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# Introduction

# En bild som visar karta Automatiskt genererad beskrivningBackground

## Current air traffic in the region

## Aviation and environment

Electric aviation is still in many aspects in an early phase of development, national goals and strategies all show this. The countries in the region are all working with these questions in some way, but there are quite big differences how far they have reached.

On an international level, which will be addressed at the end of this section, the international industry of aviation has reached an agreement of global targets for emission by the year 2050. These goals are short-, mid- and long-term goals and are followed up by the UN organization ICAO. By the year 2050 the goal is to have reduced the CO2 emissions by 50 % of the absolute numbers of the 2005 levels.[[1]](#footnote-2)

### International

As a part of the environmental work and efforts to manage the climate footprint of aviation ICAO has adopted a program called *“The Carbon Offsetting and Reduction Scheme for International Aviation”* (CORSIA). The aim of the program is to facilitate carbon-neutral growth from 2020. CORSIA is a part of ICAO:s larger program and “[…] has been adopted as complementary to the broader package of measures to help ICAO achieve its aspirational goal of carbon-neutral growth from 2020 onwards. CORSIA relies on the use of emissions units from the carbon market to offset the amount of CO2 emissions that cannot be reduced through the use of technological and operational improvements, and sustainable aviation fuels.”[[2]](#footnote-3) The goal here with this guiding tool is to stabilise the carbon emissions from aviation at the levels of year 2020. Emissions above that has to be compensated by acquisition of carbon emission rights in other sectors.

The CORSIA programs pilot phase will start in 2021 when all participation is voluntary, and the carbon emissions are being measured against the baseline established by the data collection from 2019 and 2020.[[3]](#footnote-4)

### European Union

The European Union has no explicit strategy for electrifying aviation. However, EU has an ambition about making aviation have less environmental impact. This primarily promoted through research and innovation funding within Horizon 2020 and the forthcoming Horizon Europe. One research program funded through this is Clean Sky.[[4]](#footnote-5)

## Finland

### National goals

Finland has set up the year 2035 as the target for reaching carbon neutral and soon after that become carbon negative.[[5]](#footnote-6) To the best of our knowledge there are no national strategy regarding how to reduce carbon emissions from aviation or national strategies for a green transition within aviation. However, there are initiatives for this in Finland within the aviation sector. In 2018 an agreement of cooperation between Finavia and Helsinki Electric Aircraft Association with the ambition to increase the knowledge about electric aviation and in extension be able to develop the airports.[[6]](#footnote-7) The first electric airplane to take off in Finland was the two-seater Pipistrel Alpha Electro on June 31st, 2018.[[7]](#footnote-8) Finavia operate 21 airports in Finland and has the task to develop them and the nationwide traffic control system.[[8]](#footnote-9)

#### Domestic airlines - Finnair

### Who owns the airports?

In Finland the absolute majority of the airports are owned and operated by Finavia, 21 of totally 24 airports. Regarding the three other airports one is owned by a municipality and the other two are owned by foundations and have no regular traffic.[[9]](#footnote-10)

By operating basically all airports in Finland through the state owned Finavia all airport, except three, becomes part of one network that in turn consolidates to one unit. This makes it possible to cross subsidize airports while still complying with EU directive and thereby upholding the network of airports. And in addition to this Finavia has signed agreements with the Armed Forces regarding using 10 airports at cost price.[[10]](#footnote-11)

Within the Kvarken region in Finland there are two airports organized through Finavia and one airport organized through a foundation, see Table X.

### Funding?

## Norway

### National goals

Norway has set up one of the world’s most ambitious target goals by stating that all short domestic flights shall be electrified by the year 2040. Avinor’s former CEO Dag Falk-Petersen believe that all flights up to 1.5 hours are possible to operate with fully electric planes. A first step towards this is within short to launch a tender offer to test a commercial route flown with a small electric plane with 19 seats, starting in 202516.

The Ministry of Transport and Communications has commissioned Avinor and the Civil Aviation Authority to develop proposals for a program for phasing in electrified aircraft in Norway. The report states that by 2030, the first ordinary domestic scheduled flights may be electrified; “*Our recommendation is that Norway should be one of the main arenas in the world for electrification of aviation*”.

Norway is dependent on aviation, and in large parts of the country aviation must be considered as a very important part of the public transport services. According to Avinor and the Civil Aviation Authority's assessment, it is therefore particularly important for Norway to have concrete and time-bound goals for implementation and emission reductions, and a goal to be a driving force and an arena for the development and implementation of new technology.

In the new Climate Plan towards 2030, the Government lay down guidelines for low- or zero-emission technology to be used more quickly, and for Norway to become an international arena for testing and developing low- and zero-emission aircraft. They will continue a collaboration between the European Aviation Safety Agency (EASA) and the Civil Aviation Authority, to accelerate the process towards phasing in electric passenger aircraft. The agreement includes technology, regulations, and facilitation. Together with the Norwegian Civil Aviation Authority, Avinor will contribute to make ground-based infrastructure and airspace available.17

In October 2020 Avinor published a report where Norwegian aviation for the first time gathered around a roadmap of how to reach the goal of becoming fossil free by the year 2050. This concretely means that domestic and outbound international flights must use fossil free fuel.18 As the first country in the world Norway has implemented a requirement regarding the use of sustainable jet biofuels. And *Stortinget* has, through the *National Transporation plan 2018-2029*, decided that the target will be progressive up to 30 percent in the year 2030. The first year, 2020, the target will be 0.5 percent. How the target of 30 percent drop in practically will be solved is not defined.19

Avinor has made a promise that small, electrified aircraft will be exempted from taxes and have access to free electricity up until 2025. Furthermore, Avinor has also declared that they will make sure that there will be an adequate charging infrastructure in place by the time electrified passenger planes will come into operations.20

#### Domestic airlines - Norwegian

Norwegians target goal is to by the year 2030 reduce the CO2 emissions by 45 percent per kilometre compared by the 2010 levels through an upgraded aircraft fleet and sustainable fuels. This will lead to that between 16 and 28 percent of the fuel will be sustainable before 2030.[[11]](#footnote-12)

### Who owns the airports?

The 43 state airports are financed by the Avinor system as a network. This means cross-financing between the airports of both operation and development, a model that is approved in the EU (ESA).

Most of the airports owned and operated by Avinor are not profitable. Only at the four largest airport Oslo, Stavanger, Bergen and Trondheim the aeronautical and non-aeronautical revenues exceed the operational costs. In 2019 the operating revenues from the airport operations at Avinor’s airports was 10,4 billion NOK and the operating costs (incl. depreciation and financial costs) 7,4 billion NOK. This generated an operating profit of 3,0 billion NOK. However, the operating profit at the four largest airports was 4 billion NOK while the net operating deficit on the regional airports was 1 billion NOK. There is thus a significant cross-subsidization in Avinor.

The fact that airports that make a profit finance those that make a loss is referred to as the "Avinor-model". The "Avinor-model" also implies that the airport charges, with the exception of the terminal navigation charge (TNC), are equal at all Avinor airports. The model provides a predictable operation of the airports as long as the company manages to generate large enough profits at the largest airports to cover the deficit at the regional airports while at the same time managing the necessary investments at the airports. Then the regional airports are not dependent on subsidies from the owners (the state) to be able to maintain their operations.

There are two exceptions; The state and local parties are financing the development of two completely new airports, in Mo i Rana and Bodø, even though these are owned by Avinor. The company does not have the finances to cover such large investments. In addition, three municipally owned airports receive subsidies from the state budget. These are Stord, Notodden and Ørlandet. (Ørlandet is a military airport, but the municipality owns and operates the civilian terminal). For the municipally owned airports there are some criteria’s for

Commercial income from shops, tax-free and rentals, etc. make up a large part of Avinor's income, in addition to fees for using the airport. Under normal circumstances, the Avinor network has been self-financing. Nevertheless, the pandemic has obviously hit this model hard. This has led to large government grants to Avinor, however, the company still has a strained liquidity due to the fall in revenue.

In Nordland there are currently 11 airports, all operated by Avinor.

### Funding?

## Sweden

### National goals

In 2018, the aviation sector has developed a roadmap for fossil-free competitiveness.[[12]](#footnote-13) The roadmaps, which has been developed by several sectors, has been initiated by Fossilfritt Sverige. It is a national initiative to make Sweden the first fossil-free welfare nation in the world. The roadmap describes how Sweden should reach the national goals of a domestic fossil free aviation in 2030 and a completely fossil free aviation sector by 2045. Since the roadmap was developed 2018 before electric aviation stepped in as an option, the focus is on bio jet fuel.

Swedavia make the assessment that by the year 2025 the necessary prerequisites for electrifying parts of the domestic flights will we in place.[[13]](#footnote-14) With the current battery technology it is possible to fly about 400 km. About one third of Sweden’s domestic flights are on routs up towards 400 km.[[14]](#footnote-15) In February 2020 Swedavia announced the adoption of a strategy for electric aviation as well as power supply and infrastructure at their airports. At this time Swedavia also announced that they were planning on launching a test site for electric airplanes in Åre/Östersund Airport in the fall.[[15]](#footnote-16) The test flights are proposed to be conducted in the airspace between Åre/Östersund and Røros Airport in Norway in collaboration with a variety of partners, all within the framework of the EU-project Green Flyway. And in the beginning of October 2020 the test site in Åre/Östersund was opened.[[16]](#footnote-17) The long-time ambition of Swedavia is that all of their ten airports will have a sufficient infrastructure for electric airplanes.

The project Green Flyway is a collaboration facilitated by Sveriges Regionala Flygplaser with the objective of working towards the national goals for fossil free aviation. A part of this will consist of creating infrastructure on the regional airports to be able to charge electric aircrafts as the technology evolves.[[17]](#footnote-18)

#### Domestic airlines – Scandinavian Airlines

SAS[[18]](#footnote-19) ambition is by the year 2025 to reduce their CO2 emissions by 25 percent compared by the 2005 levels. And by 2030 SAS goal is to reduce their carbon emission by half, given that there is a framework to facilitate this as well as good conditions and instruments in place. Exactly how SAS need this framework to be constructed are not specified, neither what conditions are of importance nor which instruments that has to be set in place. And to introduce sustainable fuel equivalent to the fuel consumption of all SAS domestic flights in Scandinavia.[[19]](#footnote-20)

### Who owns the airports?

Sweden has a total of 45 airports certified for instrument landing (ILS).[[20]](#footnote-21) Of these, around 38 airports have regular passenger traffic (commercial or publicly procured).

#### Governmentally owned airports

Sweden has a large airport company owned by the Government: Swedavia.[[21]](#footnote-22) They own ten airports: Kiruna, Luleå, Umeå, Åre Östersund, Stockholm Arlanda, Stockholm Bromma, Göteborg Landvetter, Visby, Ronneby and Malmö. Swedavia is responsible for these airports development and have the means of financing the investments they plan.

For these airports to invest in infrastructure for electrification is a minor problem. Planning, financing, execution – all can be handled within the corporation.[[22]](#footnote-23) Swedavia is right now planning for electrification of their airports.[[23]](#footnote-24)

At the end of the day, the Swedish government is banking Swedavia. In 2010, when Swedavia was formed, there were regional airports left outside the company. They were handed over to local or regional owners, often with a lot less financial strength.

This has been debated a lot inside the aviation industry in Sweden. Many of the regional airports only have traffic to airports owned by Swedavia (mainly Arlanda). Hence: Swedavia benefits from fees (take off, landing, pax) from all Swedish aviation movements, but only keeps, and supports, the most profitable airports within their domains of responsibility.

#### Regionally owned airports

The non-governmentally owned airports in Sweden are not a homogenous group. They differ with regarding to ownership, size, passenger volumes and so forth. The organization for regional airports, SRF, lists 33 members.[[24]](#footnote-25)

The government helps with a yearly subsidy for the operation. The amount is calculated based on several factors such as passenger volume, financial result and is designed to cover “a part of the financial loss” the airport produces.[[25]](#footnote-26) The subsidies comes either from the Transport authority (around SEK 70 million) or is distributed through the Regions (around SEK 40 million). The expectation is that the owner, normally a municipality, covers the rest of the funds needed to keep the airport in operation.

Within the Kvarken region in Sweden there is one airport in the Swedavia group owned by the state and seven airports that are owned by the municipality and organized through Swedish Regional Airports. Hemavan/Tärnaby Airport is owned both by the municipality (+90%) and by private parties.

### Funding?

As the regional airports are primarily owned by municipalities and regions, a structural organisation that have an impact on how they can receive funding. As their owners, municipalities and regions, to a large extent has to provide financial support in order uphold the operation they also have to comply with EU:s regulations regarding public funding.

The need for financial support from the owners has increased as operation aid from the state has come to be less and less substantial at the same time as new regulations has increased the cost of operations.

As of May 2017, the EU has a group exception regarding support to airports within Europe. This exception is constructed for airports with a total number of passengers that do not surpass 200.000 on a yearly basis. This group exception makes it possible to give financial aid with put first securing an approval from the European commission

The airports owned and operated by the Swedish state is not covered by the exception in the same way as they are organised within in one corporate group that has a positive total result. And for regional airports with over 200.000 passengers on a yearly basis an approval from the commission is required, this can be granted by something called a SGEI-regulation. Sweden has three regional airports approved by SGEI-regulation; Sundsvall, Kalmar and Skellefteå.[[26]](#footnote-27)

The Swedish Transport Administration oversees and administrates a state founded aid in place to cover part of deficits due to operational costs at regional airports. This aid is divided in two different categories; aid to airports with general traffic obligation and aid to airports covered by the regional plan for transport infrastructure. As a result of this division one part of the funds are distributed directly to the airports through the Swedish Transport Administration and one part distributed by the region or the Country Administrative Board through the regional plans for transport infrastructure. The total amount is about 100MSEK, roughly divided 70/30 between the two types of aid. Worth mentioning is that the funding controlled by the regions/Country Administrative Board is not earmarked for the airport.[[27]](#footnote-28)

There is also a possibility to give financial support within the “de minimis” regulation. However, there is a cap of €200 000 over a period of three years. And as the need for financial aid to cover operational cost in almost all cases exceed that this possibility is very limited.[[28]](#footnote-29)

## Regional conditions within the program area

There are two major natural barriers preventing time efficient land travel in the program area, the Kvarken strait between Finland and Sweden and the Scandinavian Mountains between Sweden and Norway.

The boarder between Sweden and Norway makes up the outer boarder for the European Union.

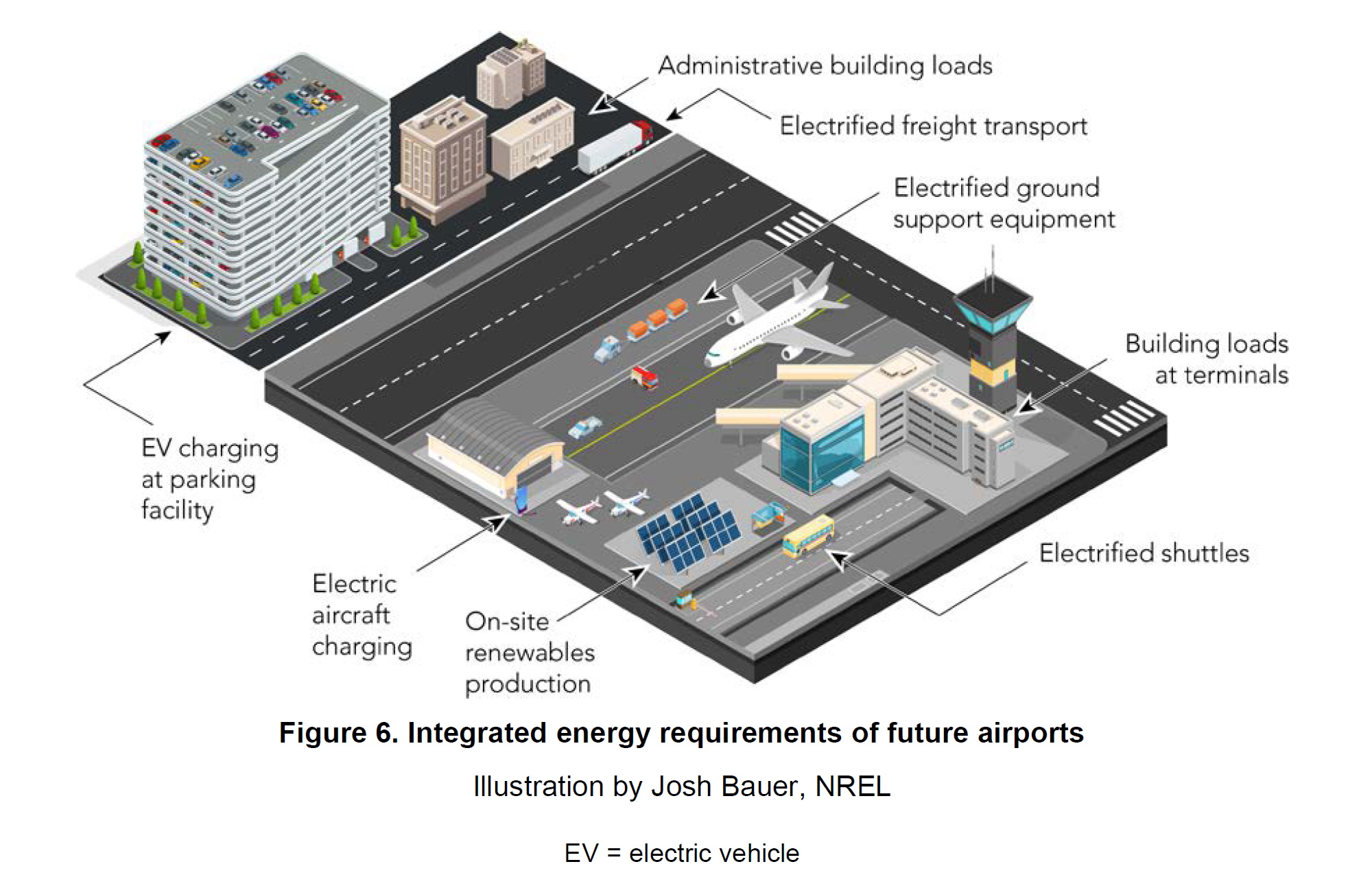
# Infrastructure and new connections

A charging infrastructure for electric aircrafts needs to provide a plug-in that can be connected to the aircraft with a certain effect. In this early stage of electric aviation development and implementation, the charging stations will probably be mobile and provided by the aircraft company. Today, almost all of the airports in the Kvarken region have subscriptions on the effect that is enough for the power needed by a charging station.

## What infrastructure is needed?

To know what kind of infrastructure that will be required at a certain airport, several parameters must be known. Along with the development of aircraft and batteries as well as a believed increase in electric aviation, the need will change. Moreover, the charging technology will probably also be developed which also contributes to a change of needs.

There is also a need for charging of other vehicles at an airport along with the ambition to electrifying the vehicle fleet both at airside and landside. At airside, it can be work machines for track preparation, fire trucks, lawn mowers, luggage transports, de-icing vehicles, and tankers. On the landside, there are taxis, buses, rental cars, and passenger vehicles.



A study on electric aviation in Norway states that regional electrical aircrafts can operate at short field airports which is defined by a runway of 800-1999 m.[[29]](#footnote-30) Heart Aerospace’s ES-19 will be able to operate at 750 m runways.[[30]](#footnote-31) This is due to their size as well as the ability of electric propulsion systems to provide short bursts of power on take-off to get the aircraft in the air quicker as well as the motors ability to be reversed and used for braking to land in a short distance.[[31]](#footnote-32) In a report by Transport Analysis there are 83 airports in Sweden that fulfils those requirements. This means that besides the 39 airports having commercial air traffic today, there are 44 more potential airports. In the Swedish part of Kvarken region it is the airports in Åsele, Mellansel, Sollefteå, Härnösand and Ånge.[[32]](#footnote-33)

### Charging

The electrical demand depends on how the aircraft is operated. For a quick stop at an airport, a fast charging is required, and for longer times on the ground, a slow charging requiring a lower capacity is needed. Battery backups is also one option for using slow charging systems for a fast charging of an aircraft.

The time required for charging depends on the battery capacity, state of charge, and time available to charge. If the aircraft is capable of a battery swap, the used batteries could be charged at a slower pace.[[33]](#footnote-34)

It is important to identify a place for a connection point for a charging station in close connection to the parking area for the electric aircraft. The connection point shall also be considered the option to handle more than one aircraft at the same time. The place used for charging overnight, either the same place or another, shall be identified and included in the calculations. Slow charging, which can be used overnight, has not the same power requirements and might be possible to solve in a different way.

Today, the flight operators bring their own chargers to the airports and connect them at a connection point (see the section about mobile chargers).

#### Stationary

The charging infrastructure is continuously developed and today, there are chargers up to 360 kW DC available from different suppliers. The technology is now robust since there are many installations within the car infrastructure around the world. One of the problems have been the high-power during charging, since it causes heating problems in the connection cables and in the connection point to the vehicle. Moreover, the usage can affect the connected electricity grid and other equipment connected to the grid.

When looking at the status at airports regarding charging infrastructure, there have been activity in Sweden started in the year 2020. In May 2020, the first charging station in Sweden was inaugurated at Dala Airport AB in Borlänge. Dala Airport AB, AB Dalaflyg and Fyrstads Flygplats AB (Trollhättan-Vänersborg) has received money from the so-called *Klimatklivet*, which is a subvention from the Swedish Environmental Protection Agency for actions contributing to reduction of CO2 emissions.[[34]](#footnote-35) The charging stations is of the same type as fast chargers for electric cars and was installed by Hybrida in co-operation with the battery charging company CTEK.[[35]](#footnote-36) In 2021, the same type of charging infrastructure with three charging stations with contribution from *Klimatklivet* was inaugurated at Visby Airport.[[36]](#footnote-37)

Also, in 2021 Skellefteå Airport has installed a connection with 1 MW. This will make it possible for electric aircrafts with their own charger to connect and charge. By doing this, providing a connection point on airside, the airport makes it possible for electric aircrafts to use the airport even though there are no charging standard in place yet. For the fact is, todays solution for electric aircrafts in operations are to bring their own charger or use the same standard as for cars. In the future the standard will probably be global and between 750 and 2000 kW.[[37]](#footnote-38) Read more about the process at Skellefteå Airport in the section “*Case Skellefteå Airport*”.

Around the world, there are some activities as well. The Australian company Electro.Aero presented their mobile DC charger with a power of 30 kW in 2019. It is able to handle 300 to 1 000 V depending on the infrastructure at the airport. The charger is constructed to connect to 3 phase 50 A and fit under the wings of most aircrafts.[[38]](#footnote-39) Their first costumer was Ampaire, who is described more in the section *Hybride Electric aircrafts under testing and development*.

Companies working specifically on charging infrastructure include Pipistrel, which is developing chargers for its own planes; Beta Technologies;[[39]](#footnote-40) and ElectroAero, which is developing a DC charging solution for this mark.[[40]](#footnote-41)

#### Mobile

Pipistrel has their own charging infrastructure that can be connected to the grid through a mobile charging station or through an installed fast charger with a capacity to charge 2 or 4 airplanes at the same time. The charging station for 2 aircrafts has a power of 2 x 20 kW. The time to fully charge a Pipistrel Alpha Electro (60 kW power) is one hour.[[41]](#footnote-42)

#### Energy storage

Battery storage is one possibility to use, which means a large battery that is slowly charged using a low power source. Then, the charged battery can be connected to the aircraft and enable a fast-charging capacity. *Mälarenergi* in Västerås has together with *Northvolt* built two battery storage systems that are available to use.[[42]](#footnote-43) The purpose is to use this battery storage system for charging of electric vehicles but also to strengthen the grid for individual users close to the limit of the available capacity. It can also be used during construction of a new areas where there might be a lack of power at certain times.

For an airport, a battery storage system opens for other usages except from serving as a charger for electric aircraft. It can strengthen own areas with a weak electric infrastructure or be used to sell grid services, like peakshawing or frequence.

Energy storage might be a good choice for both small and large airports. At small airports, to enable charging of few aircraft and still have a low power of connection to the grid and no need to increase the grid subscription. At large airports, to be able to optimize the power usage and to enable charging within the current subscription. Another option is to take the step from being a customer to an actor on the frequencymarket.

### Electric grid

Today, the power consumption in Sweden is 140 TWh. Svenska Kraftnät and the Swedish Energy Council prognosticate an increase of the power consumption to around 160 TWh in 2040. The increase is mainly expected in industrial sectors such as server storage buildings and battery fabrics but also electrifying of the industry and transport sector.

In Finland, the power consumption today is 86 TWh of where 39 TWh was consumed by the industry.[[43]](#footnote-44) In 2040, the power consumption is predicted to increase to around 100 TWh.[[44]](#footnote-45)

Region Norrbotten and Region Västerbotten has produced an analysis of the electrical grid in Northern Sweden. The report clearly describes the three different ways of situations with electricity shortages. Electricity shortage arises from power deficit, shortage of electrical energy or lack of capacity in the electricity grid. When the demand for electricity at a certain time is larger than the supply, there will be a power deficit. This can happen a cold day in winter with a high use of electricity in combination with a low production because of for example bad weather conditions or one or several nuclear power reactors out of function. Svenska Kraftnät has raised a warning flag regarding the risk of power deficit in the Swedish electricity system several times. Shortage of electrical energy is more of a long-time situation that can appear when the total supply of electricity is not expected to meet the total need of electrical energy over time. The probability for a shortage of electrical energy in Sweden is low. Lack of capacity in the electricity grid happens when at a certain location, for example in a city, there is not enough energy to meet the demand. This is due to limitations in the electricity grid and could be lack of cables, connections, or transformations to be able to use a certain power.[[45]](#footnote-46) This is the type of problem that has occurred in some large city areas and has been observed by media. The report clarifies that there are good requisites for electric intensive investments in the region of Norrbotten and Västerbotten.[[46]](#footnote-47)

The energy demand from the electrical aviation in this region will probably not be a bottleneck. It is more a question of fulfilling the requirements of power for the charging stations. However, the initial contacts with the regional airports shows that there are good opportunities for that and most of the airports already have enough power subscription.

### Connection

There is currently no global standard when it comes to charging at airports. In fact, there are no global standard at all when it comes to heavy duty vehicles or aircrafts. But there are organisations working towards establishing a global standard, the biggest of them seams to be CharIn.[[47]](#footnote-48) They are developing a standard called High Power Charging for Commercial Vehicles (HPCCV). This standard, according to CharIn, will handle powers up to more than 2 MW and will be used for charging in the range of 200-1500 V and 0-3000 A. That should be enough to meet the needs of heavy-duty electric vehicles with battery pack as large as around 1 MWh.[[48]](#footnote-49) The standardization organization SAE is also working on the topic of high power charging, there are however no concrete specifications and specs related to electric aircrafts.[[49]](#footnote-50)

### Aircraft and batteries

The cruising speed of an electric aircraft is lower as compared to a conventional aircraft equipped with a jet engine, around 300 km/h as compared to around 800 km/h, respectively. This will, however, be of marginal effect when it comes to travelling times, since there are relatively short distances.

Electric aircraft will have different needs for charging due to different battery capacity and different possibilities to receive charging. The battery development is in a strong development phase of where the cost and battery capacity are the most important parameters. More information of batteries can be found in the report “Electric aviation 2021, Technological overview”.[[50]](#footnote-51)

External parameters affect the batteries in an aircraft and set the prerequisites for the charging effect needed at airside. The external parameters are state of charge (SOC) level when arriving to the airport, SOC-level for departure, charging time at the tarmac (turn-around time) and the temperature of the battery.

Ideally, the battery temperature should be around 25°C to be charged optimally. REF? The security SOC-level for the battery is set by the manufacturer, to be able to reach the next airport including reserves. A battery can receive high power between the SOC-level of 20 to 80%. Above 80%, the charging capacity is slower as well as the degree of efficiency.[[51]](#footnote-52)

## Roadmap – charging infrastructure at airports

This roadmap is aiming to facilitate for an airport to initiate and implement charging infrastructure at airside. Each airport has their own unique prerequisites to be able to charge aircraft. There are some generic steps to go through to investigate the local conditions.

1. What does today’s power subscriptions look like? What is the electric power level needed today and how is the variations over day and night as well as seasonal. Which connections points exists today?
2. What are the possibilities to get higher power to the airport? Start a dialogue with the power supply company.
   1. Is it possible and are there any plans to strengthen up the power grid that you are connected to?
   2. Different types of subscriptions and costs on your grid connection.
   3. The time perspective on strengthening the electricity grid
3. Is it possible to decrease the airports use on the electricity grid and enable space for charging capacity at certain time slots?
4. Where are the electrical cables placed physically in the ground today? Investigate how to be able to get an electrical cable at airside, where to place a connection, a small building and being close to the aircraft.
5. Adapt the charging capacity in line with the expected air traffic including an eventual increase in traffic.
6. Other changes that might be necessary to take in mind is:
   1. Handling of arriving passengers and luggage that has to pass thru the security control before a connection flight
   2. Taxi tracks for handling all the movements on the airfield
   3. Terminals for regional planes where you can charge them
   4. Other increased electric use, need to charge cars or machines at the airport
   5. Possible disturbances on other equipment such as communication and navigation
7. Design of the new infrastructure and cost calculations.
8. Financing of new electrical infrastructure. Possible financing subsides might be initiated at an earlier step, but the searching process cannot start until the budgeted costs are known.
9. Procurement of construction and components
10. Construction work

## Possible new routes

All airports have their own system with different arrivals and departures, which makes the demand looking different at each airport. In the same way, each airline has their own flight route for each aircraft. This together with the timetable, might lead to a quite complex and different looking demand at each airport. To get a better overview of the demand for a certain airport, some simulations or calculations needs to be done.

The project *Modelflyg* has done simulations at Umeå Airport to see the power demand when five battery electric aircraft (19 pax) arrive and want to charge at the same time. Then, it should also be possible for connections flights to be at the airport at the same time. The simulations have focused on the demand when all aircraft get their required power, including an optimization that gives the aircraft power based on their flight route to limit the maximum power outlet. The conclusions are that at Umeå Airport, charging stations with a power capacity of 350 to 550 kW with a total power demand of 1.3 to 2.75 MW is needed depending on the usage of the optimization or if there would be liberal access to power for each aircraft.[[52]](#footnote-53)

For calculations on three different flight routes, see the section *Calculated routes*.

En bild som visar karta

Automatiskt genererad beskrivning

The map for electric aviation (Figure X) is based on the premiss of a maximum operational distance of 400 km. It also focuses on the possibilities not in operation now, primarily an east-west perspective. And this is not a replacement of current operations but a complement.

The development of electrical aircraft models is mainly in the 2-19 passenger section. In a regional perspective, especially in a region including a sea and a lack of railway in some directions, the small electrical airplanes might be a solution for enabling a convenient way of fast and sustainable traveling. It might also be a fast way for more specific travels, for example business travels between big industries or transportation of cargo. The range for the most close-to-market aircrafts will be enough to cross the Kvarken Sea and go to places situated in the inland region. In this relatively sparsely populated region, the number of passengers (2-19) is believed to be rather optimal to fill up the planes without having too many travellers.

What routes that might be of interest, and commercially viable, rest mainly on two type of trips; point to point trips and transfer passengers (primarily Stockholm most likely). This has the consequence that new electric flights should be connected to the morning peak, between 7-9, and the afternoon peak, between 16-17. If tourism can become a driving factor they may have another rhythm and adoptions may be necessary.

There is a difference between what cities/communities that are interesting from a business perspective and which are interesting from an airports perspective. Factors that come in to play here are for example other means of public transportations (primarily train), remote airport (and lack of public transportation), low number of possible travellers, and high value tourist locations on the road.

### Potential routes

In order to investigate the need of charging infrastructure and possible routes for electrical flights in the region, two different types of aircraft and three different flight routes have been calculated. The aircraft chosen is the 9-passenger Eviation Alice and the 19-passenger Heart ES-19. The Eviation Alice aims towards a market introduction in 2024 and Heart Aerospace’s Heart-ES19 in 2026.



Figure 3. To the left the 9-seater electric aircraft Eviation Alice and to the right the 19-seater ES-19 from Heart Aerospace Heart Aerospace. Photo: Eviation Alice and Heart Aerospace.

The parameters for the aircraft used in the calculation is shown in Table x. The state of charge (SOC) has been set as not below 40 % and not higher than 90 %. This is to meet the requirement of battery reserves and the fact that the charging speed is slower after around 80 % of battery charging. It has been assumed a temperated battery with a linear charging to 90 % of the battery. Uncertainties such as wind, temperature, cooling effect on the battery has not been included in the calculations. In the calculations on the energy consumption for a flight, assumptions on 100% of effect used during the first 3 minutes and 10% of the effect used during the last 5 minutes has been made.

Table 2. Parameters for the two different aircraft used in the calculations.

|  |  |  |
| --- | --- | --- |
|  | Eviation Alice[[53]](#footnote-54) | Heart ES-19[[54]](#footnote-55) |
| Number of passengers | 9-PAX | 19-PAX |
| Cruising speed, km/h | 407 | 300 |
| Battery energy, kWh | 820 | 720 |
| Total flight time including reserves, h | 2,75 | 1,5 |
| Maximum power, kW | 1280 | 1600 |

### Calculated examples

#### En bild som visar karta Automatiskt genererad beskrivningRoute 1: Mo i Rana – Vasa

This flight route will make it possible for a fast regional travel along the road E12, which today lacks public transports between Mo i Rana and Hemavan. This route will be a complement to the buses in Sweden and will also make it possible for a fast travel over a day from Hemavan to Umeå or the other way around. Moreover, travellers from Vasa will get a fast and smooth way to travel both to Umeå, the inland and mountain area in Sweden as well as to the ocean in Mo i Rana.

In this stage of electrical aircraft development, it is necessary to have the stops at Umeå, Vilhelmina and Hemavan between Vasa and Mo i Rana to be able to keep the SOC-level at 40 % or higher.

For the **19-passenger aircraft** to be able to keep a charging time of 20-30 minutes, the airports have to offer between 700 and 1200 kW of maximum charging capacity, see Table x.



If the maximum charging capacity instead is 700 kW at the larger airports and 350 kW at the smaller airports, the charging time is doubled at Vilhelmina and Hemavan airports, see Table x. This makes the time to travel between for example Umeå to Mo i Rana remarkably longer as compared to a higher charging capacity at the smaller airports. This shows that it is important to have a relatively high charging capacity even at the smaller airports as long as the range of the electric flights requires intermediate landings.



For the **9-passenger aircraft**, the range is longer and therefore the stop at Vilhelmina airport has been excluded in the calculations. However, it turns out that charging is not even needed at the two intermediate stops (Umeå and Hemavan) to still keep a SOC-level above 40%. This means, that it would be possible to have a direct flight route between Vasa and Mo i Rana for the Eviation Alice aircraft. Practically, it is believed that charging would be performed at Hemavan to a SOC-level of at least 60 % before take-off towards Mo i Rana. For this aircraft, a charging infrastructure with a maximum effect of 350 to 700 kW is enough to keep a good flow along the travel route.

En bild som visar karta

Automatiskt genererad beskrivning

#### Route 2: Brønnøysund – Svolvaer

This flight route starts in Brønnøysund and goes to Hemavan, which is a route believed to have a future demand. In Hemavan, it is possible for travellers from Sweden and Finland to join for a continues trip to Bodø and/or Svolvaer in Lofoten. Generally, with this flight route is the time savings on each step as compared to travelling by car. Public transports are not available on none of the steps today, except from Bodø to Svolvaer which have a flight route operated by Widerø today.

This flight route is well suited for the **19-passenger aircraft**. The distances are between 110 to 170 km and passes over sea and mountain areas. The charging effects at the airports will affect the travel time and, in the table, below, a relatively low effect between 350 to 700 kW at the airports means charging times of 30 minutes up to 45 minutes. This might be too long for intermediate stops and therefore a higher charging effect would be preferable. If the charging effect would be 1200 kW at Hemavan and Bodø and 700 kW in Svolvaer instead, the charging time would be decreased by more than half. This would also remarkably reduce the total travel time from Brønnøysund to Svolvaer.





For the **9-passenger aircraft**, there is no charging needed at the intermediate stops. Depending on the turn-around time, the charging effect at Svolvaer Airport need to be higher than 350 kW, which requires 1 hour of charging to 90% SOC-level. A charging effect of 700 kW would reduce the time of charge to half, 0.5 h, to reach the same SOC-level.



#### En bild som visar karta Automatiskt genererad beskrivningRoute 3: Mo i Rana – Kokkola

This flight route is along the so-called “battery-belt”, from Mo i Rana to Skellefteå via Lycksele and further on to Karleby/Kokkola. There are already on-going discussions on starting up a flight route between Skellefteå and Kokkola, which has a demand from a business perspective.

For the **19-passenger aircraft**, it is on the limit to be able to fly between Hemavan and Lycksele without getting lower than the security level of 40% battery capacity left. One way to be able to arrive in Lycksele with more than 40% SOC-level is to stay longer time in Hemavan to reach a SOC-level of maximum 100%. This will, however, be time consuming since the last 10-20% (between 80-100%) of the battery is known to be charged at a slower pace. Generally, it will be motivated to have a higher charging effect at both Hemavan and Lycksele Airports to improve the travel time. Depending on the turn-around time in Kokkola/Karleby Airport, a higher charging capacity would be preferable.



For the **9-passenger aircraft**, the longer range would make it possible to manage a direct flight route between Mo i Rana and Kokkola. In the calculations, the aircraft is charged for 12 minutes at Skellefteå Airport. However, regarding the charging capacity at the airports, it is not of great importance since only minor charging would be needed using this type of aircraft.



# The economy of electric aviation

All countries in the region have state-owned airports and employs some sort of cross subsidizing. However, there are substantial differences in the number of state-owned airports in relationship to the total number of airports in each country. Norway has approximately 90 % state owned airports and in Finland the number is approximately 85 % (where the share of the domestic traffic is even higher). In Sweden the state owns only about 25 % of the airports and have approximately 33 % of the domestic traffic. This gives economic security to a larger share of domestic airports in Norway and Finland than in Sweden.[[55]](#footnote-56) But this does not mean that Norway and Finland have their network of airports fixed, they are evaluated against different criteria in order to maintain funding. But Sweden’s different setup means that Sweden has a larger part of the airports in the national network that must rely on external funding, local or regional, to a higher degree.

The ownership structure, and government policy towards regional airports, have a significant impact on how regional airports can invest in, and build, infrastructure for electrified aviation. This imposes a challenge for policy makers in their respective country.

When comparing Norway and Sweden it becomes clear that Norway subsidizes routes that are not profitable to a much larger extent than Sweden, but when this is divided on the number of passengers it becomes about the same. The reason for this is that Sweden only subsidizes routes with very low numbers of passengers.[[56]](#footnote-57)

## Business models for charging

#### Today

The business model for the fuel supply at airports today, is often in a way that the fuel supply company distribute and sell the fuel, but it is handled by the internal staff at the airport.

#### Possible new business models for electric aviation

At an early stage, it is probably the airport itself that will build the charging facility with a connection point to a charger. That type of facility needs a connection point to either the airports own electricity grid, the local or the regional electricity grid. A flight operator can invest in chargers for the flights on airports where they need to charge. It can also be charging company who owns and runs the airport chargers. It is hard to say in this early stage how the business model will develop.

## The costs for infrastructure?

To get an idea of ​​how large investments are required to build charging infrastructure at the regional airports, we can look at a survey conducted by the Swedish Transport Administration.[[57]](#footnote-58)   
They have looked at the costs of building chargers for heavy traffic that can be compared to air chargers. They concluded that it is about 500 Euro/kW, which for a 350 kW DC charger is about 175000 Euro for a 350 kW charger and the double for a 750 kW charger. They also have a more recent report where in table 10 on page 66 they look at an 800 kW subscription with a division into different costs, they refer also to the above publication and then arrive at the same amount.[[58]](#footnote-59) An 800 kW DC connection costs about 400000 Euro. These calculations should not be taken for absolute truths since it depend a lot on the local conditions and the local electricity company's grid tariffs. The final cost also depends on whether you need to strengthen or rebuild the existing electricity grid.

## How can this investment be financed?

The European Union have a fund named Connecting Europe Facility (CEF) which among other things finances the expansion of infrastructure for distribution of alternative fuels for cars, trains, ships, and aircraft. The total budget for the transport sector of CEF is €25,8 billion for the period 2021-2027. Primary focuses are on infrastructure for fuel distribution in connection to the trans-European TEN-T network. However, there are also possibilities to get funds for airports in connection to this.

There is also a proposition from the commission of binding national targets for distribution and charging stations for alternative fuels for road vehicles, ships, and aircraft.[[59]](#footnote-60)

Traffic analysis in Sweden investigates various possibilities for policy instruments that can drive the development of a fossil-free flight, some of which can be useful for electric flight are:

• Support for the transmission of electricity to airports for charging electric aircraft.  
• Reimbursement for conversion of aircraft.  
• Support for the purchase of fossil-free aircraft types or the opportunity to rent.

These instruments are good and the first instrument is aimed at airports and infrastructure. The smaller regional airports that are not part of the national airport organizations and have an important role to play in starting a regional electric flight should be able to apply for support where they receive a significant share of the investment. The support should include extraction of electricity, possible transformations, connection costs, charging connection airside, any building that can house chargers, or battery backup. Annual support may also be needed to cover the operating costs of smaller regional airports.  
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#### Climate change initiative in Sweden

Climate change is an investment support for local and regional measures that reduce climate-affecting emissions. Through smart, innovative solutions, we can move towards a more climate-smart society. It has been used to finance small chargers at airports in Sweden

# Discussion

# Conclusion

# CASE: Skellefteå Airport (Lyftas ut och ligga parallellt med texten)

In Skellefteå, they want to change and move towards fossil-free and also affect the industry - they saw three tracks: biofuel, electric aviation, hydrogen. Biofuel can already be refueled, charging for electric aircraft is now available. Hydrogen is likely to come. They wanted to make it happen.  
  
They brought in expertise from outside and had good conditions as the municipality owns Skellefteå kraft and Northvolt has established itself in the municipality. They knew that 1 MW should be enough and is manageable economically. The electric aircraft that will use charging today have a 1 MW need for fast charging, they will also not come until 2026. Before its smaller planes, several but small. Parallel charging very important to keep the plane in the air as much as possible (for economic sustainability). In total, 1 MW was justified, but no more. They leaned towards the regulations for electrical installations for airports, the location is physically important. Two high voltage power supplies pass close, which made it much easier. Electrical technology is demanding and needs to be scalable and flexible. There was not much done in this area so it required a lot of thought and standardization is lacking, the concept is based on a house on the airside that houses measuring equipment, test equipment, and connection point for chargers of 1mw. The building is easy to mass-produce and has a roof that is shaped like an airplane wing. PICTURE  
  
They look at the investment in the long term and have not counted on any large income, but they have already got a flight school as a customer that charges their electric planes.

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