



Nordic
Innovation

NEA - Nordic Network for Electric Aviation

Accelerating the development of electric aviation in the Nordic countries



Project report from the Nordic Network for Electric Aviation (NEA) project 1.0 (2019-2022)

Foreword

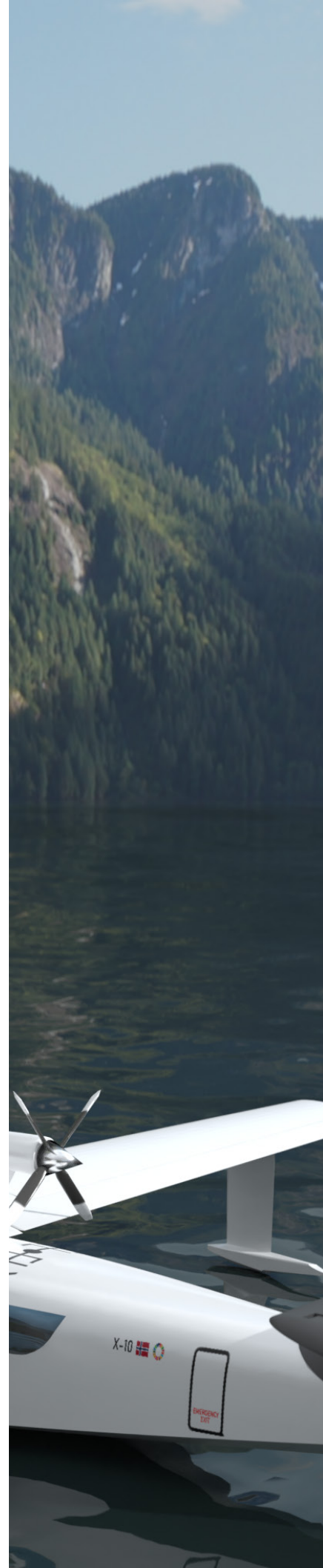
The Nordic Network for Electric Aviation (NEA) is a prime example of what can be achieved through Nordic collaboration, with shared and ambitious goals, an innovative spirit, openness and trust leading the way. Sometimes, we lack confidence in what can be done at the Nordic level, leading us to dwell on small things with limited risk. This is not the case for NEA, nor for any other Nordic project aiming to contribute to making the Nordic region the most sustainable and integrated region in the world by 2030. NEA is a change maker, committed to breaking down barriers. The NEA project, aiming to speed up the introduction of sustainable aviation, reflects the complexity of the green transition and how important it is to work across borders, across value chains and industries, and involving a broad set of actors.

Electric aviation is not only vital to the green transition; there are business opportunities involved in realizing the promise of a new improved aviation industry, which includes benefits for business, individuals, and society. After the launch of NEA in 2019, all the Nordic countries have adopted policies on electric aviation or carbon neutrality. The adoption of the The Global Biodiversity Framework in December 2022 has further strengthened the case for electric aviation.

With NEA, we hope to see cross-border electric flights, not only domestic routes. The symbolic value of this could be enormous. Industry players are taking the lead, making sure that the aircrafts and the infrastructure will be there sooner than many of us thought possible. As the Nordic population are known to be early adopters, there are reasons to believe that NEA will even succeed in nudging us into making the right choices.

Nina Egeli

Head of programme – Nordic Innovation



Introductory remarks from NEA project leaders

"The Nordic Network for Electric Aviation (NEA) is the platform where Nordic actors come together to accelerate the introduction of electric aviation in the Nordic countries." The network was founded on the firm belief that no single actor can transform the aviation industry alone. Electric airplanes are the enabler of sustainable aviation, but the system surrounding their use also needs to evolve. This can only be achieved in close collaboration with progressive partners from technology developers and market actors. NEA provides the foundation for building trust as a facilitator for innovation throughout the aviation ecosystem.

NEA was the first main project to be launched under Nordic Innovation's program Nordic Smart Mobility and Connectivity. From the beginning, Nordic Innovation has been an active partner and helped the industry advance their goals.

Our ambition has been to build a new Nordic electric aviation industry, but also to help advance the building of the new infrastructure needed. Even before we started NEA, we could sense the global visibility of our countries and partners: collaborations between SAS and Airbus, Avinor and EASA, as well as international venture capital investments in Heart Aerospace. The world was already looking at us as the leaders of electric aviation. We wanted to be the Nordic platform for the exchange of ideas between the Nordic countries and the rest of the world.

For Heart Aerospace, the support from the project partners has been incredibly important. The letters of intent that were given from the airlines have been a tangible asset

to put on the table in front of venture capital investors. This support set us apart from other startups and made us succeed in a fiercely competitive environment. The technical advancements facilitated by the project have been key to delivering on the milestones in our aircraft program.

For Elfly Group, NEA has become the platform where we can sit side-by-side with the industrial ecosystem to discuss, learn, and share. We truly appreciate that we together have built a network for electric aviation in the Nordics. This has enabled us to propel our mission of building an all-electric electric seaplane with added confidence.

The Nordic countries are small when they are considered as individual countries. To have a truly global impact, a collaborative project between the Nordic countries would have a much larger reach.

The support from Nordic Innovation with NEA 1.0 has been instrumental for the green transition in aviation. The trust between the partners in the project, and open communication has been inspiring and a guiding start for other funding agencies to strive for. We have proven, and we will prove again, that we are making a difference for our companies, Nordic countries, as well as globally.

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Eric Lithun founder of NEA and Elfly Group

Maria Fiskerud project manager of NEA

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Partners

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Summary

From zero to first movers

Electric aviation is one of many important solutions as part of the transition towards zero and low emission aviation. The aim of NEA, the Nordic Network for Electric Aviation, is to speed up the transition to a sustainable future where Nordic citizens benefit from innovative mobility and connectivity solutions.

During the NEA project, the Nordics have witnessed the emergence of an entirely new electric aviation industry. In 2018, the Norwegian government declared that all short-haul flights should be electric by 2040. Parallel to this declaration, the start-up company Heart Aerospace was founded in Sweden. The Nordics have been trailblazers in setting national targets for sustainable development targets. There are several specific conditions that have made the Nordic countries attractive to the growing electric aviation industry. These conditions include:

- 1.** The geography encourages the development of air transport, as it presents natural obstacles to the construction of road and rail networks. Notable geographic features include the long coastlines in Norway, the abundance of lakes in Finland and Sweden, and the long-stretched archipelagos, mountains and harsh winter climate in the Northern region, the islands of Iceland, Åland, Greenland and the Faroe Islands.
- 2.** The existing energy infrastructure includes access to hydro power, wind, and solar plants, creating the cleanest energy mix in the world. Benefitting from this, electric aviation will leave close to zero climate footprint in the Nordics.

- 3.** The Nordic industries are innovative and focused on export markets, and are able to attract highly skilled talents for research and development.

- 4.** The shared Nordic values encompass language, collaboration, and progress, making the Nordics a shared platform for innovation.

All these circumstances have propelled the Nordic Network for Electric Aviation and have provided the Nordics with a unique industry collaboration.

Value chain collaboration to tackle wicked challenges and act on opportunities

To make electric aviation a reality in the Nordics, key industry players along the entire value chain joined a unique collaboration, NEA, to overcome challenges and to ensure knowledge sharing and speed of implementation. Five founding project partners were soon joined by more key partners from all the Nordic countries, creating the NEA consortium, and funded by Nordic Innovation. Heart Aerospace in collaboration with Elfly have been leading the project, with focus on practical knowledge and commercial access to markets, which has created intense exchange between key industrial players. In this context, the primary focus has been on fixed-wing manned aircraft, even though the concept of electric aviation also embraces electric vertical takeoff and landing (eVTOL) and unmanned aerial systems (UAS). Four wicked challenges were identified as critical for regional electrical aviation in the Nordics:

1. New business models for regional point-to-point connectivity and new business models for new direct routes between the Nordic countries.
2. Charging infrastructure for electric aviation by consolidating national efforts into a unified standard.
3. Weather proofing and ice protection for electric planes in Nordic weather conditions. This objective involved assessing and developing technologies for battery thermal management and de-icing.
4. The fourth challenge was to create a platform for Nordic, European, and global collaboration. The climate challenges and new technical solutions need collaboration to speed up knowledge sharing.

While NEA has generated global interest as a leading example of collaboration, the project suffered when Covid-19 hit society and very much so the aviation industry. Even in these special circumstances, the interaction between project partners produced a series of opportunities and growth. Collaborations on the four project challenges yielded the following results from the project.

Increased connectivity from a point-to-point route system and new business models will change the way people travel

Electric aviation will improve connectivity and Nordic mobility. Realistic scenarios from this project include Iceland's current domestic routes replaced by electric planes, as well as new domestic and cross-border routes across Denmark, Finland, Norway, and Sweden. The route analysis tool and a feasibility calculator, developed by Elfly Group during the project,

indicate a potential for commercially viable transports in the range 50-300 km. The 20 shortest routes in the Nordic market are below 56 km long, making them ideal for operation by the first electric plane (Hellesund, 2022). Examples of potential routes are Oslo-Gothenburg-Copenhagen and Stockholm-Mariehamn-Turku. Other routes studied in the projects include Östersund, Sveg, Røros and Trondheim, as well as ports along the Norwegian coastline.

Cost efficiency in electric aviation is a main driver for new social, environmental, and business opportunities

A main economic driver is the cost efficiency due to reduced energy and maintenance costs associated with electric aircrafts. Cost efficiency in combination with a high initial acquisition cost and short-range regional routes will commercially allow for smaller electric planes for 9 to 19 passengers, and hybrid models as the Heart Aerospace ES-30 for up to 30 passengers. These electric planes will likely be in the air with more frequent departures and offering greater flexibility to travelers.

Three business models related to electric aviation were studied in the project: Air taxi-on-demand with focus on cost and travelers in need of ad-hoc transports. Public Service Obligations (PSO) on routes where commercial operations are not viable today with commuters and rural areas. High-end business service, with a differentiation focus on travelers that can afford higher costs. The combination of connectivity, cost efficiency, and new business models, ensures that electric aviation will provide more options for sustainable travel compared to current industry standards.

The project discussed the challenge of changing consumer behavior, by changing attitudes towards electric aviation. While practical data and experience concerning effective incentive schemes to change consumer attitudes towards electric aviation (and create behavioral change) are still being gathered, we are learning from the introduction of electrical vehicles in Norway. Studies by the project include the NEA initiated try-and-feel electric plane tour through Sweden (Elflygsturnén) in collaboration with Green Airport and Swedish Regional Airports. The tour proved to be successful in creating awareness and attitudes to electric aviation among stakeholders including citizens, local businesses, and politicians.

A standardized charging infrastructure, MCS, is necessary for shared electric operations

A standardized charging infrastructure for electric aviation, locally and globally, is of importance for the aviation industry. The lack of a shared standard proved to be a barrier for both manufacturer and airport investments. For larger planes, like the early Heart ES-19 where there are requirements on sub-30-minute turnaround time, the established CCS2 standard did not suffice. Research started on a Nordic charging standard, to be shared with marine applications. However, by the end of the project another solution was presented, the Megawatt Charging System, MCS standard. NEA partners concluded the MCS to be the best available solution for electric aviation in the Nordics. MCS is intended for commercial vehicles, initially with a primary focus on large trucks and buses, aviation, and marine industry.

One advantage of choosing the MCS is the opportunity to share charging infrastructure at airports and harbors. As an example, the

seaplane being developed by Elfly Group has the potential to share chargers with a ferry at the same location, since the Norwegian ferries also would use MCS.

The project did further study the electricity needs of an airport, using Sweden's Arlanda Airport as a case. Using the case of charging more than 12 aircrafts per hour, it becomes crucial for the airport to study and implement options to expand the electricity capacity. As a result, six electrification strategies were presented (de Kock, 2021).

New partnerships and collaborations are needed to support the electrification of airports

Further collaborative actions are needed to ensure the charging infrastructure at airports, including current fuel distributors and energy companies. To many smaller airports, investments in charging infrastructure provide new opportunities for point-to-point routes. However, there are still questions related to finance and ownership, as well as calculating the needed power capacity.

Electric planes will fly in the harsh Nordic winter climate

Harsh winter conditions are a challenge for operating aircrafts. The project created a solid understanding with partners regarding operator requirements and the development and certification process requirements for electric aircraft. Further, using in-house hardware, Heart Aerospace created a software to run the thermal propeller de-icing system from the aircraft's system battery pack. Project tests showed feasible solutions. From a Nordic perspective, the project concluded that flying in icing conditions, which is common in Nordic winters, will not greatly affect the range of electric aircraft.

The Nordic Network for Electric Aviation propels the collaboration between industry partners

NEA has become a platform for the exchange of knowledge between actors across the aviation industry. There is a true value in Nordic collaboration because of a shared culture of trust, transparency and informality that makes joint innovation a success. This has enabled a strong innovation ecosystem by focusing on mutual interest in electric aviation. The result is inter-personal and professional cross-Nordic networks between project partners Heart Aerospace (Sweden), Elfly Group (Norway), SAS Scandinavian Airlines (Denmark-Sweden), Icelandair (Iceland), SRF - Sveriges Regionala Flygplatser (Sweden), Copenhagen Airports and NISA - Nordic Initiative Sustainable Aviation (Denmark), Avinor (Norway), Green flyway (Sweden-Norway), Swedavia (Sweden), Finavia (Finland), Braathens Regional Airlines (Sweden), Finnair (Finland) and Air Greenland (Greenland).

The NEA partners identified a need for a second phase of the project and NEA 2.0 was launched early 2023, again with Nordic Innovation's support and funding. The next phase will further speed up the implementation of electric aviation in the Nordics.

Introduction

Background

The Nordic Network for Electric Aviation (NEA) stands as a pioneering industry-led project that unites Nordic stakeholders to accelerate the integration of electric aviation in the Nordic countries. Through cross-border collaboration and coordination, NEA has paved the way for the emergence of a dynamic Nordic aviation sector, primed for innovation and sustainability. This foundation is now poised to usher in an era of intra-Nordic and transnational electric aviation routes, endowing the region with the extraordinary gift of genuine true zero-emission aviation, enriching the lives of individuals and bolstering the businesses of the Nordic territories.

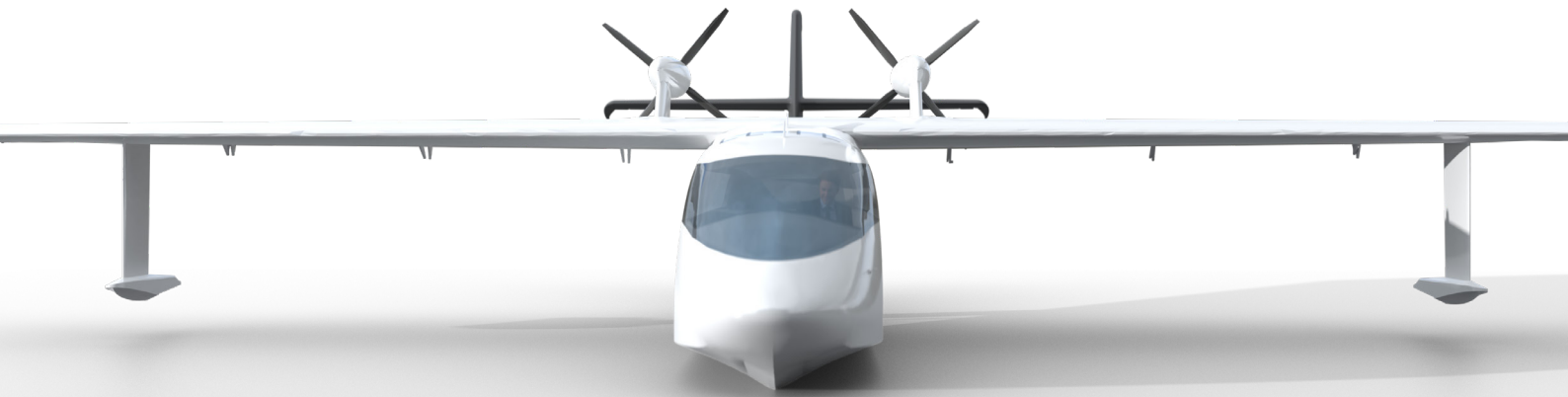
NEA finds its roots in the Nordic Innovation program, Nordic Smart Mobility and Connectivity, marking a significant milestone as the program's inaugural project. The invaluable support and active involvement of Nordic Innovation has been instrumental in NEA's journey.

The project was initiated through the collaborative efforts of Heart Aerospace and Elfly Group. Initially, five organizations from four Nordic countries joined the endeavor: Heart Aerospace (Sweden), Elfly Group (Norway), RISE (Sweden), SAS Scandinavian Airlines (Denmark-Sweden), and Icelandair (Iceland). Subsequently, SRF - Sveriges Regionala Flygplatser (Sweden), Copenhagen Airports (Denmark), Avinor (Norway), Green flyway (Sweden-Norway), Swedavia (Sweden), Finavia (Finland), Braathens Regional Airlines (Sweden), Finnair (Finland), Air Greenland (Greenland), and NISA - Nordic Initiative Sustainable Aviation (Denmark) embraced

the project shortly after the application submission, demonstrating the compelling allure and potential of NEA.

Although the Nordic countries have a substantial airport infrastructure that could connect regions in the Nordics, the current traffic flow tends to be nationalized and centralized around capital cities. Currently, 38% of the routes are domestic, and only 14% of routes are flown cross-border between Nordic countries (Ydersbond, 2020). This lack of regional point-to-point connectivity stems from the current business model of aviation, where the better unit economics of larger planes tend to concentrate air travel in larger hubs. Regional air transportation is a lifeline for many communities in the Nordics which cannot be served in a timely manner by road or rail because of the geography and topography of the region.

The project was also designed from the ongoing transformation of the aviation market, which has been fueled by a series of connected changes including environmental policy and regulations, customer demands, technology shifts and underlying changes in economics and cost structures. All these have an impact on future demands for electric aviation. Frequent comparisons have been made with the carbon emission costs for construction of new mobility networks, including charging infrastructure, EV, railways and climate neutral aviation (WEF, 2022). With a total cost of ownership for commercialisation plus regional growth and resilience, a distributed network of electric aviation could very well be outlined as the most energy efficient way of transportation. The market for electric



aviation explores different value propositions, and their importance varies depending on local structures and business logics. In short the value propositions are described as the Three C:s:

- 1.** Climate, relates to the climate footprint of electric aviation, where operations with close to true zero carbon emissions are possible due to the clean Nordic energy mix.
- 2.** Cost, as in reduced direct operating cost is possible due to the decreased maintenance requirements and increased energy efficiency.
- 3.** Connectivity relates to benefits for people and businesses from a distributed aviation route system. It includes the rebirth of old regional routes and new regional routes, while enabling faster door-to-door travel times.

However, in order to realize the potentials of electric aviation and the Three C:s in the Nordics, a series of challenges faced by the aviation industry need to be addressed. This culminated in the delineation by the project of four primary challenges:

- 1.** Developing innovative business models for regional point-to-point connectivity between Nordic countries and creating novel models for direct routes.

- 2.** Standardizing electric air infrastructure by consolidating national efforts into a unified standard.
- 3.** Advancing aircraft technology tailored to Nordic weather conditions.
- 4.** Establishing a platform for Nordic, European and global collaboration.

The working process throughout the project has been characterized as practical activities related to the four project challenges designated to four work packages. The task to lead the work on new business models and connectivity was assigned to Elfly Group. The work on standardizing charging infrastructure and the work on aircraft technology for winter conditions were assigned to Heart Aerospace, in collaboration with other NEA partners. A team from Heart Aerospace, BRA and Elfly Group, worked on project management and the challenge of establishing NEA. All NEA partners have been involved in different parts of the work packages. Documents and working material were produced primarily for use within and between partner organizations.

Overview of this report

The purpose of this report is to share the findings from the NEA project, and more specifically key insights in the work on the four challenges. This report is based on project documents, and the findings presented have been generated during workshops with project participants and online meetings during Covid-19. In addition, two public NEA reports have been used as sources: Hellesund (2022) for the challenge on new business models and connectivity, and de Kock (2021) for the challenge on Nordic charging infrastructure. Other information, findings and conclusions in this report reflect the shared knowledge and expertise of NEA partners. The conclusions and recommendations were generated during the final project workshop in March 2022.

Chapter 1 introduces the Nordic context for electric aviation. Here, targets for carbon neutral aviation are complemented with national timelines. Electric aviation activities and timelines are further outlined for NEA partner airports and airline companies. A definition of true zero aviation is also included.

Chapter 2 describes how electric aviation contributes to connectivity, as well as potential social, economic and environmental benefits. The chapter discusses project work on new business models for connectivity. Further benefits of electric point-to-point routes in the Nordics are presented, based on range calculations with electric aircrafts.

Chapter 3 outlines specific characteristics of electric aviation as a base for cost efficiency. Outline is derived from NEA working material on business models and research on charging infrastructure.

Chapter 4 presents four of the NEA partners and their contribution to the knowledge of the emerging network; Heart Aerospace, Elfly Group, Fly Greenway and Green Airport/Swedish Regional Airports.

Chapter 5 shares findings related to the project's four challenges, with an emphasis on the charging infrastructure and ice protection of electric aviation. The chapter discusses in depth the need for a standardized charging infrastructure and the introduction of MCS.

Chapter 6 discusses the process to build the Nordic network for electric aviation, and outlines the motives for project partners to contribute to shared industry knowledge. In addition, there's also a discussion on how NEA needs to work on other enablers for a system change in aviation.

Chapter 7 identifies current barriers to electric aviation, outlines partner needs, and provides a short list of policy recommendations.

Climate goals for aviation

Defining true zero emission aviation

Electric aviation needs to be defined relative to existing activities in the aviation industry to reduce the climate footprint. In particular, the attention has been focused on carbon offset activities and measurements. There are also efforts to reduce carbon emissions through the use of sustainable aviation fuel (SAF) in turboprop and jet engines. The concepts of carbon neutral and net zero are being used to describe the effects of carbon offset and the reduction of carbon emissions. In contrast, the climate footprint of electric aviation is primarily derived from the available energy source, plus the battery climate cost. Battery-powered aircraft would eliminate CO₂ and all other in-flight emissions (WEF, 2022). In the Nordics, where a green energy mix would be used to charge the batteries, the full life cycle climate impact of producing and using the electricity would be minimal. Hence, in the Nordics, electric aviation and aircrafts are often referred to as true zero-emission, because they eliminate all CO₂ emissions during flight.

Nordic timelines for carbon neutrality

The Nordic countries all have high ambitions to become more environmentally sustainable. In January 2019, the Nordic Prime ministers signed the "Declaration on Nordic Carbon Neutrality", committing their countries to strengthen cooperation to attain carbon neutrality on a domestic level. The declaration emphasizes the need to decarbonize the transport sector. Timelines differ between countries, but there are ambitious targets.

Norway has been working to reduce aviation emissions through measures that include the introduction of electric and hybrid-electric planes for short-haul flights. The Norwegian air transportation system features short-haul routes connecting airports. It includes several 800-meter-long runways, which are exposed to harsh winter conditions. Currently, there are only a few aircraft that are capable of operating under these conditions. To meet the Norwegian climate commitments by 2050, three goals were defined:

1. Norway will be a driving force and arena for the development, testing, and early implementation of electrified aircraft.
2. By 2030, the first domestic scheduled routes will be operated by electric aircraft.
3. By 2040, all civilian domestic flights in Norway will be operated by electric aircraft, to reduce GHG emissions by at least 80 percent compared with 2020 (the Norwegian Civil Aviation, 2020). A roadmap to achieve the defined goals was presented in 2020 by Avinor (Avinor, 2020).

Denmark has been investing in research and the development of sustainable aviation solutions, which includes biofuels and electric planes. In Denmark, the government has communicated an ambition that there must be a green route by 2025 and set a goal of fossil-free Danish domestic traffic by 2030.

Finland has been supporting research and innovation in sustainable aviation, including support for Finavia to reach net zero operations at their airports.

Iceland has been exploring options for decarbonizing aviation, given its remote location and reliance on air travel. The government and local industry players have been looking into sustainable aviation fuels and other innovative solutions. In 2022, Icelandair announced that it successfully flew a 100% electric airplane with the President of Iceland and the Prime Minister as passengers.

In Sweden, the industry interest group FFT2045 (Fossilfritt Flyg 2045) launched a roadmap in 2021 on how Sweden would reach two targets, all domestic air travel to be fossil-fuel free by 2030, and all international flights departing from Swedish airports by 2045.

Climate goals and timelines for NEA partner airports and airlines

Actors in the aviation industry support national and global climate targets in addition to their own development goals. During a NEA meeting in March 2022, project members described their participation in more than 40 ongoing projects related to electric aviation. Some of them were cross-collaborations for the electrification of airports, while others relate to certification issues like airworthiness. Since there has not been a governmental agency leading the coordination of Nordic or even national efforts, the larger organizations like Avinor and Swedavia have taken the lead to facilitate collaboration and knowledge sharing. In parallel with the Nordic governments' national goals, NEA partners have introduced the following timelines:

Avinor has a vision that all civil domestic aviation in Norway is electrified by 2040. The goal is to become the first market where electric airplanes have a significant market share. These assessments are based on the

possibility that small, fully electric airplanes with limited range are developed for commercial use by 2025. Avinor airports are to have net-zero carbon emissions by 2030.

BRA - Braathens Regional Airlines is a Swedish pioneer in fossil free aviation and has a net zero target by 2030 on domestic routes. BRA was one of the first airlines to sign a letter of support with Heart Aerospace to use electric aircrafts in their operations.

Copenhagen Airport has set ambitious targets to become carbon-neutral by 2050. Copenhagen airport is leading the ALIGHT project with other European partners. The project includes analyses of new propellants. One of the tasks is to analyze and present plans for the aircraft stand of the future. In 2020, the Danish Air Force leased the first electric aircraft in Denmark. The aim was to investigate the possibilities of using electric planes on shorter flights and in the training of future pilots. At the beginning of 2022, NISA and ALIGHT held the first major conference in Denmark concerning the future of aircraft and air mobility. This conference involved many Nordic and international actors. Follow-up initiatives are planned.

Finavia launched a roadmap to carbon neutral airports in 2008, and began to calculate carbon footprint and reduce emissions. Helsinki Airport aimed to achieve carbon neutrality by 2020, a milestone reached in 2017, followed by airports in Lapland 2018 and the rest of regional airports followed in spring 2019. Finavia's carbon-neutral airports will reach net zero emissions in 2025. As part of the roadmap 100% of Helsinki Airport's energy is produced using renewable energy from solar panels and wind power.

Icelandair has set goals for reducing carbon emissions by 2030 and to achieve net zero emissions by 2050. Icelandair is also working to replace older models in its fleet with more fuel-efficient aircraft, and the company is exploring the introduction of sustainable aviation fuels (SAF) into its operations. Icelandair was also one of the first airlines to use the electric Pipistrel aircraft for flight training. In 2021 Icelandair was one of the first airlines to sign a letter of intent with Heart Aerospace and Universal Hydrogen to evaluate the feasibility of using electric and hydrogen-powered aircraft.

Swedavia had a goal of zero CO2 emissions from their own operations by the end of 2020. Emissions decreased 97 % from 2005 to 2019, and the goal was reached in 2020. The reasons for this decrease include enhanced energy efficiency, in parallel with replacing fossil fuels with renewable fuels, using biofuels or renewable district heating.

SAS is moving to a net zero target by the year 2050. In the short term, this is to be achieved using sustainable aviation fuel, and in the longer run through technological developments in hydrogen and electrical aviation. In September 2022, SAS signed a letter of support for NEA partner Heart Aerospace 30-seater ES-30. In June 2023, SAS started to sell passenger tickets for their first electrical flights, to take place in 2028.



Connectivity, and the social, economic, and environmental benefits of electric aviation

Electric aviation is more than a substitute for fossil fuelled aircrafts, as it offers several significant benefits than the aviation industry of today. These benefits can have a substantial impact on various aspects of the aviation industry and the environment. The NEA project report "Business Models for Nordic Electric Aviation" (Hellesund, 2022) provides a comprehensive benefit analysis for consumers, businesses, government, and environment.

The report shows that commercially available air transport by electric aviation is likely to offer new benefits to consumers and businesses.

Businesses will experience four long-term economic benefits:

1. direct (i.e. within the aviation industry);
2. indirect (i.e. related to the supply chain of the industry);
3. induced (i.e. creation of new markets due electric aviation) and
4. catalytic effects (i.e. effects that spread out to other industries that are not related to the aviation value chain).

Governments and society can benefit from the innovation geared by electric aviation. For example, Heart Aerospace rapid growth since its founding in 2018 resulted in a global talent

acquisition and access to leading experts. By investing early in the electric industry, and making it convenient for such actors and stakeholders, governments may fuel a new climate friendly industry.

The environment will benefit via reduced green-house gas emissions in-flight and less noise pollution at and around airports. Electric aviation may also reduce the need to exploit lands for new transports and provide a competitive alternative to railway and road expansions.

Benefits of electric point-to-point routes in the Nordics

As part of the NEA project, Elfly Group developed a route planning tool to analyze possible routes within and across the Nordic countries. The NEA report (Hellesund, 2022) emphasizes that the feasibility of electric aviation depends on technological developments that impact the range of cargo, and the number of passengers the planes can lift— as well as market sizes, and customers' willingness to pay in the future. A key assumption is that, in its initial phase, electric aviation will offer cabins with limited numbers of passengers (9-19-30). This assumption guides research on new routes and more frequent departures. The low operating cost associated with electric aircraft would make this economically viable, while regions would have social and environmental benefits with carbon neutral transports, and greater mobility for labor and businesses.

Other Nordic research projects have gained insights from the work by NEA and outlined route maps for electric aviation. A main underlying principle for these route maps is the commercial development of electric routes in the range of 200 km. Hence, the implementation of the point-to-point system would depend on specific aircraft design and battery capacity.

The other main principles for a point-to-point route system have been the accessibility and time savings, in comparison with other means of transportation such as electric cars, trains or other public transport. Electric aviation would provide bridges for urban islands like Åland and Gotland, and "roads in the sky" for isolated population centers in Norway and Iceland.

In addition, the FAIR project (FAIR, 2022) illustrated the need for electric aviation to strengthen cross-border labor markets between Finland and Sweden. Businesses with high transportation costs, and limited access to skilled labor markets, like Northvolt's battery factory in Skellefteå, would benefit from electric aviation.

The NEA report (Hellesund, 2022) concludes that the new point-to-point route system would depend on the airport charging infrastructure, as well as individual airports' capacity to facilitate electric aviation. While attention is being focused on already existing airports, electric aviation could introduce new airports in areas that today are being overlooked or are not commercially viable with large cabin aircrafts.

Potential routes for electric aviation in the Nordics

To visualize the potential routes for electric aviation, Nordregio conducted an accessibility study in the Nordics (Nordregio, 2022). The routes were limited to 200 km range due to estimated battery capacity of the Heart Aerospace ES-19. The analysis was further limited to routes between rural and urban areas, as well as routes between urban areas that are separated by water.

In the first image In the first figure below, a total of 426 possible routes are visualized, with a degree of urbanization. As can be observed, the map projects routes that are in the 200 km range. This represents a dramatic departure from today's hub-and-spoke and predominant north-south route system. Instead, there's the opportunity for shorter, horizontal, and cross-border routes.

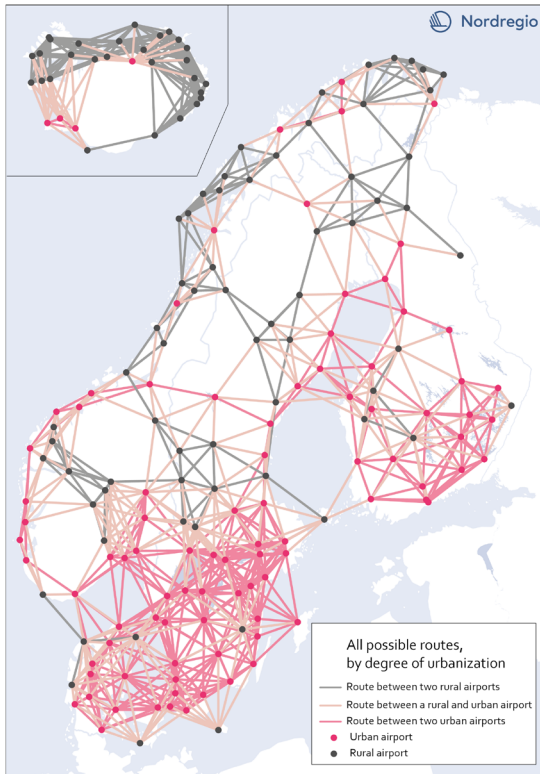


Figure 1



Figure 2

Source: Nordregio, 2022

Source: Nordregio, 2022

To realize the potential of a new route system, Nordregio visualized the reduced travel time compared to other means of transportation. According to their research, there are 203 routes in total that have a significant travel time benefit.

These route maps do not reflect the commercial potential or demand, nor do they represent the socio-economic value. However, the maps are included in this report as an illustration of the potential of electric aviation for regions, where social and labor mobility could create new economic and environmental benefits.

In other words, electric aviation is more than a substitute for fossil fuel, as it creates new opportunities for routes, true zero mobility and new partnerships. As a consequence, the NEA report (Hellesund, 2022) provides an overview of three business models related to electric aviation: air taxi-on-demand with a focus on cost and travelers in need of ad-hoc transportation; PSO with a focus on cost leadership as with commuters and rural areas, and high-end business jet with a differentiated focus on travelers that can afford higher costs.

As with any disruptive technology, it is still too early to conclude what the appropriate business models would be in each specific market. It is for this reason that electric aviation networks play a vital role in sharing skills and expertise, while exploring new benefits in collaboration along the entire aviation value chain.

Cost efficiency and technical benefits of electric aviation

While the focus of NEA in this project has been on manned and fixed wing designed electric aviation, the concept of electric aviation also embraces electric vertical take-off and landing (eVTOL) vehicles. There are many benefits for each of them, and market development is still in an early phase. The main common characteristics for electric aviation include:

Electric Propulsion: Electric aviation relies on electric motors for propulsion instead of traditional internal combustion engines. These motors can be powered by batteries, fuel cells, or other forms of electrical energy storage.

Simplified Mechanical Systems: Electric propulsion systems have fewer moving parts compared to traditional engines, leading to reduced maintenance requirements, and potentially increased reliability.

Battery Technology: Electric aviation relies heavily on advancements in battery technology. Higher energy density, lighter weight, and faster charging capabilities are critical for extending flight ranges and performance.

Charging Infrastructure: Electric aircraft require charging infrastructure for their batteries. This infrastructure needs to be developed at airports and other flight operation sites.

Range Limitations: Current battery technology limits the range of electric aircraft compared to traditional fossil-fuel-powered aircraft.

However, advancements in battery technology are gradually increasing the achievable ranges.

Main benefits of electric aviation

A listing of the benefits from electric aviation would include:

Reduced Carbon Emissions: One of the most compelling advantages of electric aviation is its potential to significantly reduce carbon emissions. Electric aircraft produce little to no direct emissions during flight since they use electric motors powered by batteries, eliminating the reliance on fossil fuels, and reducing greenhouse gas emissions.

Environmental Benefits: Electric aviation contributes to cleaner air quality, reduced local pollution, and a smaller ecological footprint compared to traditional aviation.

Noise Reduction: Electric motors are quieter than traditional combustion engines, leading to reduced noise pollution around airports and urban areas. This characteristic is particularly important for urban air mobility and short-distance flights, as it can mitigate concerns about noise disturbances. However, as with electric cars, noise can still be generated from aerodynamic designs.

Enhanced Safety: Electric motors have fewer parts and operate at lower temperatures than internal combustion engines. This can lead to increased reliability and safety in flight, reducing the risk of mechanical failures and engine fires.

Energy Efficiency: Electric motors are generally more energy-efficient than internal combustion engines. Electric aircraft can take advantage of regenerative braking designs during descent, converting kinetic energy back into electrical energy to recharge batteries.

Cost efficiency of electric aviation

A primary pillar of the business case for electrically powered aircraft is the potential for operational savings by minimizing the variable costs historically tied to aviation operations. Electric aircraft cost reductions are primarily due to

- decreased maintenance requirements,
- increased energy efficiency, and
- lower energy costs.

Electric aircraft have fewer moving parts and require less maintenance compared to traditional internal combustion engine aircraft. This results in lower operating and maintenance costs, making electric aviation more cost-effective in the long run. (Ydersbond, 2020, National Academies of Sciences, Engineering, and Medicine, 2022). A combination of factors lowering operating costs include:

- **Reduced Maintenance Costs:** The maintenance cost for an electric motor is estimated to be around 1% of the maintenance cost for a similar turbo-prop engine.
- **Fewer Operating Expenses:** Electric aircraft do not require complex and expensive aviation fuels, lubricants, or specialized maintenance procedures associated with traditional engines. This could result in lower overall operating expenses
- **Energy Efficiency:** Electric propulsion systems tend to be more energy-efficient than internal combustion engines, which means that a higher percentage of the energy from the fuel or electricity is converted into useful work (thrust). The ratio is about 80% efficiency vs 25% efficiency for a turbo-prop. The increased efficiency can contribute to lower overall energy consumption and operating costs. This is particularly true for regional aviation with short routes, as fuel burn in the take-off and climb stage accounts for a large part. The efficiency of a jet engine increases as its power rises, which is why most aircraft have only two engines. Conversely, the efficiency of electric motors is not dependent on their power. This leads to a new degree of freedom when designing an aircraft, allowing a larger number of smaller propulsors to be mounted along the wings or around the fuselage at locations that maximize the overall efficiency of the propulsion system and minimize the aircraft's drag, known as "distributed propulsion". Such an approach could reduce cruise power consumption and provide extra redundancy in the event of one motor failure, as the additional power requirements can be split over a high number of remaining motors (WEF, 2022).
- **Long-Term Trend:** As battery technology continues to improve and become more affordable, the cost of electric propulsion systems could decrease over time, leading to lower upfront costs for electric aircraft.
- **Regulatory Incentives:** Some regions and governments might offer incentives or subsidies to encourage the adoption of electric aviation due to its environmental benefits. These incentives could further reduce operating costs for operators. (Hellsund, 2022)

Early Nordic pioneers

In the Nordics there has been a growing commercial and public interest in electric aviation, due to activities by manufacturers, airlines, airport operators and from aviation societies.

Early Nordic pioneers in electric aviation took off in 2018. In general, the transformation has been driven by entrepreneurial initiatives in combination with industry needs, ahead of regulatory requirements and governmental programs. The year of 2021 was a milestone as actual orders from airlines ramped up public interest.

Four NEA project partners are presented here with activities performed during the project; Heart Aerospace, Elfly Group, Green Flyway and Green Airport (SRF).

Case 1: Heart Aerospace – a regional electric airplane

Heart Aerospace is based in Gothenburg. Founded in 2018, it is an early pioneer in electric aviation. In 2019, it started NEA in collaboration with other Nordic partners as a way to share knowledge and create markets for electric aviation. Heart's first aircraft design, ES-19, was a fully electric 19-seater presented in 2020. The design immediately gained world-wide attention. During 2021 letters of intent and orders followed from Finnair, United Airlines and Mesa Airlines. The orders of more than 200 planes signaled a breakthrough for the entire electric aviation market. In September 2022, Heart changed focus, to develop an aircraft with reserve-hybrid electric powertrain, with 30 seats, the ES-30. The ES-30 is a regional electric airplane

driven by electric motors powered by batteries. It will have a fully electric zero-emissions range of 200 kilometers, an extended hybrid range of 400 kilometers, all with typical airline reserves. Test flights are estimated to start in 2026. Heart Aerospace has LOIs for about 250 aircraft from several Nordic airlines including SAS, BRA, Air Greenland, Finnair and Icelandair.

Heart Aerospace has played an instrumental role in the emerging electric aviation industry. The company has also created new knowledge with government agencies, regulatory bodies like EASA for aircraft certification, and financial networks. Heart has also attracted talents from all over the world to Gothenburg, and thus creating a company that is able to forge new alliances on a global market.



Heart ES-30 over Åland (Photographer: Heart Aerospace, 2023)

Case 2: Efly Group – an amphibious seaplane for coastal environments

There are currently no electric aircraft types certified for passenger transport, and there are no seaplanes designed to be electric from start. NEA project co-founder Efly Group is working to cover this market opportunity. The company started up in 2018 and is headquartered in Bergen, with a research and development department located in Tønsberg, Norway. Efly Group also distributes Bye Aerospace electric aircraft to the Scandinavian general aviation market. Specific skills are further refined in developing the fastest electric aircraft in the world, as part of a partnership with the Nordic Air Racing Team.

Efly's priorities align with the Norwegian Government's goals to make domestic aviation entirely emission free by 2040. Their electric amphibious seaplane is one of the least nature-invasive means of transporta-

tion. It requires close to no infrastructure to operate, and its batteries are recharged by clean electricity that is produced by the 98 %-renewable Norwegian energy grid.

The business model and airport requirements are different from those of fossil fuel based airports. Efly will operate from city center to city center. Small and flexible sea terminals will facilitate the boarding and unboarding of passengers. Without the need to build complex infrastructure to open a new route, the network can grow in endlessly different ways.

The 9 seat electric aircraft is described as a battery-powered flying boat, able to fly at least 170 km at about 250 kilometers per hour. The travel time on a flight from Bergen to Stavanger would be 60 minutes, compared to four to five hours by car.





Figure 3. Source: Potential routes with an electric seaplane. Illustration from Elfly Group.

Given the country's more than 1000 fjords and 450,000 lakes, most of the Norwegian population lives close to a potential temporary runway. Due to Norway's mountainous profile and the limited connecting infrastructure, the seaplane is a quick, non-intrusive way of transporting people over challenging terrain. Hours spent in a car between small cities could be reduced to minutes.

As Elfly Group, in collaboration with Heart Aerospace, leads the NEA project, the company is involved in all issues related to electric aviation, from airport requirements to electric aircraft design, as well as new business model development.

Case 3: Green Flyway in Røros and Östersund – a test area for electric flights in sub-zero conditions and challenging terrain

NEA partner Green Flyway is a unique Nordic partnership between Norway and Sweden. It is a test arena for electric airplanes, unmanned aerial systems UAS, eVTOL and ground support. The idea is to develop an infrastructure where research and testing can be carried out, both on land and in the air. The research done by Green Flyway also includes the design of charging equipment and airport infrastructure.

Green Flyway explores the potential for regional development enabled by electric aviation. Test flights are executed between Åre Östersund airport and Røros airport with approximately 175 km. This is a large airspace corridor available for testing with minimal interference by other air traffic. The Nordic climate, and the region's challenging mountain terrain, provide Green Flyway a unique test environment compared to similar projects in warmer climates.

A smaller test area, with a focus on research related to energy consumption, storage and transportation is located in Trondheim. All airports in the Green Flyway project are supplied with renewable electricity. The local energy companies, Jämtkraft, in Sweden, and Ren Røros, in Norway, are working in close collaboration with the project. This makes the airports ready to start testing and flying short-haul 9 to 19 seat all-electric and hybrid airplanes.

Östersund and Røros will serve as connection points between several cities and towns in Norway, Sweden, and possibly Finland. On airplanes with less than 20 passenger seats, there is no requirement to pass through the security lines at the airport. Fast and seamless point-to-point travel with zero emission transportation is envisioned as a "green



Illustration from Green Flyway

corridor". These green corridors are expected to create a more flexible customer experience with a minimum of waiting time between arrival at the airport and departure with an electric flight.

Among the critical findings from NEA collaboration in Green Flyway is the generation of new knowledge for energy grid and peak management. Being in harsh winter conditions, the challenges are different, not only for airport considerations but also for the local community. Green Flyway envisions airports that are net energy producers. Equipped with solar parks, they will act as fossil free mobility hubs capable of supporting local public transport and drones. As with other NEA partners, this has led to new alliances for the airport with energy companies, new mobility operators, and intense discussions with government agencies on regulatory issues.



Figure 4. The figure shows relevant locations for the project. Östersund, Sveg, Røros and Trondheim are test arenas in the project. *Illustration from Green Flyway.*

Case 4: Grön Flygplats – the electric aviation tour

In collaboration with the Swedish Regional Airports (SFR), the NEA partner Grön flygplats (Green Airport) works to make Sweden the world's first fossil-free country. Its targets include fossil-free domestic flight by 2030, and a completely fossil-free Swedish flight by 2045.

To create attention to electric aviation, and awareness of the challenges and benefits that lay ahead, NEA initiated an electric aviation tour run by Grön Flygplats in 2021. The tour included stops at regional airports through Sweden using the Pipistrel electric aircraft. The idea was to invite all relevant stakeholders— including local and regional politicians, businesses and local chambers of commerce, citizens, and the media. During the day at each airport, stakeholders lined up to be first-time passengers in an electric

aircraft. Many of the participants said that the experience changed their view on fossil free aviation. In addition, there were workshops and presentations on local needs and opportunities within electric aviation.

Since 2021, the tour has been held on an annual basis. In subsequent iterations, the electric aviation tour (Elflygsturnén) became widely known. To local airports it has become a tool for dialogue with politicians and citizens about the future; for government agencies it has become a forum for compiling information on upcoming regulatory needs; and for the media it has become a story for positive change that is easy to share. As a result, politicians from local and regional levels have started to meet in new forums. Airport managers were also invited to newly formed meetings. The dialogue continues and insights in electric aviation are growing.



Picture from Elflygsturnén, 2021 (Photo by Maria Fiskerud)

A project with four wicked challenges for electric aviation

The project started with seemingly four very distinct challenges of charging infrastructure, de-icing, and business models, plus the need for an aviation industry network. In reality, and especially in emerging technologies, there is an accumulated effect of knowledge that is being shared. Thus, the project partners' own networks have proved invaluable for NEA's success, and the exploration of what is needed but not yet known in electric aviation.

The continuous work on business models in NEA has already been mentioned in this report. Findings from three challenges are here presented in detail, and the fourth on building the industry network in the next chapter.

New business models and connectivity

New business models are essential for electric aviation between Nordic countries and regional point-to-point connectivity. The result could be increased mobility with reduced carbon footprint across the borders of the Nordic countries. Hence, NEA is working to explore new business models for regional point-to-point connectivity between Nordic countries.

Activities in the project included analysis of potential route systems and a development of a feasibility calculator by Elfly Group, overview of business models that are adaptable by electric aircraft operators, proposals on governmental incentive schemes, and impact modeling.

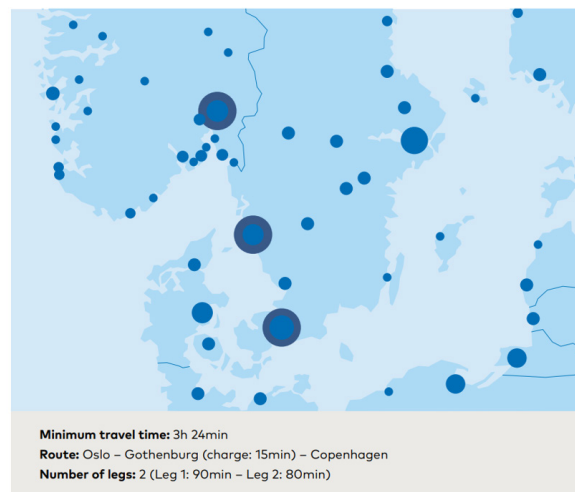


Figure 5. Output from our route planning tool showing the fastest route between Oslo and Copenhagen with an aircraft with a range of 400 km. Illustration from NEA report, Hellesund, 2022.

Examples of the consequences from electric aviation include the profitability resulting from operators serving the air transport market reducing the need for public spending, through no longer needing to pay airlines to provide Public Service Obligations (PSO) on routes where commercial operations are not viable, as well as significant reductions of greenhouse gas emissions from the aviation industry, and increased connectivity. (Hellesund, 2022)



*The picture shows the ES-19 powertrain demonstrator charging with a CC2 charger, at the Heart Aerospace hangar.
Source: Heart Aerospace*

Solutions for a standardized electric air infrastructure in the Nordic countries

A standardized infrastructure for electric aviation, locally and globally, is of importance for the aviation industry. When the project was initiated, the lack of a shared standard was a barrier for the planning as well as implementation of electric aviation. It has therefore been of utmost interest to work on a solution that benefits the Nordic market and infrastructure. To achieve this, the project conducted a series of activities, including a projective mapping of several charging infrastructures; analysis of the charging infrastructure, and finally a recommendation to start analyzing the use of MCS. As a result there is a shared repository of knowledge, which can be used as a first step towards a Nordic standard for electric aviation charging infrastructure. This includes a better understanding of a timeline for standardization in relation to aircraft development and different airport requirements.

The standardization of charging infrastructure was researched extensively. At the beginning of the project, very few standards for aircraft charging were available. The ones that were focused on small batteries which were not made for aviation propulsion. For example the well-established CCS2 standard, provided sufficient power for smaller aircraft and longer turn-around-times. For larger aircraft, like the early Heart ES-19, where there are requirements on sub-30-minute turn-around time, the CCS2 standard did not suffice. The MCS, Megawatt Charging System, standard was developed later in the project. This allows for full charging using one connector. If it had been developed earlier, there would have been time to build a MCS demonstrator, which would have been close to what will eventually be applied as a standard. By the end of the project, the MCS standard was officially released, and will be applied in future electric planes.

By choosing the MCS for charging trucks, aviation and marine vehicles, there is an opportunity to share charging infrastructure at airports and harbors. As an example, the seaplane being developed by Efly Group has the potential to share a charger with a sea ferry at the same location, since the Norwegian ferries also would use MCS.

The project work also included Copenhagen Airport collaborating with NISA in the ALIGHT-project with initiatives on SAF, and other propulsions and energy- and sustainability solutions for airports. A central part of the project was to develop solutions for the "Aircraft stand of the future". In terms of content, this work is in many ways linked to NEA, and the experience from NEA has been gained partly through participation in the project, as well as by virtue of individuals' participation in knowledge activities and workshops organized in Denmark. The work with the future aircraft stand will continue and networks and information will also in the future be coordinated and developed in benefit for NEA and ALIGHT.

The report "Stockholm Arlanda Airport's Opportunity to Become the First Hub Handling Battery-Electric Aircraft" (de Cock, 2021) is another project outcome. The report calls attention to the impact electric aviation will have on airport design. It investigates different aspects that will affect an airport's long-term planning, from future stands for electric aviation to the power output needed for charging electric aviation. Six strategies for managing airport electricity needs are outlined in the report.

1. Enhancing the electricity grid: The airport is dependent on the Stockholm area grid, which currently faces capacity challenges.

Surveys held by Swedavia energy shows that expansion until an extra demand of 10 MW is possible, but after that, new lines and cables need to be built.

2. Battery storage: When the electricity grid cannot be enhanced, energy storage is required. This storage would increase cost, but also capacity. Energy storage through batteries is typically used for a 24-hour period to store excess generation.

3. Solar panels: Solar panels could support the electricity needs of the airport in terms of own production. It is typically used to support the grid and in combination with battery electricity storage, to store excess generation by solar panels. While several Nordic airports, like Copenhagen and Kalmar airport, have already implemented solar parks, Swedish regulations prevented Stockholm Arlanda Airport from locating solar parks near the airport. These regulations include EMC regulations on the disturbance for the radio communication systems and the regulations on solar reflections, causing disturbance for the pilots' vision in the surrounding area of the airport.

4. Vehicle to Grid: Vehicle to grid designs support the grid by transferring excess power from the electric car to the grid.

5. Peak shaving: An opportunity to lower the required grid demand, which is an important factor given the challenges the electricity grid is having, with increasing demand not only from the electric aircraft, but also from households, transportation and the airport's facilities, and ground equipment.

6. Power management: A comprehensive solution for peak demand involves decreasing

the aircraft's required power at the same time. From this energy management perspective, the ability for all electric aircraft to charge at full power at the same time would be limited. Airports would be required to map the time in which the aircraft needs to be charged— according to turnaround times of the aircraft shown by the arrival and departure times, as well as the charge needed, according to the aircraft's next destination shown by the flight data.

As can be noted, there are several issues related to the electric aviation charging infrastructure that are not isolated to airports. Rather the charging infrastructure is related to a combination of interests and stakeholders, among current fuel distributors, energy companies, and airports. The potential roles and responsibilities for the charging infrastructure include ownership, maintenance, finance and billing, safety and security, long-term stability, and resilience. Some airports, like Kalmar Airport, have solutions with a local energy company, while others, like Östersund Airport, envision the future of the airport as a collaborative power grid. Power grid management becomes an issue not only for local airport needs, but indeed for Nordic regional infrastructure when an electric aviation cross-border route system comes into play. In this case, it becomes necessary to explore the consequences of airports' need or access to a charging infrastructure as part of a shared climate neutral mobility.

Weather proofing and ice protection of electric aviation

The specific Nordic geo-economic characteristics are ideal for development of electric aviation, as sub-zero winter climate is a

challenge for battery and charging infrastructure. In addition, icing of aircrafts is a common Nordic challenge. Hence, the project challenge was to develop aircraft technology for Nordic weather conditions.

NEA mobilized global expertise on the challenge, including knowledge scouting, overview of technological developments, and assessing weather proofing for the Nordic conditions. The specific challenge has been to scout the market for energy efficient solutions for de-icing, which is a particular concern for electric aviation. The project was successful in engaging potential suppliers with suitable technologies.

Heart Aerospace has further worked on weather proofing for the ES-19 and later aircraft, catering to the Nordic conditions. The interest from possible suppliers for de-icing systems has been overwhelming, making the selection of suppliers technically and commercially viable. During the project Heart Aerospace hosted several calls and meetings with project partners regarding operator requirements and to increase understanding of the development and certification process requirements for electric aircraft.

Heart Aerospace has been performing tests of the propeller de-icing systems. Using in-house hardware, Heart Aerospace created software to run the thermal propeller de-icing system from the aircraft's system battery pack. The propellers on Heart's aircraft have thermal de-icing boots installed on the propeller leading edges. By running a current through these, the propeller leading edges heat up, and the ice is melted. Project tests showed that at -10C, less than 0.5kW of power is needed to heat the leading edges to

+30C. These tests were done without any propeller spinning. From a Nordic perspective, this means that flying in icing conditions which is common in Nordic winters will not affect range to a large extent. However, there are other areas besides the propellers— including the probes, the windshield, and the wing leading edges— that also require de-icing systems. Heart is now working with suppliers to address these areas as well. Preliminary results show that the aircraft range will only be affected about 1-2% by running the systems required from weatherproofing.



Illustration of icing on an aircraft wing. Source: NASA GRC

Building the Nordic network for electric aviation

Testimonials from project partners add the creation and exchange of new knowledge as one main result on their behalf. The learnings include the following testimonials.

Green flyway: "The most important Nordic Added value of NEA was the creation of the Nordic arena for exchange of knowledge between actors from the entire Nordic air transport industry. This made it possible to empower electric air transport as a real game changer based upon the differences as well as commonalities within the Nordic countries. For example, the fact that the challenges are so much larger when it comes to addressing national as well as cross-Nordic connectivity needs in Greenland, Iceland and Norway compared to Denmark, Finland, and Sweden. There are also industrial differences, where Sweden has a tradition of development and production of aircraft oriented towards the regional short haul market."

Finnair: "NEA has cross-functionally brought together airlines, suppliers, developers, airports, and other key actors in aviation. The network has catalyzed the understanding of and collaboration around electric aviation, building on the Nordic heritage of innovation, transparency, and responsibility for the environment."

Heart Aerospace: "The openness in discussions is truly an asset of the Nordics. Collaborative innovation requires such openness, which is why we have come so far in our common understanding of what needs to be

done. Having that established will help us in coming projects to generate a Nordic standard, from airports, airspace, operators, and aircraft developers, that can act as a reference case for other countries to follow." Swedavia: "NEA has created a platform for different stakeholders to interact and exchange questions and ideas about how to push the electrification of aviation forward. By increasing our common understanding of the future, we have been able to better pinpoint the questions to be asked and to formulate better approaches to solve those questions. Swedavia, as airport operator, had the opportunity to exchange information about the role of an airport in the electrification of aircrafts and inform about the need for standardization of ground handling equipment or harmonization of charging procedures."

SRF, Swedish Regional Airports/Green Airport: "It is important to show that we in the Nordic region are at the forefront of developments when it comes to the introduction of electric aviation and that we are working together to speed up the process even more."

Moving from challenges at hand to enabling system change

Shifting to more sustainable mobility with a net zero climate footprint is a complex task. It requires a holistic understanding of the different system layers that constitute the world where people live and move, while also expanding on science and practical knowledge in the very details that build technology. These knowledge layers are mutually dependent to create transformation.



NEA Hangar Days in Gothenburg, two-day workshop. All project members are not visible in the photo, March 22-23, 2022. (Photo by Anders Lundkvist)

In short, the project changed as participants gained knowledge over time. This process has evolved through three stages:

First: The very practical challenges identified by NEA partners as most urgent ones were the starting points for the project. Four wicked challenges for electric aviation required skills and global expertise that could not be isolated to a single company or institute, as they needed collaboration and shared knowledge. In many ways this pragmatic and practical approach has been the guiding methodology for the project and partners.

Second: When NEA partners brought expertise from different knowledge domains along the aviation value chain, these were seen as vertical domains. However, the wicked challenges needed to be worked on in a horizontal collaboration, as the electric

aviation challenges required new types of knowledge. In NEA, the networks that constitute personal and professional relationships are of crucial importance. These require both time and patience to build and nurture. Professionals found the peer-to-peer and the relevant people to connect with in the partner network. As such NEA developed into a collaborative mind from the aviation industry, leveraging shared findings to speed up the potential for implementation. Examples on issues include airport capacity, and battery hazards, where in-depth knowledge can be found in one stakeholder, but not in others. Hence, vertical and holistic integration were necessary to understand the full transformation of the value chain.

Third: While working on identified challenges it also became evident that solutions for electric aviation needed to be open-ended,

as they are often complex and require multidimensional intervention. Solutions for charging infrastructure related to several dimensions that needed to be explored in the context of the emerging electric aviation. These are related to specific system enablers that need to be in place for the transformation to happen. NEA identified the following critical enablers; financial models for investing in the infrastructure, viable business models for electric aviation, induced market demand from the benefits of electric aviation, industrial capacity and know-how, while government policies and

re-regulations are critical to accommodate the transformation. To conclude, NEA played an integrative role when many small projects tended to generate valuable, but fragmented knowledge.

For an individual company it would not be possible to act on these system enablers, but in collaboration and in new value constellations there is an opportunity to tackle challenges that eventually will lead to the implementation of electric aviation and reduced climate footprints.

NEA project compressed conclusion

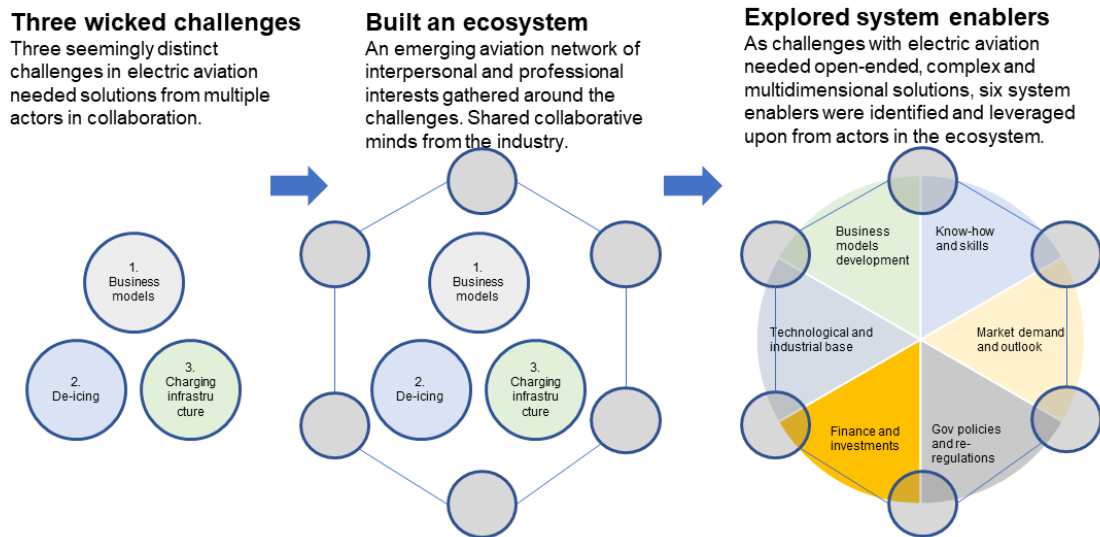


Figure 6. Illustration of project process from specific challenges to a knowledge creating network of industry actors and professionals.

Barriers, needs and recommendations.

Every shift to new technology faces challenges to change behavior, as well as barriers in regulations and systems integration. The same goes for electric aviation, where NEA partners have identified specific barriers for change in their domain.

- 1.** Business models that would accommodate short route electric aviation are still missing. NEA's report (Hellesund, 2022) on connectivity and business models provides an overview of the specific challenges and opportunities, including route and planning models for electrical aviation. Incentive programs for electric aviation and public procurement of true zero aviation routes are advocated for in the report.
- 2.** National targets and roadmaps to true zero mobility are welcomed. Multiple actors in the Nordics and the world share the same challenges, yet, there is no shared political Nordic timeline related to electric aviation. In the best case, new timelines would align on a Nordic and European level, to provide a shared ground for the development of electric aviation. In addition, the transformation needs to be met with appropriate funding and practical activities to be realized.
- 3.** Regulations are not in tune with the speed of technological developments. This is not unusual, but parts of this can be explained by an overall lack of human resources and experts, not only related to electric aviation, but also within relevant agencies and departments. This was partly due to the pandemic, but the developments in technology, society and climate challenges put even more demand on expertise. Specific needs identified by NEA include air space control and certification processes.
- 4.** Missing sustainable financial frameworks and guiding principles for investments in electric aviation is another restriction. As fossil fuelled aircrafts become more expensive to operate due to carbon emissions, this will favor electric and hydrogen aviation. Of specific interest is the EU Zero Carbon Act, and the introduction of carbon pricing and taxation, which will eventually change the market dynamic for electric aviation. There is a need to explore the financial market mechanisms that will support aviation as an essential part of carbon neutral mobility in society.
- 5.** For many smaller airports, electric aviation is a matter of survival, as they would find opportunities beyond the current hub-and-spoke model with an alternative to large cabin aircrafts. However, this would also require investments in an electrical charging infrastructure, where ownership and operation management need to meet the specific safety and security requirements of airports. Some airports may also develop on-site power generation to reduce their vulnerability and dependency, increase their operational resiliency, and lower their carbon footprint. Governmental incentive schemes and interventions would need to be considered in order to speed up the implementation.

6. As noted, the Nordics share unique conditions for electric aviation. A green energy mix in combination with a potentially new route system also puts focus on grid and power management on a Nordic scale. This new market needs to be further addressed in respect to resilience and regional growth.

7. There is an evident need for coordinating the efforts in electric aviation on a Nordic level, and thus speeding up the implementation and practical use for the benefit of Nordic communities. An objective should be the realization of Nordic cross-border electric aviation, in a time frame no less than 2030.

8. An important lesson learned is that the Nordic collaborative culture works, and that is an essential part of the Nordic success in electric aviation. Climate challenges need open solutions with deeply integrated technologies. For that purpose, professional networks like NEA share new knowledge, create new markets for fossil free mobility, and have the potential to push regulations to change for more rapid implementation.

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