

# Business models for Nordic electric aviation

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# Foreword

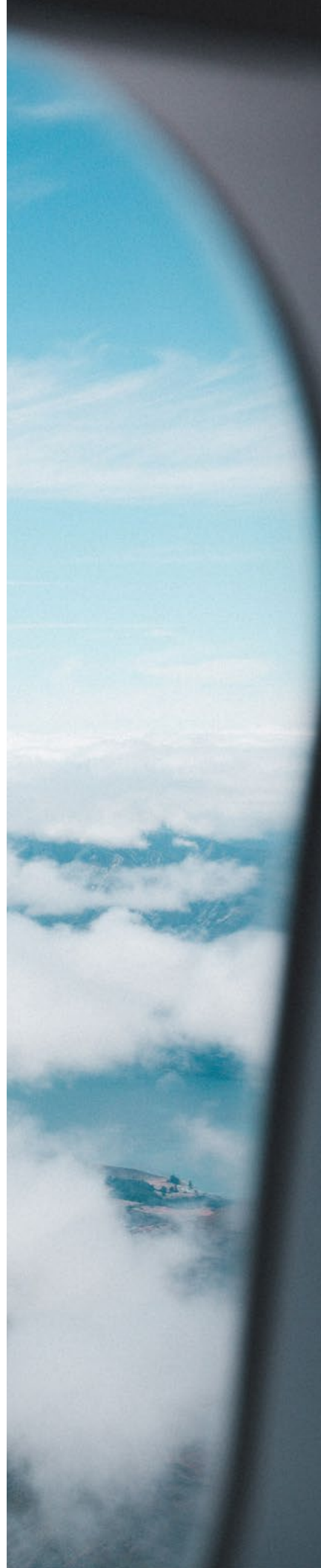
The Nordic Network for Electric Aviation (NEA) was the very first project to be launched under Nordic Innovation's Nordic Smart Mobility and Connectivity programme and represents an important building block in what we now refer to as the Nordic Mobility Universe. Connecting the Nordic region through electric aviation will also be a great contribution to the Nordic vision of becoming the most integrated and sustainable region in the world by the end of the decade.

With the aim of accelerating electric aviation in the Nordics, the NEA project partners have since 2019 coordinated actions, shared learnings, and aligned goals and ambitions. Nordic Innovation welcomes the great efforts made by the industry to advance technological and structural developments and literally preparing the ground for the introduction of electric aircrafts through the NEA project. NEA has ensured commitment from key players throughout the value chain – which is key for electric aviation to become a reality soon and also an example of the game changing power that reside within the Nordic model of collaboration.

NEA gathers manufacturers of electric aircrafts, airline companies, infrastructure owners, Nordic airports and other ecosystem members in what can be seen as the creation of a new industry, with NEA as a driving force. This means that new business models must be identified – which is exactly what this report contributes to. New opportunities await Nordic companies and new sustainable and flexible modes of air transport awaits the Nordic travellers. Nordic Innovation is part of the journey.

**Nina Egeli**

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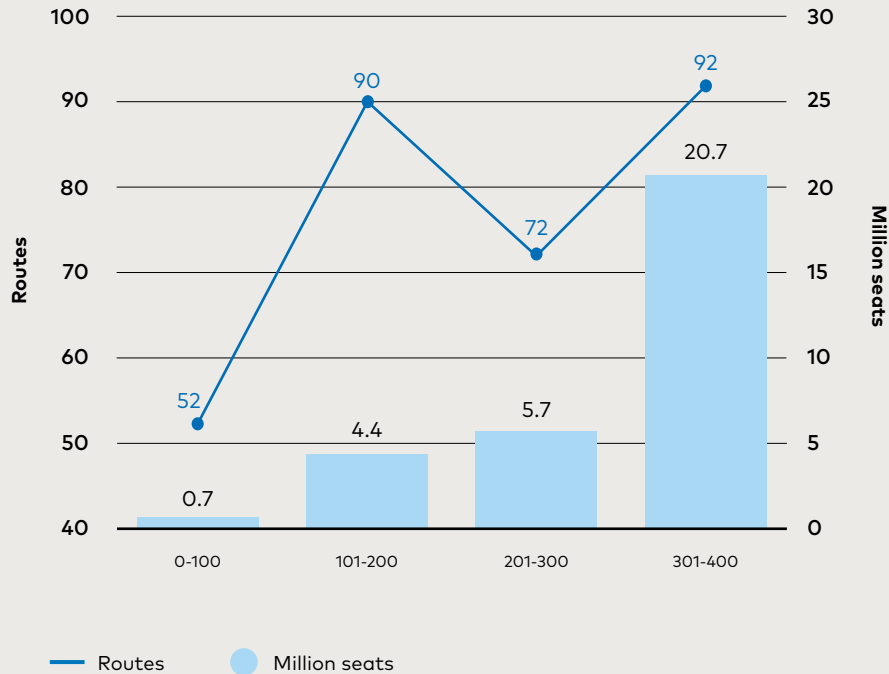
# Summary

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. In the Nordic Network for Electric Aviation (NEA) the task of looking into new business models was led by project member Norwegian Elfly Group, a company developing an electric flying boat. Main takeaways from this report include how the transition from today's conventional aviation activities to the future's electric operations will affect the industry, communities, passengers, and air transport markets. Read the full report for more insights into the business and financial aspects of electric aviation.

One of the main goals of NEA's first project period (2019-22) was to develop business models for regional point-to-point connectivity between the Nordic countries in order to increase mobility across the borders of our countries.

As a consequence of the implementation of electric aircraft, and the fact that the transition may not be incremental, the air transport industry faces a business revolution. Examples of such consequences is the profitability resulting from operators serving the air transport market with electric aircraft 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.

The share of today's market that could become subject to competition from electric aviation in the next ten years are likely to include routes with relatively short distances (50 - 300 km).



Distribution of scheduled capacity in the Nordics categorised across ranges from zero to 400 km. Numbers are from 2019. Retrieved from Ydersbond, Kristensen and Thune-Larsen (2020).

The report describes the development of electric aircraft going from small light-sport aircraft to increasingly larger aircraft, and how this affects the parallel development of business models. Smaller aircraft with room for fewer passengers will entail those aircraft serving a part of the market that is very small today (e.g., private charter of helicopters), but that may grow bigger and become available to more people as such routes become commercially available at a lower rate than what is currently offered.

The main factors causing lower operational costs are reduced energy and maintenance costs. Limited passenger carrying potential and shorter-range capabilities of the first-generation commercial aircraft will operate in a competitive landscape in which air transport will be, to a larger degree than today, in direct competition with land- and sea-based transport. The first movers will be able to tap into an underserved market as well as customer segments. New entrants will be served oppor-

tunities to cherry pick customer segments with lower price elasticity of demand than the regional market on average, creating a solid competitive advantage.

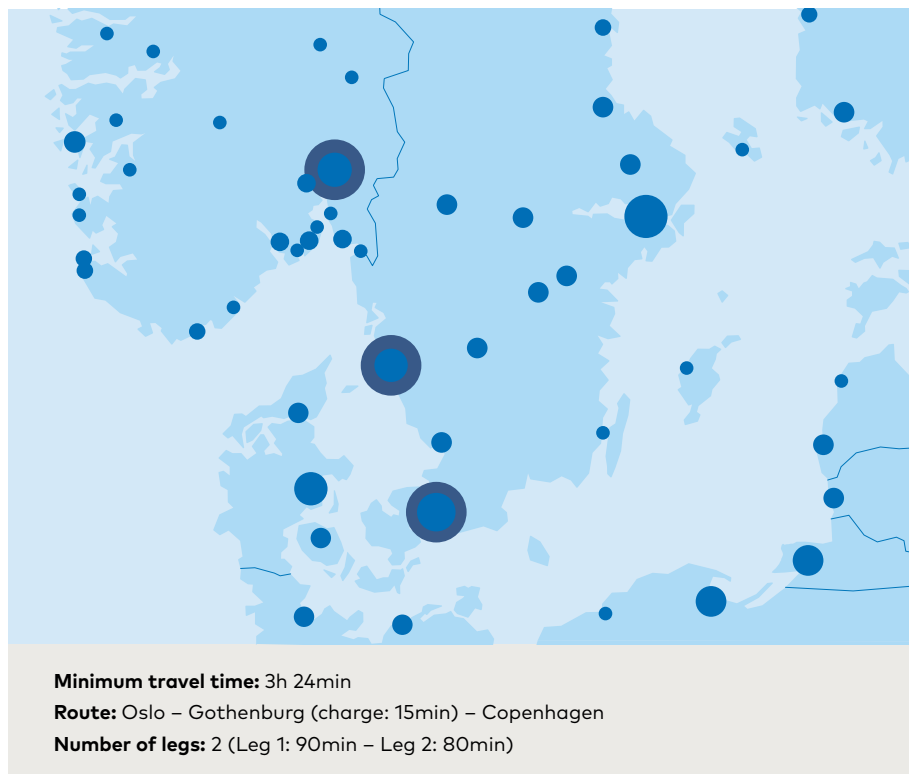
Changes in the commercial aviation industry following the implementation represent opportunities for new emerging business models as well as they may entail the end for older business models relying on today's flow of value creation. An example of a business model we may see less of is airlines providing routes on public service obligation (PSO) tenders, which is the case where commercial operations are not viable. This example illustrates that new travel opportunities may arise as the cost side of electric operations looks quite different in comparison to conventional air travel. The transition to electric aviation may affect consumer behaviour through their attitudes towards electric aviation by changing their transport preferences as well as increasing their acceptance to increase travel time in order to fly as sustainable as possible.

Business models for operators of electric aircraft based on Michael Porter's classification of generic business strategies are presented with corresponding competitive advantages and associated risks. We have taken legal, technological and social factors into account when we sketched three general business models for airlines that seem like they will be likely to be introduced into the Nordic market.

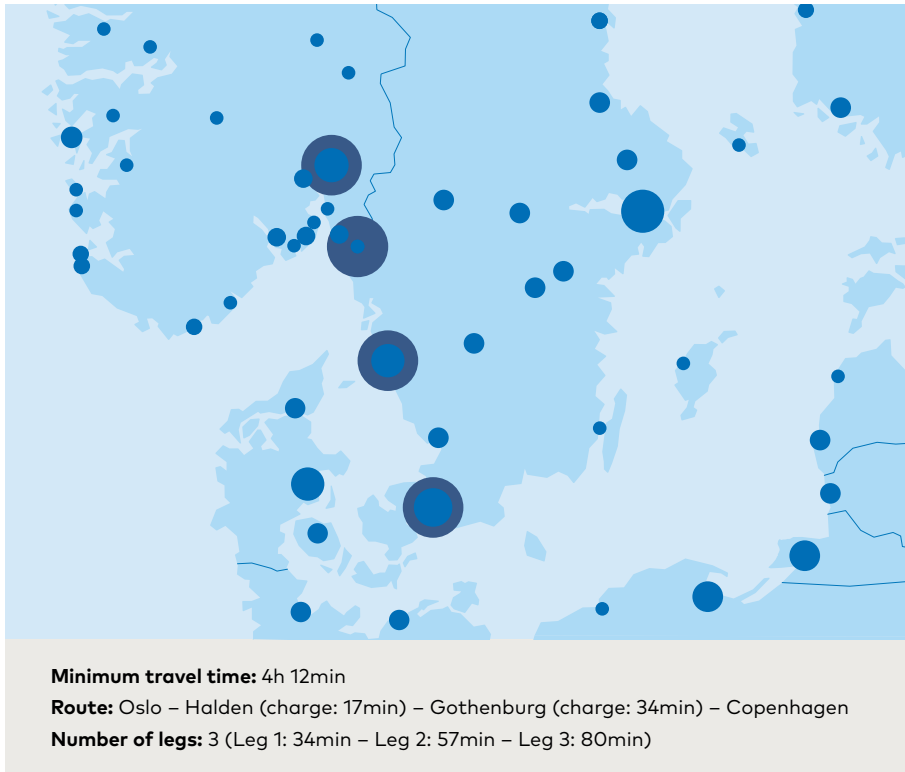
| Business model                 | Generic strategy (Porter, 1980) | Customer segments                      | Viability                                                                                                                                                                                                                                    | Risks                                                                                                                                                                                |
|--------------------------------|---------------------------------|----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Air taxi on-demand</b>      | Cost focus                      | Travellers in need of ad-hoc transport | <ul style="list-style-type: none"> <li>• If operating costs are significantly lower than today's air taxi companies, then a correct pricing would probably make it a viable business model</li> </ul>                                        | <ul style="list-style-type: none"> <li>• Lack of demand with charter prices that cover costs of operation</li> <li>• Consumers not used to booking on-demand air services</li> </ul> |
| <b>PSO</b>                     | Cost leadership                 | Commuters, inhabitants of rural areas  | <ul style="list-style-type: none"> <li>• It is likely that authorities are going to expect stricter limits as to pollution associated with PSO routes</li> </ul>                                                                             | <ul style="list-style-type: none"> <li>• Reduced need for PSOs in the future</li> </ul>                                                                                              |
| <b>High-end "business jet"</b> | Differentiation focus           | Travellers with big travelling budgets | <ul style="list-style-type: none"> <li>• Growing market</li> <li>• The richest people in the world pollute the most, and it is therefore likely that they will experience pressure from the public and from authorities to reduce</li> </ul> | <ul style="list-style-type: none"> <li>• Failure to create perception of luxury within the limitations imposed by technological readiness in the next ten years</li> </ul>           |

A point-to-point feasibility study shows how there are plenty of potential routes within the ranges that are predicted to be attainable for electric aircraft in the near future. Elfly Group has developed a route planning tool to analyse possible routes within and across the Nordic countries. As seen in the table below, the 20 shortest routes in the Nordic market are below 56 km long, making them ideal for operation by the first electric aircraft, seeing as these are expected to have a limited range compared to today's standard. Three of these routes are already in service, and with the reduction of operational costs, it becomes likely that more of them will be as well.

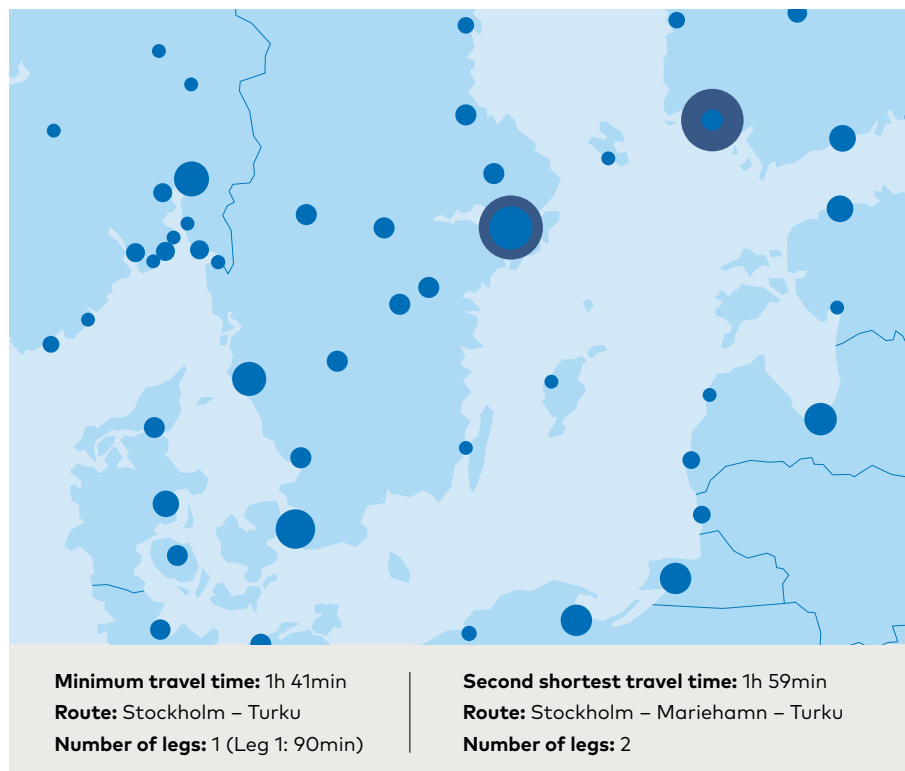
To exemplify some of the potential routes we may see covered by electric aircraft in a ten-year time frame we display the routes Oslo-Gothenburg-Copenhagen and Stockholm-Mariehamn-Turku. These estimates are based upon Elfly Group's own planning tool, in which some of the operational parameters are a MTOW of 5670 kg, including nine passengers and one pilot, and a maximum speed of 240 km/h. Additionally, we calculated the routes with two different ranges, 400 km and 250 km. The planning tool calculates the need for charging time at stopover locations. The charging time can be eliminated for passengers by providing more planes on each route, allowing for them to always be charging on ground.



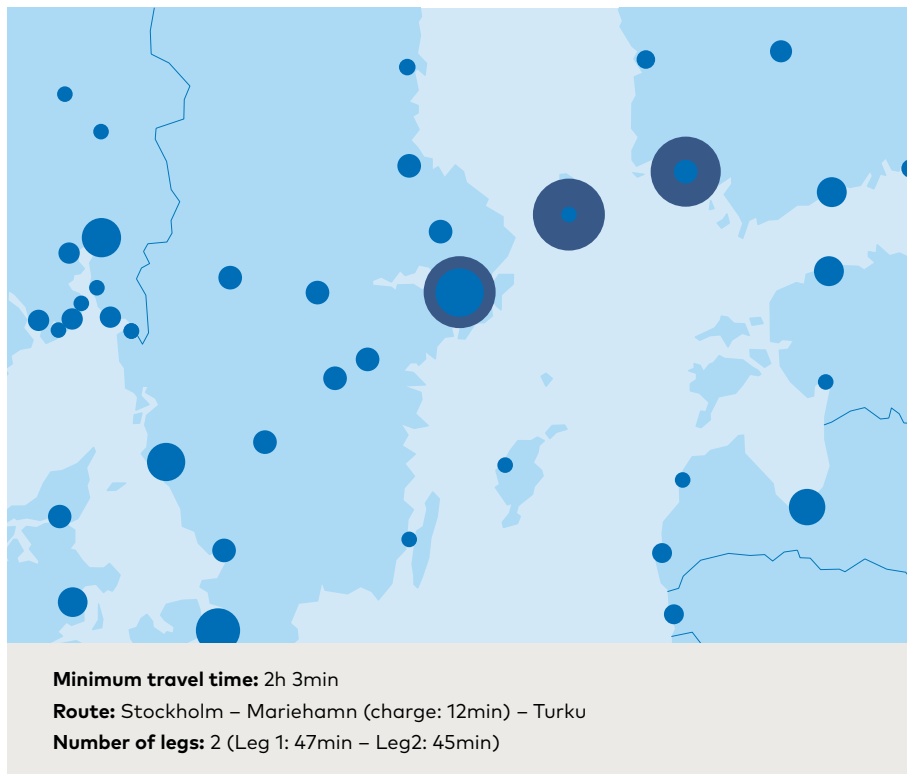
Output from our route planning tool showing the fastest route between Oslo and Copenhagen with an aircraft with a range of 400 km.



Output from our route planning tool showing the fastest route between Oslo and Copenhagen with an aircraft with a range of 250 km.



Output from our route planning tool showing the fastest route between Stockholm and Åbo with an aircraft with a range of 400 km.



Output from our route planning tool showing the fastest route between Stockholm and Åbo with an aircraft with a range of 250 km.

## 20 shortest routes in the Nordics

| From                             | To                             |
|----------------------------------|--------------------------------|
| Stockholm Bromma Airport         | Stockholm Arlanda Airport      |
| Malmö Airport                    | Copenhagen Airport             |
| Reykjavik Airport                | Keflavík International Airport |
| Kristiansund Airport Kvernberget | Molde Airport Årø              |
| Halmstad Airport                 | Ängelholm Helsingborg Airport  |
| Ørsta–Volda Airport, Hovden      | Ålesund Airport Vigra          |
| Norrköping Airport               | Stockholm Skavsta Airport      |
| Norrköping Airport               | Linköping City Airport         |
| Vadsø Airport                    | Kirkenes Airport Høybuktmoen   |

|                          |                             |
|--------------------------|-----------------------------|
| Svolvær Airport Helle    | Leknes Airport              |
| Svolvær Airport Helle    | Stokmarknes Airport Skagen  |
| Esbjerg Airport          | Billund Airport             |
| Førde Airport Bringeland | Florø Airport               |
| Mosjøen Airport Kjærstad | Sandnessjøen Airport Stokka |
| Rørvik Airport Ryum      | Namsos Airport              |
| Sandane Airport Anda     | Ørsta–Volda Airport, Hovden |
| Sandane Airport Anda     | Førde Airport Bringeland    |
| Stord Airport Sørstokken | Bergen Airport Flesland     |
| Stord Airport Sørstokken | Haugesund Airport Karmøy    |
| Vardø Airport Svartnes   | Vadsø Airport               |

Benefit analyses shed light from the consumers', businesses', governments', and the environment's perspective. Findings show that commercially available air transport by electric aviation is likely to offer new benefits to the consumers. For example, the new possible service offerings that are not available in today's air transport market, enabled by less operating costs, will benefit consumers by increased flexibility, which is a valuable benefit in itself.

Businesses will experience direct (i.e. within the aviation industry), indirect (i.e. related to the supply chain of the industry), induced (i.e. spending done by direct and indirect employees of the aviation industry) and catalytic effects (i.e. effects that spread out to other industries that are not related to the aviation value chain)

of a change in the air transport system in the Nordics. The benefits expected by businesses are associated with increased traffic outside of the hub-and-spoke travel pattern that is dominating today, in other words the expected change that will follow the introduction of electric aviation. Businesses that are located in rural areas can get much better connections to regional and national markets and capitals, as well as the rest of the world, which can be translated into economic growth for these businesses.

Governments can benefit greatly from the shift. In order to realise electric aviation, a huge amount of innovation is vital. Accordingly, the aviation industry is changing up its mode of production, whereby producers are moving

away from working with known concepts into an innovative work process where new ideas are being prototyped and tested. A great example of this is Heart Aerospace's great expansion from its establishment in 2018. Their growth has resulted in a talent acquisition from many different parts of the globe, providing ample opportunity for resourceful people to migrate to Sweden. By embracing such effects of an innovative industry, governments can reap indirect benefits such as additional tax payers, but most importantly accumulation of valuable knowledge. By investing in the electric industry early on and making it convenient for such actors and stakeholders, governments, both local and national, may see themselves in the centre of a new and booming global industry.

When electric air transport is available to customers, it is likely that the increased flexibility offered may help slow down or shift the trend of urbanisation. By offering ways of commuting that are flexible, cheap and environmentally friendly, local governments may see themselves being able to keep young inhabitants and being lucrative places to establish businesses. Greater connectivity will result in increased welfare for many by providing more available health care services, universities and colleges, and recreational destinations.

The environment will benefit via reduced greenhouse gas emissions in-flight and less noise pollution at and around airports. Electric aviation may also reduce the need for encroachment of nature by providing a better alternative than railway and road expansions, which demand a lot of land area and can have detrimental effects on natural habitats' ability to house and foster wild animals. Electric aviation also does not pollute via climate effects occurring in higher atmospheric levels, which is a significant contributor to aircraft's negative climate effect.

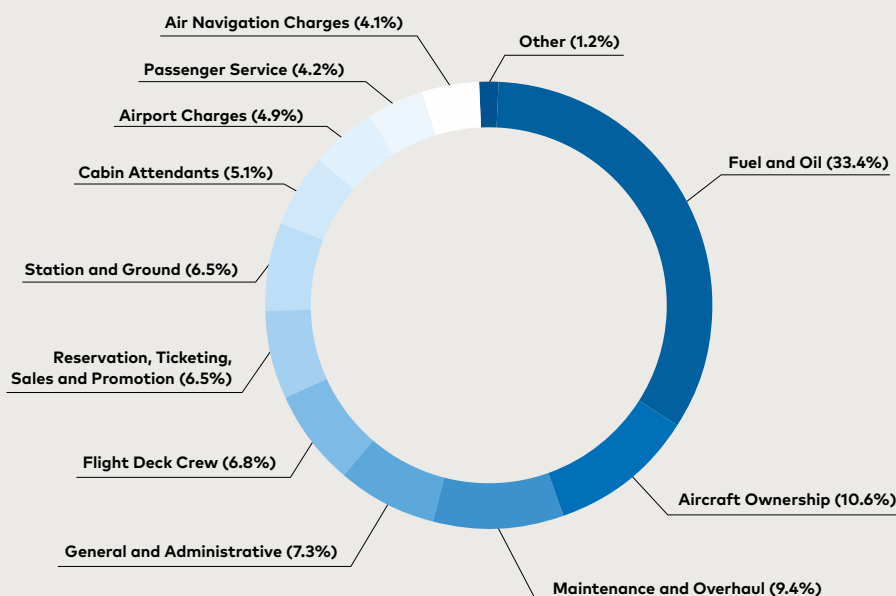
Finally, this project has examined the successful financial and behavioural schemes implemented by the Norwegian government to accelerate the transition from diesel and petrol cars and ferries to electric vehicles and ferry boats. A similar incentive scheme is proposed for sustainable aviation to accelerate the transition from conventional to innovative technological solutions.



# Current situation in the Nordic region

There are relatively few (95 according to our estimates carried out in May 2022) intra-Nordic routes in today's market, especially when comparing them to routes that serve Southern Europe and other popular holiday destinations. The way the route structure is set up, passengers bound for non-capital cities often have to transfer at the big hubs (i.e. Stockholm, Copenhagen, Helsinki, and Oslo) to reach their final destination. Flights with electric propulsion are not yet offered on the market.

The aviation industry is marked by cyclic financial performance with overall low profit margins (e.g. Doganis, 2010). Some key factors affecting profitability for airlines are economic growth, which affects demand; technological advances, which enable more efficient operations; market liberalisation, which affects the competition in markets clearly exemplified by the introduction of low-cost carriers (LCCs); airport competition, and finally oil prices. The Nordic market consists of a mix of legacy carriers (e.g. SAS, Icelandair and Finnair) and LCCs (e.g. Norwegian and Ryanair). Over the past few years there have been new introductions of carriers (e.g. Flyr and Wizz Air), and some have had to discontinue their operations due to saturations in the market combined with high operational cost.



**Figure 1**

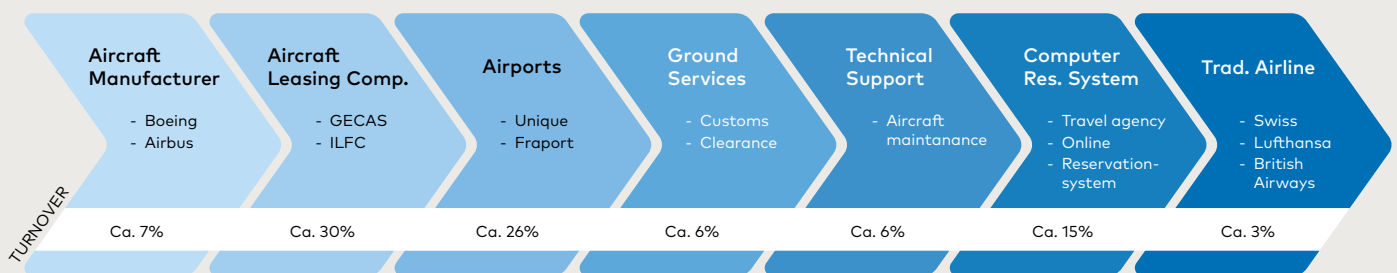
Total distribution of airline cost. Retrieved from Richter and Witt (2017). The diagram gives an overview of the distribution of airline costs across the main expense items.

The biggest proportion of costs originates from fuel and oil expenses needed for combustion engines, accounting for as much as one third of total expenses, second biggest is aircraft ownership (i.e. leasing or depreciation costs) and third biggest is maintenance and aircraft overhaul. With airline tickets being more affordable to more people (Thune-Larsen), the airline industry has experienced a growth in their Revenue Passenger Kilometre (RPK), but in parallel to this trend, yields per Available Seat Kilometre (AKS) have been reduced (see Ritcher and Witt). This can be explained by the increase of passengers who are more price sensitive than the previous customers of air transport. Airlines have responded to this development by reducing their Costs per Available Seat Kilometre (CASK) by means such as changing seat pitch and replacing old seats with ultra-thin ones in order to be able to fit an additional row in the cabin.

The value chain for airlines today is illustrated in Figure 2. The way value creation flows through today, the majority of profitability and favourable profit margins lies within the link of motor designers and manufacturers. The financial ecosystem of aviation is ever changing due to shifts in demand and competition.

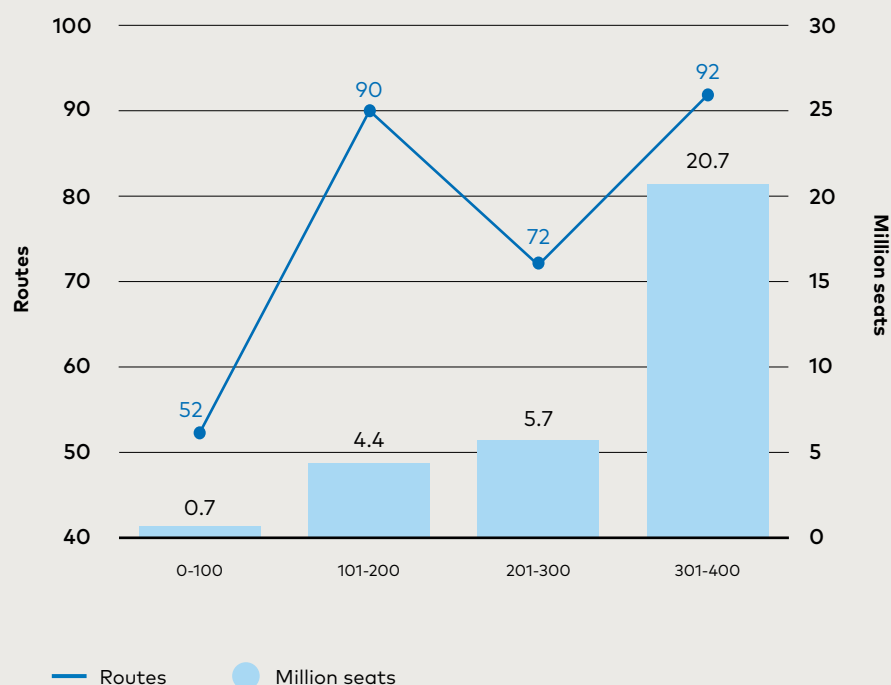
**Figure 2**

Commercial aviation value chain from airlines' perspective with respective turnover presented. Retrieved from Bieger and Wittmer (2011). The airlines provide the final product for the customers of air transport, and they are the binding element for all other stakeholders in the value chain as they are dependent on their production in order to deliver their own services.



According to Eurocontrol's prognosis for high and baseline scenarios, the Nordic market will see an increase in aircraft movements from 2020 to 2027 (Eurocontrol, 2021). Most of the growth in the Nordic market is due to foreigners travelling to, from and within the Nordic countries as well as population growth in the region, and not Nordic inhabitants travelling increasingly more (e.g. Madslien, Steinsland & Kwong, 2014; Avinor AS, 2020). This trend may have implications for what service offerings will be more popular in the future. Companies looking to start operations in the Nordics should follow the demand and attempt to predict the future demands within the tourist industry.

The shares of today's market that could become subject to competition from electric aviation in the next ten years include routes with relatively short distances (50 - 300 km). This is due to the battery technology not yet being ripe enough to enable light enough battery packs to realise development of aircraft on the size of popular jets used in the Nordic regional market such as Boeing 737-700/800, Airbus N320 used by SAS and the Embraer E190-E2 used by Widerøe. The Nordic market consists of many routes that are relatively short, and some of these are amongst the most trafficked routes in Europe (e.g. Bergen-Oslo, Stavanger-Oslo, and Trondheim-Oslo). The development within electrification follows a logical path from the production of small trainer-sized light-sport aircraft to larger aircraft with cabins allowing up to nineteen passengers and so on. Therefore, we might see electric aviation competing with land-based transportation at a more extensive level than we do today.



**Figure 3**

Distribution of scheduled capacity in the Nordics categorised across ranges from zero to 400 km. Numbers are from 2019. Retrieved from Ydersbond, Kristensen and Thune-Larsen (2020).



The unequal distribution between number of routes (i.e. 306) and million seats offered (31.5) in the range of scheduled air traffic from zero to 400 km highlights the fact that there are many potential routes that are relevant for electric aircraft to operate and the fact that operators would be able to fulfil the demand on these short routes more easily than with longer distance routes. See a comprehensive overview of calculated estimates with number of aircraft across different size passenger capacities (nine vs. 19) in Ydersbond, Kristensen and Thune-Larsen.

The Nordic market varies much from county to country due to factors such as differences in topography, demography and politics. For countries Norway, Sweden and Finland, some routes are subsidised by public funding, PSO routes, though most of the market, measured in number of passengers, is covered by routes that are commercially viable for airlines to operate. The PSO system is designed for scheduled services between any airport in a local and perhaps also sparsely populated community to an airport serving a peripheral region, or on a thin route to any airport in its region, including cross-border services. The route should be vital for the economic and social development of the region served by the airport in order to be granted political support. If no airline is willing to provide a service under the conditions imposed, the government may restrict access to the route to a single carrier and award financial compensation to the carrier in return for compliance with the PSO. In Norway, the budget proposal for purchasing PSO routes in 2022 is 828.5 million Norwegian Kroner (approximately 82 million Euros; Norwegian Ministry of Transport, 2021), of which most are located in the Northern and Western regions of the country.

PSO tender rounds in the Nordics are open to all airlines with Air Operator's Certificates (AOCs) listed within the European Economic Area (EEA) and the European Union.

There are several factors affecting the ticket pricing of air transport services. Passenger service pricing is discounted from full fare, per passenger, by restrictions or services such as weight of baggage, time and day of flight, time between arriving and departing same destination, time of purchase, class of carriage. Classic airline revenue management is a form of dynamic pricing whereby prices change based on variables that are not related to the customer, such as competitor pricing, booking time, supply and demand. Revenue management is a common pricing strategy for services that have a known supply and a "perishable" product, of which the demand is dynamic in accordance with the same determinants that regulate the ticket prices.

Price elasticity of demand varies across different airlines and customer segments. For the most part, the Nordic market is homogenous when it comes to price elasticity, seen as prices between LCCs and legacy carriers vary little, and that the variation between the products they offer also vary to a very small degree. There were bigger differences between LCCs and legacy carriers before, but today both LCCs and legacy carriers offer varying degrees of premium to no-frill journeys. However there is still a divide between market segments (i.e. business and leisure travellers) when it comes to price elasticity (e.g. Kopsch, 2012) and consequently price sensitivity, which affects customer group distribution across airlines (e.g. most frequent business travellers preferring legacy carriers while leisure travellers' choices are mostly guided by price) and consequently also pricing strategies.



# New market opportunities

Operators of electric aircraft will have lower operational costs due to reduced fuel costs than operators in today's market, incentivising them to offer services for as much time during the day as possible. Another source of competitive advantage in electric operators' favour is that of the ever increasing price of CO<sub>2</sub> quotas that conventional operators face. The first few electric aircraft in commercial use will be able to carry a significantly lower number of passengers than today's jet and turboprop aircraft used in the Nordics.

Thus we can expect there to be an increase in aircraft movements to compensate for lacking size by more frequent departures. New market opportunities arise then in the wake of such developments. Keeping in mind the limited passenger carrying potential and shorter range capacities, operators of these first generation commercial electric aircraft will be operating in a competition in which more land-based transport alternatives are present compared to today's competitive landscape. Such shifts will be marked in the value chains within aviation.

Aircraft manufacturers and developers of aircraft components may experience an increased demand for production as the number of units ordered increases. With an increase of traffic comes a higher demand for Air Traffic Management (ATM) services, and if the traffic flow is to be more evenly distributed throughout the day, more so than today, then airport services (e.g. ground handling, kiosks, restaurants and retailers) may see less of spikes in demand and more of an even stream of work requirements, which can affect personnel's shift arrangement. The same shuffle of passenger streams would affect the distribution of demand for access transportation (i.e. transport services responsible for the leg of the journey before the air transport, for example from home to the airport).



As previously mentioned, the composition of operational costs will vary greatly from electric aircraft operators to today's operators in the market. Even though the unit cost of shorter routes are bigger than for longer routes, electric operators may still find this profitable due to reduced overall operational costs, and it is therefore likely that new, short routes will be established and served as the shift towards commercial electric aviation progresses. These first movers will be able to tap into an underserved market and customer segments. New entrants will be served opportunities to cherry pick customer segments with lower price elasticity than the regional market on average. Early adopters and environmentally conscious consumers may in general have lower price sensitivity than other customer segments.

The changes in the commercial aviation ecosystem represent opportunities for new emerging and innovative business models, as well as they may entail the doom of older business models, relying on today's flow of value creation. The impact of introduction of electric aviation is dependent on the way in which new technologies and business models are implemented - will it be incremental or abrupt? As previously mentioned, the shift for

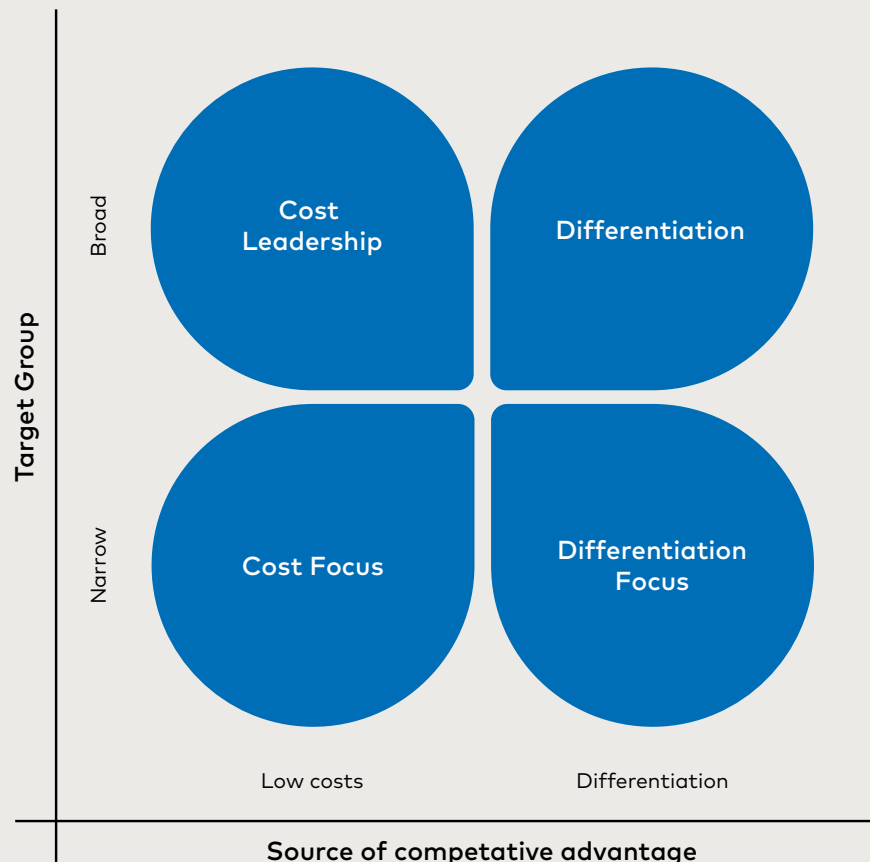
some businesses will mean the end, and for others it will be a beginning. Likewise operations will change: for example, for aircraft with nineteen passenger seats or less, there is not a requirement for cabin crew. On the other hand, the shift will require more pilots on duty if we are to fulfil the same demand for transport as the industry is covering today.

Another impact we may see following the introduction of electric aviation is changes in consumer behaviour. By offering ways of transportation that compete with land-based transportation, but that will be significantly faster for many routes (i.e. places at which high-speed trains are challenging to build due to destruction of large areas and emissions in relation to building and maintaining the tracks) and that emit minimal amounts of greenhouse gases, we are sure to see changes in travellers' preferences and attitudes towards electric aviation. An example of such a change in consumer behaviour is that maybe future air travellers will accept an increase in legs of each journey and travel time due to aircraft's shorter range. If electric aircraft are well-received by the public, acquired electric aircraft may very well become competitive advantages for airlines.



# New business models for airlines

A prerequisite to be able to answer what business models will be profitable and that will be flexible enough to mitigate risks associated with operation, is adequate data concerning the parameters within which electric aircraft will operate. Further research is needed on this topic. Table 1 exhibits a few business models that we predict are realistic to exist in the future, based on Porter's (1980) classification of generic business strategies, in which strategies are defined according to two dimensions, namely strategic target group (broad vs. narrow) and source of competitive advantage (low costs vs. differentiation).



**Figure 4**

Illustrates Porter's (1980) classification of generic business strategies, as determined by the two dimensions, target group and source of competitive advantage.

We have taken legal, technological and social factors into account when we sketched three general business models for airlines that seem like they will be likely to be introduced into the Nordic market. The first movers may be businesses who already operate within such business models, or they may be complete newcomers with innovative business models not yet seen in the air transport market.

**Table 1** New business models for airlines with electric aircraft

| Business model                 | Generic strategy (Porter, 1980) | Customer segments                      | Viability                                                                                                                                                                                                                                    | Risks                                                                                                                                                                                |
|--------------------------------|---------------------------------|----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Air taxi on-demand</b>      | Cost focus                      | Travellers in need of ad-hoc transport | <ul style="list-style-type: none"> <li>• If operating costs are significantly lower than today's air taxi companies, then a correct pricing would probably make it a viable business model</li> </ul>                                        | <ul style="list-style-type: none"> <li>• Lack of demand with charter prices that cover costs of operation</li> <li>• Consumers not used to booking on-demand air services</li> </ul> |
| <b>PSO</b>                     | Cost leadership                 | Commuters, inhabitants of rural areas  | <ul style="list-style-type: none"> <li>• It is likely that authorities are going to expect stricter limits as to pollution associated with PSO routes</li> </ul>                                                                             | <ul style="list-style-type: none"> <li>• Reduced need for PSOs in the future</li> </ul>                                                                                              |
| <b>High-end "business jet"</b> | Differentiation focus           | Travellers with big travelling budgets | <ul style="list-style-type: none"> <li>• Growing market</li> <li>• The richest people in the world pollute the most, and it is therefore likely that they will experience pressure from the public and from authorities to reduce</li> </ul> | <ul style="list-style-type: none"> <li>• Failure to create perception of luxury within the limitations imposed by technological readiness in the next ten years</li> </ul>           |



EU regulations licit foreign companies to bid on the PSO routes in the Nordic countries, and freedoms of air are regulated through the EU jurisdiction, with the general practice being that foreign companies are also allowed to establish commercial flights within and between countries in the EU and within the EEA. General risks include grid capacity and need for changes in customer behaviour (e.g booking tickets on-demand within a short time frame vs. booking tickets months in advance). If costs of operating electric planes are substantially lower than conventional planes, then this may open up for new markets to be offered. The demand may not be substantial, it would perhaps be enough to only have a few passengers who are willing to pay for the service. This opens up for niche cross-border routes that otherwise would not be economically feasible.

# 1

## Air taxi on-demand

The airline could own or lease a fleet of electric planes that circulated between places where there is a small and steady demand for fast and flexible transport. Customers would be able to book their trips a short time in advance, specifying where they needed to go without necessarily knowing whether a trip to that destination was already planned due to others' demand. Other passengers could then be able to join the trip until the cabin was full. Since smaller aircraft are not dependent on a high demand in order to fly profitably, new travel patterns may emerge through this business model, intra-Nordic routes for instance. Such a business model is dependent on IT systems facilitating the main value creating activity, namely the journey from A to B. Since operating costs for airlines with electric aircraft are expected to be less significant than they are today, the air taxi company would probably see their business profitable by tapping into a market of price sensitive customers, not needing frills in addition to their journey. The innovators of this business model will probably need to advertise their product, seeing as this sort of flexible way of travelling is novel to most customers in the air transport industry, which would require a marketing budget of appropriate size in order to raise awareness and create a customer base.

2

## PSO

It is expected that governments will formulate stricter demands for emission-free air transport as technology evolves into more mature stages. The biggest risk we have identified with this business model is that PSO routes may not be as needed in the future as they are today given that the shift from conventional to electric aircraft may prompt a paradigm shift within air transport. On a shorter time scale, a risk involved in this business model is the potential for governments to formulate disadvantageous tenders, for example by requesting aircraft technical features that are not necessary to fill the need for certain routes (e.g. a pressurised cabin on very short routes where cruise altitude is far from reached). By setting the bar too high in terms of technological complexity, it will be more difficult for operators to be introduced to the market. A risk mitigating initiative would be for governments to have an innovative approach to the PSO routes where they collaborate with aircraft manufacturers and operators to ensure a sufficient service offering. Likewise, today's PSO tenders are structured in a way that secures passengers the possibility of travelling to major cities and back to their origin in one day, at specific times of the day (with the exception of a few locations). By adopting the previously mentioned innovative approach, perhaps inhabitants in rural areas will see more flexibility in the air transport services offered, and no longer be needing the scheduling requirements present in today's tenders.

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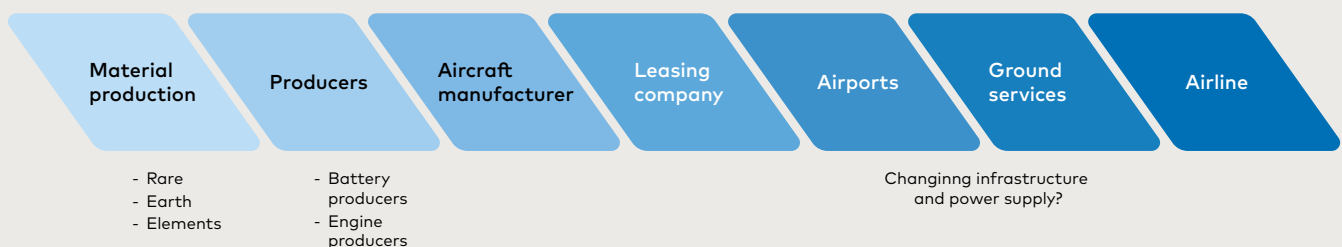
## High-end "business jet"

This business model would be centred around transporting customers willing to pay high ticket or subscription prices to travel with zero-emission aircraft. Their service offering would need to be perceived as quite different from the air-taxi's by for example offering frills in addition to the journey per se, for example bottle service, exclusive interior, lounges and fast-track channels through airports. The potential to reduce emission through this business model is large since the richest amongst us are those who statistically pollute the most. There may be more extensive restrictions imposed upon individuals who pollute disproportionately more than the rest of the population, and so therefore the demand for such services may increase substantially with time as CO2 quotas rise in value as well.

# Value chain

The biggest difference between today's value chain and the value chain of the future aviation system is the inclusion of the battery producers, electricity producers and power grid providers (utility providers), increased need for ground handling (due to more frequent flights), and different needs within maintenance of aircraft (e.g. reduced demand for engine mechanics and increased demand for battery engineers). Fuel companies and distributors will be obsolete in the new value chain. For electric aviation to be as sustainable as possible, it is important to consider initiatives to reduce social injustice and exploitation on the material sourcing side of production as well as having a circular approach to batteries' life cycle. Since weight is the biggest physical limitation in electric aviation, it is likely that hulls designed especially for electric propulsion systems will be made out of light-weight composite materials to reduce weight. Thus there may be an increased demand for composites in the future. Figure 3 shows an exemplified value chain from the airlines' perspective.

**Figure 5** Future value chain from the perspective of electric airlines.



# Point-to-point feasibility study

The feasibility of electric aviation is dependent on the technological limitations and possibilities affecting range and the number of passengers and cargo the planes are able to lift, as well as the market sizes and customers' willingness to pay in future. Following the logic that the first aircraft that get certified for commercial operations are relatively small, we include the 20 shortest routes in the Nordic countries in table 2. All 20 routes are within the range of 56 km. Of these routes, three are already in service today, operated on PSOs by Widerøe (Vadsø - Kirkenes, Rørvik - Namsos, and Vardø - Vadsø).

**Table 2** 20 shortest routes in the Nordics

| From                             | To                             |
|----------------------------------|--------------------------------|
| Stockholm Bromma Airport         | Stockholm Arlanda Airport      |
| Malmö Airport                    | Copenhagen Airport             |
| Reykjavik Airport                | Keflavík International Airport |
| Kristiansund Airport Kvernberget | Molde Airport Årø              |
| Halmstad Airport                 | Ängelholm Helsingborg Airport  |
| Ørsta-Volda Airport, Hovden      | Ålesund Airport Vigra          |
| Norrköping Airport               | Stockholm Skavsta Airport      |
| Norrköping Airport               | Linköping City Airport         |
| Vadsø Airport                    | Kirkenes Airport Høybuktmoen   |
| Svolvær Airport Helle            | Leknes Airport                 |
| Svolvær Airport Helle            | Stokmarknes Airport Skagen     |

|                          |                             |
|--------------------------|-----------------------------|
| Esbjerg Airport          | Billund Airport             |
| Førde Airport Bringeland | Florø Airport               |
| Mosjøen Airport Kjærstad | Sandnessjøen Airport Stokka |
| Rørvik Airport Ryum      | Namsos Airport              |
| Sandane Airport Anda     | Ørsta–Volda Airport, Hovden |
| Sandane Airport Anda     | Førde Airport Bringeland    |
| Stord Airport Sørstokken | Bergen Airport Flesland     |
| Stord Airport Sørstokken | Haugesund Airport Karmøy    |
| Vardø Airport Svartnes   | Vadsø Airport               |

Our analysis of Nordic airports included a semi-structured interview with Tanja Sabel, airport manager at Mariehamn airport in Finland. Mariehamn has upgraded ground infrastructure to be able to welcome electric aircraft when they arrive in the future, and the small island's inhabitants view electric aviation as a great opportunity to increase connectivity to the mainland of Finland as well as Sweden. We also had discussions with representatives from Icelandair, in which it was concluded that electric aviation is ideal for Iceland, seeing as the distances there are relatively short. Similar conclusions have been drawn on the behalf of Denmark in discussions with the director of NISA, Martin Porsgaard. Bengt-Ove Lindgren, airport manager at Umeå Airport in the Norther region of Sweden is confident that the more flexible routes electric aviation will offer would contribute to improved mobility across people, cultural entities as well as academics

in the region, and across the border to Norway and across the Gulf of Bothnia to Finland. Olav Mosvold Larsen from Avinor views the shift as a promising change that Avinor will be ready to facilitate when the time comes for commercial aircraft to require ground services and other support from the public Norwegian airports.

Airport operators such as CPH, Avinor and Swedavia are working on preparing their service offering to facilitate a greater need for electricity at their airports. Initiatives include mapping out the need for charging infrastructure and mapping out required improvements of the local electricity grid (e.g. Elnett21 at Sola Airport, Norway). It is crucial that there is an adequate charging infrastructure in place in order to facilitate electric aviation between airports.

# Aircraft requirements

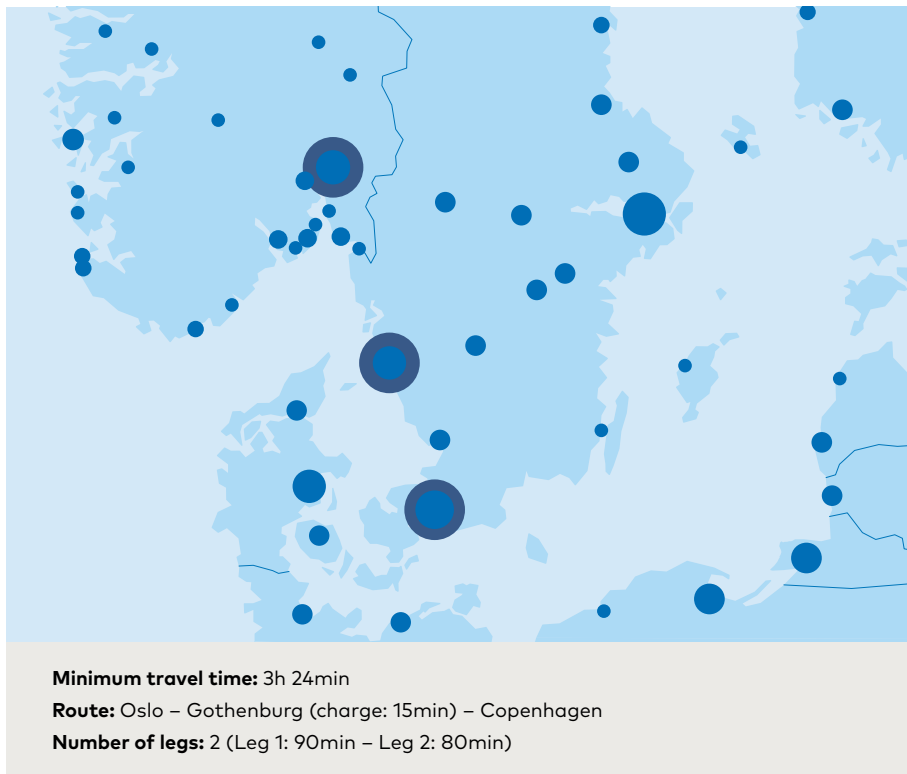


During the course of the work we have done through the NEA project we have been in contact with many different types of stakeholders within the aviation ecosystem. A few observations are worthwhile mentioning, and they include a wish from both producers, users and infrastructure operators for charging to be standardised (e.g. that the nozzle does not vary in size between aircraft) in order to minimise extra costs and to grant a large capacity. In our opinion, the electric aircraft industry should follow the CCS 2.0 standard or newer, developed for cars and lorries. Information of such infrastructure systems is lacking on the airport management side of operations, but while this is yet unknown to producers as well, one should ask whether this debate at airports may be premature.

## Possible routes

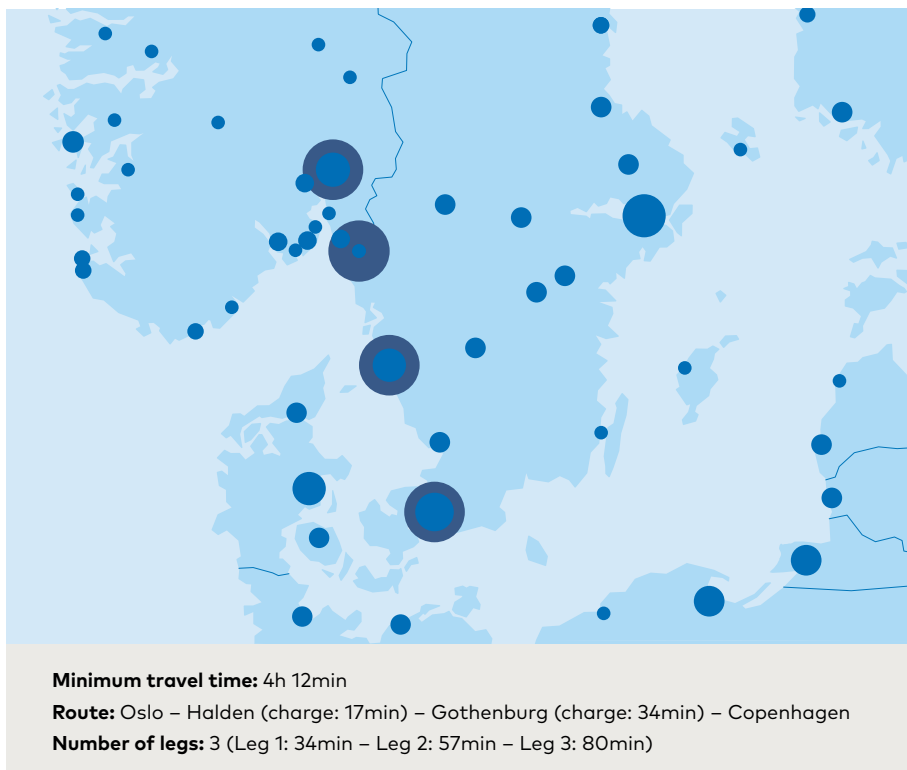
Elfly Group has developed a route planning tool to analyse possible routes within and across the Nordic countries. As seen in Table 2, the 20 shortest routes in the Nordic market are below 56 km long, making them ideal for operation by the first electric aircraft, seeing as these are expected to have a limited range compared to today's standard. Three of these routes are already in service, and with the reduction of operational costs, it becomes likely that more of them will be as well.

To exemplify some of the potential routes we may see covered by electric aircraft in a ten year time frame we display the routes Oslo - Stockholm - Copenhagen and Stockholm - Mariehamn - Åbo. These estimates are based upon Elfly Group's own planning tool, in which some of the operational parameters are a MTOW of 5670 kg, including nine passengers and one pilot, and a maximum speed of 240 km/h. Additionally, we calculated the routes with two different ranges, 400 km and 250 km. The planning tool calculates the need for charging time at stopover locations. The charging time can be eliminated for passengers by providing more planes on each route, allowing for them to always be charging on ground.



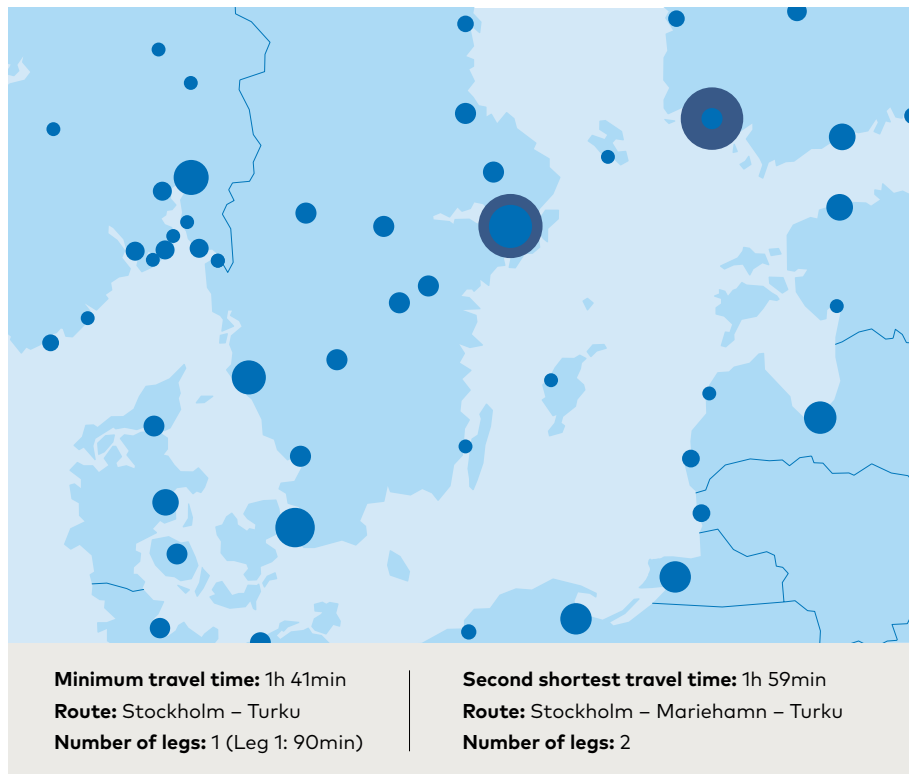
**Figure 6**

Output from our route planning tool showing the fastest route between Oslo and Copenhagen with an aircraft with a range of 400 km.



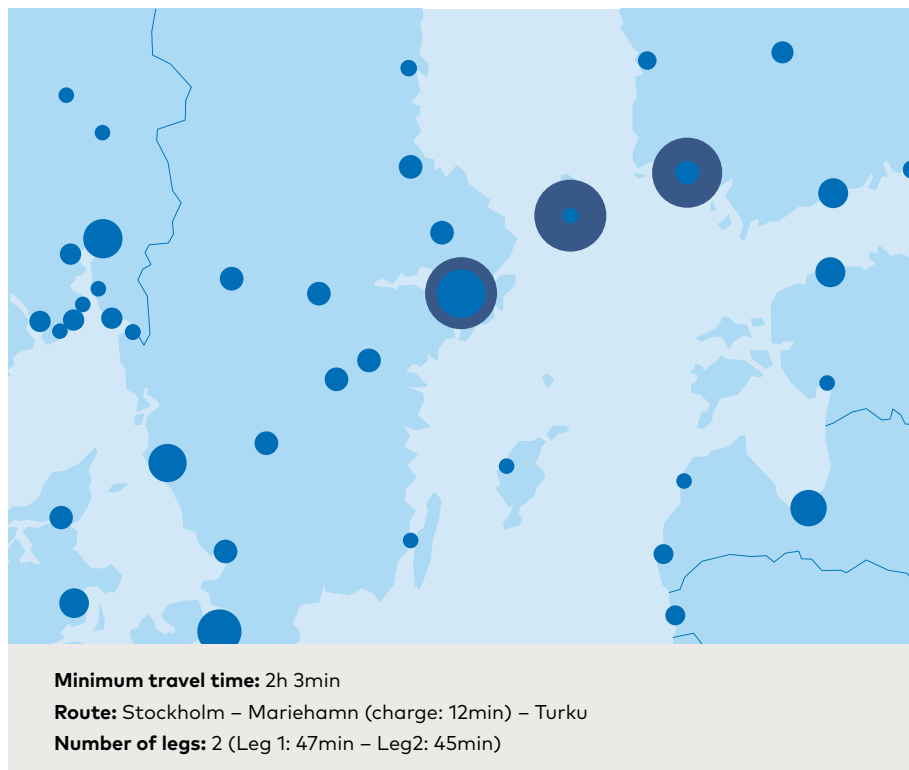
**Figure 7**

Output from our route planning tool showing the fastest route between Oslo and Copenhagen with an aircraft with a range of 250 km.



**Figure 8**

Output from our route planning tool showing the fastest route between Stockholm and Åbo with an aircraft with a range of 400 km.



**Figure 9**

Output from our route planning tool showing the fastest route between Stockholm and Åbo with an aircraft with a range of 250 km.

## Shortcomings and mitigations

As with all new technology systems, the ecosystem surrounding electric aviation will need time to adapt to new ways of operation. In the beginning, the shift may require changes in airlines, air traffic management (ATM), customers, local governments, and international authorities. One shortcoming is electric aircraft limitations on weight. Are the planes designed to carry a certain amount of passengers, but not necessarily their luggage in addition? In that case, an expensive mitigation could be to adjust the cabin interior to fit fewer passengers and more luggage. At the interface between aircraft and airport are several potential issues that will need to be addressed before the introduction occurs. Smaller cabins and lower capacity to accommodate passenger demand per aircraft means that to serve the same amount of passengers in the future, there will have to be more traffic at and around airports. It is essential that airports are prepared for this development and that ATM services have enough capacity to accommodate the increase in traffic to service them in a safe manner. Airspace will consequently be more crowded than it is today, so a mitigation that is already discussed frequently in the context of new aerospace technology, and drones especially, is priorities and arrangements of mixed airspace.

With an increased amount of aircraft in traffic, there will be an increase in the ratio between pilots and passengers on board. Thus, there will be an increased demand for pilots in the future. This needs to be addressed by airlines, civil aviation authorities, and by institutions educating pilots. Pilot training is likely to change in the future as well. As more pilots will find themselves working alone on the flight deck, they will have fewer opportunities to exchange experiences with their colleagues. It is therefore imperative that the consequences of single pilot operations are mapped out and that safety measures are put in place to mitigate the potential negative effects.



# Benefit analysis



## Consumers

Commercially available air transport by electric aviation is likely to offer new benefits to the consumers. For example, the new possible service offerings that are not available in today's air transport market, enabled by less operating costs, will benefit consumers by increased flexibility, which is a valuable benefit in itself. This flexibility may be translated into increased comfort for passengers who would like to travel at off-peak hours, by not having to plan their travels according to how the majority of travellers commute.

Additionally, the flexibility offered may reduce generalised costs (i.e. ticket price + time costs, which is an individual value + other costs associated with the trip) associated with travelling the same route with an electric plane compared to alternative means of transport. Comparing what customers are willing to pay with what they actually pay for the service could inform the value of the utility perceived by the customer (i.e. consumer surplus). If the customer finds they were willing to pay more for the service than what they did, the consumer experiences a sense of surplus after consumption or purchase of the service.



## Businesses

Businesses will experience direct (i.e. within the aviation industry), indirect (i.e. related to the supply chain of the industry), induced (i.e. spending done by direct and indirect employees of the aviation industry) and catalytic effects (i.e. effects that spread out to other industries that are not related to the aviation value chain) of a change in the air transport system in the Nordics. The benefits expected by businesses are associated with increased traffic outside of the hub-and-spoke travel pattern that is dominating today, in other words the expected change that will follow the introduction of electric aviation. Businesses that are located in rural areas can get much better connections to regional and national markets and capitals, as well as the rest of the world, which can be translated into economic growth for these businesses.

Actors in the value chain of electric aviation operations that will benefit greatly from the transition are battery manufacturers, airframe manufacturers (due to need for specialised competence in making ultra-light-weight airframe), electric engine manufacturers, and aircraft manufacturers. Additionally, if the shift contributes to changing the travel patterns within the Nordics, then there will be a higher demand for airport operators and ground handling services in the future.



### Government

Governments can benefit greatly from the shift. In order to realise electric aviation, a huge amount of innovation is vital. Accordingly, the aviation industry is changing up its mode of production, whereby producers are moving away from working with known concepts into an innovative work process where new ideas are being prototyped and tested. A great example of this is Heart Aerospace's great expansion from its establishment in 2018. Their growth has resulted in a talent acquisition from many different parts of the globe, providing ample opportunity for resourceful people to migrate to Sweden. By embracing such effects of an innovative industry, governments can reap indirect benefits such as additional tax payers, but most importantly accumulation of valuable knowledge. By investing in the electric industry early on and making it convenient for such actors and stakeholders, governments, both local and national, may see themselves in the centre of a new and booming global industry.

When electric air transport is available to customers, it is likely that the increased flexibility offered may help slow down or shift the trend of urbanisation. By offering ways of commuting that are flexible, cheap and environmentally friendly, local governments may see themselves being able to keep young inhabitants and being lucrative places to establish businesses. Greater connectivity will result in increased welfare for many by providing more available health care services, universities and colleges, and recreational destinations.



### Environment

The environment will benefit via reduced greenhouse gas emissions in-flight and less noise pollution at and around airports. Electric aviation may also reduce the need for encroachment of nature by providing a better alternative than railway and road expansions, which demand a lot of land area and can have detrimental effects on natural habitats' ability to house and foster wild animals.

In 2019, aviation contributed to approximately 2 % of total CO<sub>2</sub> emissions (Air Transport Action Group, 2020). However, in addition to these emissions, aviation also contributes with quite unique climate effects with chemical and physical processes that occur in higher atmospheric levels, at the location of emission. Such effects include creation of condensation strips and cirrus clouds, and they are likely to produce a larger climate effect than the emissions of CO<sub>2</sub> do alone (Lund, Aamaas, Berntsen, & Fuglestad, 2016). Battery electric aircraft will not contribute to any of these effects. Thus electric aviation will be as environmentally friendly as the electric power that charges its batteries.



# Benchmarking analysis

There is political will to incentivise operators of electric aircraft, and sources of inspiration to invent effective options can be found in the incentive schemes for electric vehicles and ferries in Norway. To illustrate the importance of positive incentives, we can look at the reduction in the sale of electric cars that occurred after Denmark increased the amount of registration tax (4605 vs. 1369 cars), which was 20 % of that of cars with combustion engines (Klingenberg, 2018).

In Norway, there are several incentives in place to accelerate the adoption of more environmentally friendly cars from combustion cars. The government has set a goal that all new car sales shall be emission-free cars from 2025 (EVBox). The incentives include inter alia exemption from registration tax and VAT, discounted toll passes and parking in public car parks, and access to bus lanes (EVBox). For the incentives to have effect, it is crucial that supporting infrastructure is robust and eases the use for the consumers (Fearnley & Figenbaum, 2016). The sum of these financial and regulatory incentives increase consumers' likelihood of purchasing an electric car rather than one with a combustion engine, thereby being efficient tools to reaching the goal of emission-free car sales in just a few years.

The origin of the introduction of incentives for electric vehicles was to compensate for the disadvantages compared to more mature concepts of technology (Fearnley & Figenbaum). Fearnley and colleagues (2015) conducted a model to investigate the effect of each incentive as well as the additive effects of incentives clustered together. They found that the most effective incentives in terms of CO<sub>2</sub> reduction was the exemption of registration tax and access to bus lanes. Bjerkkan, Nørbech and Nordtønne (2016) found that the registration tax was especially significant for consumers. They found no synergy effect between the incentives, but they did find that the incentives have additive effects, meaning that for each incentive that is introduced, the amount of CO<sub>2</sub> saved is corresponding. In other words, the success of the electric vehicle adoption has, and is, completely dependent on long term political commitments and signals. Consumers need to know how long the incentives will last, and how they might change after a certain period of time.

Incentives for electric vehicles have resulted in a reduction in fiscal income. However this loss of revenue can be compensated for by increasing the fees and taxes for the use of fossil fuelled vehicles (Fearnley et al., 2015). The plan in Norway is to gradually, as the disadvantages of owning an electric vehicle



versus a fossil fuelled vehicle are diminished, reduce the incentives (Fearnley & Figenbaum). Fearnley and Figenbaum point to the development of battery technology, ensuring increased range and cheaper acquisition costs, has been the main driver to increase the advantages of owning electric vehicles. The fact that the technological development of electric vehicles is accelerated is a very welcome side effect of the incentive scheme.

In sum, the incentive scheme for electric vehicles in Norway teaches us valuable lessons as to how an industry's development can be accelerated and how innovators (i.e. the first users of a new technology) can be compensated for their experience of disadvantages in relation to the technology's immaturity. These lessons are directly transferable to the electric aviation industry. The takeaways that politicians need to keep in mind is the additive effect of incentives: the amount of incentives have an effect, the incentive scheme should be presented with a long term horizon, and any changes to them should also be announced a long time in advance. If done in this way, we are likely to see cumulative effects whereby technology improves in line with the gradual adoption, operators will welcome the new technology as it will become a source of competitive advantage, and consumers will embrace the technology and eventually view it as an equal (or even superior) alternative to fossil fuelled aircraft.

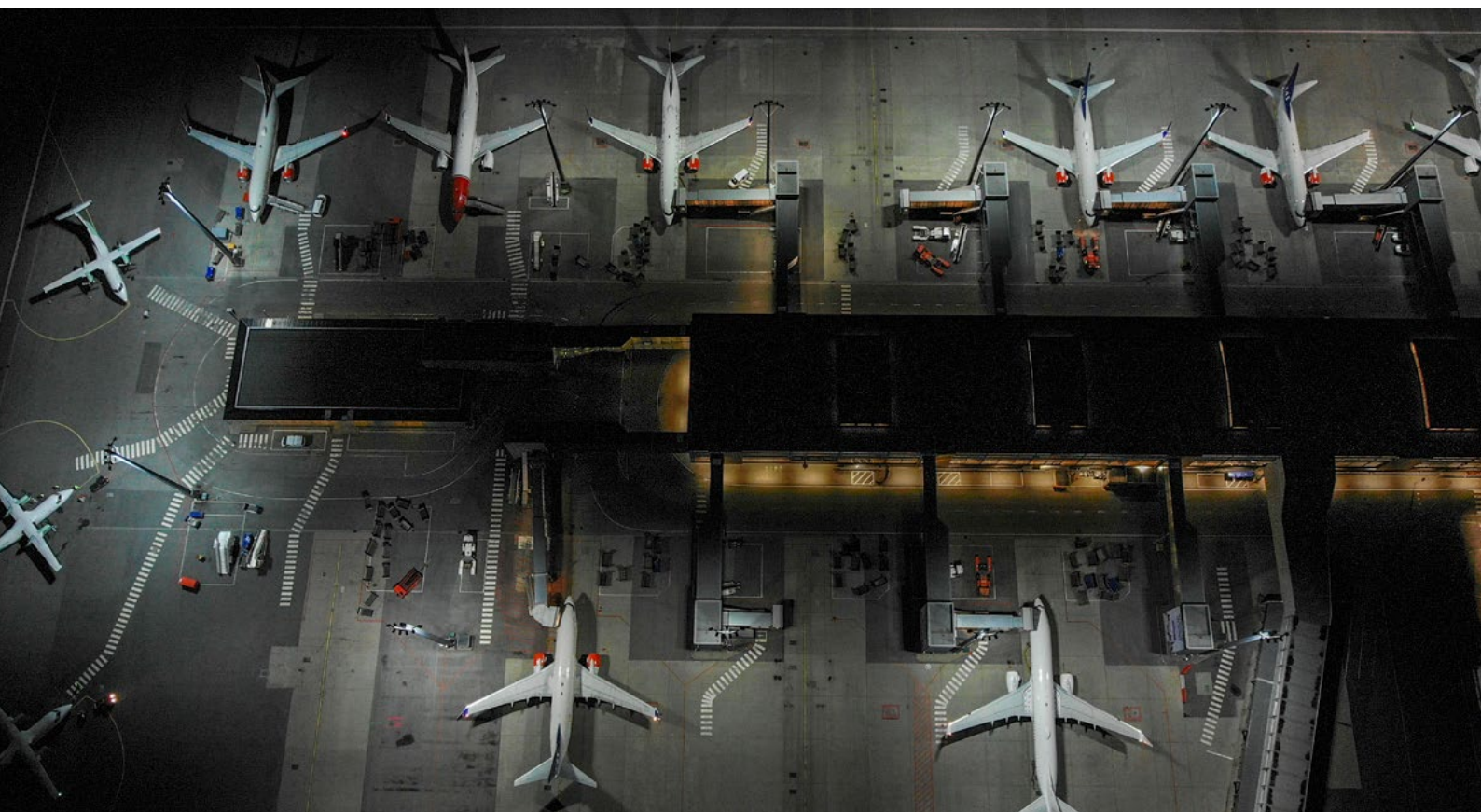
The Norwegian government has also set ambitious goals towards reducing greenhouse gas emissions from ferries: by 2030 the aim is for two thirds of all ferries to be battery electric

while the rest is either fuelled by hydrogen or biofuels (Stensvold, 2017). In 2015, Norway set the first large car and passenger ferry, Ampere, into use between Lavik and Oppdal (Bellona & Siemens, 2015). Ferry companies are covered by several governmental programmes for financial aid, both for investments in new more environmentally friendly technology and for piloting new technology and equipment.

As opposed to the car industry, ferries have yet to standardise their charging equipment. Part of the reason why may be the government's decision not to favour any technology in order to initiate a sort of "technological evolution" in which the best solution wins the race and becomes the standard. Today there are approximately ten to twelve different solutions available in Norway, and this approach has caused inflexibility in the network of ferries.

Since different solutions are placed at different ferry connections, moving the ferries around is impossible in several places (Stensvold, 2017).

According to the feasibility study conducted by Bellona and Siemens on the background of the experiences harvested from the Ampere introduction, it will be economically feasible to replace fossil fuelled ferries with battery and/or hybrid electric ferries. This accounts for 70 % of the ferries in Norway. There is a large potential for reduction of emissions within the Norwegian ferry network: there are in total 111 ferry connections and 180 ferries operate on these routes. The reason why it is not economically profitable to replace the ferries on the remaining 30 % is that the reduction of operational costs does not cover the acquisition costs.



# Conclusion

To summarise the findings from our work in this project, we believe that electric aviation will be able to improve Nordic mobility and connectivity. Realistic scenarios include Iceland and Denmark being covered by electric aviation for their domestic routes and the establishment of local as well as cross-border routes. There are several factors contributing to making the Nordic region an ideal location to be the first place to make electric aviation commercially available, including a relatively environmentally friendly power grid, highly competent research facilities and institutions, and political will in the whole region. The Nordic region has a unique potential to be the power hub and the North Star for electric aviation and associated technology.

As previously discussed, the conditions for operations with electric aircraft vary greatly from today's conditions for operations. We expect to see a significant reduction of costs (e.g. by omitting fuel and using electricity to power the aircraft), a great incentive for airlines to attempt to keep acquired aircraft in the air with paying customers for as much time as possible. Additionally, in the beginning as electric aviation is commercially available, cabins will be smaller than in fossil fuelled aircraft. Therefore, in order to meet the demand for air transport that already exists, there will have to be more frequent departures, consequently providing greater flexibility for passengers. Moreover, new business models may focus on shorter routes that are not economically feasible with conventional aircraft due to expensive unit costs, but that will be profitable with electric aircraft.

In order to realise the conversion that all actors in the industry (battery and engine manufacturers, airlines, airports, local governments, and national governments) are welcoming, the regulatory framework and financial aid programmes need to take on a holistic approach to be able to accelerate the process of the ongoing research and development. The Nordic countries have a lot to learn from the very successful incentive schemes for electric vehicles in Norway. Should we be ambitious about realising the adaptation as soon as possible, then we shall work towards creating the corresponding solutions that would lift the electrification of the aviation industry as much as it did to the car and lorry industry. We need stable and long term solutions and schemes in order for actors to take on the risks associated with adopting a completely new technology. The disadvantages from doing so, we feel, should be compensated for by those in the industry that pollute. That way, there is no doubt that electric aviation within and between the Nordic countries will rise up as the most crucial element in the winning business models.

By collaborative efforts such as NEA we enable uniting the Nordic initiatives' experiences to better cope with an uncertain development of the electric aviation industry. We would welcome initiatives that strengthen the connection between more diverse stakeholders that are important for shaping the future, such as regulators and politicians. If the Nordic countries succeed in a combined effort we may be able to reap the benefits of having a flexible aviation system (e.g. by having a standardised charging infrastructure) and regulators, manufacturers, airlines and politicians can benefit from mutual exchanges of experiences, which may save years of development.

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