Production and use of sustainable aviation fuel in East-Iceland and Northern-Norway

A feasibility study

Written by Austurbrú & Energi i Nord
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A final report for the NORA project Sustainable aviation fuel

The East-Iceland Regional Development Agency, Austurbrú, and the Northern Norwegian energy cluster, Energi i Nord conducted a study on the opportunities and barriers regarding the introduction of Sustainable Aviation Fuels (SAF) in Northern Norway and in Eastern Iceland. The projects received financing through the North Atlantic Cooperation – NORA funding scheme[1].

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SUSTAINABLE AVIATION FUEL

Sustainable Aviation Fuels or SAF is the term used for a group of different synthetic aviation fuels that have a lower carbon footprint than fossil-based fuels but that still can be used in most current aircraft and in current fuel distributions systems. SAF is typically based on either biological feedstock,or based on hydrogen produced from renewable energy sources, in this study referred to as e-SAF, e-fuel or electro fuel.

Because of SAF being a liquid fuel that has mostly identical properties as standard jet fuel there are relatively low technical barriers to implement SAF in the aviation industry, at least compared to other low carbon pathways like electric aviation or hydrogen-based aviation. SAF is typically blended with standard jet fuel in different blending rates depending on blending mandates. Fuel blends can include up to 50% SAF without any technical modifications and within current legislation. Blends containing more than 50% SAF will require some technical modifications to engines and fuel systems as well as modifications to legislation.

It is generally considered that e-SAF has a better potential than bio based SAF to reach sufficient production volumes since there is expected to be abundant renewable energy available globally in the future but that relevant biological feedstocks have natural limits.

SAF LEGISLATION

In 2023 the EU Council and EU parliament agreed on a proposal for introduction of an EU-wide SAF blending mandate to enter into force from 2025. From 2025 the minimum SAF blend will be 2%, going up to 6% in 2030, 20% in 2035, 24% in 2040, 42% in 2045 and finally 70% in 2050. There is even a sub-mandated for a e-fuel share of the total SAF blend. The EU Parliament has also proposed the establishment of a Sustainable Aviation Fund to help finance upscaling of production of SAF.

The Norwegian government did implement a blending mandate of 0,5% biofuel in all domestically sold jet fuel from 2020, making Norway among the first countries to implement such legislation. "biofuel" in this regard means biobased SAF. Also, e-SAF is accepted under this blending mandate.

The Norwegian Parliament has approved an increased blending mandate of 2% to enter effect from July 2023. However, the implementation has been delayed until further notice by the Ministry of Climate and Environment due to perceived insufficient supply in the market. There is currently no defined plan for further increase in the blending mandate in Norway, but it is generally assumed that Norway will align with EU legislation on this topic going forward. In Iceland there are currently no domestic blending mandates.

HIGHLIGHTS

» The focus of this report is both production and use of SAF in Northern Norway and Eastern Iceland. The hypothesis for this project was that the two regions have advantages concerning production and use of SAF. Sustainable Aviation Fuels are viewed as a good short-term solution to reduce climate emissions from the aviation industry. There is a lot of activity concerning SAF globally.

» Using qualitative research methods, 34 key stakeholders in the industry both in Norway on Iceland and abroad were interviewed. Stakeholders include aircraft manufacturers, airlines, fuel suppliers and fuel producers.

» The stakeholders have both technical and practical knowledge regarding SAF; the production and business aspects is substantial; however, the knowledge of production is higher in Norway and is related to their decades long experience in the oil and gas industry.

» Most of the stakeholders are aware of and positive regarding the EU blending mandates, the ReFuel Aviation initiative, but the relevance to their operations is varied. Most stakeholders were initiating or partaking in projects interfacing sustainable aviation or electric fuel, stating the reasons being the legal obligations, social responsibility, and economic incentives.

» Key areas of opportunity were identified, such as access to renewable energy and an extensive network of airports, at least in the case of Northern Norway. Other opportunities included the creation of new jobs and new infrastructure.

» Key barriers identified were access to feedstock at competitive prices and public acceptance. Access to renewable energy and electricity were also mentioned as a possible barrier, these factors closely related to the complex public attitudes towards increased energy production and natural preservation views.

» One stakeholder webinar was held with presentation of preliminary results. The webinar was attended by around 40 participants from the stakeholder group. The webinar concluded the study presentation with group discussion confirming the current interest and development regarding SAF.

» The hypothesis that the two regions have advantages concerning production and use of SAF seems to be provisionally verified. However, there is a long way to go towards finding common strategies, solutions, and testing such. Therefore, the project partners plan to follow up this project with a new project and include partners from the stakeholder group including partners from other countries.

INTRODUCTION

Sustainable Aviation Fuel (SAF) is a term describing a group of different synthetic aviation fuels with a lower carbon footprint than fossil-based fuels that is still usable for current aircraft and in current fuel distributions systems. SAF is typically based on either biological feedstock, or based on hydrogen, produced from renewable energy sources, in this study referred to as E-SAF. Because of SAF being a liquid fuel that has mostly identical properties as standard jet fuel, the technical barriers to implement SAF in the aviation industry are low. At least compared to other low carbon pathways like electric aviation or hydrogen-based aviation.

It is generally considered that SAF produced using renewable power has the greatest potential of becoming the main source of SAF because renewable power is and will be more abundant than relevant biological feedstocks. However, there are substantial commercial barriers as well as challenges related to the industrial upscaling of production.

This report describes a feasibility study regarding the use and production of SAF. The work is funded by NORA, an intergovernmental organization under the regional cooperation program of the Nordic Council of Ministers that brings together Greenland, Iceland, Faroe Islands, and coastal Norway. The study is carried out by Norwegian partner, Energi i Nord and Icelandic partner, Austurbrú.

The aim is to answer the following questions:

- Could sustainable aviation fuel (SAF) be produced in Iceland and Norway?
- How is the interest from relevant actors like producers and supplier industries, airports, and aircraft, as well as authorities?
- What airport infrastructure is required, and how can it be implemented in Iceland and Norway?
- What is the market and the possibilities in the short and long term for SAF produced in the North Atlantic Region?
- How could flights based on SAF instead of ordinary jet fuel contribute to more sustainable transport of tourists and travelers in addition to export of goods from local producers, which struggle to be greener?

Austurbrú and Energi i Nord

The project is carried out by two regional entities in East Iceland and Northern-Norway. The partners work on a regional level with various networks and projects on an interdisciplinary scale and in the international setting. The areas are in many ways similar in terms of resources, geography, climate, and infrastructure.

Austurbrú and East Iceland

East Iceland consists of four municipalities that cover 16 thousand square kilometers and has a population of just over 11 thousand inhabitants. The region's economy is based on industries such as fishing, fish farming, energy- and aluminum production, increasing tourism and vibrant culture. There is a need to attract new businesses and more people to further the development of the region with a focus on the contribution it can make to the global shift to green energy. Austurbrú is a self-governing organization, representing the municipalities in the region and aims to provide coordinated, interdisciplinary intends to lead and coordinate business development, research, government administration, university-level studies, continuing education, and social and cultural activities in East Iceland. Austurbrú as an organization operates all matters related to the Association of Local authorities in Austurland (Samband sveitarfélaga á Austurlandi – SSA).

Energi i Nord and Northern Norway

Energy in the North is a cluster of around 50 companies and institutions working together in Northern Norway. www.energiinord.no. The energy cluster contributes to the energy transition and value creation for companies and societies in the north. International cooperation is one of the ways to succeed together. Northern Norway has large resources and extensive expertise in the production, transmission, storage, and industrial processing of carbon-neutral energy. To trigger the opportunities that this part of the country has within this field, we must work together. Northern Norway is the northernmost part of the country and consists of the counties of Nordland, Troms and Finnmark. The region has an area of 112.967 square kilometres and has a total population of 484.749.

The region has long distances to the markets, scattered settlements, and a lack of people, especially between 30-45 years. There is a need to attract more people, and a need for the industries to create a rise in the value chain and more skilled jobs. The region is dependent on natural resources-based industries like energy, minerals, sea food and tourism, as well as an R&D and innovation culture focused on the green shift. There is also a good welfare and cultural sector.

Participants

A stakeholder mapping was conducted, analyzing both regional as well as vitally relevant international players. Approximately 50 stakeholders were mapped, with 34 participating in the study.

Qualitative data was gathered in a series of interviews to acquire a broad comprehension of the stakeholders and their position and views on the feasibility of production in the study areas.

The nature of stakeholder operation varies, all having interfaces with SAF and aviation to some extent. Participants subsequently being classified into appropriate groups. Each group consists of parties that have similar interfaces with SAF and the aviation sector, this being finalized and confirmed by similar factors such as views on barriers and feasibility. This resulted in six groups being formulated.

Research questions

The research questions regarding the feasibility, knowledge, and interest regarding sustainable aviation fuel in the areas were six and grouped into two main interview topics as laid out in table 1.

Table 1. Interview framework

Interview topics	Interview questions	Research question
Interview topic I Career and education, knowledge of SAF and EU mandates, company status with regards to on-going projects, interests, and incentives for interest in SAF.	Q: Education, experience, and knowledge (of the interviewee)	Feasibility with regards to knowledge and expertise
	Q: Blending mandates	Knowledge of ReFuelEU, blending mandates
	Q: Company status: on-going projects, interest, and incentives	How is the interest from relevant actors like producers and supplier industries, airports, and aircrafts, as well as authorities?
Interview topic II Feasibility of SAF production in the areas, w.r.t. local knowledge and access to relevant expertise, advantages of the areas if any, possibilities with regards to the areas and other opportunities as well as the main obstacles of SAF production in the areas.	Q: Local Knowledge	Referring to knowledge in the area E-Iceland/N-Norway. Feasibility with regards to knowledge and expertise
	Q: Possibilities and advantages	RQ: Feasibility of producing sustainable aviation fuel in the regions, East-Iceland, and Northern-Norway
	Q: Obstacles	Obstacles as a factor of studying feasibility

METHODOLOGY

Chosen methodology was a qualitative one to get a broad comprehension of the stakeholders, their interface and status regarding sustainable fuel as well as views on the barriers and possibilities regarding production and use of SAF in the study areas, E-Iceland, and N-Norway.

As mentioned in the "about the partners" chapter above, diverse stakeholders participated in the study. The nature of their operations covers the entirety of the value chain of sustainable aviation fuel. This includes power companies, hydrogen manufacturers, fuel producers, vendors and transporters, airlines and relevant government institutions, municipalities, and ministries.

Around 50 stakeholders were mapped, those being both regional and domestic operations, as well as a few international organizations that are highly relevant to the study. Of the 50 stakeholders mapped, 34 participated in the study.

The participants were interviewed by the project team within the first quarter of 2023. The interviews were recorded and transcribed. A significant amount of qualitative data was gathered from the interviews, which the project team formed a series of codes around to draw out reoccurring views and pinpoint common themes. Themes were used to detect differences and similarities within the groups, as well as between groups. The resulting common themes were analyzed in context with the research questions, to answer the hypothesis.

This method resulted in six groups being formulated. Each group consists of stakeholders that have similar interfaces with SAF and the aviation sector.

- The first group being a collection of power companies and hydrogen producers. Power companies being an umbrella term for both energy producers as well as companies dealing exclusively in the distribution of energy.
- The second group being a collection of organizations projecting or currently producing sustainable aviation fuel, as well as one organization operating exclusively in the retail of SAF, being closely intertwined to the other stakeholders in the group as subsidiary of a fuel producer.
- The third group being aircraft manufacturers, those organizations not being regional nor domestic to the study areas, however critically pertinent to the study as key stakeholders.
- The fourth group consists of government entities. For example, officials from various government and public institutions, municipalities leaders and ministries. Significant variances in views and knowledge can be analyzed between stakeholders in this group, however, still adhering together having fundamentally comparable interfaces and position regarding sustainable aviation being government or public workers.

» The fifth group is a collection of airlines, which are those in the commerce of aviation services and or freight. These stakeholders have very similar views as well as legal obligations towards SAF as they are directly affected by the EU mandates.

» The sixth group consists of stakeholders having various interfaces with sustainable aviation and SAF. Not being belonging to any other groups with regards to the precedents and grouping conditions mentioned above. Some common themes were analyzed within the group. The nature of these stakeholders' operations and incentive for interest in the subject vary. These are consultants, unions, apposite clusters, heavy-industry, and airport operators.

The groups and participants are exhibited in table two below.

Table 2. Participants

Group	Iceland	Norway	Other regions
Power producers, hydrogen producers and distributors	Landsvirkjun HS Orka Rarik VON (ON)	Troms Kraft Nordkraft Glomfjord Hydrogen Norwegian Hydrogen	
Producers and retailers of SAF	Iðunn H2	ST1 Norsk e-fuel Nordic electrofuel AFSN	Sasol (SA) Neste (FIN)
Airlines	Icelandair	Norwegian Widerøe	
Aircraft manufacturers			ATR (FRA) Deutsche Aircraft (GER)
Government and public institutions	Múlaþing municipality Fljótsdalshreppur municipality Vopnarfjörður municipality Ministry of infrastructure Ministry of environment, energy, and climate	Bodø Municipality CAA Norway	
Various interfaces with sustainable aviation fuel	Isavia ohf. Clara Artic Energy Norðurál Samtök Iðnaðarins Grœnvangur VOR		

The table below exhibits each group proportionally to the whole, with regards to the sum of participants. As well as the proportion of participants with regards to their native country of operation, within each group.

Half of the participants are from the power producer and SAF producer groups, which is appropriate and adds credibility as they are the experts and the main components of the research questions and answering the hypothesis: is production and use possible in these areas? Airlines are also highly relevant to the study and accumulate to 9% of the participants. Which is an adequate proportion due to the limited size of the study countries, Iceland for example only having two airlines.

Table 3. Participant categories, proportions

Stakeholder category	Conditions for category	Ratio of Σ	Ice % wi.g.	Nor % wi.g.	Other reg wi.g
Producers and retailers of sustainable aviation fuel	Currently or project to produce sustainable aviation fuel, or vendor the produced product	25%	25%	50%	25%
Aircraft manufacturers	Design and development of aircrafts	6%	0%	0%	100%
Power producers and distributors	Energy and hydrogen producers, vendors, and distributors of energy	25%	50%	50%	0%
Government	Municipalities, agencies, public institutions, and ministries	22%	71%	29%	0%
Airlines	Engage in air transportation	9%	33%	67%	0%
Various interfaces with sustainable aviation fuel	Contains consultants, unions, clusters, heavy-industry, and airport handlers	13%	100%	0%	0%

In total the ratio of participants from each region are as follows:

Table 4. Participants in the regions

Icelandic participant	Norwegian participant	Participants, other regions	Σ
18	12	4	34
53%	35%	12%	100%

Excluding other regions, shows a moderately even distribution of participant between the countries and study regions, Iceland/E-Iceland, and Norway/N-Norway.

Table 5. Participants from Iceland and Norway

Icelandic participant	Norwegian participant	Σ
18	12	30
60%	40%	100%

RESULTS

This section presents the results of the research questions as they are presented in table 1 where the questions regard two topics, each containing three subject questions. The first topic covers the general status of knowledge and the status of the respective companies regarding SAF and the second one with the more local aspects of the stakeholder's knowledge and their views on possibilities and obstacles regarding the feasibility of SAF use and production. The results are presented in the order of the question layout for readability and direct quotes from the interviews are inserted to give a voice to the stakeholders and underline and summarize the views that emerged from the analysis.

Interview topic I

Interview topic one asks three questions intended to identify the interviewee scope of knowledge regarding SAF. Firstly, in terms of technical and practical application. Secondly, the interviewee knowledge of the EU blending mandates and how they affect their company's operations. And thirdly, a question on their relevant company projects, such as production and usage of SAF.

Knowledge & expertise

The education level among the stakeholder interviewees was high. In five out of six stakeholder categories the interviewees have a minimum of a master's degree. Except for one category, power producers and distributors, where 75% had the equivalent of a master's degree, not promulgating a lack a of education as furthermore 38% had more than one master's degree in that category. The nature of interviewee education varies, with some coherence throughout groups, with the most frequently mentioned educational background being in engineering.

Most of the interviewees throughout the stakeholder categories have work-related experiences. Most having experience spanning many years in their respected field, those fields having various interfaces with sustainable aviation fuel and aviation.

We learned that the knowledge can be divided into two aspects, which is knowledge of technical factors regarding SAF and SAF production, and the second aspect being knowledge of business factors and policy. The nature of the interviewee's knowledge in most cases being in context with their respected field of occupation, job specification and educational background. For example, most interviewees in the production stakeholder category view themselves as having more technical knowledge than knowledge of business-related factors, or regulations and policy. While on the other hand, most of the interviewees from the aircraft manufacturer group view themselves as possessing more business-related knowledge of SAF. Perhaps, as specific production processes of sustainable aviation fuel are not their field of work, but rather being experts in the production of aircraft.

"My knowledge of SAF is more substantial in the technical aspects, which is the production side."

ReFuelEU Aviation Initiative

As an aspect of knowledge, we set out to examine familiarity of the ReFuelEU Initiative blending mandates within the subject group. The ReFuelEU Aviation Initiative is an EU effort to increase the use of sustainable aviation fuels (SAF) and reduce emissions in the aviation sector. It proposes blending mandates for SAF in aviation fuel, sets sustainability criteria, promotes research and innovation, and emphasizes international cooperation. The initiative aims to make aviation more environmentally friendly and align with the EU's climate neutrality goals.

Almost all the interviewees view themselves as being familiar to some extent with the impending blending mandates by the European Union. Thereof, only a small group of interviewees would be considered as experts, them being from the air carrier category and a few interviewees from the government category that specialize in related policy. However, the remaining interviewees from the government category did not possess such expertise knowledge. Furthermore, most of the interviewees that view themselves to possess little knowledge regarding the blending mandates are within the government category as well as a few within the power providers and distributor category.

The level of knowledge of the EU mandates is generally equal in both areas, being neither more nor less in either Iceland or Norway. In most subject groups the knowledge of the blending mandates was consistent throughout the category, except for the government category wherein all the Norwegian interviewees viewed themselves as having good knowledge of the mandates, whereas only 25% of the Icelandic interviewees viewed their familiarity with the mandates as good.

"The voluntary marked will increase, but the prices are still too high to be a driver, and that is why mandates are so important."

Those who disclosed their sentiment towards the blending mandates, believe that the mandates are positive, being an accelerant or incentive to speed up the development of sustainable aviation by legally obliging companies to utilize green solutions.

"I consider such mandates to be a positive and accelerate development."

Company status

The question regarding company status was asked to identify on-going projects, interest, and incentives. Those being the actions as well as the position of the interviewee´s organization regarding or towards sustainable aviation fuel.

When asked about company status, most of the interviewees referred to some on-going projects; in-house projects or collaboratives that have certain interfaces with sustainable aviation or electric fuels.

Even though not necessarily being projects aiming towards direct production of sustainable fuel, rather being industry specific projects. For example, some of the interviewees from the power providers and distributors group mentioned collaborative projects with potential SAF producers, as well as research projects regarding the energy need of SAF production. Another example is aircraft manufacturers looking into the production of SAF optimized aircraft or government parties researching SAF or sustainable aviation from various perspectives; social, economic or with regards to infrastructure.

When asked about the incentives or motivation for interest in climate neutral aviation and sustainable aviation fuel, most of the interviewees in five out of six stakeholder groups mentioned being incentivized by environmental factors and achieving climate goals. Furthermore, most interviewees in four stakeholder groups stated economic incentives for interest in sustainable aviation fuel. Three groups mentioned being incentivized by social goals such as creating new jobs and industry development, and interviewees in one stakeholder group frequently mentioned being incentivized be legal obligations.

> "We are incentivized by the public interest, and prevention of harm and lasting effects of climate change."

Interview topic II

Interview topic two asked three questions intended to identify the interviewee opinions on the feasibility of SAF production and usage. Firstly, in terms of knowledge and feasibility in their respective areas. Secondly, their views on possibilities and advantages of producing and using SAF in their areas and thirdly, a question regarding barriers and obstacles that affect feasibility.

Local knowledge

The question of local knowledge referred to knowledge and expertise regarding SAF present in the areas, Norway, and Iceland. Local knowledge plays a key role in the feasibility of local production.

One of the stakeholder groups did not disclose views on local knowledge, due to the international nature of their operations.

None of the Norwegian interviewees disclosed explicit views regarding local knowledge. This result could either be explained by the Norwegian interviewees believing the knowledge already being present due to decades of experience in the oil and gas industry. As one Icelandic interviewee explained:

> "In Norway, there is a lot of knowledge about oil and gas that has been built up over the last few decades, knowledge that can significantly be transferred to SAF production."

As for the Icelandic interviewees a common consensus is that knowledge, expertise, and technology need to be imported at first, then learned and acquired locally.

"This is new knowledge, and we need to import the knowledge and technology."

Feasibility

The interviewees were asked about their views on the possibilities of SAF production in the areas, N-Norway, and E-Iceland, and furthermore about location specific advantages if any. Local advantages referring to geographical, social, economic, industrial, or infrastructural factors present in these areas making them preferable.

Possibility or feasibility factors regarding sustainable aviation fuel production are multiple and diverse. In general, the main downright production factors being access to feedstock, such as CO2 and electricity, as well as the presence of supporting infrastructures interfacing with the production, for example transport infrastructures, shipping routes, and the, preferably nearby, demand for the product to make the logistics of a business case pan out.

When asked about the possibilities and advantages of production in these areas, interviewees in two of out six stakeholder groups mention the suitability of both areas, N-Norway, and E-Iceland.; most mentioning access to renewable energy at affordable prices, as well as many mentioning accesses to water and the presence of relevant or supporting infrastructures, such as ports.

Interviewees in four out of six groups mention specific advantages of N-Norway, them being access to funding possibilities, access to energy, and accessible experience from related industry fields. The locational convenience or advantage of Bodø was mentioned several times, interviewees furthermore stating proximity to the regional airport and shipping lanes for possible exportation of sustainable fuel produced in the region.

Furthermore, interviewees in four out of six groups mention specific advantages of E-Iceland, them being access to energy and possibilities to increase energy output and the possibilities or opportunities to create new power production and infrastructures, e.g., mentioning the vast amounts of available territory for wind turbines. Interviewees in four of the stakeholder categories also mentioned the creation of new jobs, infrastructural development and other social benefits that follow the establishment of a new industry as a feasibility factor for E-Iceland. In the sense that the various subsequent benefits and value of a new industry make it desirable and perhaps needed to the area, correspondingly inducing feasibility.

"I think we are in a really great position for electric fuel production,
... a lot of energy, and opportunities to increase power production,
energy transmission infrastructure, heavy industry and a large shipping port."

Similarities can be noticed throughout the possibilities and advantages expressed by the interviewees for either area, N-Norway, and E-Iceland. Those, for example being advantages due to geographical factors, e.g., access to water and territory. The interviewees find similarities regarding advantages due to present energy infrastructures and mention for both areas opportunities to create new energy producing resources. Other similarities

can be perceived in the advantages mentioned, as well as differences. A dissimilarity in sentiment and views can be noticed between interviewees regarding access to funding. Funding for research and industry development being hinted as accessible in Norway, and in contrast, some interviewees explicitly criticizing the lack of funding for said projects and development in Iceland.

"There is a lack of funding for SAF related projects in Iceland."

Barriers

As stated earlier in the report, there are substantial commercial barriers as well as challenges related to the industrial upscaling of the production of sustainable aviation fuel. The commercial and production barriers are complex, and solutions need to be developed if, firstly a production of sustainable fuel is to be possible in the study areas, and secondly for production to be economically and socially viable.

In general, the main barriers for SAF production no matter the location is access to feedstock at favorable prices. Main feedstocks for SAF being either biological feedstock to produce HEFA-SAF or hydrogen produced from renewable energy sources as well as sustainably captured carbon to produce E-SAF. A prerequisite of renewable or green hydrogen being access to electricity and water for the process of electrolysis.

In some cases, the possibilities and obstacles are closely intertwined, as mentioned in the previous chapter, many of the interviewees believe the areas to be advantageous for E-SAF production due to access to renewable energy as well as having opportunities to build new power infrastructures and produce more energy. However, in contrast most also state the main barrier for E-SAF production to be lack of electricity, not being a problem exclusive the regions, moreover, being a worldwide impediment, which then the study-areas might be well suited location and infrastructure wise to resolve.

In five out of six stakeholder groups, interviewees mention access to renewable power and available electricity as one of the main barriers for SAF production, an international barrier. While the study areas are perhaps better suited location and infrastructure wise to resolve this impediment, many mention the complications of building new power infrastructures and increasing energy production due to environmental factors and social acceptance. On that topic, interviewees from the power producers and distributors group mention the antipathy towards wind turbines, hydroelectric dams, and power-transmission masts. As one interviewee puts it, the public supports the energy transition, that is the transition to green solutions and relying on renewable energy, while at the same time, not supporting the construction of any new power infrastructures, often from an environmental point of view. Blatantly stating this to be a socially common paradox that needs to be brought to light.

"There are different tastes in the appearance of electricity infrastructure, such as masts and wind turbines. So, this would be a controversial project like everything we do."

And

> "We have come to realize that those who want to electrify everything, that is to power society by electricity are the same ones who do not want large-scale construction to increase the supply of electricity, construction such as power plants, dams, and wind turbines. This is a paradox; the electricity must come from somewhere."

Throughout the interviews, more common themes can be noticed between stakeholder groups regarding views on what the main obstacles are to produce sustainable aviation fuel in the areas, N-Norway, and E-Iceland.

In all stakeholder groups, both Icelandic and Norwegian interviewees mention the lack of government incentives and regulations. As well as concerns of government inaction regarding sustainable aviation and SAF. Interviewees mention the importance of subsidies, tax benefits and clear framework. One interviewee stated his organization is having projects on hold due to governmental idleness or fecklessness in providing clear structure and policy. Furthermore, stating this as a halting factor to the energy transition and fighting climate change in general.

> "We have several projects on hold due to government inaction. The ball is in the government's court if they intend to achieve their energy transition goals."

In five out of six stakeholder groups, interviewees state concerns of not reaching an economically viable scale for production of SAF in these areas, N-Norway, and E-Iceland due to distance to significant demand centers for the product. In that regard, N-Norway perhaps being in a better position as some interviewees mention with the presence of the regional airport in Bodø. Subsequently, some interviewees state exporting the product to be a solution to reaching economic viability. As one interviewee states, the distance and shipping costs are redundant if feedstock can be acquired, and fuel consequently produced at favorable prices.

> "If it is possible to produce SAF at optimal costs in East-Iceland, then transporting the product to the demand is a minor factor, the demand is so high."

Some mention concerns from a supply point of view, which is the supply of sustainable aviation fuel being insufficient and productions being far from sufficient scales when significant demand is created. Moreover, mentioning the time it takes to construct and upscale a new production industry, and how it might be unrealistic to achieve industry growth concomitantly or in sequence with blending mandates.

Interviewees in four out of six stakeholder groups consider feedstock acquirement and cost of feedstock to be one of the main barriers of production, mainly referring to the complication regarding acquiring CO2 for production. But also referring to other production feedstocks, such as electricity, water, hydrogen, and bio-waste. The feedstock barrier is twofold, that is cost and access. As the cost of feedstock increases, being the

main determinant of retail price, results in higher fuels costs for airlines, consequently resulting in a price to consumers increasing. Sustainable fuel is already considerably more expensive than regular jet-fuel. The second aspect being access. As some Icelandic interviewees mention, the volume of high concentration CO2 or carbon needed to produce E-SAF is such that it cannot be acquired locally, it then needing to be imported.

"The most feasible thing today is importing CO2."

Industry specific barriers and opportunities can be noticed in some stakeholder groups, which is a barrier or opportunity being highlighted frequently by interviewees in one group but not necessarily being mentioned by interviewees in other groups. For example, in the aircraft manufacturer group, interviewees state concerns regarding SAF fuel efficiency of current aircraft, implying that insufficient fuel efficiency should be penalized. Therefore, accelerating the renewal of air fleets as well as retail of more sustainable or SAF optimized aircraft.

Furthermore, even though mentioned by some interviewees in other groups, most interviewees within the air-carrier group are concerned about the price gap between current regular fuel and sustainable fuel, and how it affects the price to consumers and the price elasticity of aviation services: is aviation to be a luxury service?

Other industry specific or highlighted barriers is the public acceptance of the construction of new power infrastructures, being frequently mentioned by interviewees within the power producer and distributor group, as well by some interviewees in other groups. In that regard, several Norwegian stakeholders mention the issue regarding the aboriginal landspace, which can be difficult to negotiate about when planning to construct new power producing or distributing infrastructures.

"The energy needed for the energy transition just does not exist.
I think the electricity is the biggest barrier, it can take such
an incredible amount of time to make decisions about things like that."

CONCLUSION

The study identifies key potentials and barriers for SAF production and use in Northern Norway and East Iceland. It is a first step in assessing the feasibility of production and usage in the areas. This includes stakeholder mapping and an outline of their views. However, there is need for more data to conclude if SAF production is feasible and to identify the capabilities for production in terms of volume and consumption.

Next step is to quantify the possibilities and explore in a bigger context. The energy transition challenge is a global one and the project would benefit by expanding the partner network and extending the analysis to other Nordic areas. Also, broadening the research setting is advantageous, specifically regarding SAF usage, to include other transport modes such as shipping (including both cargo and the fishing fleet) and land transport.

Stakeholders mentioned various barriers as well as opportunities and possibilities throughout the interviews. The primary barriers being threefold.

» Firstly, government inaction regarding sustainable developments in aviation.

» The second primary barrier being access to and cost of production feedstock, mainly CO2.

» The third one being access and availability of large volumes of green renewable energy.

The primary barrier mentioned by interviewees in all groups is government inaction. Sustainable fuel is more costly than regular fuel and it is not possible for SAF to be a viable option compared to fossil fuel. This results in significantly higher consumer prices, unless governments implement considerable subsidies, taxation, and incentives. Furthermore, interviewees emphasized the importance of a clear framework, policy, and regulations, which are not in place at time. An example of this is an interviewee who stated his organization is having projects on hold due to governmental idleness or fecklessness. Another example is a lengthy licensing process which is a halting factor to the energy transition and fighting climate change in general. Clear standards, regulations, framework, and guidelines minimize industry specific barriers, for example a framework standardizing the method of handling SAF, making it easier to obtain the EU blending mandates.

The other primary barrier to the production of sustainable aviation fuel is access to and cost of feedstock such as carbon. The production of E-SAF requires large volumes of CO2. Carbon capture is a developing industry, making promising developments in recent years, but is still a significant cost driver impacting the willingness to accept the challenges and take part in the development. Most interviewees state the impossibility of locally capturing the large volumes of CO2 needed. The volume needed is not on an economically viable production scale. Economic viability of production refers to a certain size efficiency of production in the areas, so they are operationally sustainable. Therefore, to produce

SAF, CO2 importation is necessary. Throughout the study, this obstacle is frequently portrayed along with the fact that the study areas are far from significant demand centers.

The third barrier frequently observed is access to renewable energy for production. The building of new power infrastructure is often controversial, both on a local and international level. The reasons for controversy are mainly environmental factors but also social such as bargaining with Aboriginals about landspace. The complications of building new power infrastructures and increasing energy production is a lengthy process and requires rigid licensing due to environmental factors and social acceptance.

The possibilities, opportunities and barriers closely intertwine, and while being one of the main barriers, access to renewable energy is also the main opportunity of Northern Norway and East Iceland. Interviewees find the areas advantageous for E-SAF production due to access to renewable energy, water, and opportunities to build new power infrastructures and produce more energy. Both areas have a reliable infrastructure to build on. They have well-established communities, a transport system with airports, roads, and large harbors, already well equipped for import and export, and are geographically well situated regarding natural resources.

The study indicates the areas to be well suited locations to further explore the production and usage of SAF. A new project is underway, expanding the partner network and the research scope. It will build on the current knowledge and further attempt to figure out greener solutions with SAF to the impending energy transition.