FAIR PROMOTES ELECTRIC AVIATION

FINAL REPORT

HOW TO ACCELERATE THE IMPLEMENTATION OF ELECTRIC REGIONAL AVIATION

EUROPEAN UNION

Interreg Botnia-Atlantica

European Regional Development Fund

KVARKENRÅDET MERENKURKUN NEUVOSTO

ABOUT FAIR

The aim of this report is to explain why electric aviation should capture our interest and describe how the region should proceed in order to enable electrified regional air travel.

FAIR (Finding Innovations to Accelerate Implementation of Electric Regional Aviation) is a two-year project to support the early and efficient commercialization of electric regional flying in the Kvarken-Nordland region.

The Kvarken-Nordland region consists of the counties of Ostrobothnia, Southern Ostrobothnia and Central Ostrobothnia in Finland, the County of Västerbotten and the municipality of Örnsköldsvik in Sweden and the County of Nordland in Norway.

FAIR is preparing the Kvarken-Nordland region for early implementation of electric aviation. The project increases the knowledge base on electric aviation, investigates possibilities and surveys both needs and required technical investments.

PROJECT PARTNERS

region västerbotten

UMEÅ UNIVERSITET

BioFuel Region

RISE Research Institutes of Sweden

MidtSkandia

Vaasan yliopisto UNIVERSITY OF VAASA

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1.WELCOME TO KVARKEN-NORDLAND AND THE FUTURE OF AVIATION!

Kvarken-Nordland is a unique region in northern Europe, spanning the north of Finland, Sweden and Norway. It encompasses a growing, healthy and well-educated population, a distinctive culture, interesting cities, a lively countryside in a stunning natural environment with mountainous areas as well as attractive coastlines. The region offers tourism destinations with extensive recreational opportunities. There are abundant resources, ranging from those used in building, transportation and industry, to those used to generate clean electricity. Emerging throughout the region are new industries related to electrification and the transition to a low-emission society, which supplement the existing strong industrial and commercial base. The character of the region means that it is well suited to fostering tightly-knit international cross-border relations and intraregional collaboration, building on mutual projects and initiatives and promoting knowledge-sharing. All these features make the region attractive in an international context.

However, the apparently boundless potential for expansion in this northern region is currently limited by a lack of the interconnectivity needed to further enhance support for existing and emerging industries, services and overall societal development. The major challenges faced by the region include long travel times and the underdeveloped east-west communications that are typical of Northern Europe.

Figure 1. Electric aviation has the potential to connect everything that is happening in the Kvarken-Nordland region in a fast and sustainable way.

FAIR PROMOTES ELECTRIC AVIATION

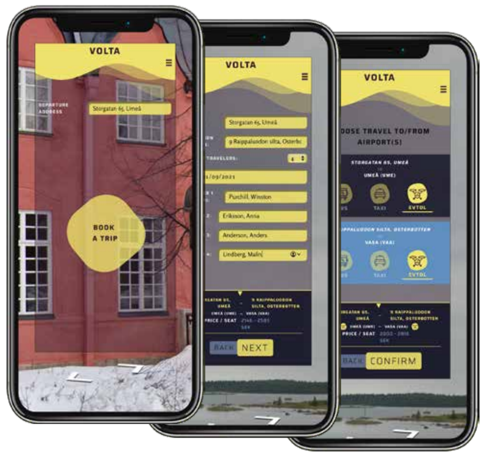
Electric aviation is advancing rapidly. New regional-range electric aircraft will reach the market in just a few years' time, a development that has the potential to extend, deepen and increase the accessibility of the Kvarken-Nordland region and unlock its true potential. The potential for rapid travel, zero operational emissions and lower operating costs makes electric aviation a promising technology. The Kvarken-Nordland region is already a pioneer when it comes to electric aviation, with smaller electric aircraft already being tested in the region. The real impact, however, will come when electric passenger air traffic starts.

Aviation is in a new era of rapid change and new solutions to our demand for airborne communication are not far away in the future. Let us fast-forward to 2030 and imagine four different future scenarios:

Meet Tone. She wakes up in the morning and receives a notification from the Volta app[1] about her upcoming trip from Lovund, the beautiful island on the Nordland coast where she lives, to Skellefteå where she works as an aircraft battery engineer. She packs her backpack, locks the house, and walks down the street. After a short stroll, she reaches a vertiport that has recently been constructed to enable quick connections to the mainland. Soon, a soft buzzing sound quickly grows louder. A small electric aircraft approaches and lands vertically.[2] Tone boards and is quickly in the air and on her way to the airport. She sends a few short emails en route. At the airport, she is dropped just outside the entrance and walks in to board her electric flight to her workplace in Sweden.

[1] For a visual demonstration, visit: https://fair-volta.ri.se

[2] What could future regional electric aviation sound like? The FAIR Soundscape is exploring how close can we get to experiencing an electric flight. It is about making the abstract and futurist idea of electric aviation something you can sense. It is developed to boost imagination of what travelling can be like when electric aviation is implemented in the region. For an auditory experience, visit: https://fair-soundscape.ri.se



FAIR Volta is a booking website for the imaginary airline Volta, specialised in regional electric air travel in the Kvarken region.

Meet Frida. After finishing their class at the University of Vaasa on a fine Friday, she and two friends use scooter shares to travel to the airport and board an affordable electric plane that will take them straight to the ski slopes at Hemavan. They simply could not resist a hostel's offer to students of an attractive weekend stay, skis included. After arriving on Friday night, they will have two full days of skiing before flying back on Sunday evening, in time for the lecture on Monday at 8:00.

Meet Christoffel. He is an expat from the Netherlands and now that remote working has become the norm, he is pondering his next move. He has fond memories of a semester abroad at Umeå University and the booming development in Vaasa in recent years has attracted his attention. The electric aviation network might just make Västerbotten the perfect place for his work as a consultant on the green transition; he can reach any part of Kvarken-Nordland using same-day return flights!

Meet Juha, a nurse from Finland. He was keen to work in Sandnessjøen, Norway. He was lured by attractive working conditions but was unsure whether the arrangement would work, given his shared custody arrangement and desire to keep his inherited house in the countryside at Seinäjoki. Electric regional aviation helped him find a solution. He flies to and fro once a week for back-to-back shifts and has managed to combine both aspirations. One week he is at home spending valuable time with his children, and during the other week he is busy pursuing a rewarding career and gaining international experience.

Although these glimpses into the near future are not yet a reality, they serve to show where we may be heading. We have embarked on a journey into the future of aviation!

2. WHAT IS ELECTRIC AVIATION?

Electrification of the transport sector is gaining momentum and aviation is no exception. An electric aircraft is, simply put, an aircraft with an electric engine instead of a jet engine. The electric aircraft currently being developed range from smaller vertical take-off and landing aircraft for a few passengers, to more traditionally designed passenger aircraft for regional operations. These types of aircraft will be available on the market in just a few years' time.

2.1. Electric aircraft

A whole range of different aircraft powered by electric engines are under rapid development. One example is the certified electric powered aircraft from the Slovenian company Pipistrel - the Velis Electro. It is a two-seat light aircraft primarily intended as a trainer and was licensed by EASA in 2020. Electric aircraft designed for commercial passenger use are on their way and within a couple of years they will be ready for take-off.[3]

Several different types of electric aircraft are currently under development, ranging from conventionally designed planes to electric vertical take-off and landing (eVTOL) aircraft. The first generation of electric aeroplanes, expected to hit the market in the mid-2020s, will be smaller planes such as the Eviation Alice with 9 seats and 800 km range or the Heart ES-19 with 19 seats and 400 km range. Furthermore, several start-ups are developing eVTOL models with up to five seats and operational ranges of up to 250 km. Interesting examples include Lilium, Volocopter and Joby. Both electric aeroplanes and eVTOLs have also generated interest in freight transportation.

Given the maximum number of passengers and operational ranges of the aircraft under development, it is obvious that the target application for the first generation of electric aircraft will primarily be local and regional air mobility. For longer flights, other solutions for lowering the carbon footprint will have to be relied on, such as Sustainable Aviation Fuels (SAF) and hydrogen. Both offer higher energy density than batteries. Transatlantic journeys with electric aeroplanes are a long way from reality, but electric powered regional flights are just a few steps away.

2.2. Energy carriers

The development of electric aircraft is possible thanks to the major improvements in battery technology during recent decades. The cost of lithium-ion batteries fell by nearly 90% between 2010 and 2020, while the energy density offered by batteries has improved dramatically during the same period (Figure 2).

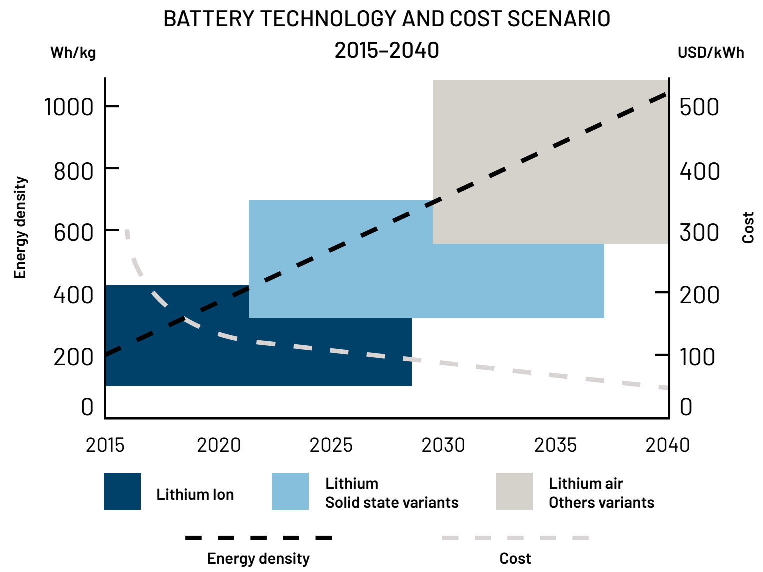


Figure 2. The assumed development of the energy density and cost for different types of lithium-ion batteries between 2015 and 2040.[4]

[3] Smedberg et al. (2021). *Electric Aviation. Technology overview.* https://www.kvarken.org/wp-content/uploads/2021/06/Electric_aviation_2021_technology_overview.pdf

[4] Reimers, J.O. (2018). *Introduction of Electric Aviation in Norway, Feasibility study by Green Future AS.* p. 20.

This is related to the general developments in the electrification of the transport sector, which are pushing battery technology forward, in terms of both production volumes and rising research and development expenditure. This will enable development of more cost-effective options with higher energy densities, leading in turn to lower costs and increased range.

However, the batteries currently available have limitations. Compared to jet fuel, the energy density in lithium-ion batteries is significantly lower and this affects the specifications for electric aeroplanes. The result is that the first-generation of electric aeroplanes will mainly be focused on regional aviation. More energy-efficient aircraft designs, paired with continued improvements in battery technology, can enable better performance. But, if electric aircraft specifications are to be significantly improved, new types of batteries need to be developed.

The next generation of batteries, solid-state batteries, will be able to store approximately twice as much energy as lithium-ion batteries. This will double aircraft range. Another future battery technology is lithium-air batteries, whose energy storage potential is almost three times higher than lithium-ion batteries. However, the development of the new generations of batteries is still at an early stage, making predictions uncertain.

Hydrogen fuel cells are another potential energy carrier for powering electric engines. A fuel cell generates electrical energy through an electrochemical reaction, fuelled by hydrogen and oxygen, where water is the only emission. A challenge is that water emissions at high altitudes can impact the climate due to increased cloud formation. Hydrogen is in its gaseous phase at room temperature. It has three times higher energy density per kg than jet fuel, but it has a low energy density measured by volume. This makes storage and transportation of hydrogen very space-intensive, as it requires about 4 times more space than jet fuel with the same energy content.[5] As fuel cells are not able to produce enough power for lift-off, they must be supplemented by a battery. The range offered by hydrogen fuel cell aircraft will be longer than for battery-driven electric aircraft, but will still be shorter than for conventional jet engines.

2.3. Charging infrastructure

Charging electric aircraft batteries will require new infrastructure at airports and vertiports (eVTOL heliports). There are relatively few airports and aeroplanes compared to the vast road network and number of road vehicles, which suggests that the need for investment in charging points for the electrification of aviation will be smaller in comparison.

Airlines generally favour short turn-around times at airports, for which fast charging will be required. Enabling fast charging of aeroplanes with big battery packs will require a large amount of power. Heart Aerospace has stated charging times of about half an hour with a 1 MW charger to prepare the plane for its next mission.

Most airports will need to provide simultaneous charging for more than one aeroplane at a time, which will require adequate grid capacity. In order to understand the kind of chargers to install and the grid capacity required, the number of planes that will be charging simultaneously, and how fast they need to

[5] Smedberg et al. (2021). *Electric Aviation. Technology overview.* https://www.kvarken.org/wp-content/uploads/2021/06/Electric_aviation_2021_technology_overview.pdf

charge, will need to be analysed. The time required for charging depends on the battery capacity, the state of charge, and the power output of the charger.

When the aircraft can stay longer on the ground, for instance overnight, slow charging with a lower capacity requirement is possible. Battery backup is another option, whereby battery packs can be slow charged from the grid and then used for fast charging of the aircraft.

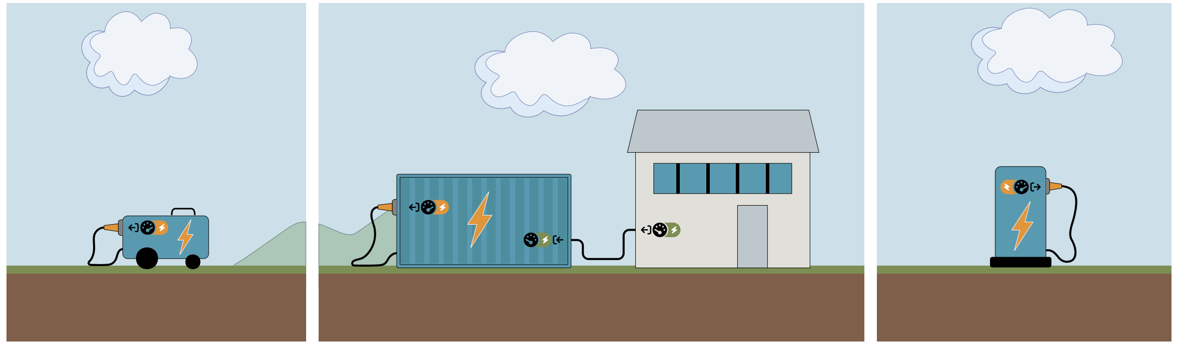


Figure 3. Visualisation of different kind of chargers - mobile charger, battery pack and stationary charger.

2.3.1. Regional example

To help us understand the charging infrastructure requirement, we have simulated a fictional electric air route in the region. It runs from Mo i Rana via Hemavan, Lycksele and Skellefteå to Kokkola. The simulation is based on the 9-seater Eviation Alice (Figure 4). Based on specifications stated on the Eviation website, we have estimated a cruising speed of 407 km/h, battery capacity of 820 kWh, 2.75 hours of flight time including reserve and 1280 kW maximum power.[6]

Figure 4. The 9-seater electric aircraft Eviation Alice. Photo: Eviation.

[6] Eviation (2022). https://www.eviation.co/aircraft/#alice-specifications Accessed 31 January 2022.

We found that the stated range makes it possible to fly between Mo i Rana and Skellefteå without charging (see Table 1). With 700 kW or more of charging power at the airports, turnaround times of 30 minutes or less will be possible. It is worth noting that the estimated range is based on theoretical calculations. In real-world operations, both range and charging speed will be affected by weather conditions.

We have carried out further calculations using different routes and a different aeroplane - the 19-seater Heart Aerospace. The results can be found in the report "Electric aviation 2022. Regional prerequisites for electrical aviation".[7] It is important to note that due to its shorter range, the Heart ES-19 needs to charge more often and will be unable to achieve the longest stretches of the region. However, it has greater passenger capacity than the Eviation Alice.

Table 1. The charging effect and charging time for the Eviation Alice along the fictional route Mo i Rana-Hemavan-Lycksele-Skellefteå-Kokkola. SOC = State of Charge.

City	Start Mo i Rana	Stop 1 Hemavan	Stop 2 Lycksele	Stop 3 Skellefteå	Stop 4 Kokkola
Distance, km	0	70	220	110	150
Time of flight, min	0	10	32	16	22
Charging power at airport, kW	700	700	700	1000	700
Charging time at tarmac, min	-	0	6	12	30
SOC after travel, %		89%	66%	60%	67%
SOC after recharging, %		89%	74%	84%	100%

3. WHY ELECTRIC AVIATION?

Electric aviation appears to offer increased accessibility, lower emissions and lower costs in comparison with fossil fuelled aviation. In general, electric solutions may be a way to provide new and appealing specifications for aeroplanes and other aircraft, thus opening up new possibilities for transporting people and freight in situations where communication is weak at present and an airborne solution is too costly to be considered.

[7] Smedberg, A., et al. (2022). *Electric aviation 2022 – Regional prerequisites for electrical aviation.* https://www.kvarken.org/wp-content/uploads/2022/06/FAIR_Regional_Rapport_._FINAL-VERSION.pdf

3.1. Increased accessibility

Accessibility can be defined as how easy it is to reach different destinations. It is determined by a combination of land use (i.e., location of destinations), features of the transport system and the characteristics of the travellers. All these factors must be analysed to fully understand how electric aviation can change travel patterns between different destinations, different groups of people and different individuals. In this report, we have focused on the transport system and the possible role of electric aviation in increasing accessibility for the population of the Kvarken-Nordland region.

Aviation often offers the fastest way to travel from one place to another, especially over large distances. Aviation therefore has a large market share for journeys in excess of 600 km. However, the first-generation electric aircraft may also offer competitive travel times over shorter distances, thus improving local and regional accessibility to cities and businesses and creating new job opportunities. Universities, hospitals, theatres, leisure facilities, tourist destinations etc. will also benefit.

For shorter trips, the travel time from door to door is often a key factor when the mode of transportation is chosen. For this reason, the car is the dominant mode of transport for short trips. A large proportion of journeys up to 800 km are also made by car. The car provides short transfer times and easy baggage handling. It also has the advantage of offering departure without waiting time. The logic behind public transportation is to gather people for a shared journey. Buses, trains, ferries and aeroplanes thus have schedules for departure and arrival, so journeys often involve waiting times. Generally, public transport also involves a longer transfer time to and from the bus stop, station or airport. Over longer distances, the transfer and waiting times associated with rail and aviation may be compensated for by their faster speed and reduced cost, due to returns to scale.[8]

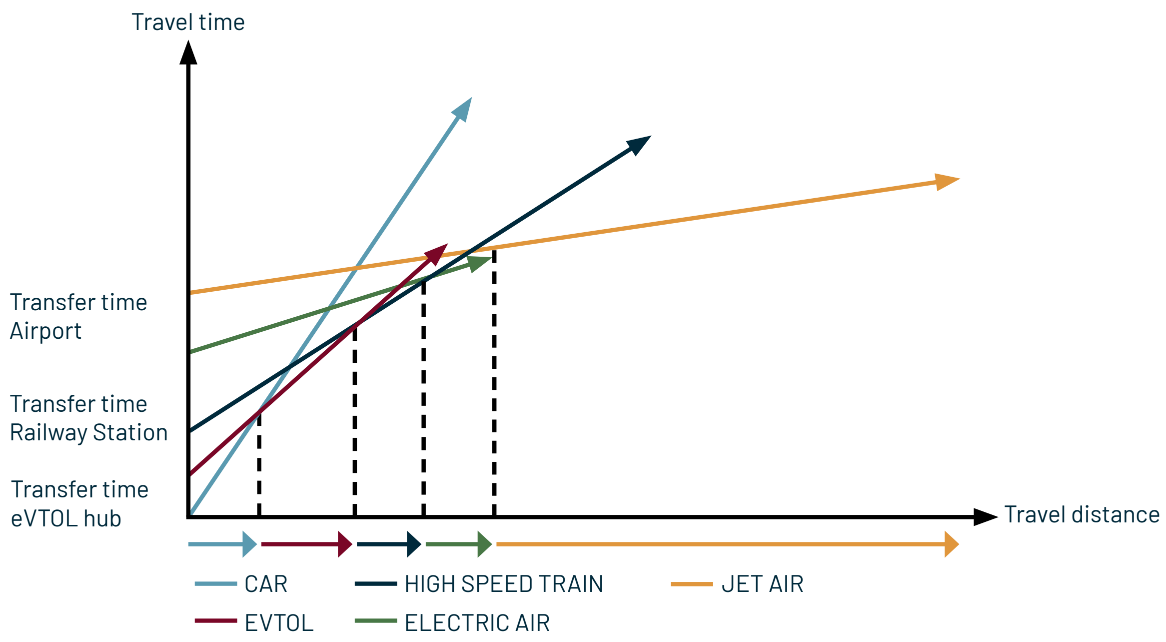


Figure 5. Door-to-door travel time for car, high-speed rail, electric aeroplane, eVTOL and jet air with their market segment over distances.

[8] Westin, L. (2021). *Towards electric aviation in the Kvarken region.* https://www.kvarken.org/wp-content/uploads/2021/08/Westin-2021-FAIR-Electric-aviation-CERUM-70-202138.pdf

First-generation electric aircraft will carry only a few passengers in small machines and this could lead to less time spent on boarding and ground handling. Such aircraft may also be attracted to airports located closer to residential, recreational and working areas, thereby shortening transfer time.

As far as we can see at present, the maximum range of a direct flight with an electric aircraft will be constrained by battery capacity. Hence, jet aircraft will compete with electric aircraft over longer distances, in the same way as jet aircraft currently outperform rail. Since there will be journey distances where rail, electric aviation, and to some extent and for some travellers, cars and buses compete with one another, it will be important for society to take into consideration the full costs and benefits of the different modes before investments in fixed infrastructure are made. For routes where there is no land-based communication, such as over straits, seas and mountainous areas, electric aviation should be very competitive.

An eVTOL aircraft may offer transportation capabilities that lie in between an aeroplane and a helicopter. Its advantages may come to rival those of a car or a coach. It only needs a vertiport to land and take-off, and a vertiport requires much less land than an airport. A vertiport can thus be integrated into denser urban environments and in the future eVTOLs may compete with both cars and buses over short to medium distances. They may operate almost like taxis and offer commuters a time-efficient and flexible alternative for travelling between home, office and airport.

Electric aeroplanes and eVTOLs seem to be capable of reducing travel times and offering increased accessibility in some situations. In order to maximise the benefits of electrified aviation for both society and individuals, it will be important to empower all potential travellers in ways that make it possible for as many people as possible to share the benefits of increased regional accessibility.

3.2. Low environmental impact

One of the main advantages of electric aircraft is their environmental performance. As with all electric transport modes, electric aircraft produce zero operational emissions. This means that no local emissions are created that can adversely affect the health of people living close to airports. It also means that the global warming effects of high-altitude emissions produced by jet aircraft can be avoided. There will still be non-operational emissions, such as emissions from producing the aircraft, the batteries and producing the energy used for charging. We have estimated the life-cycle climate impact of electric aviation and compared it to other transport modes (figure 6). The overall climate impact will be considerably lower than for jet aircraft and will also be lower than for most other transport modes. The climate impact will be fully comparable with that of electric trains.

The operational sustainability of electric aircraft, as with electric trains and electric cars, depends on how the electricity is produced. In a life-cycle analysis for an electric aircraft, it is noticeable that the largest part of the climate impact per passenger kilometre depends on how the electricity is produced. This becomes especially clear when the EU average electricity mix (281 g CO_2/kWh) is compared with the Nordic electricity mix (91 g CO_2/kWh).[9] Progressively cleaner Nordic electricity production thus makes our region ideal for introducing electric aircraft, from a sustainability perspective.

[9] European environmental agency (2021). "Greenhouse gas emission intensity of electricity generation in Europe — European Environment Agency." https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-3/ Accessed 13 December 2021.; Sandgren, A.M. and Nilsson, J. (2021). *Emissionsfaktor för nordisk elmix med hänsyn till import och export, SMED Svenska MiljöEmissionsData. SMED Rapport Nr 4 2021.*

The second largest contribution to climate emissions per passenger kilometre during the life cycle comes from battery production and maintenance. That means that ongoing investment in cleaner battery production and recycling in the Kvarken-Nordland region make an important contribution, as we pursue our efforts to reach truly zero emissions from regional aviation.

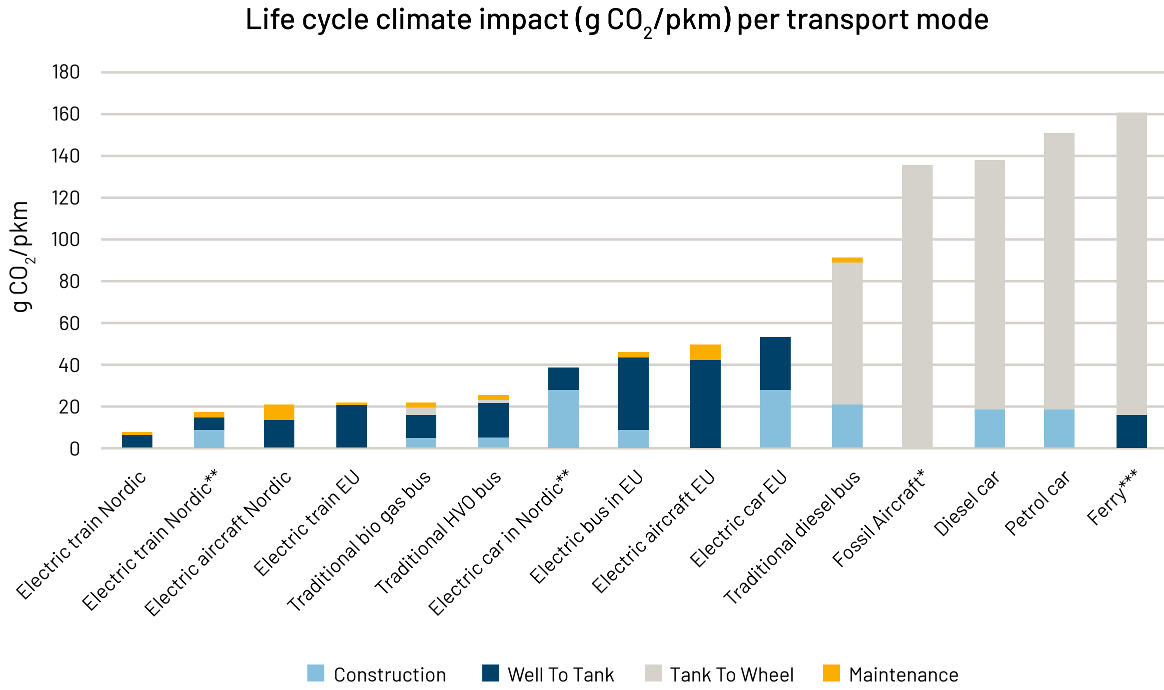


Figure 6. Life cycle climate impact of different transport modes. A report detailing the methodology and assumptions behind these results is to be published soon via https://www.kvarken.org/en/project/fair/
* Maintenance not included.
** The climate impact from electricity production is modified so the production equals Nordic energy mix. Emission factor for electric production assumed to be 91 gCO_2/kWh.
*** Construction and maintenance not included. Tank to wheel based on ferries between Stockholm and Finland.

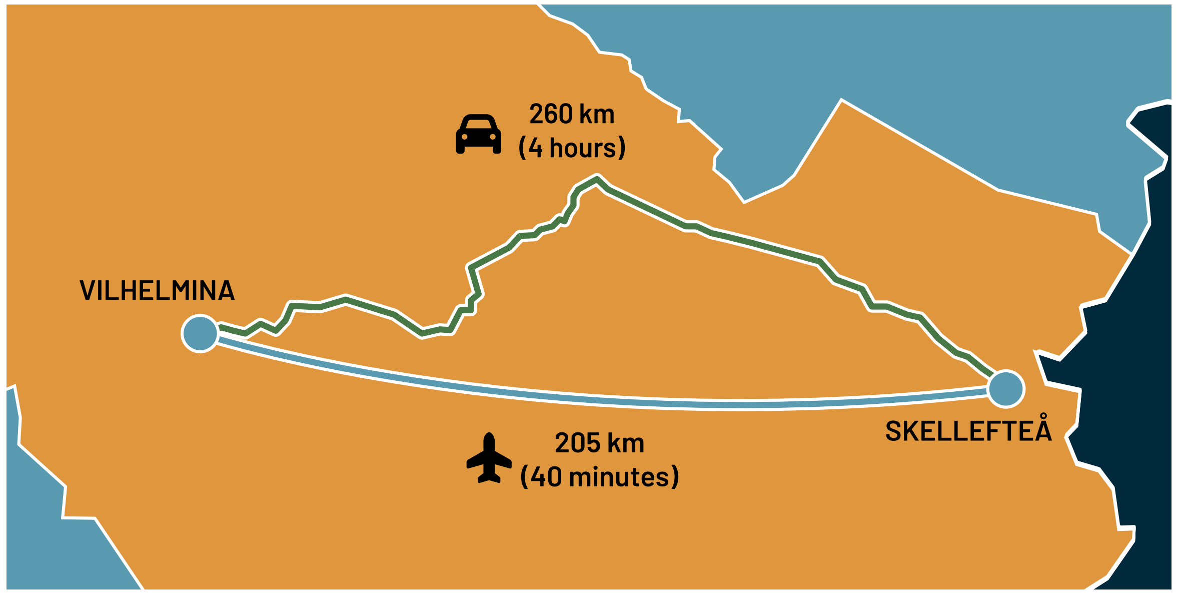


Figure 7. When discussing emissions per passenger kilometre, it is also important to note that the number of kilometres travelled from A to B is almost always lower for aviation than for land-based transport modes.

Electric aviation also affects noise levels. The engine noise is considerably lower than that of jet engines. Still, it is important to remember that the propellers also produce noise. Electric aircraft will thus not be completely quiet, but initial experiences with electric aircraft seem to indicate significantly lower overall noise levels.

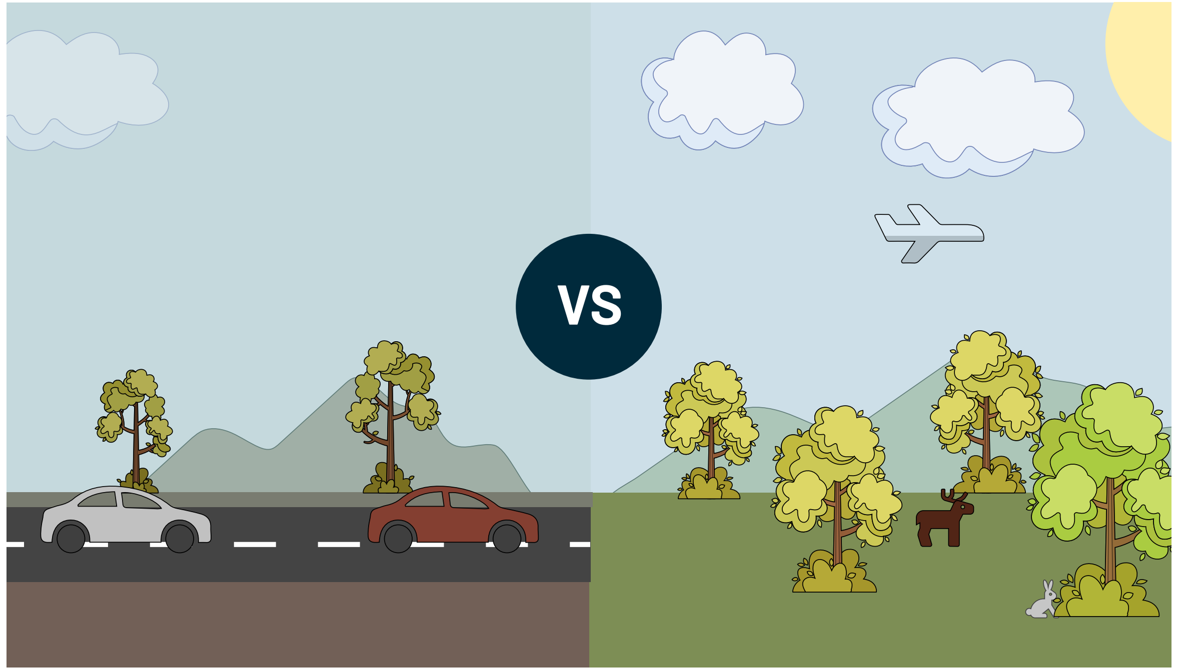


Figure 8. Air travel requires far less ground infrastructure than land based travel modes.

One often overlooked factor in environmental comparisons of different transport modes is the impact of the transport infrastructure itself. The building and maintenance of roads and railways demands considerable energy and resources, with attendant climate emissions. Building land transport infrastructure also has an impact on nature and biodiversity, since new roads and railways both take up considerable space and they cut through the landscape, resulting in barrier effects for humans, animals and plants.

3.3. Lower costs

One of the main advantages of electric aviation is said to be its cost-efficiency compared to conventional aircraft. Advocates of electric aviation maintain that the lower costs will be enough to make regional routes profitable, thus changing the way we travel in the future.

For airlines operating a certain route, switching to electric aeroplanes will directly affect the operating costs for items such as fuel and maintenance. The fuel cost of an electric aircraft is a function of energy efficiency and charging cost. Electric engines are more efficient than jet engines, which implies that the energy consumption of an electric aircraft will be lower compared to a similar-sized conventional aircraft. Slow charging is available at a low cost, while fast charging can be more expensive due to the need for more power output. During the spring of 2022, fast charging of electric vehicles costs about 0.5 EUR/kWh in the Nordic countries.

Maintenance costs relate to securing the airworthiness of an aircraft. There are several regularly scheduled maintenance checks that need to be performed at certain intervals of time or usage.

Since electric motors are cheaper, have fewer moving parts and produces less vibration compared to internal combustion engines, most manufacturers expect lower costs for maintenance of electric aircraft. Heart Aerospace expects the maintenance costs for its engines to be 90% lower than for turboprop engines. However, it is unclear what the cost of maintaining the batteries will be.

Another cost item that can differ between electric and conventional aeroplanes is the cost of purchasing/leasing and owning an aircraft. Generally, new technology implies smaller production volumes and in turn lower returns to scale, which can lead to higher prices. Thus, at an early stage, high capital cost may be a challenge. However, the price tag for upcoming electric aircraft models is still uncertain. The Eviation Alice 9-seater aircraft has reportedly been priced at $4 million per plane.[10] This would make the Eviation Alice less expensive than similar-sized conventional aircraft. Heart Aerospace doesn't disclose the price of its ES-19 yet, but some sources indicate a price of $8.8 million per plane[11], which would make it more expensive than similar-sized conventional planes.

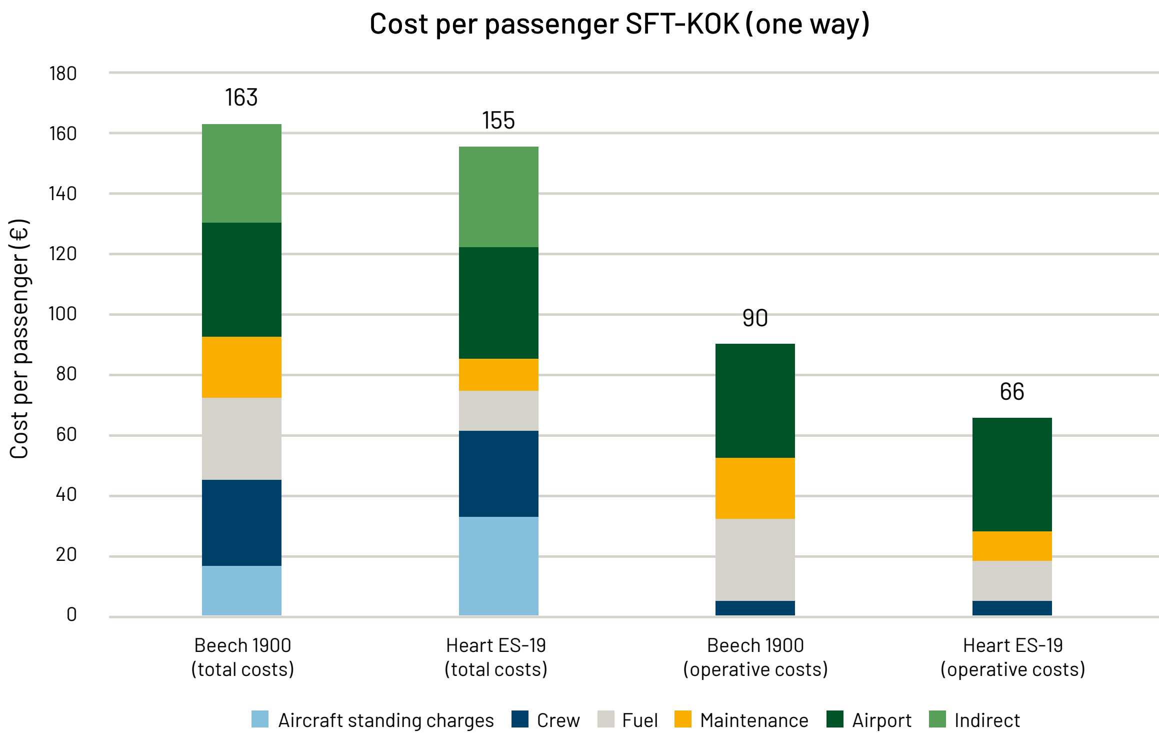


Figure 9. Comparison of costs per passenger for the route Skellefteå (SFT) to Kokkola-Pietarsaari (KOK). Beech 1900 represents a conventional 19-seater aircraft, while the Heart ES-19 is an electric aircraft under development. This example has been calculated using RDC Apex and the following assumptions: 50% load factor, Jet A1 0,7 EUR/l, charging cost 0,5 EUR/kWh, electric aircraft 50% maintenance cost, electric aircraft 2x aircraft standing charges.

According to calculations done by the FAIR project, on a regional route between Skellefteå in Sweden and Kokkola-Pietarsaari in Finland, the cost per passenger can be lowered by 5% by switching from jet propulsion to electric (provided that the assumptions about electric aviation costs are correct). Lower fuel and maintenance costs outweigh higher ownership costs in our analysis. If we isolate the operating

[10] Narishkin, A. and Appolonia, A. (2020). "Inside a $4 million electric plane, the first full-size, all-electric passenger aircraft in the world". Business Insider. https://www.businessinsider.com/inside-alice-first-full-size-passenger-electric-plane-eviation-2020-10?r=US&IR=T Accessed 30 August 2022.

[11] Alcock, C. (2020). "Heart Unveils Electric Propulsion System for ES-19 Airliner". AIN Online. https://www.ainonline.com/aviation-news/air-transport/2020-09-23/heart-unveils-electric-propulsion-system-es-19-airliner Accessed 30 August 2022.

costs, the effect of electric aviation is more visible. In this case, electric aviation can result in 27% lower operating costs compared to a conventional aircraft. This means that the marginal cost of using an electric aeroplane is lower than for a conventional aircraft, which in turn provides an incentive to achieve high utilisation of the aircraft.

Given our assumptions, we see economic potential for airlines in moving away from jet fuel and towards electric aircraft for existing regional routes. If the cost reductions are big enough to enable previously unprofitable routes to become profitable, the focus will then turn to a more difficult issue – whether it will be feasible to establish entirely new routes. The answer to this trickier question will be determined by the overall demand for regional air traffic.

4. REGIONAL AVIATION IN KVARKEN-NORDLAND

Electric aviation is in a rapid state of development and has the potential to connect the Kvarken-Nordland region in a sustainable and cost-effective way. But in order to understand the role that electric aviation may play in the region, we first need to gain a better understanding of the routes that are available in the region today.

4.1. Air routes in Kvarken-Nordland region

International cross-border regional aviation has a long history in the Kvarken-Nordland region. The first flight over the Kvarken Strait was made between Umeå and Vaasa as early as in 1918.[12] Since then, there has been a whole range of different airlines operating routes between Finland, Sweden, and Norway, with Finnair as the most consistent operator. In recent years it has become more difficult for airlines to offer regular cross-border traffic. However, during the spring 2022, intensive work has been carried out in order in order to establish a new, scheduled flight route between Skellefteå Airport (SFT) and Kokkola-Pietarsaari Airport (KOK). Operations started August 15th 2022.

Apart from the lack of regular international cross-border traffic, there is also a lack of domestic regional air routes within the region in Finland and Sweden. The route Umeå-Östersund is the only scheduled route in the Swedish part of the region that does not have Arlanda as its final destination. The route is subject to public procurement and is currently operated by Jonair.

Contrary to this, in the county of Nordland, and in northern Norway generally, there is a quite extensive regional network of airports and scheduled air services. This may be explained by the natural geographical conditions of northern Norway, where the mountains and fjords separate the centres of population from one another, making other modes of transport non-competitive. Here, natural barriers tend to make infrastructure investments in rail and road rather costly by comparison.

[12] Read more about the history of aviation in: "FAIR Infosheet #6. Aviation in the Kvarken region - a short history and some lessons learned". https://www.kvarken.org/wp-content/uploads/2022/06/FAIR-Infosheet-nr-6.pdf

However, the explanation may also lie in differences in priorities between countries. The Ministry of Transport in Norway purchases scheduled air services. Public Service Obligation routes (PSO-routes) apply in areas where the quality of transport is poor, and where an appropriate scheduled air service cannot be established on commercial terms. The regional routes in Nordland are all operated by Widerøe. In Sweden the national transport administration instead procures intraregional bus services over quite extensive distances, between destinations where aviation would offer drastically reduced travel times.

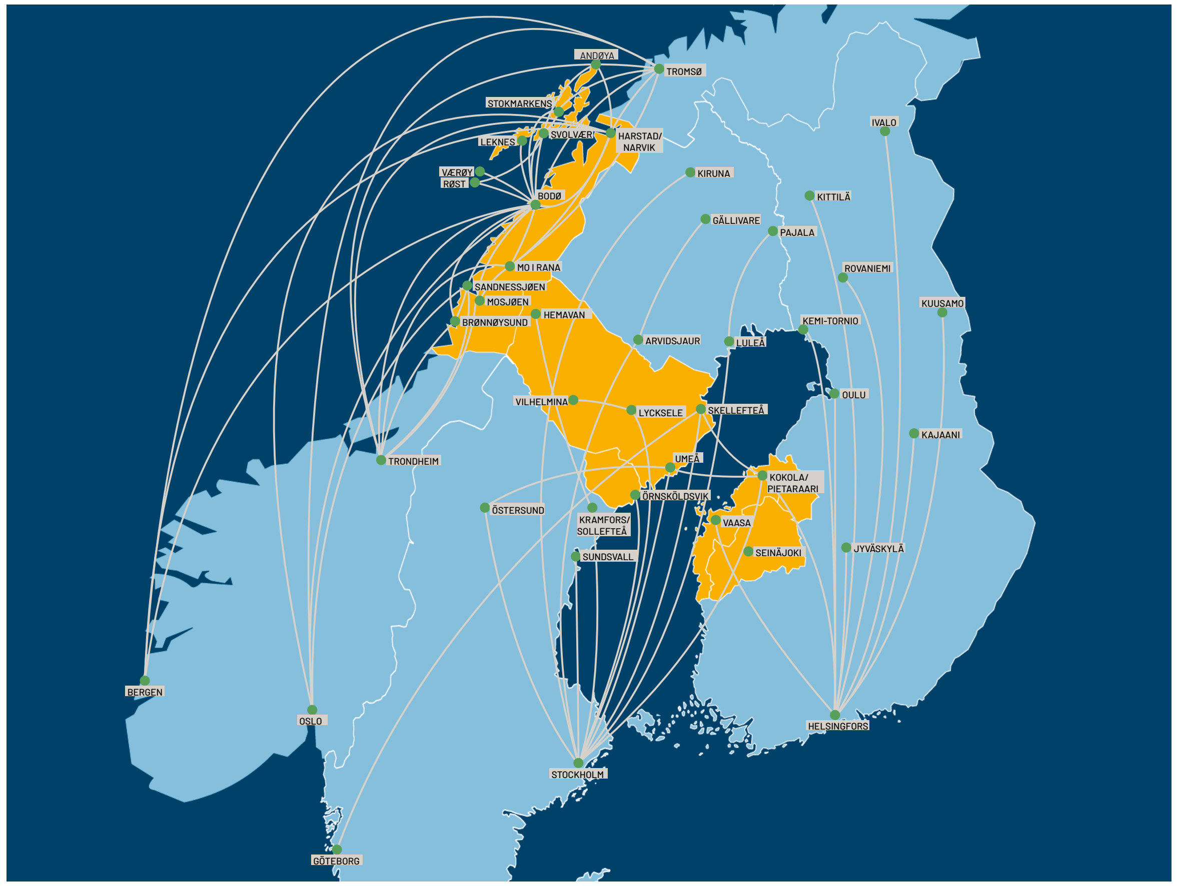


Figure 10. Air routes operating the Kvarken-Nordland region. This map is a representation of air routes in the region as of August 2022.

The PSO system in all three countries is administered by national transport agencies. Decisions about which routes to procure are generally based on a set of accessibility criteria suggested by the national transport administration. These criteria tend to promote connections between the regions and the national capital, rather than internal connectivity within the three countries' extensive northern regions. Consideration is generally not given to the possible societal and cost-effectiveness benefits of creating international cross-border transport connections. The regional public transport authorities on the other hand, may well be more interested in providing such intraregional or international cross-border connections, but they are generally not allowed to procure air services under the current legislation and decision-making framework in Sweden and Norway. In Finland this is possible, as exemplified by the procurement made by the City of Pori.

4.2. Airports of the Kvarken-Nordland region

Airports will play a crucial role in enabling electric aviation. There are 20 airports with regular passenger traffic in the Kvarken-Nordland region. Eleven of these are Norwegian, six Swedish and three are located in Finland. In Norway all airports are owned by Avinor. In Sweden one airport is owned by Swedavia (Umeå Airport) while the remaining five are owned by municipalities. In Finland, Finavia owns and operates two airports, while one is privately owned (Seinäjoki Airport).

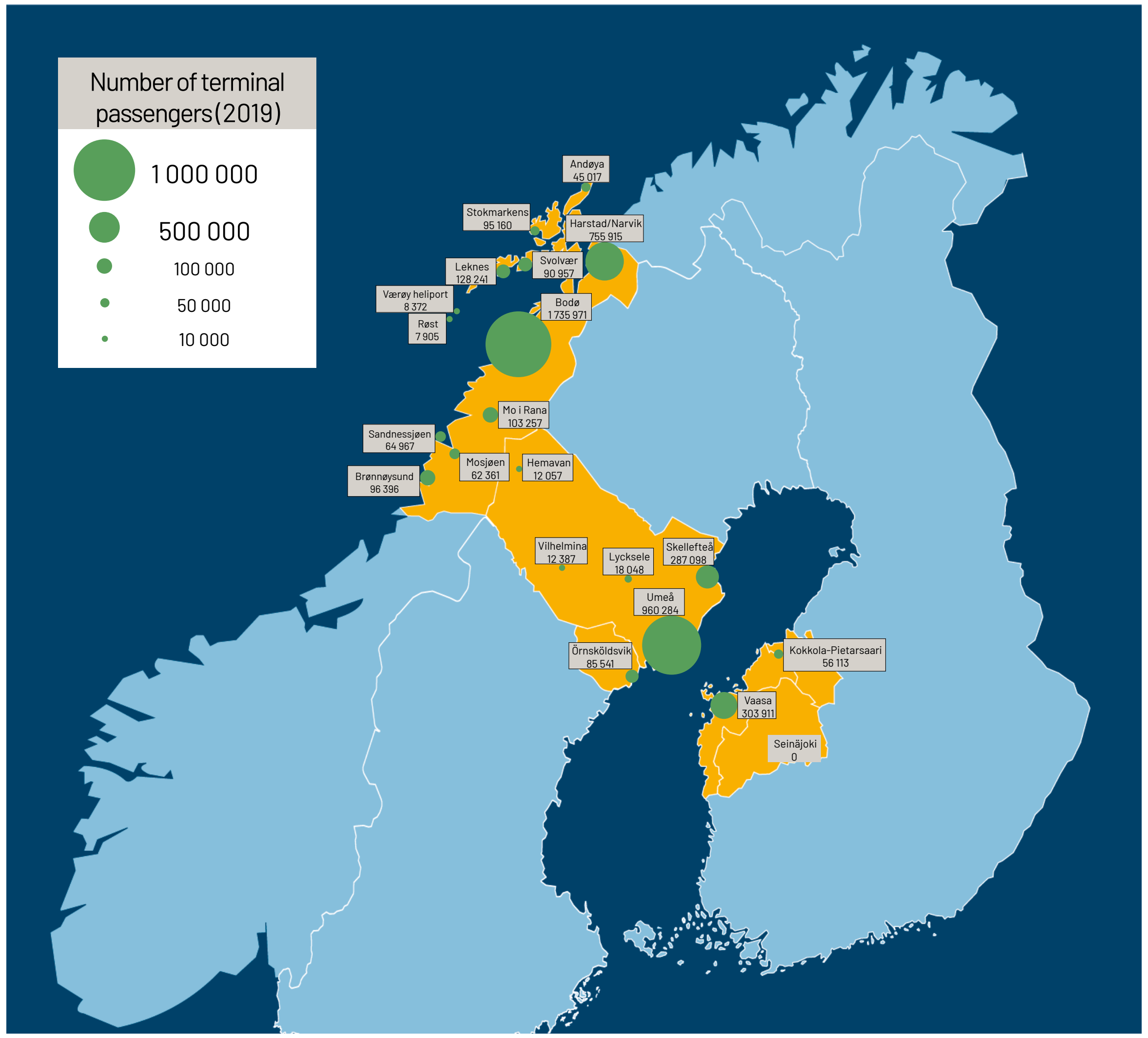


Figure 11. Airports of the Kvarken-Nordland region.

Several examples of innovative electric aviation processes are already to be found in the region and the airports are important partners in these projects. Skellefteå Airport has already installed a 1 MW connection point for chargers airside, which has enabled the establishment of Green Flight Academy, a unique flight school using Pipistrel Velis Electro trainers. Furthermore, Skellefteå is also planning a new vertiport and the introduction of an eVTOL route between the airport and the Northvolt Ett Gigafactory. Seinäjoki Airport will in the near future become a droneport for the British-Bulgarian company Dronamics, which aims to conduct unmanned cargo transport flights throughout Europe. The Civil Aviation Administration's LFV Aviation Research Center (LARC) is located at Örnsköldvik Airport. At LARC, tests of automated and electrified airport service vehicles and drones are conducted, with the aim of establishing safe and cost-efficient airport operations.

The 20 airports in the region have different prerequisites for electrification. There are differences in grid capacity, airfield design, numbers of departures and passengers, ownership and economic situation. Therefore, it is challenging to find a single solution that fits all cases. Nevertheless, all the airports in the region can share experiences, learn from each other and provide mutual support in the implementation of electric regional aviation.

5. RECOMMENDED ACTIONS

This chapter presents proposed actions to enable early and efficient implementation of electric regional aviation in the Kvarken-Nordland region. These actions can be implemented by regional actors, such as regional councils, municipalities, airports, regional development companies, power companies, research institutions and business interests. There is a history of successful cross-border collaboration in the region and the action plan can serve as the foundation for new collaborative projects. As demonstrated by their existing extensive commitment to the FAIR project, the partners share strong ambitions. They have a clear sense of direction and are keen to take the project forward in the region on a collaborative basis.

By implementing the actions suggested below, the region will be ready for sustainable regional aviation in a few years' time, when electric aviation becomes commercially available. Furthermore, there will be a sound basis for generating a wider systemic transformation towards sustainability, in a broad partnership that works across the traditional boundaries between the public, private and third sectors. Innovations in sustainability often require a new, collaborative approach to business modelling, emphasising long-term commitment and relationship-building between various societal stakeholders. In our continued work on the actions proposed here, we believe it is crucial to keep a user-centred perspective, to adopt a norm-critical approach and include as many people as possible in the benefits of a prospective electric air network in the region.

The recommended actions are divided into three tasks that support the goal of being a pioneer in the implementation of electric regional aviation:

- Create a regional air network.
- Enable early electrification of aviation.
- Enhance regional development opportunities related to electric aviation.

5.1. Create a regional air network

Establishing a regional and cross-border air network of airports and actors will improve connectivity and will be financially and environmentally beneficial, thanks to the lower operating costs and sustainable accessibility offered by electric aviation. The groundwork for creating a cross-border regional air network needs to start now, so that the region will be ready when aircraft are commercially available.[13]

[13] The potential to be an early-bird was recognised in the beginning of the project, when stakeholders were interviewed in order to see how they approach electric aviation. Mäenpää, A., et al. (2021). *Potential impacts of electric aviation in the Kvarken region. Stakeholder views in 2020.* https://www.kvarken.org/wp-content/uploads/2021/06/Potential-Impacts-of-Electric-Aviation-in-the-Kvarken-Region-Stakeholder-views-in-2020-MA%CC%88ENPA%CC%88A%CC%88-KALLIOMA%CC%88KI-AMPUJA.pdf

5.1.1. Marketing of regional air routes

To create a regional air network, it is vital to attract commercial airlines. This calls for an early dialogue with the airlines, followed by a shared investigatory effort to increase mutual understanding of the latent demand for regional aviation, and the destinations between which routes operated using electric aeroplanes may be established. Such investigations of the market potential should contain the following tasks:

- Commission surveys to identify the potential demand for regional aviation and traveller preferences in relation to electric aviation.
- Initiate dialogues with the airlines to highlight destinations and possible routes in the region.
- Prepare business cases for potential routes and networks together with the airlines.
- Carry out targeted marketing activities to raise public awareness of the possibilities of electric regional aviation.

5.1.2. Procure regional cross-border air routes

In a thin market, where commercial routes may be considered susceptible to underperformance, public procurement of regional and cross-border air routes is an option. Procurement should be performed for routes where societal benefits will be gained from increased accessibility, but where the market fails to provide a suitable service. Public sector involvement in air traffic can ensure continuity and reduce risks for operators. The regional focus of the first-generation electric aircraft makes it important to clarify the relationship between national (state) actors, regional actors and the aviation market in the procurement of air traffic. Actions that may be taken include:

- Influence national and Nordic policy and government agencies to include cross-border routes in a Nordic PSO system.
- Commission regional public transport authorities to review the possibility of including aviation in the regional public transport system.
- Develop new regional accessibility criteria and cost-benefit measuring tools to provide a basis for decisions regarding which routes to procure.
- Use innovative procurement methods to promote a smooth shift to electric aviation in the whole system of aviation. See for example the procurement method used to introduce low emission technology on Norwegian ferry routes.[14]

5.1.3. Update airport design to support regional air travel

For short journeys, the transfer time to and from airports or vertiports will constitute a relatively high share of total travel time. Innovative airport design can support functionality, shorten transfer times,

[14] Solvoll, G., et al. (2022). *Public service obligation as a tool for implementing flight routes operated by electric aircrafts.* https://www.kvarken.org/wp-content/uploads/2022/08/New_FoURapport8422.pdf

and increase the accessibility provided by regional aviation. To ensure accessibility for all inhabitants in the region, the design of airports and aeroplanes must be functional and accessible for everyone, regardless of disabilities:

- Airfield design – investigate the need for new taxi runways and aircraft/passenger handling layouts for regional electric aircraft.
- Airport terminal design – redesign terminals to allow for fast boarding and disembarkation, with swift security handling for regional passengers.

5.2. Enable early electrification of aviation

The Kvarken-Nordland region has already taken ambitious steps in the field of electric aviation and test flights with electric aircraft have begun. However, there is still a lot to be done to truly implement electric aviation for passenger traffic in the region. With ongoing, intensified focus, it will be possible to enable early electrification of aviation in the whole region.

5.2.1. Prepare airports for electric aviation

Airports are key locations for enabling electric aviation. Measures at airport level include upgrades of the electricity grid and charging infrastructure, as well as new routines for handling electric aircraft:

- Assess the charging needs at each airport by estimating the number of planes that need to charge at the same time and the rate at which they need to charge in order to meet preferred turnaround times.
- Analyse the grid capacity at each airport, as well as timeline and costs for enhanced capacity and consider implementing smart grid features.
- Invest in charging infrastructure. Slow chargers can be installed at hangars early on. Fast chargers can be installed at airports where grid capacity allows. Examine the possibility of introducing battery pack solutions to lower peak demands on grid capacity.
- Apply for external funding to keep investment costs down.
- Electrify ground handling vehicles at airports. Develop business models for charging both aeroplanes and ground handling vehicles.
- Initiate dialogue with national authorities regarding protocols for fire, rescue and handling relating to electric aircraft.
- Review take-off and landing fees to reward sustainable aircraft.

5.2.2. Test and demonstrate electric aircraft

The Kvarken-Nordland region is ideal for testing electric aircraft as there is plenty of green energy, no airspace congestion and weather conditions can be demanding. Ongoing projects, such as ELIS in Skellefteå, LARC in Örnsköldsvik and the Dronamics droneport in Seinäjoki are key to both understanding and promoting the new technologies:

- Open regional airports for testing of electric aeroplanes and eVTOLs.
- Test new use cases for electric aviation in the region.

5.2.3. Continue cooperation to generate knowledge and innovation, conduct research, influence decision makers and coordinate implementation

The strong cross-border cooperation and electrification know-how in the region are key assets that will facilitate early implementation of electric aviation:

- Establish a cross-border network of airports in the region where electrification and other issues can be discussed.
- Cooperate in influencing national, Nordic and EU decision-makers regarding the measures required to enable electric aviation.

5.3. Enhance regional development opportunities related to electric aviation

Electric aviation may provide various societal benefits for the region including enhanced accessibility and cost effectiveness, sustainable mobility and potential for business development. Regional actors should strive to realize the development opportunities that regional electric aviation provides.

5.3.1. Integrate electric aviation in the region's spatial planning

Integrating aviation in the region's spatial planning will reduce travel times and thereby open opportunities for regional development. Joint, cross-border, strategic planning will support the further integration of the region:

- Analyse the need for and locations of vertiports and corridors suitable for unmanned air traffic.
- Analyse how electric aviation noise levels and characteristics impact the built environment and integrate electric aviation into transport strategies.
- Plan for an expansion of sustainable energy production in the region and local energy production at airports.

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5.3.2. Enhance regional business development opportunities related to electrification

The emerging Kvarken-Nordland electrification and battery production cluster (i.e., the Nordic Battery Belt) is an important contributor to the development of the region. Adding aviation to the regional electrification value chain would provide new opportunities:

- Develop a cross-border regional innovation or smart specialization strategy,[15] focused on electrification, where electric aviation (both products and services) is a key element.
- Host events to inspire students and start-ups to engage in themes related to electric aviation.

5.3.3. Use increased accessibility to enhance cooperation between existing businesses

A new, fast, and sustainable air network will also open up new opportunities for existing businesses in all sectors. Enhanced business integration and matchmaking will both create demand for regional air travel and increase the overall level of business activity in the region:

- Establish a network of businesses in all parts of the region and use electric air routes to facilitate meetings and matchmaking events.

[15] Read more about smart specialization in: "FAIR Infosheet #5. Smart specialisation as a potential tool for enabling electric aviation in the Kvarken region". https://www.kvarken.org/wp-content/uploads/2020/12/FAIR-Infosheet-nr-5.pdf

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To try out the FAIR Soundscape for yourself, visit: https://fair-soundscape.ri.se

FINDING INNOVATIONS TO ACCELERATE THE IMPLEMENTATION OF ELECTRIC REGIONAL AVIATION

FAIR is to be seen as a first step of preparing the Kvarken region for an early implementation of electric aviation.
The project increases the knowledge base about electric aviation, investigates the possibilities and surveys both the needs and the required technical investments.

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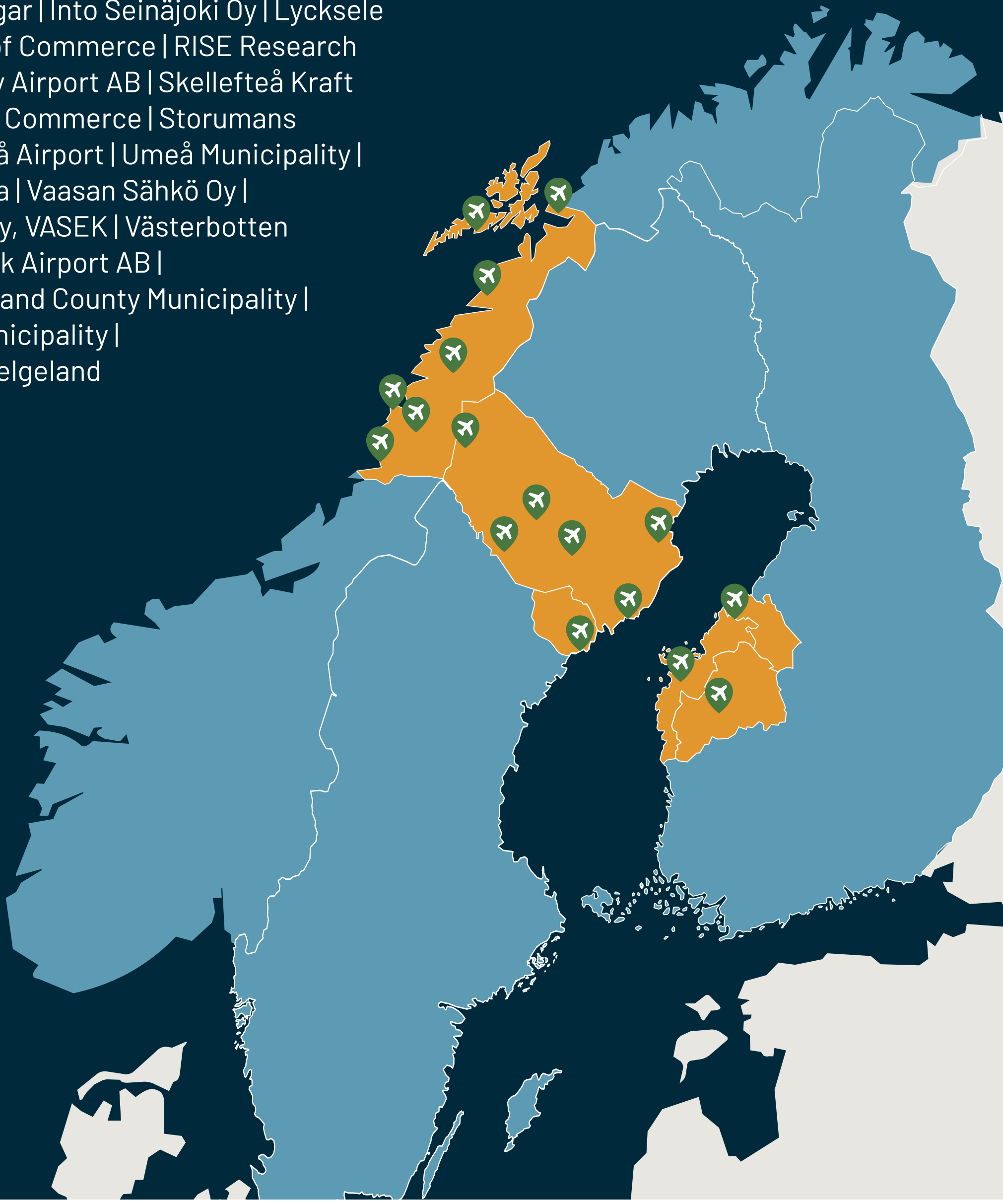

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