Nordregio

Electric Aviation Outlook in the Nordics

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Widerøe plane at Svolvær Airport in northern Norway.
Photo: iStock

1. Summary / Sammanfattning

English

Regarding geographical accessibility questions, the five Nordic countries stand out in Europe due to their low population density, geographic variety including fjords, lakes, and mountains but also the prominence of sustainable energy sources. Before this backdrop, electric aviation holds the potential to make the region's transport sector more sustainable while helping to overcome regional development and accessibility challenges, particularly in rural areas. The introduction of electric airplanes in local transport networks promises the reduction inter alia greenhouse gas emissions and air pollution. This novel supply and consolidation of transport routes into the less populated areas of the Nordic region with a reduced environmental footprint is in line with central climate goals laid out by international policy frameworks such as the European Green Deal, the Paris Agreement and the 2019 Nordic Ministers' "Declaration on Nordic Carbon Neutrality".

While several options to achieve zero- or low emission aviation are currently being developed, this report focuses primarily on the electrification of aviation. Yet, electric aircraft still face several technical and economic challenges, including limited range and passenger capacity. Despite these limitations, this working paper highlights a heightened interest in the introduction of electric aviation, exploring the existing situation, challenges and knowledge in the 5 Nordic countries. This interest stems from partly policy-induced incentives to make domestic travels across natural obstacles greener (e.g. in the case of Denmark's island structure or Norway's landscape of jagged mountains and lakes) or to grant better accessibility to a country's more sparsely populated areas (e.g. in the case of Finland, Sweden and Iceland).

Svenska

När det gäller tillgänglighetsfrågor sticker de fem nordiska länderna ut på grund av sin låga befolkningstäthet, sin geografiska variation med fjordar, sjöar och berg, men också på grund av att hållbara energikällor har en framträdande roll. Mot denna bakgrund har elflyg potential att göra regionens transportsektor mer hållbar och samtidigt bidra till att övervinna regionala utvecklings- och tillgänglighetsutmaningar, särskilt på landsbygden. Införandet av elflygplan i lokala transportnätverk lovar bland annat en minskning av utsläppen av växthusgaser och luftföroreningar. Detta nya utbud och konsolidering av transportvägar till de mindre befolkade områdena i Norden med ett minskat ekologiskt fotavtryck är i linje med centrala klimatmål som fastställs i internationella politiska ramar, t.ex. European Green Deal, Parisavtalet eller de nordiska ministrarnas 2019 års "Deklaration om nordisk koldioxidneutralitet".

Även om flera alternativ för att uppnå en luftfart med noll eller låga utsläpp för närvarande utvecklas, fokuserar denna rapport främst på elektrifiering av luftfarten. Elektriska flygplan står dock fortfarande inför flera tekniska och ekonomiska utmaningar, bland annat begränsad räckvidd och passagerarkapacitet. Trots dessa begränsningar framhäver denna rapport ett ökat intresse för införandet av elflyg, och utforskar den befintliga situationen, utmaningarna och kunskapen i de fem nordiska länderna. Intresset beror delvis på politiska incitament för att göra inrikesresor över naturliga hinder grönare (t.ex. när det gäller Danmarks östruktur eller Norges landskap med kuperade berg och sjöar) eller för att ge bättre tillgänglighet till ett lands mer glesbefolkade områden (t.ex. i Finland, Sverige och Island).

Aerial view of the raps field on the inhabited island Kegnæs in Denmark.
Photo: iStock

2. Introduction and methodological choices

This working paper aims to understand the national context and status of electric aviation in the Nordic region. The publication also provides a brief background of the current state of aviation globally and in Europe.

The Nordic countries have ambitious plans for the use of electric aircraft and different commitments are amended to promote sustainable solutions in the aviation domain, such as electric aviation. Several Nordic and national reports, research projects and collaboration initiatives have delivered first results, highlighting that the first-generation electric aircraft are suitable for the Nordic region (RISE, 2021; FAIR, 2022; Ydersbond et al., 2020).

The main arguments for electric aviation in the Nordic countries are that electric aviation can be suitable on short routes where landscape and geographies, such as large bodies of water, vast forest areas, long coastal lines, mountains, and fjords make train and car travel difficult and time consuming. Electric aviation therefore has the potential to improve accessibility in such remote and rural areas as well as to facilitate access to public services, new work opportunities and the larger national and international transport system.

In the Nordic Region, routes up to 400 kilometers are identified as an initial market for introducing electric airplanes. Shorter distance routes under 200 km, where cruise speed is less important is also in focus since the first generation of aircraft that rely solely on electric power have a defined maximum range of 200km (Heart Areospace, 2022). This can be particularly interesting for sparsely populated regions where passenger volumes are small (Ydersbond et al., 2020). It is important to investigate where and how accessibility can be improved by implementing electric

aviation on these short distances to understand the potential effect in the first stages of the transition towards more sustainable aviation.

The overarching reason for implementing electric aviation is the impact that conventional airplanes have on climate and the environment. Aviation is said to generate more than two percent of all greenhouse gas emissions in the world, but when including the impact on high altitude the number is closer to constitute a share of five percent (IEA, 2022). Airplane emissions, occurring at high altitudes (approx. over 8.000 m), are particularly damaging to the climate as they can lead to cirrus clouds and condensation trail formation, trapping heat between the earth's surface and the clouds (European Commission, n.d). Before the Covid-19 pandemic started in 2020, the International Civil Aviation Organization (ICAO) estimated that the emissions from international aviation could triple by 2050. Even though the aviation sector releases proportionally large amounts of greenhouse gases and CO2, the sector has for a long time been exempt from extensive regulation. For electric aviation to influence CO2 emissions, the origin of the energy consumed is crucial. The large shares of renewable and low-carbon energy sources in the Nordic Region, between 45 and 85 percent of total energy consumption is therefore another argument for introducing electric aviation in the region (European Environment Agency, 2022).

The working paper is structured as follows: After this introduction, a brief policy background is presented, including climate and environmental impact of fossil fuel aviation, global climate and environmental goals, international aviation regulation and EU commitments (chapter 3). The next chapter presents different types of sustainable aviation with a focus on electric aviation. Chapter 5 starts with an overview of electric aviation in the Nordic region and how experts believe electric aviation can be used in the Nordic countries. Nordic research projects and programmes are also presented. Afterwards, the five Nordic countries are presented individually in terms of national policy, research projects and recent developments regarding electric aviation.

The Nordic countries in focus for this study are Denmark, Finland, Iceland, Norway, and Sweden. As will be presented in the publication, the countries share many similarities but also many differences. The regional aviation systems in the countries have for example developed differently and Norway stands out as the country with the most extensive regional aviation network. The other autonomous areas, Åland, Greenland and the Faroe Islands are not specifically included in the publication even though Åland might be included in the larger project since it is close to both Sweden and Finland and could be a suitable testbed for electric aviation (Ydersbond et al, 2020). The working paper is conducted through document review, including national reports and policy documents and a few interviews with Nordic and national experts.

This publication is a part of the "Electric Aviation and the Effects on Nordic Regions" project that analyses the electric aviation effects on Nordic regional development. The project is funded by the Nordic Council of Ministers and their cross sectoral work with the green transition of the transport sector. The project is a collaboration between Nordregio, Nordic Energy Research and University of Akureyri and is active between June 2022-December 2024.

Aerial view of a road in the winter snow forest in Lapland, Finland.
Photo: iStock

3. Policy Background

The overarching reason for developing electric aviation and other sustainable aviation solutions is based on the need to reduce global greenhouse gas emissions. Even though the aviation sector releases proportionally large amounts of greenhouse gases and CO2, the sector has for a long time been exempted from international, European, and national agreements and climate goal agreements as well as from extensive regulation. This section will present the climate and environmental impacts of aviation and the current climate policy framework in which the sector operates.

3.1 Climate and environmental impact of aviation

In 2021, commercial aviation accounted for over two percent of the total global energy-related CO2 emissions. As seen in figure 1, emissions from aviation decreased significantly during the Covid-19 pandemic in 2020 due to global travel restrictions. The aviation sector recovered partly in 2021, but the number was still lower than in pre-pandemic levels. The estimation from the International Energy Agency (2022) is that emissions from aviation will continue to grow rapidly, surpassing their 2019 level in the coming years. Before the pandemic started in 2020 the International Civil Aviation Organization (ICAO) estimated that the emissions from international aviation could triple by 2050 (ICAO, n.d.).

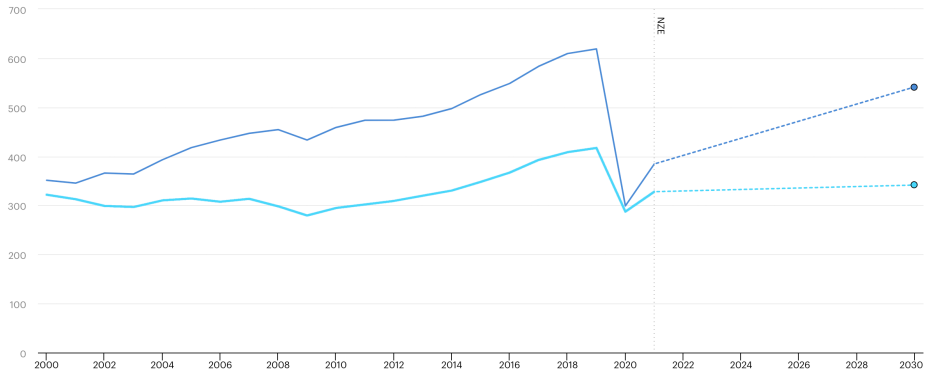

Figure 1. Direct CO2 emissions from aviation in the Net Zero Scenario, 2000-2030
Figure 1 shows direct CO2 emissions from fossil jet kerosene combustion; emissions from bio jet kerosene are accounted for as net zero emissions, as per UNFCCC accounting. Source: International Energy Agency (2022). Light blue indicates domestic aviation and dark blue indicates international aviation.

Within the EU, direct emissions from aviation accounted for 3.8 percent of CO2 emissions in 2017. The whole transport sector accounts for almost a quarter of all emissions in the EU and the aviation sector accounts for 13.9 percent of those emissions. This makes aviation the second biggest transport mode emitters after road transport (European Commission, n.d.).

Even though *fuel per passenger* was reduced by 24 percent between 2005 and 2017 due to improved fuel efficiency, the environmental benefits were outnumbered by the 60 percent increase in passenger distance during the same years (European Commission, n.d). Between 2019 and 2020, there was a 54 percent reduction of aviation emissions in Europe because of the Covid-19 pandemic (European Environment Agency, 2021). However, also in Europe the number of flights increased again during 2021, and the prognosis is that aviation will continue to increase globally, and in the EU (Ydersbond et al, 2020).

In addition to the releases of CO2 and other greenhouse gases, the aviation sector impacts the climate and environment in other ways. Climate change is accelerated by the release of nitrogen oxides, water vapour, sulphate and soot particles from airplane engines. Airplane emissions, happening at high altitudes, are particularly damaging to the climate as they can lead to cirrus cloud- and condensation trail formation, trapping heat between the earth's surface and the cloud (European Commission, n.d). Aviation is said to generate more than two percent of all greenhouse gas emissions in the world but when including the impact on high altitude, the number is closer to five percent of human climate impact (IEA, 2022).

Releases of nitrogen oxides (NOx) emissions and ultrafine particles are also a considerable problem for local air pollution, which can cause premature deaths and health issues (European Environment Agency, 2019). This is a larger problem in some parts of the world, although neither insignificant in Europe nor in the Nordic region (Ydersbond et al, 2020). In addition, there are problems regarding noise pollution in proximity to airports (Basner et al., 2017) as well as documented negative effects on biodiversity through disturbance of birds and local maritime systems.

3.2 Global climate goals and international regulations for aviation

The Paris agreement is the main overarching global climate and environmental framework with goals to limit global warming to well below two percent, preferably 1.5 degrees Celsius compared to pre-industrial levels (UN, 2022). For this to be met, significant actions to reduce greenhouse gases are needed in all sectors. A disadvantage of the Paris agreement is that aviation is not directly included, and there are few climate regulations for aviation at an international level compatible with the target. However, over the last ten years, a strong climate movement has put more pressure on the ICAO and the aviation sector to reduce their emissions.

The fact that there is almost no taxation (VAT) on international aviation outside of Europe is because most goods are taxed either in the country where they are produced or consumed. This is also the case for other international transport goods (Ydersbond et al, 2020). There are not fuel charges on international aviation (Amsterdam Economics & CE Delft, 2019). In a report from Transportøkonomisk institutt (TØI) and Nordic Energy Research, Nordic Sustainable Aviation (Ydersbond et al, 2020), several suggestions and schemes are presented on how to tax or regulate aviation including fuel tax, VAT, or passenger tax.

International standards are important in the aviation sector, where both private and public actors are highly dependent on international cooperation. ICAO is therefore an influential actor. The mission of ICAO is to achieve sustainable growth of the global civil aviation system and develop policies and standards, undertake compliance audits, perform studies and analyses, provide assistance and build aviation capacity, and the cooperation of its Member States and stakeholders.

In 2016, the members of ICAO made a historic decision when they agreed on a new global regulation, Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), with the aim to stabilise CO2 emissions at 2020 levels by requiring airlines to offset the growth of their emissions after 2020. The regulation means that all international airlines must monitor emissions on all international routes and offset emissions from routes included in the scheme by purchasing eligible emission units generated by projects that reduce emissions in other sectors (e.g., renewable energy). The scheme is voluntary for the first two phases (2021-2023, 2024-2026), but all EU countries are participating from the start (European Commission, n.d). Many critics, however, argue that this regulation is weak and far behind what is needed to reach the targets of the Paris agreement (Naturskyddsföreningen, 2021).

Since the number of trips by airplane is expected to increase in the coming years, the aviation sector needs to perform significant changes to contribute to reaching the Paris Agreement. ICAO has estimated that the emissions from international aviation could triple in 2050[1] (European Commission, n.d).

1. This estimation was done before the Covid-19 pandemic, (European Commission, n.d).

3.3 EU commitments, regulations, and the European Emission Trading System

In 2021, the European Commission adopted a series of legislative proposals under the European Green Deal to achieve climate neutrality by 2050 and a target of at least 55 percent net reduction of greenhouse gases until 2030. The package includes revisions of the EU Emissions Trading System (ETS), the Effort Sharing Regulation and transport and land use legislation (European commission, n.d.). In April 2022, the European parliament voted to gradually increase the share of sustainable aviation fuel (SAF), from two percent in 2025 to 85 percent in 2050 (European Parliament, 2022).

All trips within the European Economic Area (EEA) are since 2012 regulated by the EU ETS. The ETS within aviation means that a price is placed on CO2 emissions from aviation, which can be traded (bought) among airlines that release more or less emissions. This implies that all airlines operating in Europe (also non-European) are required to monitor, report, and verify their emissions and surrender allowances against those emissions. The ETS for Aviation is, however, only applicable for flights within the EU/EEA (Ydersbond et al, 2020).

In December 2022, the European Council and European Parliament decided to make the aviation sector 'Fit for 55', setting in law its contribution to the target of reducing net greenhouse gas emissions by at least 55 percent by 2030. It is stated that the updated rules on emissions trading will accelerate the implementation of the *the-polluter-pays*-principle by phasing out free allowances for the aviation sector by 2026. The new agreement will, until 2027, still only apply to flights within the EU/EAA (including departing flights to Switzerland and the United Kingdom). In 2026, the Commission will assess how and if the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), set up by ICAO, sufficiently delivers on the goals of the Paris Agreement. Depending on the outcome of the assessment, the Commission might extend the scope of ETS to all departing flights of the EU/EEA. The deal also provides for a new support scheme to speed up the use of sustainable aviation fuels (European Commission, 2022a).

There is a great deal of critique to this system, since there is a surplus of emission rights which does not compare to the environmental costs they cause. In addition, the emissions only include CO2 and no other emissions, and they do not include the increased impact of emissions on a high altitude (IEA, 2022). The impact of greenhouse gas emissions on high altitude is neither included in the overall measuring of climate impact at the UN or EU level. It is also an issue that the international reporting to the UN and EU is only based on the fuel used within the national borders and not on the emissions produced by the national citizens over the course of for example a transatlantic flight (Naturvårdsverket, n.d.c).

On the Nordic level, there is no common legislation or strategy regarding aviation. There has been no formal cooperation on transport at the ministerial level after the Nordic Council of Ministers for Transport (MR-Transport) was dissolved in 2005 as part of a large reform agenda. However, there are several Nordic initiatives and collaborations both regarding aviation and electric aviation as well as national strategies and targets about aviation and different forms of sustainable aviation. This will be presented later in the report.

Aerial view of farm houses and green countryside hills in Skogar, Iceland.
Photo: iStock

4. Sustainable Aviation

Currently, several zero or low emission alternatives for aviation are investigated and developed. All of them have different challenges to overcome and opinions vary on which will be the best solution for the future. In this report we focus on electric aviation and batteries, however it is important to also describe the process of sustainable aviation fuel since it is developed in parallel and can be used together with batteries in hybrid solutions.

4.1 Sustainable aviation fuels

Most experts agree that sustainable aviation fuel (SAF) will have the greatest impact on the aviation sector in the near future, at least until 2030. SAF includes various fuel types with low lifecycle greenhouse gas emissions that have been certified as sustainable according to independent third-party bodies such as Roundtable on Sustainable Biomaterials and certified for safety and performance by American Society for Testing of Materials (ASTM International). Included in SAF are both Bio jet fuel and electro jet fuel (Ydersbond et al, 2020).

Bio jet fuel is mainly produced from waste oil and animal fat residues, but can also be produced from residues from agriculture or forestry. In the Nordic countries, bio jet fuel is today mostly utilised for road transport, but in June 2022 the first ever commercial flight (airline BRA) flew with only biofuel in both engines between Malmö and Stockholm in Sweden (Neste, 2022). The problem with bio jet fuel is that the production process is expensive and the dependence on biomass makes is difficult to scale up to the necessary level. The solution can also create other problems, such as deforestation or land use change (Ydersbond et al, 2020).

The other relevant SAF is e-jet fuel (electro-jet fuel), where hydrogen is produced from water and electricity. As with bio jet fuel, this process requires carbon which can come from carbon capture directly from in the air, biomass, or forest residue. E-jet fuel is considered more sustainable in the long run, because it does not require feedstock. However, the process is very expensive and require a large amount of renewable energy as well as technology development to be commercialised. A third option is to create fuel through direct combustion of liquid hydrogen in turbines. However, this process is currently not as technically mature as the other two options (low TRL) (Ydersbond et al, 2020).

One of the main arguments in favour of SAF is that existing infrastructure, engines, and planes can potentially be used while only replacing the drop-in fuel. This is important since new aviation infrastructure is expensive. However, infrastructure and engine technologies must be upgraded or replaced in terms of e-jet fuels because of different performance specifications and chemical compositions of the alternative fuels compared with fossil fuels. Also, emissions released from SAF have an impact on higher altitude, mainly due to the creation of condensation trails, which effects the temperature on Earth. The extent of this effect in comparison to fossil fuels is not fully known (Naturskyddsföreningen, 2021).

4.2 Electrification of aviation

The other solution to achieve sustainable aviation is through electrification. Electric aviation comprises various types of technologies that use electric motors for propulsion. It can be both battery electric and hydrogen electric depending on how the energy is stored.

Over the last decades, accelerated development in battery technologies has highlighted electric aviation as one of the future solutions to sustainable aviation. The battery technology development is additionally expected to continue, improving the energy intensity at significantly lower production costs. Electric propulsion can contribute to more sustainable aviation in two ways; firstly, by higher energy efficiency of electric motors compared with conventional combustion engines and secondly, by battery storage and utilisation of renewable electricity (Ydersbond et al, 2020).

There are two types of electric solutions to aviation. The first is electric aviation driven by a battery and the second is based on electric fuel cells. Electric fuel cells work as a battery, but the propulsion system relies on an electrochemical reaction, why a fuel such as hydrogen is required. Both solutions are associated with benefits and challenges, but according to experts at the Research Institute of Sweden (RISE), batteries are the preferable solution since these provide higher energy efficiency considering the technology development of the batteries will continue at expected speed (Hampus Fredriksson at RISE, 2021). Lithium-ion batteries have advanced significantly over last 20 years and today they have a specific energy density of 100–265 Wh/kg (FAIR, 2021). Today's batteries are still both heavy and expensive, and currently only suitable for small planes on short distances, but they are assumed to reach their maximum energy density of 400–450 Wh/kg around year 2025 (FAIR, 2021).

In the Accessibility study for Electric Aviation conducted within this project, the first-generation aircraft speed for battery electric aviation has been calculated to 300 km/hour. This estimation is done in communication with experts. Since today's commercial planes travel at average 900 km/hour the electric planes will in the first stage be most beneficial on shorter routes. The possible speed of planes run with electric fuel cells is significantly slower, and the plane can at times only travel at 150 km/hour. The advantage of electric fuel cells is that they can conquer longer distances (RISE, 2021).

In addition to the mentioned challenges of energy density of batteries and speed of battery electric planes, are the challenges of charging time of batteries and the limitation of minerals to produce the batteries. In addition, the sustainable and just extraction of minerals used in batteries is an important aspect to consider, especially if the production is expected at large scale. Minerals used in batteries often stem from conflict-ridden countries. In this context, a report from Trafikanalys, a Swedish government agency, further highlights the case of cobalt, often originating from the Republic of Congo where several studies from inter alia UNICEF have revealed the use of child labour in cobalt mines (Trafikanalys, 2020). In January 2023 the Swiss battery manufacturer Leclanché announced that they made a breakthrough in the environmentally friendly production of batteries where the use of cobalt can be reduced from 20 to 5 percent in the production process (Electrive.com, 2023). How this will develop in the future is relevant to follow. More critical factors to the implementation of Electric aviation are presented in WP3 *Task 1. Critical factors and Relevant Policy Instruments for the Implementation of Electric Aviation*.

The development of electric aviation has progressed more rapidly than the public might expect and both airplane manufacturers and airline operators believe that some routes can and will be operated by electric airplanes within 5-10 years. Today, there are several test projects and pilot educations, where electric airplanes are used, and the short commercial flights are according to the industry, a possibility in the near future. Even so, as stated in the Norwegian electric aviation programme (2020), electric aviation is still in its infancy, and it is difficult to perform accurate estimations of timelines and costs.

On the 10th of June 2020, the first battery electric airplane, the two-seater Velis Electro from the Slovenian company Pipistrel, was certified by the European Union Aviation Safety Agency (EASA) for pilot training (EASA, 2020). The Swedish company Heart Aerospace, that many experts consider most mature in their development of large electric aircraft with more than 9 seats, announced in September 2022 the development of a new airplane design at their production site in Gothenburg. This new model (ES-30) will have 30 seats and will replace the company's previous 19-seat design (ES-19). The other difference is that the plane is a hybrid, which implies that it will be driven by electric motors powered by batteries, but also include a reserve-hybrid configuration, consisting of two turbo generators powered by sustainable aviation fuel (Heart Aerospace, n.d). Hybrid-electric aircraft, where one of the engines is replaced by an electric motor and SAF is combined with hydrogen fuels cells can be first steps toward "pure" electrification (Ydersbond et al, 2020). Other companies focusing on electric aircraft are Eviation, who builds a 9-seat plane, and Wright, who has advertised a 130-seat electric plane. However, experts are skeptical about the credibility to develop such a large functional electric plane in that time frame. Several large global industry actors are also dealing with producing electric airplanes, such as Airbus, Boeing, Rolls Royce and Safran (RISE, 2022).

The assumption of the last years has been that the first first-generation commercial battery electric aircraft will have an effective average range of 350-400 kilometres (Avinor & Civil Aviation Authority of Norway, 2020). Some experts are sceptical of

this and are convinced that because of range, loading capacity, and security measures, the first-generation aircraft will most likely be implemented on short routes around 200 kilometres with fewer passengers and where cruise speed is of less importance (communication with expert at Swedavia).

In addition to the benefits for the climate and environment, it is anticipated that electric aircraft in the long run will have lower operation and investment costs than comparable fossil fuel-based aircraft (Avinor & Civil Aviation Authority of Norway, 2020; Hellesund, 2022). In a report from the Nordic Network for Electric Aviation (Hellesund, 2022) it is argued that the biggest proportion of costs of today's aviation originates from fuel and oil expenses, accounting for as much as one third of total expenses. The second biggest cost is the aircraft ownership and the third is the maintenance and aircraft overhaul. The report state that electric aviation therefore will have lower operational costs, which overtime will be further reduced because of reduction of energy consumption. Another mentioned competitive advantage of electric aviation is the estimated increased price of CO2 quotas that conventional operators will face. The report presents several new business models necessary for the implementation of electric aviation in the Nordic Region.

The long-term perspective of reduced costs is an important incentive to bring stakeholders and investors on board. However, the challenge is that the implementation costs of electric aviation will be high at start. Both the technology, the planes, and the developments in infrastructure are expensive. Political commitment and subsidiaries will therefore likely be of importance. In addition, since the first planes will be small, the costs per passenger will be high and this can counteract and possibly outweigh the potential cost savings related to propulsion energy. The multi-function of electric aviation is therefore important. There is a belief that electric planes can be beneficial in not only transporting people but also transporting goods, medical samples, or organs (RISE, 2021).

The European Union has no strategy for electric aviation, but it is stated within the framework of the European Green Deal that Horizon Europe is to support research, development, and innovation in the transport field, including batteries and clean hydrogen. Much of the R&D funding is being channelled through the Horizon 2020 programme. This includes the funding of the Clean Sky research programme that develops aviation technology (Trafikanalys, 2020). The Commission has also initiated the Alliance for Zero-Emission Aviation (AZEA) in 2021. AZEA is voluntary and consists of private and public stakeholders that prepare the entry into commercial service of hydrogen-powered and electric aviation by providing solutions and recommendations (European Commission, 2022b).The solutions for electric aviation and production of e-fuels need significant amounts of energy in the process. To ensure that the different solutions are sustainable and fossil free, the origin of the energy is crucial.

Aerial view of Bruksvallarna in Sweden.
Photo: Unsplash.com

5. Electric Aviation in the Nordic countries

5.1 Potential of Electric aviation in the Nordic Region

In January 2019 the Nordic Prime ministers signed the "Declaration on Nordic Carbon Neutrality". The document states that the countries commit themselves to working towards carbon neutrality and to pursuing Nordic climate diplomacy in international forums to deliver solutions with impact on the global emissions. The declaration also includes the aim to meet the goals of the Paris Agreement and to catalyse the scaling up of Nordic sustainable solutions. In relation to aviation, the declaration states to reduce global greenhouse gas emissions, maintain, or enhance carbon sinks and remove carbon dioxide from the atmosphere by, among other things, decarbonizing the transport sector through an inter-modal shift, efficiency, electrification, and use of sustainable renewable fuels. (The Nordic Prime Ministers, 2019). After Greenland joined the Paris Agreement during COP26 in 2021, all Nordic countries and autonomous areas have committed to the agreement (Nordic Council of ministers, 2021). The Nordic countries also have national goals and targets for CO2 and greenhouse gas reduction toward 2030 and climate neutrality by 2050 or earlier. This will be further explained below in the individual country chapters.

Several actors highlight that the first-generation electric aircraft are suitable for the Nordic region (RISE, 2020; Ydersbond et al, 2020). The main arguments are that electric aviation would be most suitable on short routes where difficult landscape and geographies make train and car travel difficult and time consuming. A researcher at RISE, for example, concludes that "we think that electric aviation will make it possible to live in rural areas in a different way" (RISE, 2021). The Nordic Council has highlighted electric aviation in their work connected to improving transport in sparsely populated areas (Nordic Council, 2021). Additionally, Ydersbond et al (2020) argue that battery electric aircraft are seen to hold the largest potential

in the next decades for the Nordic countries due to the amount of small Nordic airports and short routes, the challenging geography, the high and increasing share of renewable energy and relatively strong support among politicians, airlines, and operators. Furthermore, many routes with few passengers in the Nordic region are subsidised by the state (public service obligation routes, PSO routes).

The countries in the Nordic region share many similar accessibility challenges for remote and rural regions. Citizens in some of these regions, for example, have limited access to public services, to work opportunities, and to the larger national and international transport system. In addition, companies and public administrations have difficulty attracting skills to the regions. The geographical characteristics of some of these areas, such as large bodies of water, vast forest areas, long coastal areas, mountains and fjords, limit mobility to and from these areas. Poor road quality or limited public transport also impact the situation negatively. Some of these places are therefore more accessible by airplane than by any other mode of transport and inhabitants would experience a significant reduction of travel time using airplanes in comparison with other transport modes such as train, bus, or car. Many of these routes furthermore have a limited number of passengers which means that conventional airplanes can be exchanged for small electric planes. The reduced cost of electric aviation will also likely also allow for increased frequency in the number of flights which will benefit the region's companies and the possibility to attract skills to remote regions.

The solutions for electric aviation as well as the production of e-fuels need significant amounts of energy in the process. To ensure that the different solutions are sustainable and fossil free, it is crucial to both ensure energy capacity as well as monitor the origin of the energy. Because of the high shares of renewable energy in the Nordic region, electric aviation would furthermore be suitable. In 2021, 22 percent of the energy consumed in the EU was generated from renewable sources, according to early estimates from the European Environmental Agency. According to the same estimates, Iceland has the highest share of renewable energy in their energy consumption in the EU, at approximately 85 percent. Norway is number two with approximately 81 percent. Sweden had approximately 60 percent. Finland and Denmark had between 45-50 percent. Denmark was one of the countries that increased their renewable share the most between 2020-2021 with more than 10 percent (see Figure 2 below). (European Environment Agency, 2022).

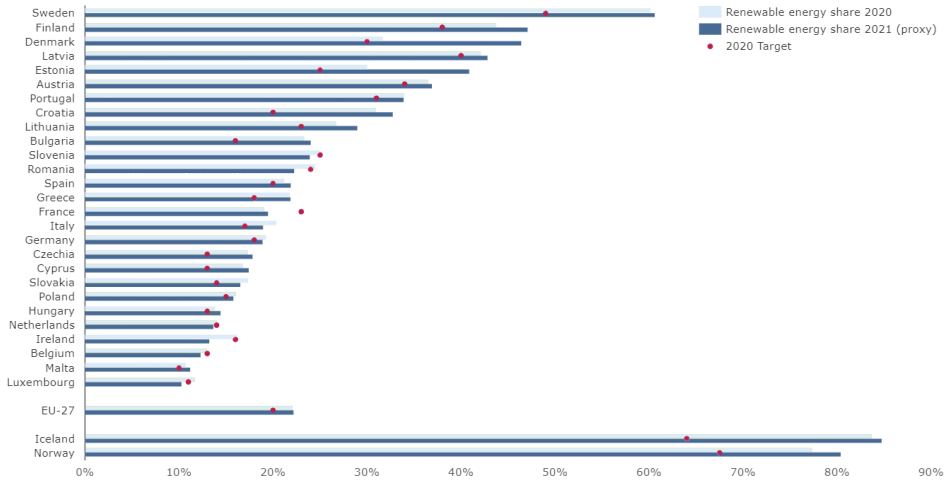

Figure 2. Progress towards renewable energy source targets, by country
Source: European Environment Agency, 2022, https://www.eea.europa.eu/ims/share-of-energy-consumption-from

Another aspect that must be considered is the capacity of the electricity grid and the access to renewable energy in the regions where the airports are located. Some airports can be in regions with capacity restraints with regards to energy in general or to renewable energy sources, such as Svalbard. A full transfer to 20+ seater aircraft may require multiple charging pods and, in some circumstances, the heavy load on the grid must be abated by deploying battery-banks or capacitors[2].

The global energy crisis that began in 2021 during and in the wake of the Covid-19 pandemic, has placed increased focus on energy in the Nordic region. In the Nordic Region and in Europe, the crisis has been further sparked by Russia's invasion and war on Ukraine and weather conditions (European Commission, 2022c; SVT, 2021). This has increased the energy prices also in the Nordic region. Political discussions are being held in the Nordic countries on how to solve the situation, including how to save electricity. This development is important to consider since it can affect the implementation of electric aviation.

In a report from TØI and Nordic Energy research (Ydersbond et al, 2020), it is emphasised that battery electric aircraft will initially probably be most competitive on routes with very short distances where cruise speed is less important and in sparsely populated regions, where passenger volumes are small. It is recommended that Nordic cooperation should promote electric aviation on short routes up to 400 km. It is further recommended that demonstration projects should start with the routes of 200 km. Similar recommendations are given by other research projects and sector experts (FAIR, 2022; Avinor & Civil Aviation Authority of Norway, 2020). For longer ranges, given current known battery technology, it will be necessary to rely on a series of hybrid solutions (Avinor & Civil Aviation Authority of Norway, 2020). The report also recommends a common Nordic vision, where an agreement of financial support for parallel demonstration projects in the Nordic countries can be included.

Even though the Nordic countries and regions share similarities, there are also differences. There are differences in terms of national policies on electric aviation as well as the preconditions of the existing aviation system. For example, Norway is the

2. Information from informal conversation with Norsk Elbilforening.

Nordic country that still has an extensive regional aviation system with short routes with small airplanes operating. In the next section, the countries and their recent development on electric aviation is presented individually.

5.2 Nordic research projects and initiatives

Nordic Network for Electric Aviation (NEA)

The Nordic Network for Electric Aviation was established by Nordic Innovation in 2018 and is funded by the Nordic Council of Ministers. NEA is a platform where Nordic actors come together to accelerate the introduction of electric aviation in the Nordic countries. The network connects five airline companies Finnair, Icelandair, Air Greenland, Braathens Regional Airlines (BRA) and SAS AB with public authorities, research projects, and technology innovation companies such as Heart Aerospace. Their mission is to standardize electric air infrastructure in the Nordic countries, develop business models for regional point-to-point connectivity between Nordic countries, develop aircraft technology for Nordic weather conditions and create a platform for European and global collaboration. NEA plan to explore the business case for electric aviation for selected routes. In 2023 the development of NEA 2.0 is expected to launch.

Finding Innovations to Accelerate the Implementation of Electric Regional aviation (FAIR)

FAIR aims provide suggestions on where to implement electric regional flights in the Kvarken region and increase knowledge about the effects on the region. Kvarken is an area in the Gulf of Bothnia, connecting the High Coast on the Swedish side and the Kvarken Archipelago on the Finnish side. Since Kvarken on the Swedish side includes region Västerbotten, the area stretches all the way to the Norwegian border as well. The project also aims to investigate which measures must be considered at the hubs and examines financing options, to develop innovative concepts and business models that support the early implementation of regional electric aircraft. Subsequently, the purpose is to improve the awareness of and knowledge on regional electric air traffic to promote demand and accelerate realization. The project states that an early implementation of electric aviation in the Kvarken region has the potential to effectively address some of the region's major challenges, such as demographic change and the lack of strong urban structures, long distances, and weak communications in the east-west direction, as well as the global need to reduce both emissions, greenhouse gases and environmental impact. The project is funded by the Kvarken Council, Interreg Botnia-Atlantica and other regional actors and delivered their final report in 2022 (FAIR, 2022).

Green Flyway International Test arena

Green Flyway is an international testbed for electric flights and drones in the middle of Sweden and Norway. The project states that the area is meteorological and topographically interesting and has existing infrastructure and knowledgeable players in the aviation sector, which together create good conditions for a test arena. The project is financed by Interreg Sweden-Norway and constitutes a collaboration between Östersund municipality, Rørosregionen Næringshage, the County Administrative Board of Jämtland, Region Jämtland Härjedalen, Swedavia, Røros Flyservice, Avinor and Trondheim municipality.

Nordic Initiative for Sustainable Aviation (NISA)

NISA is a Nordic association working to promote and develop a sustainable aviation sector. The organisation particularly focuses on making jet fuel more sustainable. NISA was formed in 2013 and is driven by the members consisting of Nordic airlines, airports, industry organizations, aircraft producers and technology developers. The members are Air Greenland, Airbus, Atlantic Airways, Avinor, Boeing, Copenhagen Airports, Brancheforeningen Dansk Luftfart, Finavia, Finnish Transport Safety Agency (Trafi), Finnair, International Air Transport Association (IATA), Icelandair, Isavia, Ministry of Transport and Communications of Finland, NHO Luftfart, SAS, SkyNRG, Svenska Flygbranschen, Föreningen Svenska Flyg, Swedavia, Swedish Transport Agency, Trafikstyrelsen (Danish Transport Authority) and Sunclass Airlines.

5.3 Denmark

Aviation in Denmark

Denmark is geographically small, which results in a low number of domestic aviation trips since cars and trains are good alternatives. Even though Denmark is small, it consists of three main land areas, Jutland, Fyn, and Zealand, separated by water. Some distances would therefore benefit from more air transport to avoid long detours to travel over the bridges. After Norway, Denmark is said to have the largest potential for electric aviation when counting how many seats on conventional planes can be exchanged to seats on an electric plane. The calculations are performed by Nordic Energy Research and based on the number of flight routes that exist under 200 km.

The transport minister *(Transportministeren)* and the Ministry of Transport *(Transportministeriet)*, have primary responsibility for the planning, construction, maintenance, and supervision of the national system of public transport infrastructure. This includes roads, railways, harbours, fixed links, and airports, as well as vehicles, rapid transit systems, ferry operations, and aviation. The Danish Civil Aviation is together with the Railway Authority *(Trafikstyrelsen)* responsible for creating advantageous framework conditions (rammebetingelser) for transports on railways, airways, and public transport, with a view of enhancing safe, sustainable, and cohesive transport solutions for people and for the business and industry sector.

The number of Danish passenger traffic increased from 22 million to over 32 million between 2005 and 2016. The passengers mainly fly to and from Europe, but the largest increase occurred in intercontinental travel. Copenhagen airport is the

largest airport in the Nordic Region both in terms of the number of passengers and the accessibility to other destinations (Transport-, Bygnings- og Boligministeriet, 2017). The airport functions as a hub, which results in high volumes of passengers to Europe and the rest of the world. The airline Scandinavian Alliance (SAS) has historically used Copenhagen airport as their network hub, and the airline is still of great importance for the airport.

In the latest Danish aviation strategy from 2017 (Transport-, Bygnings- og Boligministeriet, 2017), the aim to strengthen the foundation for the establishment of an increased number of domestic and international aviation routes in Denmark was highlighted. The aim is to increase the accessibility for the Danish citizens, while increasing the economic growth, sustainability, and cohesion between regions. The strategy consists of five focus areas (1) number of passengers and capacity; (2) workforce; (3) taxes and fees; (4) traffic conditions, and (5) marketing and support from public authorities.

The regional airports in Denmark have been important for the accessibility and cohesion in Denmark. According to an accessibility index developed by Copenhagen Economics, the regional airports jointly contribute with one fourth of the direct and indirect accessibility. The aviation strategy also states that accessibility to and from Denmark has grown by 26 percent between 2005 and 2016 and that a considerable development has happened regarding "fixed route traffic" (in Danish: *fast rutetrafik*), which has resulted in an increase in direct connections from the western parts of Denmark to other European airports (Transport-, Bygnings- og Boligministeriet, 2017).

National climate goals and national emissions from aviation

In June 2020, the Danish parliament approved a climate law with binding climate targets (Danish Parliament, 2020). The law states that Denmark should reduce their emissions of greenhouse gas emissions by 70 percent in comparison to 1990 levels by 2030. The emission reduction is to be attained domestically and comprises both the EU ETS and the non-EU ETS sectors. Denmark is to be climate neutral at the latest in 2050. Based on this law, the Danish government presented a new Climate programme in 2022 (Climate, Energy and Utilities Department, 2022). The programme presents 75 priorities and funds for DKK 110 billion in total (approx. EUR 15 billion). The government states that this plan will lead Denmark three quarters of the way to reaching the 70 percent reduction target.

The energy agreement was adopted by the Danish parliament in the Summer of 2018. The agreement states that 55 percent of the total energy consumption shall stem from renewable energy sources in 2030, that 100 percent of the electricity shall stem from renewable energy sources, and that 90 percent of the district heating shall stem from sources other than coal, oil, and gas (Climate, Energy and Utilities Department, 2018.)

The Climate Council's latest climate political assessment from 2019 shows that the total Danish greenhouse gas emissions decreased from 75.2 million tonnes in 1990 to 51,0 million tonnes in 2017. If the agreed upon initiatives continue as assumed the emissions are expected to decrease to 41,5 million tonnes in 2030. This is less than 50 percent which indicates that the 70 percent reduction target is not close. The decrease is mostly driven by reductions within the electricity and heating sector. The transport sector has increased its emissions because of increased activity. These numbers are from 2017 and do not reflect the effect that the Covid-19-pandemic

had on transport related emissions (The Climate, Energy and Utilities Department, 2019).

In 2019 The Danish Climate Partnership for Aviation (Luftfartens Klimapartnerskab) was formed as one of the fourteen partnerships launched by the Danish Government. Partnership includes a group of core stakeholders, such as the main airlines, Copenhagen airport, the Danish Aviation Association, and others. The aim of the initiative is to support Danish businesses and the private sector in the green transition and to support the national Danish climate goal of 70 percent reduction of GHG-emissions in 2030 (Climate, Energy and Utilities Department, n.d.). In the partnership's final report from May 2020, they presented several recommendations to reduce emission from the aviation sector. Statistics from the report outline that emissions from domestic aviation have decreased between 1990 and the start of the Covid-19 pandemic while international aviation has increased (see figure 3 and 4). Their 2030 prognosis for both domestic and international aviation is that the CO2 emissions will not increase as much if the climate partnership's proposed initiatives are adopted.

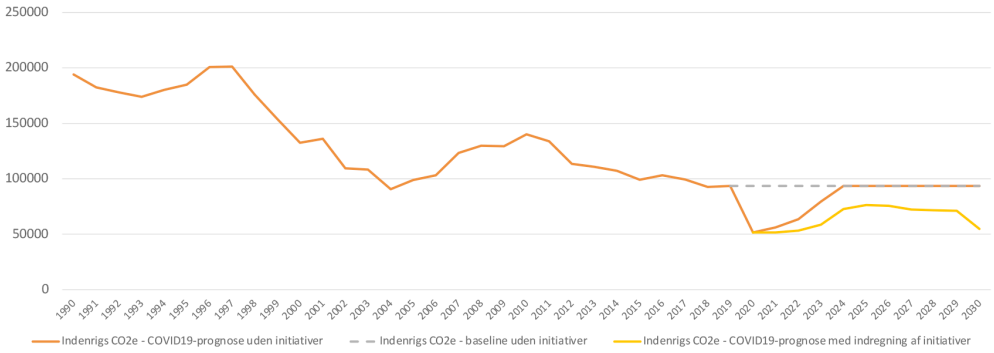

Figure 3. Development in CO2 emissions (tonnes of CO2 equivalents) in domestic aviation, and COVID19-related prognosis with / without the climate partnership's proposals for initiatives 1990–2030

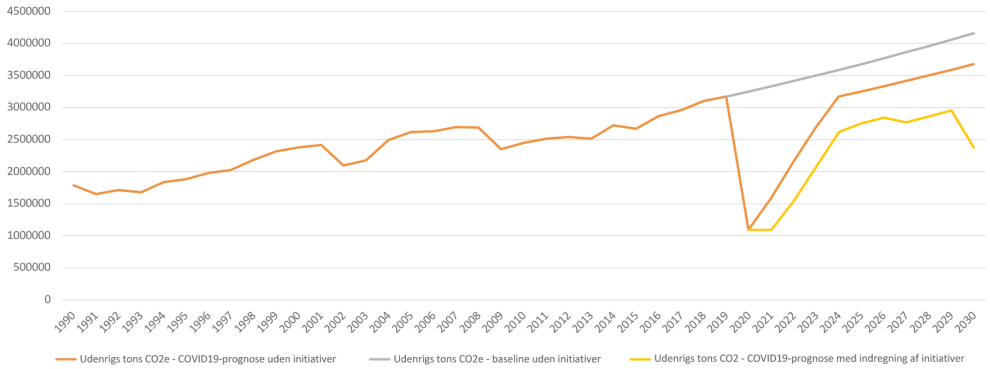

Figure 4. Development in Co2 emissions (tonnes of CO2 equivalents) in international aviation, and COVID19-related prognosis with / without the climate partnership's proposals for initiatives 1990–2030

The figures show 1) the basic growth without the climate partnership's proposed measures and before COVID-19 (the orange line), 2) the development without the climate partnership's proposed measures and after COVID-19 (grey line) and 3) the development with the climate partnership proposed measures and after COVID-19 (yellow line). *Source: The Climate Partnership for Aviation, 2021*

The Climate Council highlights the aviation sector as different from other sectors because of its cross-border element, which is regulated differently. They argue that it is wrong that flying is favoured over other activities in Denmark since the airlines do not have to pay VAT or energy taxes. In addition, Denmark is one of the few countries in Western Europe that does not have passenger charges on flights. A passenger tax of DKK 75, regardless of travel length, was operational in Denmark from 1997–2007. The absence of tax regulation increases the demand for flying and consequently also increases emissions from aviation (Climate, Energy and Utilities Department, 2019). A new green plan was presented by the government in 2022, which reintroduced passenger tax to finance the plan. This plan is explained in the section below.

Strategies for electric aviation and/or other relevant policies for sustainable aviation

On the 20th of September 2022 the Danish government presented a plan for green aviation, *Green Aviation for all* (In Danish: Grøn luftfart for alle) (Transportministeriet, Klima-, Energi- and Forsyningsministeriet & Skatteministeriet, 2022). The plan presents the aim to make all domestic flights 100 percent green from 2030. The proposal is to finance the plan through a passenger bill per flight of DKK 13. The focus is mainly placed on sustainable fuels, but it is also stated that the support scheme should be neutral when it comes to technology, to make it possible to develop both solutions based on electricity, PtX, and sustainable fuels. In Denmark, SAFs will primarily be produced from agro-biomass and waste, while in Sweden and Finland, and to some extent Norway, biomass is usually from the forest (Nordic Energy Research, 2020).

Elements in the green aviation plan:

- 100 percent green domestic aviation should be available in 2025.
- Support the transition to 100 percent sustainable aviation fuel for 2030. The support scheme should be issued in 2027.
- The transition should be financed by a passenger tax of DKK 13 /passenger.
- The support scheme and the passenger tax should be reevaluated in 2024 and 2029 since there is uncertainty related to the prices of green aviation fuels.

There are also other agreements and initiatives to support the green transition of aviation in Denmark. In 2022, an agreement was made between the social-democratic government and eight other parliament parties[3] concerning the development and support of hydrogen and sustainable aviation fuels, the so called "power to X strategy" (Danish government, 2022).

In the Climate Partnership for Aviation's final report from May 2020 several suggestions was presented. Among other things, they recommend that the sector should establish an independently governed climate fund for promoting production and use of SAF in combination with a blending mandate of 30 percent within 2030. The fund should collect a passenger fee which should finance the price difference between fossil jet fuel and SAF. However, until this is implemented, they recommend that the aviation industry voluntarily establishes a non-governmental climate fund (Luftfartens Klimafond) to be financed via passenger fees. (Brancheforeningen Dansk Luftfart, 2020). According to an interview conducted with a NISA (Nordic Initiative for Sustainable Aviation) representative for the report Nordic Sustainable

3. Venstre, Socialistisk Folkeparti, Radikale Venstre, Enhedslisten, Det Konservative Folkeparti, Dansk Folkeparti, Liberal Alliance og Alternativet.

Aviation, the Climate Partnership for Aviation includes electric aviation in the long-term plan, i.e. after 2030 (Ydersbond et al., 2020).

Status of electric aviation

Copenhagen Airport aims to become emission free by 2030 (Copenhagen Airport, 2019). The customers of SAS can today, for a fee, choose to fly and reduce emissions using bio-jet fuel tanked at Copenhagen airport, as well as other airports in Scandinavia (SAS, 2019b). The airport would like to see electric airplanes using their facilities and they are involved in the project *Smart Airports* where they are cooperating with NISA, SAS, Teknologisk Institut, IATA, and the Roundtable on Sustainable Biomaterials (RSB) to investigate the development of SAF, e-fuels and hydrogen, as well as the preparation for electric aircraft and electrification of ground activities (Ydersbond et al, 2020).

The Nordic Initiative for Sustainable Aviation (NISA) is an important Nordic actor with headquarters in Denmark. They are involved in several initiatives such as The Climate Partnership for Aviation, NEA and the EU project ALIGHT, which is coordinated by Copenhagen airport and focuses on electric aviation. The plan is also to work within the new NEA project that will start in 2023 to increase the interest of electric aviation in Denmark. In April 2022, NISA organized the conference "Future Aviation and Air Mobility Conference" together with Danish Aviation, Copenhagen Airports, Naviair, NISA and ALIGHT. The conference gathered many relevant actors within the field of sustainable aviation.

As the first country in the world, the Danish air force will test electric aviation in their fleet. This was presented by Danish Defence on their web site in 2022 (Forsvaret, 2022). The planes are used at the aviation station Karup by pilot students and will be a part of the air force for the next two years to test the potentials, limitations, and challenges of electric airplanes. As such, the aim is to gain experiences with the technology and clarification on how it can be used, so the air force is prepared when it becomes a green alternative. The two planes are from the Slovenian producer Pipistrel of the type Velis Electro and leased on a 10-year contract from the company Green Aero Invest. The planes can be manned by 2 people, have a reach of 100 km, and have a flying time between 30-50 minutes. The idea is not to replace the existing planes with electric ones, but it will be investigated how electric planes could replace some planes in certain areas, for example in training and status flying.

Selected research projects about electric aviation

The Danish company Nordic Seaplanes, who operates seaplanes between Aarhus and Copenhagen, is collaborating with Equator Aircraft in developing larger electric seaplanes. The planes are designed to be easily converted to cargo and other applications (Equator Aircraft, 2020).

Several research projects are going on in Denmark about the development of sustainable aviation fuels, such as biofuels and hydrogen. For example, Maersk, DSV Panalpina, DFDS, Ørsted, SAS and Copenhagen Airports have joined forces in a partnership that will build a hydrogen plant in the metropolitan area as early as 2023. Other projects are EUDP (Danish Energy Technology Development and Demonstration Program), the SYNFUEL project and the Future Liquid Aviation Biofuels Based on Ethers for Gas Turbine Engines (FLABBERGAST).

Partners in these projects are airports, airlines, universities, private companies, and public innovation funds. However, these projects are not specially focused on electric aviation but rather on sustainable aviation fuels (Ydersbond et al, 2020).

5.4 Finland

Aviation in Finland

The Finnish network of airports and airfields is relatively comprehensive, albeit not as wide as the rail network, and especially Northern tourist destinations depend on air traffic. Most flights are operated from the Helsinki-Vantaa airport, located in Vantaa (Mäntynen et al., 2022). There are 20 airports in Finland and the number of domestic passengers surpasses three million in 2022, of which the share of Helsinki-Vantaa airport is over 1,5 million. Before Covid-19, the number of domestic passengers surpassed five million annually. There will be over 11 million international passengers in all Finnish airports in 2022, compared to 20 million in 2019. Overall, the number of passengers is currently at 65 percent of the pre-pandemic level. The share of aviation of Finland's GDP is 3.2 percent (Finavia 2022a; Statistics Finland 2022).

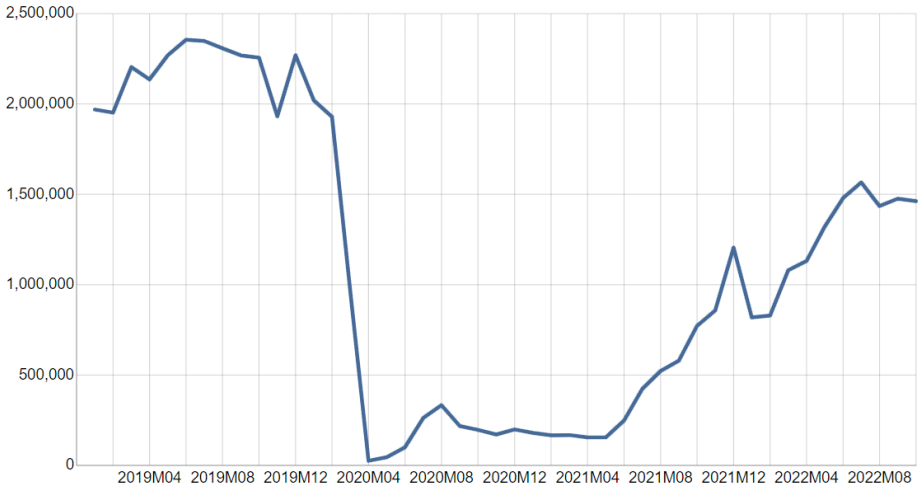

Figure 5. Passengers on Finnish domestic and international flights between January 2019–October 2022.
Source: Statistics Finland 2022.

Finnish airports are owned and managed by the state-owned company Finavia. Its operations are not funded by taxes but instead from air traffic fees and other similar revenues. Air space and air traffic control fall under the responsibility of Fintraffic Oy, and the official agency in charge of aviation security and regulations, Traficom (Finavia 2022).

Regional aviation to small airports received considerable temporary support during Covid-19, which was a decision criticised by the director of Finavia. He pointed out that the public subsidy for a single ticket to a remote domestic airport rose to EUR 1.000 in 2021, with planes only 20-30 percent full. The additional subsidy for domestic aviation has risen to EUR 40 million since 2021 and has targeted especially routes that Finnair has ceased to operate (between Helsinki and Kokkola, Kemi,

Joensuu, Jyväskylä, and Kajaani), as well as those that suffered most from the decrease of traffic due to Covid-19 related travel restrictions and the war in Ukraine (MTV Uutiset 8.8. 2022). However, the Minister of Traffic and Communications, Timo Harakka, noted in 2022 that subsidising small airports, especially during crises (when market conditions are irregular) is necessary for various reasons, one of which is the future needs of electric aviation (MTV Uutiset 2.7. 2022; Valtioneuvosto 2022b).

Figure 6. Map of Finland's airports
Source: Finavia website (2023).

National climate goals and national emissions from aviation

Finland aims to reach carbon neutrality by 2035 and decrease emissions by 50 percent compared to the level of 2005. Globally, aviation aims at decreasing its share of emissions mainly by making operations more efficient through technological

development and increasing the use of biofuels. However, domestic aviation is not part of the effort sharing sector and therefore does not fall under Finland's current Climate Change Policy Act (Valtioneuvosto 2021c). Domestic aviation constituted up 2 percent of national traffic emissions in 2019, before the drop to one percent due to the Covid-19 pandemic in 2020 (Valtioneuvosto 2021a). The current national goal is to achieve an emission decrease of 43 percent in 2030 compared to 2005, and 15 percent compared to 2018. By 2045, the aim is to cut aviation emissions by 50 percent compared to 2018 and to have all domestic aviation emission neutral. Measures to reach these goals mainly concern the use of renewable energy sources, improving energy efficiency (for example by shortening flying routes) and by using emission trade tools (Liikenne- ja Viestintäministeriö 2021; Valtioneuvosto 2021c).

The public company managing Finnish airports, Finavia, published its first climate strategy in 2008 with efforts for all Finnish airports to secure a carbon-neutral status, which they achieved by 2019, and the next objective is to produce zero emissions. Finavia's involvement in experimenting with and developing electric aviation is part of the same climate strategy (Finavia 2022b). Optimal environmental benefits from electric aviation could be achieved by electrifying flights between Helsinki and other domestic destinations (Mäntynen et al. 2022).

Strategies for electric aviation and/or other relevant policies for sustainable aviation

The development of the Finnish aviation system is based on a twelve-year strategic plan spanning between 2021 and 2032 with aims reaching up to 2050. Due to Finland's geographic position, aviation is crucial from the viewpoints of business and reachability. The main objective regarding accessibility is that all places should fall within a three-hour travelling time and that the state must meet this aim in areas that cannot be accessed via rail. Other government goals important for developing electric aviation include improving conditions of scheduled air service to benefit businesses and to decrease emissions to meet the carbon neutrality goals set for 2030. The belief is that having several alternatives, such as electric aviation, could increase domestic air service provision without adding to emissions (Valtioneuvosto 2021a). Among the strategic goals related to decreasing aviation emissions are the aim to support technological development and production of electric fuels via research and innovation funds and to support the work by ICAO and EASA to create standards for electric and hybrid planes (Valtioneuvosto 2021c).

Regulation considering the unique needs and characteristics of electric aviation is still under development. Finland's network of airports and airfields is comprehensive enough to incorporate electric aviation but recharging and hydrogen distribution infrastructure need considerable investments. For example, very remote airfields would fall under EU regulations if they began receiving regular passenger traffic. The more public status of these airfields would imply that they must meet more demands compared with their current state, from fencing the airfield to organizing security checks, air traffic services (ATS) such as air traffic control, and emergency and fire protection capabilities (Mäntynen et al. 2022).

From a regulatory point of view, uncontrolled airfields may not be used for scheduled air services (only for taxi flights), but this problem could be solved via distant air traffic control. Airports and airfields must prepare for specific new threats, such as battery fires. In addition, most small airfields are not maintained during winter, which would pose additional problems for increasing air traffic. Finally, the availability of possible airfields and airports may be restricted by regulations and

technical properties determining which are accessible enough to be used as actual or as backup airfields, considering how much energy reserves the planes can carry. There are less regulations if an airport is only used for intermittent taxi air services with small planes. The regulation regarding electric aviation in Finland is still under development and subject to changes soon. Under-developed law and the resulting assumption that all aircraft have engines which burn combustible fuel pose challenges to the industry's growth. Regulation is likely to be reformed at several stages to adapt to changes while remaining based on the realities of traditional aviation (Finavia 2022a; Mäntynen et al. 2022).

The Ministry of Transport and Communications ordered a report in 2022 to map alternative ways to establish a low-flight network[4]. Initially, the network would be used only by authorities, but utilizing low-flight airspace more efficiently in the future is the first step required to develop electric aviation networks in Finland. Next, financial options needed for establishing a low-flight network are reviewed before making an official decision (Valtioneuvosto 2022).

Status of electric aviation

19 percent of the terrain and 70 percent of the population are within reach of airfields suitable for electric aviation. The level of demand remains an open question, but most likely, the demand will come from the needs of industry and tourism. Electric aviation may offer a way for the industry to achieve better carbon neutrality and for tourism to develop more sustainable concepts (Mäntynen et al., 2022).

Adequate access to electricity would probably not pose problems for airports and airfields in Finland. In addition to technological development, air carriers need new types of simulators, education and training for pilots and cabin crew, and long-term agreements between the companies and manufacturers to make the leap. Most demand for charging stations on scheduled air traffic is focused on the Helsinki-Vantaa airport, which in the first stage could have the capacity for three electric routes (Mäntynen et al. 2022; Finnair 2022).

The best prospects for electric aviation are found in remote areas where a limited but regular number of people wish to live, work and travel. Electric aviation could be most competitive within distances of approximately 200 km, on routes without rail connections and when large bodies of water or other geographical barriers must be crossed. New routes could also improve public transport connections traversing the country, which currently are almost nonexistent. In addition, they could create tighter networks of connections, for example, by linking manufacturing industries with major cities, thus improving overall regional competitiveness (Helsingin sähkölentokoneyhdistys 2019; Harakka 2022; Mäntynen et al. 2022).

Electric planes could serve both in scheduled air service and as a taxi service and transporting light cargo. The assumption is that by 2030, there will be a small number of planes running on battery electric power in operation with a capacity of 9-19 seats and a reach of 200 km, as well as taxi air services with nine seats. As for routes, by 2030, the highest potential could be within scheduled air services with an average of fewer than 20 passengers (from Helsinki to Pori, Savonlinna, Maarianhamina, to optimise the capacity of the plane); in new taxi or scheduled routes that serve the tourism and industry of Northern Finland (for improving accessibility); and in new ways between Finland and its neighboring countries, such as Northern Norway, Sweden, and Estonia (to reduce travelling times). By 2040,

4. A low flight network refers to a network that utilises satellite positioning, which would make it possible to also fly in poor weather conditions (Ministry of Transport and Communications, 2021).

there could be a considerable increase in the capacity and travelling distance of electric aviation with international connections up to 1.000 km and capacity up to 100 seats. At this stage, there will be increased demands also towards developing hydrocarbon infrastructure and extending the then-established recharging park. Electric aviation, unmanned drones, and eVTOL planes[5] could also carry light cargo (Mäntynen et al., 2022).

Selected research projects about electric aviation

Currently, there is one electric plane in operation in Finland owned by the electric aviation association of Helsinki and not within commercial traffic (Helsingin sähkölentokoneyhdistys 2022). In addition, Finnair has signed a statement of interest with the Swedish company Heart Aerospace to purchase up to 20 electric planes. Finnair's goal behind the purchase is to decrease its emissions, especially on short domestic flights (Finnair 2021).

The Finnish state supports the private initiative Helsinki East Aerodrome, which develops a digital airport in Pyhtää, with an investment seed money of EUR 2,5 million. In connection with the airport, a new research centre will focus on future aviation. The concept aims to solve issues around, e.g., distant air traffic control, satellite-based approaches, and distant maintenance (Redstone AERO 2022).

The University of Tampere and the municipality of Pirkkala started the project TMP Zero in 2022 to develop an aviation and logistics complex based on low-carbon energy solutions to and around the Tampere-Pirkkala airport. Its main goal is to figure out the demands for equipment for future aviation, from planes to machinery and even buses operating in the area, pose to airport infrastructure (EU:n rakennerahastojen hallintajärjestelmä, 2022).

Finland also participates in the FAIR project aiming towards early and efficient commercialisation of electric aviation; the regions involved are South, Central and Northern Ostrobothnia (Mäntynen et al. 2022).

A report depicting the status and prospects of electric aviation in Finland by Traficom, recommends investing in the following issues to support the future of the field. The issuing alternatives include decreasing the costs of airport maintenance and subsidizing purchases of electric equipment, supporting investments in recharge infrastructure and influencing the market situation via procurement measures, for example by evaluating the need for utilizing aviation depending on the accessibility and requirements of each municipality, and finally by improving conditions for conducting experiments (Mäntynen et al. 2022).

5. eVTOL (electric vertical takeoff and landing) is a standard term to describe helicopters and tilt-rotor aircraft that land and take off vertically instead of rolling down a runway. The "e" means the craft is powered by electricity.

5.5 Iceland

Aviation in Iceland

The number of domestic aviation passengers in Iceland peaked in 2007 when over one million passengers used domestic flights. The high passenger number that year was connected to heavy industry construction in East Iceland (Isavia, 2012). There has been a decline in the number of domestic passengers since then, despite an increase in tourism during the same period. During the period 2009-2021, the lowest number of domestic passengers recorded was in 2020 during the Covid-19 pandemic when it declined to 320 000 passengers. There was a 73.6 percent increase in domestic passengers the following year despite continuing impacts of Covid-19 related travel restrictions, leading to a total of 556 000 passengers in 2021 (Isavia, 2018; 2019; 2021).

In Iceland, there are four international airports, Akureyri, Egilsstaðir, Keflavík and Reykjavík (Samgöngustofa, n.d. (b)) that also service domestic flights. Additionally, airports are used for scheduled domestic flights in the following places: Bíldudalur, Gjögur, Grímsey, Höfn, Húsavík, Ísafjörður, Vestmannaeyjar, Vopnafjörður and Þórshöfn (Samgöngustofa, n.d. (a)).

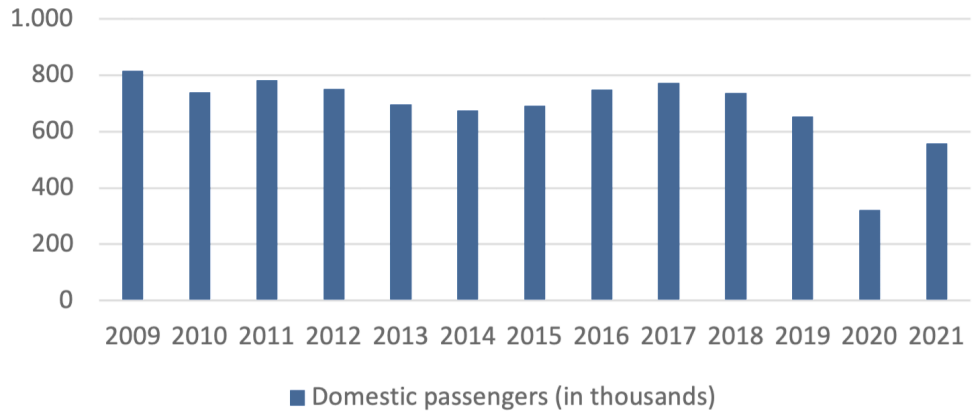

Figure 7. Domestic passengers 2009-2021
Source: Isavia, 2018; 2019; 2021

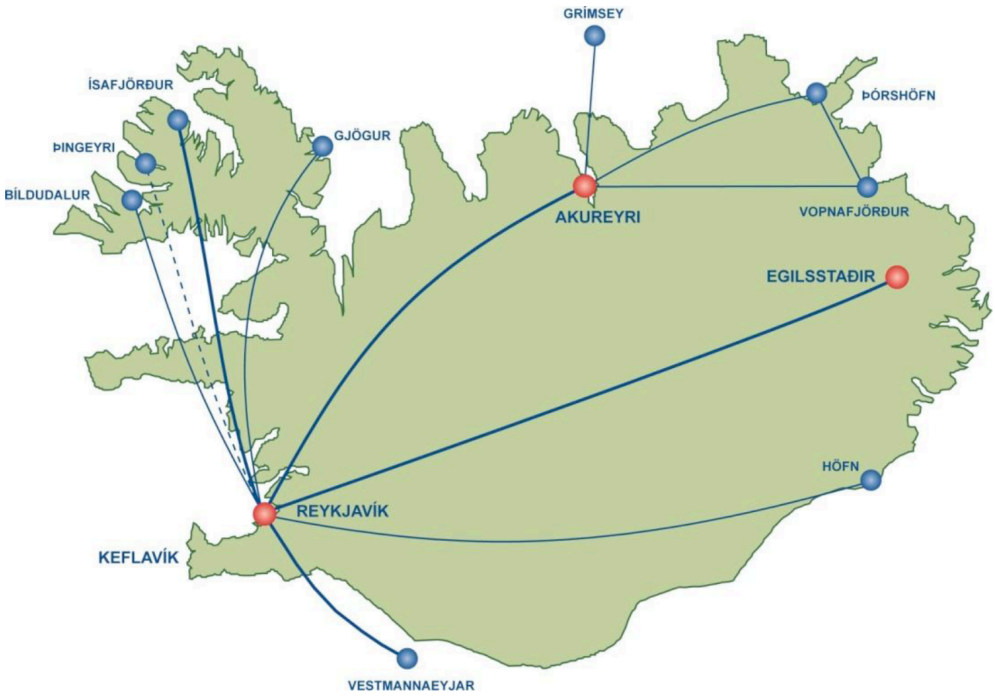

Figure 8. Domestic flight routes in Iceland
Domestic flight routes in Iceland (with the exclusion of Húsavik, near Akureyri, Þingeyri is a back-up airport for Ísafjörður
Source: Isavia, 2012

Isavia (a public limited company) manages all airports owned by the government as well as managing 30 other landing strips in Iceland (Isavia, 2021). There are nearly sixty registered landing strips in the country (Samgöngustofa, n.d.) (b)

Three airlines provide domestic flights, Icelandair (which also flies internationally), Eagle Air and Norlandair. Their fleet is as small as 7 seat planes and could therefore transition to electric aircraft. Information from Icelandair and Norlandair's fleets was obtained via email correspondence.

Icelandair operates domestically using the following planes[6]:

- Two DHC-8-400 planes for **76 passengers**
- Three DHC-8-200 planes for **37 passengers**

Eagle Air operates using the following planes (Flugfélagið Ernir, n.d.)

- Three Jetstream 32 planes and one Jetstream 31, for **19 passengers**
- Dornier 328 for **32 passengers**
- Cessna 207 for **7 passengers**

Norlandair operates using the following planes[7]:

- DeHavilland Twin Otter DHC-6 (TF-NLC, TF-NLD and TF-POF) for **19 passengers**
- Beechcraft Super King Air 200 (TF-NLA and TF-NLB) for **9 passengers**

The Icelandic government subsidises routes of regional airports for passengers for whom it takes more than 3.5 hours to reach necessary governmental services by public transport and where air transport does not operate due to market failure

6. Informant 1.
7. Informant 2.

(þingskjal nr. 297/2017-2018. Svar samgöngu- og sveitarstjórnarráðherra). Currently, the government subsidises the routes to Höfn, Bíldudalur, Gjögur, Grímsey, Vopnafjörður and Þórshöfn. A public procurement of the routes is managed by Vegagerðin (Vegagerðin, 2021). The subsidy amounted to ISK 530.9 million (around EUR 3.76 million) in 2020 (a 15 percent increase year on year) (Vegagerðin, 2021) and according to an interview with a staff member of Vegagerðin, this increased substantially in 2021 and 2022 due to increasing fuel prices[8].

Additionally, on September 1st in 2020, the government introduced a new flight discount on domestic flights which provided inhabitants living at least 270 kilometers from the capital region with a discount of 40 percent on domestic flights. The discount could be applied to up to six flights per year starting on January 1st, 2021 (Jóhannsson, 2020).

Furthermore, Isavia receives an annual sum from the ministry of transport for the management of airports and landing strips in Iceland (except for Keflavik international airport). The sum equaled ISK 1.9 billion in 2019 (EUR 13.5 million)[9]. This sum supports several airports that could be used for electric aviation.

The Icelandic Transport Authority handles administration, licensing, and supervision of companies in aviation-related operations, in the field of air navigation, and air traffic protection. It additionally manages surveillance regarding flight safety in Iceland.

The Icelandic Road and Coastal Administration (IRCA) manages the procurement of flight routes that are not commercially viable (six routes currently, see above).

National climate goals and national emissions from aviation

The government of Iceland aims to achieve carbon neutrality before 2040 and to cut greenhouse gas emissions by 40 percent by 2030 as part of the Paris Agreement. In 2018, the Icelandic government presented a new Climate Action Plan, the first long-term comprehensive plan that was fully funded. In 2020 this plan was updated, with increased funding and it now contains 48 action points (Government of Iceland Ministry for the Environment and Natural Resources, 2020).

According to the Climate Action Plan, Aviation and Heavy industry were responsible for 1,307 kilotonnes of CO2 equivalents in 2005 and the target for the EU Emissions Trading System (EU-ETS) is to reduce emissions in the system by 42 percent from 2005 to 2030.[10]

The actions concerning aviation to reduce emissions in connection with EU-ETS include participation in international system.

In Iceland's Energy Policy towards the year 2050, it is noted that the energy transition in air transport is in its initial stages. Therefore, it is important to expand the strategic planning and actions on energy transition to cover areas that remain largely dependent on the use of fossil fuel. According to the policy it is the aim that fossil fuels will be entirely replaced by renewable energy sources by 2050 (Government of Iceland Ministry of Industries and Innovation, 2020).

Air transport emissions (both domestically and internationally to and from Iceland)

8. Informant 3.
9. Informant 4.
10. The Agreement on the Platform for the Coalition Government notes that this should happen by 2040.

declined between the period 2007 and 2012 but started increasing again in 2013 reaching their peak in 2018. There was a decline between 2018 and 2019 and in 2020 and 2021 emissions were much lower than in previous years being 489.47 kilotonnes and 466.37 kilotonnes respectively. It is worth noting that these calculations only include emissions from companies belonging to the Icelandic economy. (Hagstofa Íslands, n.d.) This indicates that the decrease in emissions between 2018 and 2019 could be explained by the bankruptcy of WOW air, one of Iceland's largest airlines in March 2019 (Harðarson B. P., 2019). Furthermore, this number does not capture emissions emitted by foreign airlines operating to and from Iceland. CO2 emissions from air transport seem to increase again, according to provisional numbers from Iceland Statistics. In the first quarter of 2022 emissions were 86 kilotons which is a fourfold increase, year on year. This is however much lower than at the peak in 2018 when emissions in the first quarter were 541 kilotons (Hagstofa Íslands, 2022).

Strategies for electric aviation and/or other relevant policies for sustainable aviation

Iceland's first aviation policy was introduced in the government's transportation plan in June 2020, which covers the period 2020-2034. The purpose of developing an aviation policy is to create an environment that supports the base for flight operations and the operation of aviation-related activities in Iceland, as well as supporting growth in aviation. A goal of the policy is to enhance domestic aviation which has declined in recent years. Domestic flights currently form a part of Iceland´s public transport system in the sense that they are subsidized for inhabitants of rural areas and aim to connect the public to other parts of the public transport system. Additionally, as mentioned above, air transport is subsidised in areas where it would not otherwise operate due to market failure. This is to ensure access to services for people living in remote rural areas, as well as ensuring public transport in rural areas, where roads may close during difficult weather conditions. One of the key components of the aviation policy is to decrease the negative environmental impact of aviation and related operation as well as to ease the energy transition in air transport (Stjórnarráð Íslands Samgöngu- og sveitarstjórnarráðuneytið, 2019).

When developing its transport plan, the government works in line with the goal that transport policies in Iceland should be environmentally sustainable and support positive regional development (Innviðaráðuneytið, n.d.). According to the aviation policy, the main focus to achieve the goals for environmentally sustainable air transport will concern:

- Incentives for energy transition in aviation when adequate technology is developed and to promote the use of domestic environmentally friendly energy sources.
- Infrastructure for airplanes using environmentally friendly energy sources in airports.
- Service equipment in the country´s airports will be powered by eco-friendly energy sources.

The aviation policy additionally addresses the importance of using Iceland's strength in renewable energy for flight operations, such as energy transition in air travel.

In early 2021, the Icelandic parliament approved a proposal for establishing a working group to develop a strategy and a plan for action concerning energy

transition in aviation in Iceland (Sæmundsdóttir, 2021). The working group was supposed to propose solutions and discuss the following:

- How Iceland can become a leader of the energy transition of aviation.
- How to support innovation concerning energy transition of aviation.
- The country's capability with regard to weather and the infrastructure that needs to be in place in the country due to energy transition in aviation, including innovation, environmentally friendly energy sources and participation in testing and the international development in energy transition in aviation.
- Setting a goal that environmentally friendly energy sources be used in domestic flights before the year 2030 and how that plan is in line with other governmental plans with regards to energy transition, innovation, and climate issues (þingskjal nr. 386/2020-2021. Tillaga til þingsályktunar).

In the proposal it is noted that it is realistic to plan and encourage development so that eco-friendly sources of energy will be used in domestic flights by 2030. Thereby making it possible to use solely eco-friendly energy sources in domestic flights in the coming years. It is additionally highlighted that the energy transition of the country's aviation fleet can lead to 80 percent lower operating costs regarding fuel- and maintenance costs (þingskjal nr. 386/2020-2021. Tillaga til þingsályktunar).

The group released a draft of its report for commentary in March 2022. In the draft, it is claimed that using electricity for short flight routes will create the opportunity to increase the frequency of flights with increased energy efficiency. This in turn could increase the number of passengers domestically. Additionally, it is noted likely that hybrid airplanes can play a role in decreasing emissions in domestic flights (Stjórnarráð Íslands Innviðaráðuneytið, 2022).

In the draft report (2022), it is observed that transporting jet fuels across long distances to airports in the countryside constitutes a large part of the cost of domestic flights. To increase the share of eco-friendly domestic flights, it is therefore worth exploring increased grants to eco-friendly domestic flights beyond the support that is provided to domestic flights today. An example of this could be the production of renewable energy for air transport, construction of new airport infrastructure or to change in fees for eco-friendly domestic flights. Additionally, the draft report notes that in some cases the distribution network for electricity in rural regions must be improved for the largest airports to service the airplanes.

Furthermore, it is emphasised that the uniqueness of the Icelandic electricity system is that all energy production is categorised as green since it produces from renewable energy sources.

The report lays out a 12-step action plan. The steps that involve electric aviation include:

- The third step: to work towards domestic flights running solely on renewable fuel (including electricity) by 2040. Additionally, renewable energy sources should constitute 20 percent of energy sources used for domestic flights by 2030.
- The fourth step: to promote Iceland as a destination for testing airplanes that run on renewable energy sources. It involves an experimental project with domestic flights using renewable fuel by 2026.
- The fifth step: to perform an analysis on how to best support air carriers with the goal of making flights using renewable energy sources cheaper than other modes of transport that pollute more emissions.

The draft report was open for commentary. Among the comments received was

Landvernd's commentary (Icelandic Environment Association), which pointed out that using electricity would be the most economically beneficial for the energy transition in aviation. The association believes there should be a focus on direct use of electricity due to energy efficiency and current infrastructure which is mostly in place (Magnúsdóttir, 2022). Reykjavík Energy and Veitur Utilities also stated that an emphasis should be put on electric aviation in domestic flight in their commentary (Sæmunsdóttir, 2022).

Status of electric aviation

Recently, a lot of attention has been paid to electric aviation in Iceland with media coverage of the first electric flights using Icelandic energy as well as commitments to energy transition.

In September 2022, Icelandair announced that the company will support the development of a 30-seat electric airplane by Heart Aerospace to use it for passenger transport in 2028. Previously, Icelandair and Heart Aerospace signed a declaration of intent to develop a 19-seat plane ES-19 which was supposed to be completed in 2026. The new airplane will be of great use for domestic flights in Iceland according to Icelandair. Previously, the airplane was supposed to be fully electric but current plans involve a hybrid version with the option to use jet fuel for increased flexibility. The airplane will be able to travel 200 kilometers with 30 passengers solely using electricity, 400 kilometers using a mix of electricity and sustainable jet fuel and up to 800 kilometers with 25 passengers. Icelandair said that this airplane could be used on all domestic routes and significantly decrease carbon emissions (as mentioned above. the airline currently uses three airplanes for 37 passengers in their domestic flights, as well as two airplanes with 76 passengers). Heart Aerospace believes that the plane will be able to travel 300 kilometers solely on electricity by 2035 and 400 kilometers by 2040 (Unnarsson, 2022b).

The first electric passenger flight in Iceland in July 2022. Photo: Ingibjörg Friðriksdóttir

In July 2022, the first flight was performed by an electric airplane running on Icelandic electricity in Iceland using a two-seater Pipistrel. The airplane flies at 170 kilometers per hour and can fly up to 50 minutes. It takes about 30 minutes to charge it (Unnarsson, 2022a). The first passenger flights on the plane were flown in August 2022, when the president of Iceland Guðni Th. Jóhannesson and Prime Minister Katrín Jakobsdóttir flew with Matthías Sveinbjörnsson, the founder of Rafmagnsflug ehf., which is the company that owns the airplane. Rafmagnsflug was founded by Mr. Sveinbjörnsson and Friðrik Pálsson at the end of 2021 and is supported and financed by Icelandair, Isavia, Landsvirkjun, Hótel Rangá, Landsbankinn, Flugskólinn Geirfugl, Flugskóli Reykjavíkur, Flugakademía Íslands, as well as three individuals (Magnúsdóttir, 2022).

According to a news report, pilot training using the Pipistrel should have begun in September 2022 (Unnarsson, 2022 (c)).

Landsvirkjun, Icelands National Power Company, declared upon the first flight using Icelandic electricity that Iceland was in a unique position to be a world leader regarding energy transition in flights due to short flight distances domestically and great access to environmentally friendly electricity. Furthermore, the country's geographical position between Europe and North America can in the future create opportunities, when it comes to possibilities in energy transition regarding international flights (Landsvirkjun, 2022). This includes Keflavík airport becoming an important charging centre for the first generations of electric airplanes intending to cross the Atlantic. (Unnarsson, 2020).

Two of the main constraints concerning electrifying the domestic fleet is electricity transmission and electrical safety. A recent report noted that electrical safety calls for an increase in electricity production and a stronger transmission grid and distribution system which in turn calls for a holistic management of the energy system and the integration of new work processes (Stjórnarráð Íslands Umhverfis-, orku- og loftslagsráðuneytið, 2022). There are particularly vulnerable locations regarding electricity in Iceland, such as Þórshöfn remotely located in Northeast Iceland, where domestic flights are currently operating.

Selected research projects about electric aviation

In February 2022, Landsvirkjun (Iceland's National Power Company) and Icelandair announced a two-year cooperation to evaluate the situation and prepare a project that will contribute to the progress in energy transition in aviation (Ritstjórn, 2022). The project will have three goals:

- To evaluate the possibility of starting a development project, where the first steps in energy transition will be taken.
- To create a platform for stakeholders and to support cooperation regarding energy transition in aviation.
- To inform the public and stakeholders about the importance of energy transition in aviation and what steps need to be taken.

5.6 Norway

Aviation in Norway

The Aviation system in Norway has developed in another direction than the systems in the other Nordic countries. In comparison to the other countries, Norway still has a developed regional system with short routes, many small airports and small airplanes. This development has different explanations. One being that Norway is more dependent on aviation than the other countries because of the special geography with high mountains and fjords and islands, which makes mobility on land difficult. In several reports, it is also mentioned that aviation is important for people's welfare e.g., travel for medical treatment and to maintain contact with family at home and abroad (Avinor, Federation of Norwegian Aviation Industries, Norwegian, Norwegian Confederation of Trade Unions, SAS, 2020). According to the Norwegian electric aviation programme (Avinor & Civil Aviation Authority of Norway, 2020), the short-haul network is the result of a strong regional policy initiative that over years supported the settlement, food, services, and defence in the whole of Norway.

Norway has one of the most extensive regional aviation markets in Europe. Of the Nordic countries, Norway has by far the largest number of origin airports and destination pairs with routes that are equal to or shorter than 200 kilometers. Norway is therefore said to benefit significantly from electric aviation. There are 46 airports in Norway with regular route traffic (Avinor & Civil Aviation Authority of Norway, 2020p. 21) and the airlines, SAS and Norwegian, together cover more than 70 percent of the airline passengers in Norway (Ministry of Transport, 2019).

The Ministry of Transport (Samferdselsdepartementet) is responsible for ensuring a safe and adequate access to aviation throughout the country. Some routes with low demand are therefore subsidized when it comes to ticket price, capacity, and frequency of travel through public procurement (FOT in Norwegian). These routes are mostly located in the west (Vestlandet) and in the north of Norway (Samferdselsdepartementet, 2021). The routes that have a contract for public procurement until March 2024 are:

Southern Norway (mostly west): Røros–Oslo, Florø–Oslo, Førde–Oslo, Sogndal–Oslo, Sandane–Oslo, Ørsta-Volda–Oslo, Ørsta-Volda–Bergen, Sogndal–Bergen and Sandane–Bergen.

Northern Norway: routes between Kirkenes, Vadsø, Vardø, Båtsfjord, Berlevåg, Mehamn, Honningsvåg, Hammerfest and Alta; Hasvik–Tromsø, Hasvik–Tromsø, Hasvik–Hammerfest and Sørkjosen–Tromsø; Lakselv–Tromsø; Andøya–Bodø v.v. and Andøya–Tromsø; Harstad/Narvik–Bodø and Harstad/Narvik–Tromsø; Stokmarknes–Bodø and Stokmarknes–Tromsø; Svolvær–Bodø; Leknes–Bodø; Røst–Bodø; Brønnøysund–Bodø v.v. and Brønnøysund–Trondheim; Sandnessjøen–Bodø v.v. and Sandnessjøen–Trondheim; Mo in Rana–Bodø v.v. and Mo in Rana–Trondheim; Mosjøen–Bodø v.v. and Mosjøen–Trondheim; Namsos–Trondheim v.v. and Rørvik–Trondheim v.v.

In addition to the Ministry of Transport, the Civil Aviation Authority of Norway (Luftfartstilsynet) is a relevant actor responsible for ensuring that aviation run in a safe and efficient manner. The Authority provides regulations, set standards for aviation activities, offers grants, permits, and approves operation activities as well as supervises those regulations and conditions are followed. (Civil Aviation Authority

of Norway, n.d.). Another important actor is the state-owned company Avinor AS that is responsible for operating and developing 43 out of the 47 airports in Norway. Also, the airlines Norwegian and SAS are influential actors.

National climate goals and national emissions from aviation

The Norwegian goal is to reduce CO2 emissions with 50-55 percent before 2030 and with 90-95 percent before 2050. The goal was presented in 2020 when the government announced that they are strengthening the commitment to the Paris agreement and increasing the pace in reduction from a 40 percent reduction in 2030 compared with 1990, to a 50-55 percent reduction (Ministry of Climate and Environment, 2021a). In 2021, the Solberg government[11] presented the climate plan for 2021-2030, which includes actions on how to reach the targets (Ministry of Climate and Environment, 2021b). The National Transport Plan 2022–2033 will contribute to the ambition to reduce transport sector emissions by 50 percent by 2030 and contribute to Norway achieving its climate and environmental goals. Even though Norway is not part of the EU, the country is included in the EU-ETS and cooperates with EU to reach the climate targets.

There has been raised criticism to the new increased goal to reduce emissions with 50-55 percent. An article in Aftenposten states that Norway has a habit of strengthening their goals and not fulfilling them. The goal of reducing emissions with 30 percent in 2020 compared with 1990 levels was not fulfilled, instead the emissions increased by 1.1 percent (Mathismoen, 2020).

In 2019, Norway released 50,3 million tons CO2 equivalents which is an increase by 2.3 percent in comparison with 1990 level (Environment Norway, 2020). In 2021, the statistics instead showed a 4.5 percent reduction from 1990 levels (Statistisk sentralbyrå, 2021) which is probably due to the Covid-19-pandemic which had a significant effect on transport emissions.

The most significant CO2 emission sources in Norway are oil- and gas extraction, industry, road traffic and other transport. Road transport and other transport increased by 15 and 25 percent respectively since 1990. Between 2018- and 2019, there was a decrease in emissions from shipping, fishing vessels, aviation, and non-road mobile machinery. The reduction is a result of, among other things, electrification of ferries (Environment Norway, 2020).

According to a report by Avinor et al. (2020), air traffic (domestic and foreign) corresponds to around 5.5 percent of Norway's emissions. Domestic aviation solely accounts for 2.3 percent. Aviation navigation and motor equipment accounted for 7,5 million tons of the emissions in 2021 (same number as in 2018). This is an increase by 40.8 percent since 1990. (Statistisk sentralbyrå, 2021). Even though the emissions per passenger have decreased by over 50 percent in the last twenty years, the large increase in the number of passengers using aviation means that emissions have gone up. Like the other European countries, Norway's domestic emissions figures only include transport emissions linked to the Norwegian territory. Emissions from international aviation, for example, are not included. (Environment Norway, 2020).

Norway has one of the highest shares of renewable energy in total consumption in the whole of Europe at approximately 81 percent (See figure 2). Norway also has the

11. The conservative government of the former prime minister Erna Solberg.

highest share of electric cars and electric ferries in the world (Ydersbond et al, 2020). This makes implementation of electric aviation in Norway a logical next step.

Strategies for electric aviation and/or other relevant policies for sustainable aviation

The Norwegian transport Ministry works on a new strategy for aviation. During the autumn 2022, the strategy has been on referral to gather insights and opinions on the topic from various stakeholders such as Norwegian, SAS, Widerøe, LO, NHO Luftfart, and Miljøstiftelsen Zero og Framtiden i våre hender. The strategy will focus on four areas: a climate and environmentally sustainable aviation, a socially sustainable aviation, a geographical sustainable aviation, and an economic sustainable aviation. The geographical focus is included to strengthen the short distance network and to ensure low prices and more departures. The strategy will also describe how access to the short-haul network can be improved including how prices can be reduced and the number of departures increase (Samferdselsdepartementet, 2022).

In 2020, the Norwegian aviation industry developed their fourth report on the social benefits, climate and environmental impacts from aviation. The report was initiated and led by Avinor and conducted in collaboration with the airlines SAS, Norwegian and Widerøe, and the Norwegian Confederation of Trade Unions (LO) and the Federation of Norwegian Aviation Industries (NHO Luftfart). The report includes a roadmap towards the 2050 goal of fossil free aviation (Avinor et al, 2020).

The goal is that Norwegian aviation should be fossil free in 2050 and to reach this goal, significant changes and investments are needed in the coming decades. The report concludes that measures to reduce emissions from aviation are underway. This especially refers to replacement of the aviation fleet and efficiency in the airspace. In 2020, Norway was also the first country in the world to have a blending mandate for advanced biofuels in aviation. Norwegian airlines have plans for increased phasing in of sustainable fuels, and the Norwegian authorities have signaled a target of 30 percent biofuel in aviation by 2030. (Avinor et al. 2020).

Regarding electric aviation, Norway has gone further than the other Nordic countries and developed a national programme. The programme, Proposal for programme of introduction of commercial electric aviation[12], was finished in 2020 and commissioned by the Norwegian Ministry of Transport to Avinor and the Civil Aviation Authority of Norway (CAA Norway).

The goal is to make Norway the first country where electric aircraft accounts for a significant share of the market and to electrify all domestic flights by 2040. The initiative is supported by the government, and the project partners are Widerøe, SAS, the Norwegian Association of Air Sports, and Zero Emission Resource Organisation.

Goals for electric aviation presented in *Proposal for programme of introduction of commercial electric aviation* (2020):

- Norway will be a driving force and arena for the development, testing and early implementation of electrified aircraft
- By 2030, the first ordinary domestic scheduled flights will be operated with electrified aircraft
- By 2040, all civil domestic aviation in Norway will be operated with electrified

12. In Norwegian: Forslag til program for introduksjon av elektrifiserte fly i kommersiell luftfart (2020).

aircraft, reducing greenhouse gas emissions by at least 80 percent compared with 2020.

The programme also highlights the potential for Norway to be used as a development arena and test market to influence or provide emission reduction initiatives outside of Norway. The belief is that small aircraft can operate on the short-haul network in Norway (with up to 19 seats and capable of withstanding Norwegian winter conditions) between 2025 and 2030. The programme emphasises the importance of the technological development taking place within the framework of international cooperation. *

Status of electric aviation

Norway aims for all domestic aviation to be 100 percent electric by 2040. This is claimed to reduce greenhouse gas emissions from aviation by 80 percent from 2020 (Avinor & Civil Aviation Authority of Norway, 2020). Several projects and initiatives are underway to make this happen.

In addition to the before mentioned report, *Proposal for programme of introduction of commercial electric aviation (2020)*, Avinor is involved in several initiatives. In 2020, the state-owned company signed a collaboration agreement with SINTEF to take part in common research projects about electric aviation (Ydersbond et al, 2020). Several Avinor airports are also preparing for electric aviation. At Stavanger Airport and Bergen Airport, they plan on charging infrastructure for electric airplanes and will contribute with the necessary infrastructure once the electric airplanes are market available (Ydersbond et al, 2020).

The Bergen based company, Flyby, and the Norwegian research institute, Sintef, have started a project to link the small cities in Norway with an electric seaplane. The plane will fit 9 passengers and will be able to fly about an hour which gives it a range of approximately 200 km. The goal is to have 15 or 20 aircraft operating by 2030. The Research Council of Norway provides NOK 16 million in funding for the seaplane project. (SINTEF, 2022).

Start Norge AS is a newly established company started by Avinor, Sparebanken Vest, Berg-Hansen, Aircontact Group, and the Business organisation in the Stavanger Region (Naringsforeningen i Stavanger-regionen). The company offers a forum to collaborate on introducing the first commercial electric passenger route in the world between Stavanger and Bergen. Start Norge AS commissioned a report by the Institute of Transport Economics TØI to investigate opportunities and challenges of introducing electric airplanes between Stavanger and Bergen. The report, *Accelerating the phase in of electric aircraft in Norway - Possible societal impacts and policy instruments* (2021), concludes that a demonstration case between Bergen and Stavanger will have greater net benefit than not investing.

It is stated that the implementation of electric aviation on this route can support green tourism, sustainable work trips and new business opportunities for technology development for companies. The belief is also that the electric planes will make it faster and cheaper to transport time-critical goods from industry than today. Representatives of several small towns and villages that have short-haul airports, envision that passenger routes by electric plane can provide improved conditions for the business community and local society. The assumption is that electric aviation in the long term results in more departures and lower prices. The estimation is that the small electric planes can provide the same number of seats as a conventional small aircraft but lead to cost advantages as result of lower energy costs. On short

distances, the players envision that electric plane can constitute a type of "taxi bus". Most interviewed businesses in the Bergen area and the Stavanger area have a positive attitude towards the development of an electric flight on this route. The biggest challenge is to document and convince the business market that electric flights are safe and hassle-free with positive environmental effects (TØI, 2021).

The Norwegian airline Widerøe is also working to implement electric planes on its routes. Widerøe has its main office in Bodø, in the country Nordland, but flies all over Norway and is the largest regional airline in the Nordic countries. The airline has a goal to electrify the short routes that today are operated by their Dash 8-fleet. According to Avinor, Norway and particularly the north of Norway are suitable for the first generation of electric aviation because of the large network for small airports and short routes. In 2021, the aim was to have a commercial operation ongoing in the middle of the 2020s (NRK, 2021)

In addition, the aviation group Widerøe AS started the project Zero, which is an air mobility incubator. It tackles all the regulatory, commercial and financial challenges involved in purchasing and entering new aircraft concepts into revenue service (Widerøe zero, 2021). Within this project, it is also launching an Air Mobility Lab to take a leading position within customer experience and new air mobility concepts.

Widerøe and Rolls-Royce Electrical Norway also collaborate on developing electric airplanes. They signed an agreement about research collaboration in 2019 (Nordic Energy Research, 2021) and has produced a nine-seater plane (Tecnam P-Volt) that is planned to be operational in 2026. The Covid-19 crisis is, however, claimed to postpone some of Widerøe's projects (Ydersbond et al, 2020).

The county Troms and Finnmark in the north of Norway highlighted the need for Avinor to continue the ambitions in the "Nordområdestrategin" to utilise the airport network in the region for the development of electric aviation in Norway, in the response to the National transport plan (Troms og Finnmark fylkeskommune, 2020).

Selected research projects about electric aviation

Flightsmart
The project aims to realize an energy efficient control and flight management system for light aircraft employing hybrid electric propulsion. The project is proposed by Norwegian SMEs Maritime Robotics AS and Equator Aircraft SA and supported by Norwegian Research Council, SINTEF, and Norwegian University of Science and Technology.

Demonstration case for electric planes between Bergen and Stavanger
The project partners Avinor, Sparebanken Vest, Berg-Hansen, Aircontact Group, and the Business organisation in the Stavanger Region (Næringsforeningen i Stavanger-regionen), have together started the company Start Norge AS and the aim is to set up the first commercially fully electric route in the world between Bergen and Stavanger. The project and the report from the Institute of Transport Economics, TØI, is explained in the previous section.

Elnett21
Elnett21 aims to facilitate emission-free and electric transport by increasing local energy production, testing solutions for storing and distributing electricity, as well as smart management of energy that ensures optimal use of the existing grid. The demonstration program will develop solutions to meet the increased need for power. The solutions will contribute to increased local production, storage, and management of energy. The aim is to show that an improved utilisation of resources

can be achieved by large players collaborating on solutions adapted to needs and consumption. The partners are Avinor, Forus Næringspark, Lnett, Smartly, and Stavangerregionen Havn. The project started in 2019 and will end in 2024.

Elfly Group
Elfly group was founded in 2018 and has its headquarters in Bergen. Today, the company is active in three core projects. A project to design commercial electric seaplanes that will be operational in 2029, the distribution of Bye Airspace electric aircraft to the Scandinavian general market, and the development of the fastest electric aircraft in the world as part of the Nordic Air Racing Team. It is also part of the Nordic network for Electric Aviation. (El-fly, n.d).

The flight school at the University of Tromsø (UiT)
The flight school is also an actor dealing with electric aviation. Its branch at University of Tromsø School of Aviation (UTSA) collaborates with the research centre Arctic Centre for Sustainable Energy (ARC) in making aviation as sustainable as possible. They have purchased two electric airplanes of the type Pipistrel Alpha Electro.

5.7 Sweden

Aviation in Sweden

The highest number of domestic aviation passengers in Sweden was measured in 1990. Since then, the number decreased until 2010, from when it slowly increased again. During the same time, the numbers of airports with domestic flights was reduced and small planes was replaced by larger ones. The discontinuation of short regional routes means that there is no comprehensive regional aviation system that can start implementing electric aviation without changing the structures of how aviation is managed.

The domestic flights in regular passenger traffic in Sweden are flown with three major airlines, SAS (49 percent), BRA (30 percent) and Norwegian (19 percent) (in 2019). The small airlines are usually specialised in taxi aviation. In 2019, there were 142 airlines flying domestic in Sweden and 84 of them had some form of passenger traffic. The rest are specialised in post or goods (Trafikanalys, 2020).

Trafikanalys (2020) estimated in 2019 that there are around 248 airports in Sweden. 39 of the airports are approved for commercial, line, charter, or taxi traffic, and all of them are approved by the Swedish Transport Agency (Transportstyrelsen) and have the necessary equipment to manage commercial aviation. Of the 39 airports, 10 are state-owned and managed by Swedavia. The rest of the airports are owned by municipalities and regions except for Skavsta, Ängelholm and Hemavan which are owned by private actors. Since 2005, the number of state-owned airports has been reduced from 18 to 10.

The Swedish Transport Administration (Trafikverket) is responsible to ensure basic transport availability in all areas, which includes areas with limited commercial condition for transport. Public procurement of routes of regional airports is steered by the EU regulation 1008/2008. This means that only the Transport Administration can decide on routes. There are discussions about whether regions and municipalities should have bigger influence deciding on routes since they have the regional incentives and local knowledge (Discussion at Transportforum, 2022). The public procurement of aviation is called "allmän trafik" and the included routes are re-

evaluated every fourth year. In the new regulation for 2023, 12 routes are included (2023-2026):

Arvidsjaur–Arlanda, Gällivare–Arlanda, Hagfors–Arlanda, Hemavan–Arlanda, Lycksele–Arlanda, Pajala–Luleå, Sveg–Arlanda, Torsby–Arlanda, Vilhelmina–Arlanda, Östersund–Umeå, Kramfors–Arlanda, Mora–Arlanda

During the Covid-19 pandemic in 2020, a temporary public procurement was introduced, which implied that several routes were included on the list of airports eligible for support. This decision expanded several times during the pandemic. The routes were:
Kiruna–Arlanda, Luleå–Arlanda, Umeå–Arlanda, Östersund–Arlanda, Skellefteå–Arlanda, Örnsköldsvik–Arlanda, Sundsvall–Arlanda, Visby–Arlanda
(Ministry of infrastucture, 2020b)

Other important public aviation actors in Sweden are LVF (Luftfartsverket), a state Agency responsible for providing safely, effectively, and environmentally adapted civil and military aviation, and the Swedish Transport Agency (Transportstyrelsen), which is responsible for national regulation and safety in the Swedish transport sector.

National climate goals and national emissions from aviation

Sweden's overarching long term goal is to reduce all net emissions of greenhouse gases before 2045, and after that achieve negative emissions. The framework also consists of a goal to have 100 percent renewable energy in 2040. The goal is based on the climate policy framework adopted in 2017 and consists of a Climate Act, climate goals and a Climate Political Council. The background to the framework is a broad coalition including 7 of the 8 parties in the parliament (Ministry of Environment, 2017).

In 2020, the Swedish government presented the Integrated National Energy and Climate Plan in accordance with regulation from European Parliament and European Council. The plan sets out climate priorities and energy policies up to 2045, including energy and carbon taxes, renewable energy initiatives and energy emission performance standards. In this plan, it is stated that Sweden should have 50 percent more efficient energy use in 2030 in comparison to 2005, and that emissions from transport should be reduced by at least 70 percent in 2030 compared with 2010 levels (Ministry of Infrastructure, 2020a).

In 2019, the total of Swedish transport emissions was 16.6 million tons CO2 equivalents, which accounted for 32.7 percent of total emissions (Statistics Sweden, 2022). Out of these emissions, 0.48 million tons derived from domestic aviation and 2.68 million tons from international aviation. However, when counting all emissions released from travel by Swedish inhabitants (including trips in other countries) the impact is much higher. The presented numbers above do not include trips fuelled outside of Sweden and neither do they include the impact of "altitude emissions". According to Naturvårdsverket, the Swedish impact from domestic and international aviation, including altitude impact, was 10.28 million tons, which is double what was presented in international and EU statistics (see figure 9). During the Covid-19 pandemic, the emissions from international aviation decreased by 4 percent. During 2021, the emissions continued to decrease slightly (Naturvårdsverket, n.d.b).

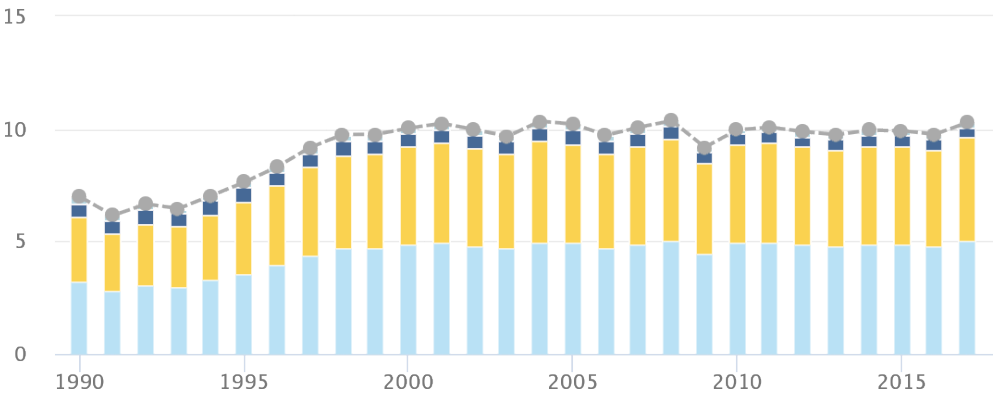

Figure 9. Climate impact from aviation of the Swedish population (in Million tonnes CO2 equivalent) (including altitude effect) 1990-2017
The light blue field represents the Swedish populations international aviation travel. The yellow field represents the altitude impact of international aviation. The small dark blue field represents the Swedish populations domestic aviation travel.
Source: Naturvårdsverket (n.d.c)

Strategies for electric aviation and/or other relevant policies for sustainable aviation

Although the climate goals are ambitious, there are no parliamentarian or governmental targets that directly include aviation. The reason is that emissions from aviation are included in the European Trading System (ETS). Swedish aviation contributes to climate change, and emissions from international aviation and maritime (emissions from fuels that are refuelled in Sweden) have increased by 150 percent between 1990-2021 (Naturvårdsverket, n.d.b). The reason for the emissions not having increased more is because of technological development in energy efficiency.

In 2017, the government decided on a Swedish aviation strategy (Ministry of Enterprise and Innovation, 2017). One priority in the strategy is to reduce aviation's impact on the environment and climate and that aviation should contribute to the Swedish and European goals to reduce climate emissions. However, no target goal has been decided on. Within the government initiative, Fossil Free Sweden, the aviation industry has decided on the goal that all domestic air travel in Sweden should be fossil free by 2030 and all international flights departing from Swedish airports to be fossil free by 2045.

In 2020, the Swedish government launched an electrification strategy (Ministry of infrastructure, 2022a). The focus of the report is not aviation, but it highlights that maritime and aviation transport should be electrified in the extent that it is feasible. It is stated that even though the development of electrification of maritime and aviation transport is in an early stage of development, the transition requires increased access to electricity, grid capacity and charging infrastructure. Many of the action points in the report are directed towards analysing and investing in different infrastructure at airports and harbours. It is also mentioned that cooperation regarding energy in Europe and in the Nordic region will be more important in the future. The report highlights that a proactive approach is required to investigate the needs and secure the reduction of hinders. Several initiatives have been initiated by the government in this direction.

For example, the Energy Agency is to analyse and suggest how climate premiums

(klimatpremier) can be used to stimulate an early market adoption of electric aviation. In 2020, Transport Analysis received the governmental mission to analyse measures to further the development of electric aviation in Sweden. The mission resulted in the report "Electric aviation – the beginning of an exciting journey[13]". In January 2022, the Swedish Transport Administration received a mission from the government to analyse and present suggestions on how the support to research and innovation about electric aviation can be developed, coordinated and organized. It is stated that the analysis shall especially focus on how electrification of aviation in small and medium sized companies can be supported as well as innovation and technology in different maturity levels. The report was handed to the government on the 15th of June 2022 (Ministry of Infrastructure, 2022b). In 2019 there was an investigation presented to the government (SOU 2019:11) which analyzed the instruments to increase the use of biofuel in aviation to make aviation more sustainable.

Fossil free Sweden is a national initiative aiming to make Sweden the first fossil free welfare state. It was developed on initiative from the government and gathers industry, companies, regions, and municipalities. Within the initiative, all sectors create roadmaps where all actors agree on goals and action points. The roadmap for fossil free aviation has the goal to make domestic aviation fossil free in 2030 and all aviation fossil free in 2045 (all planes departing from Sweden). In parallel with the development of the roadmap, the project Fossil Free Aviation (Fossilfritt flyg) was founded in 2018 by SAS, Swedavia and RISE to "establish and run an innovation cluster that will lead the process towards fossil free aviation". The cluster was created to coordinate with all actors in the value chain from the forest to the plane and to translate the roadmap developed by the aviation industry in 2018, into concrete measures.

Another important actor in Sweden is the state airport operator Swedavia that owns ten airports in Sweden, including four of the largest international airports. In 2020, Swedavia adopted a strategy for electric aviation. The goal is to enable all ten Swedavia airports to handle electric aircraft and to be able to place the first commercial electrified route in service by around 2025. The strategy is part of the overall goal to transform into fossil-free domestic air transport in Sweden by 2030 and fossil-free air transport for all flights originating in the country by 2045. Swedavia is part of several of the below presented initiatives from airports such as Östersund, Visby and Umeå, as well as collaboration with for example RISE, Vinnova, Heart Aerospace, and a number of regional companies and other organisations (Swedavia, 2020a; Swedavia, 2020b).

Status of electric aviation

Even though there is no Swedish national strategy for electric aviation, several airports and airlines work with electric aviation.

Over the past years, booming green and industrial investments in data storage, mining, energy and battery production have had a significant impact on the north of Sweden. The industrial investments in energy and battery production are particularly interesting for the development of electric aviation and actors in the north of Sweden, who have tied together the so called "battery belt" with the development of electric aviation both in research projects and communication.

13. in Swedish: Elflyg – början på en spännande resa, 2020.

During 2021, Sweden's most powerful electricity supply was installed at Skellefteå Airport. The initiative is a collaboration between Skellefteå Airport and Skellefteå Kraft, an energy company, and the aim is to become a test bed for electric aviation in a real environment. It is a step towards commercial electric aviation and the aim is to operate the first electric aviation routes in Europe in a few years (Skellefteå Airport, 2021).

Several other airports are also starting to investigate electric aviation. Swedavia has the goal for all its ten airports to handle electric aircraft and to be able to place the first commercial electrified route in service by around 2025. The primary focus is on Åre Östersund airport, where they plan for parking stands, aircraft charging infrastructure and power supply as well as necessary permits to introduce electric aviation. Åre Östersund Airport has an international test bed within the project Green Flyway. The project is financed by interreg Sweden-Norway and includes the airports Härjedalen Sveg and Røros in Norway. Umeå airport investigates electric aviation both to Vaasa and to Åre Östersund Airport. Visby Airport investigates regular electric flights during 2026 through the airline BRA. Örnsköldsvik Airport tests small electric drones in Åsele and Fredrika (DN, 2022). Aeroklubben in Gothenburg was in September 2020 the first in Sweden to use the approved electric airplane, Pipistrel Velis Electro, for its pilot education and private use (DN, 2022). The plane can fit two people and is driven by two batteries and can fly for approximately one hour.

Moreover, the airlines BRA and SAS work with sustainable aviation. In June 2022, BRA flew the first commercial flight on only biofuel in both engines between Malmö and Stockholm (Neste, 2022). In addition, SAS and the airplane manufacturer, Airbus, announced in 2019 that they will join forces to plan for large scale commercial electric aviation (SAS, 2019).

Selected research projects about electric aviation

RELISH
The project is funded by the Swedish Transport Administration (Trafikverket) with SEK 1.8 million and carried out by VTI (Statens väg- och transportforskningsinstitut). The aim of the project is to conduct a socioeconomic analysis of the possibilities for electric aviation, suggest policies that can support the introduction of electric aviation or contribute to the reduction of possible negative effects. The researchers will perform calculations to determine whether electric aviation can become socioeconomically profitable or not for the years 2030, 2040, 2050. They will also investigate which of today's airports and routes can be used as electric airports during the respective years (VTI, 2021). The project ends in 2023.

Electric aviation transport in Sweden ("Elektrisk Lufttransport i Sverige" – ELISE)
The project ELISE is building an electric aircraft in Sweden. The idea is that electric flights in the future can be used for short distance flights and contribute to reduced carbon dioxide emissions and noise pollutions related to operations. The project is a collaboration between Chalmers University of Technology, KTH – Royal Institute of Technology, Linköping University, Luleå University of Technology, Uppsala University, the Civil Aviation Administration and RISE Viktoria research institute with the aerospace industry and other actors. The project is funded by the Swedish innovation agency, Vinnova, with a project period between 2018-2019.

Swedish sustainable aviation technology and ability assessment towards 2045 (Svenskt hållbart flygteknologi och förmågebedömning mot 2045)
The project is financed by Swedish Energy Agency and is a cooperation project between SAAB, GKN Aerospace Sweden, Chalmers and Linköping University. The goal of the project is to create representative scenarios for traffic needs in Sweden and the Nordic region with an expansion to the European market, and to create aircraft concepts for both the medium (2030-2035) and long-term horizon (2045) from a selection of technologies and aircraft architectures, such as turboprop, turbofan, fuel cell, battery, pressurized or liquid hydrogen, biofuels, etc. The project period was 2021-2022.

Fossil free aviation in the north of Sweden – a pilot study (Fossilfritt flyg i norra Sverige – en genomförandestudie).
The project financed by the Swedish Energy Agency will gather knowledge on how aviation can switch to fossil-free fuels and identify required measures to achieve the national objectives of developing fossil-free aviation. The project includes a pilot study about the route between Umeå Airport and Åre Östersund Airports. Involved in the project is also Swedavia, BioFuel Region, Municipality of Umeå, RISE Research Institutes of Sweden and RISE Processum. The project period was 2021-2022.

Pilot study for sustinable flight connections in the North of Värmland (Förstudie hållbara flygförbindelser i Norra Värmland)
The goal was to prepare the North of Värmland for electric aviation, so it can be implemented as soon as the technology is ready. The study consists of three parts, a cost- and income analysis, a financial part, and a survey targeting the citizens in Torsby municipality. The project was financed by Region Värmland and the final report was delivered in October 2021.

Aerial view of Lofoten in Norway.
Photo: Unsplash.com

6. Concluding remarks

The working paper explores several aspects that make the implementation of electric aviation particularly beneficial for the Nordic region. First, the paper highlights the potential regional benefits of introducing electric aircraft to connect remote areas, where accessibility is challenging due to geographical characteristics of the Nordics, i.e., where mountain chains, fjords, lakes and other bodies of water render access to essential services or nearby urban areas difficult. Second, Nordic countries benefit from a large share of renewable energy supplies, which make the electrification process of aviation easier compared to other contexts. Third, as conventional aircraft constitute a considerable source of CO2 emissions, the transition to electric aviation becomes a crucial point for the achievement of climate goals set both at the national and at the European level.

This working paper has farther documented the current status of electric aviation in the five Nordic countries, showing important differences, challenges and potentials. In Finland, for example, there is a great potential for electric aviation to connect remote areas to improve regional competitiveness and tourism, but significant investments will be needed to introduce necessary infrastructures. In Iceland, there is strong support for electric aviation for both environmental reasons as well as for the need to increase domestic flights to favour regional development. At the same time, an important concern is represented by electrical safety. Indeed, there are "vulnerable" locations for electricity in the country where a holistic approach to electricity management, including an increase of production and strengthening the transmission grid, will be needed. In Norway, the potential that electric aviation might have on reducing environmental impacts is linked to the existence of several short-haul aviation routes in the country, which are used for medical treatments, family and recreational reasons. In this sense, Norway has different starting conditions compared to the other countries and ambitious aims of having all

domestic flights completely electric by 2040. While Sweden is lacking a policy goal specific to electric aviation, the country aims at making both domestic flights and international flights departing from Swedish airports fossil free - by 2030 and by 2045, respectively. As an industry location for both battery development, R&D in the field of electric aviation as well as a mining site for rare earths, Sweden emerged as a central actor with regard to the advancement of electric aviation. In Denmark, electric aviation offers an alternative way of connecting communities that live across the different islands and Jutland. Denmark is furthermore the first country in the world, aiming to integrate electric aircraft in their air force.

These country reports highlight that electric aviation may entail a range of advantages to the region, helping to boost sustainability, connectivity as well as competitiveness in the region.

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