022).," 2023. Available: https://orkustofnun.is/upplysingar/talnaefni/eldsneyti.

[5] Alþingi, "Lög um loftslagsmál," 12 04 2024. Available: https://www.althingi.is/lagas/nuna/2012070.html.

[6] Alþingi, "Svar umhverfis-, orku- og loftslagsráðherra við fyrirspurn frá Þorbjörgu Sigríði Gunnlaugsdóttur um markmið stjórnvalda um kolefnishlutleysi fyrir Ísland árið 2040," 23 11 2023. Available: https://www.althingi.is/altext/154/s/0610.html.

[7] Government of Iceland, Ministry of Industries and Innovation, "A Sustainable Energy Future," September 2020. Available: https://www.stjornarradid.is/library/01--Frettatengt---myndir-og-skrar/ANR/Orkustefna/201127%20Atvinnuvegaraduneytid%20Orkustefna%20A4%20EN%20V4.pdf.

[8] Government of Iceland, "SDG7 ambition," Available: https://www.un.org/sites/un2.un.org/files/2021/09/energy_compact_template_version_21_september_final.pdf.

[9] Umhverfis-, orku- og loftslagsráðuneytið, "Vegvísir að vetnis- og rafeldsneytisvæðingu á Íslandi," Umhverfis-, orku- og loftslagsráðuneytið, 2024.

[10] Innviðaráðuneytið, "Drög að stefnu og aðgerðaráætlun um orkuskipti í flugi," Stjórnarráð Ísland, 2022.

[11] European Commission, "European Climate Law," 29 july 2021. Available: https://climate.ec.europa.eu/eu-action/european-climate-law_en. [Accessed may 2024].

[12] "Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC," 13 10 2003. Available: http://data.europa.eu/eli/dir/2003/87/2023-06-05.

[13] Ministry for the Environment and Natural Resources, "Aðgerðaáætlun í loftslagsmálum (e. Climate Action Plan)," Government of Iceland, 2020.

[14] "Directive (EU) 2023/958 Of The European Parliament And Of The Council" 10 05 2023. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023L0958.

[15] "Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport (ReFuelEU Aviation)," 31 10 2023. Available: http://data.europa.eu/eli/reg/2023/2405/oj.

[16] Stjórnarráð Íslands, "32023R2405," 18 October 2023. Available: https://gagnagrunnur.ees.is/32023r2405. [Accessed 2024].

[17] "Directive (EU) 2018/2001 Of The European Parliament And Of The Council," 11 12 2018. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001.

[18] "Commission Delegated Regulation (EU) 2023/1184," 10 February 2023. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R1184.

[19] "Commission Delegated Regulation (EU) 2023/1185," 10 February 2023. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R1185.

[20] ICAO, “Conversion Process,” july 2023. Available: https://www.icao.int/environmental-protection/GFAAF/Pages/Conversion-processes.aspx. [Accessed 2024].

[21] Topsoe, “Sustainable aviation fuel,” Available: https://www.topsoe.com/sustainable-aviation-fuel. [Accessed 15 06 2024].

[22] Isavia, *Energy Sources for the Future.* 24 May 2024.

[23] Icelandair, *Personal communication on the future vision and SAF at Icelandair.* 17 May 2024.

[24] J. Bernódusson, “Repjuræktun á Íslandi til skipaeldsneytis,” Samgöngustofa, 2018.

[25] “Loftslagsvegvísar atvinnulífsins: Flug,” Available: https://www.loftslagsvegvisar.is/flug.

[26] IEA, “Net Zero by 2050,” October 2021. Available: https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf. [Accessed 2024].

[27] IðunnH2, *Personal communication on the future production of SAF in Iceland.* 29 May 2024.

[28] ICAO, “Post COVID-19 Forecasts Scenarios,” ICAO, Available: https://www.icao.int/sustainability/Pages/Post-Covid-Forecasts-Scenarios.aspx. [Accessed 2024].

[29] Icelandair, “Welcome to Icelandair Capital Markets Day 2023,” Icelandair, 2023. Available: https://assets.contentstack.io/v3/assets/blt7c94950eb7f3edcb/blt156b45ad417f4cef/655e1961d28c5a726b3ddc66/231122_icelandair-capital-markets-day-v01.pdf. [Accessed may 2024].

[30] Isavia, *Personal communication on Isavia's passenger forecast 2024-2033.* 15 May 2024.

[31] Danish Energy Agency, “Power to jet fuel,” DEA, 2024.

[32] Danish Energy Agency, “Liquid fuels from biomass gasification and Fisher Tropsch,” DEA, 2024.

[33] Danish Energy Agency, “Technology catalouge for green fuels,” 2024. Available: https://ens.dk/service/teknologikataloger/teknologikatalog-fornybare-braendstoffer. [Accessed 2024].

[34] Umhverfsstofnun (National Energy Agency in Iceland), “Losunartölur byggðar á hnatthlýnunarmætti úr fimmtu matsskýrslu (AR5) milliríkjanefndar um loftslagsbreytingar,” IPCC V3, 2023.

[35] “Commission Delegated Regulation (EU) 2023/1185,” 10 02 2023. Available: http://data.europa.eu/eli/reg_del/2023/1185/oj.