



Nordic Council
of Ministers

Nordic Sustainable Aviation



Preface

The Nordic countries have high ambitions to become more environmentally sustainable. This ambition was further strengthened in January 2019 when the Nordic Prime Ministers signed “Declaration on Carbon Neutrality”. This declaration highlights transport as an important common Nordic challenge in the fight to reduce Greenhouse gas emissions. Aviation is probably one of the most challenging sectors to decarbonize. Although the Nordics seek to maintain leadership and cooperation in their climate efforts, aviation is a global enterprise where regional frameworks such EU-ETS and global agreements and conventions restrict the Nordic policy menu.

The following publication was commissioned by the Danish presidency of the Nordic Council of Ministers (2020). The report has been prepared by the Institute of Transport Economics (TØI) and the process towards publishing and dissemination has been overseen by Nordic Energy Research (NER). NER is the platform for cooperative energy research and knowledge development that is used for policy development under the auspices of the Nordic Council of Ministers. NER also prepared a report in 2016 entitled “Sustainable Jet-Fuels for Aviation” and have since then worked closely with stakeholders in the Nordic aviation industry through the Nordic Initiative for Sustainable Aviation (NISA). In 2020, an update of the 2016 report was published. This report - “Nordic Sustainable Aviation”- complements the previous reports presenting current policy frameworks in each Nordic country and exploring alternative policy measures. Nordic Sustainable Aviation also explores sustainable aviation fuel (SAF) and the potential of electric aviation in the Nordics.

The intention of this report is to explore challenges and opportunities for increased Nordic cooperation to increase the sustainability of aviation in Nordics, possibly with a trickle-down effect on the aviation industry globally. Nordic Sustainable Aviation presents current policy frameworks in each Nordic country and explores alternative policy measures. The report covers five policy measures and possible combinations of these; blending mandates, CO₂ equivalent reduction requirements, establishing a joint Nordic SAF-fund or parallel national SAF funds, as well as various types of fuel and passenger taxes. These measures are complemented by a summary of distances, passenger loads between all airports in the Nordics.

Suggested policy options include; A common Nordic vision for sustainable aviation backed by an ambitious joint target for the share of renewable energy in aviation by 2030. Such a plan should address both demand-side and supply-side measures with the aim of bringing up the share of SAF and stimulating the increased production of SAF internationally. Implementing a combination of a SAF-fund/SAF funds financed by joint Nordic passenger tax reduces the risk of carbon leakages and bridges the price gap between conventional jet-fuel and sustainable aviation fuels.

The COVID-19 outbreak has led to a temporary significant decline in air traffic, changes in Nordic policy frameworks, and an aviation industry in need of substantial governmental economic support to stay in business. These changes are not fully accounted for in this report. It is nevertheless our hope that this report offers Nordic politicians’ guidance as to what is possible to achieve on a Nordic level independently, and what needs to be addressed within EU and in global bodies such as ICAO and UNFCCC.

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Contents

1	Summary and conclusions	1
2	Introduction	14
2.1	Strong growth in aviation and its emissions.....	14
2.2	A regulatory gap in international aviation.....	15
2.3	Ambitious goals for GHG reductions in the Nordic countries	15
2.4	Strategies to reduce emissions from aviation	16
2.5	Sustainable aviation fuel (SAF)	17
2.6	Electrification.....	18
2.7	Report structure and scope	18
3	Overview of aviation in the Nordic countries.....	20
3.1	Internal and international travel patterns	20
3.2	Airline market shares	21
3.3	Future demand for aviation fuel.....	22
3.4	Biomass potential for sustainable aviation fuels in the Nordics	23
4	Aviation and climate policy: International context	25
4.1	Convention on International Civil Aviation, 'The Chicago Convention'	25
4.2	International Civil Aviation Organization (ICAO) and Carbon Reduction and Offsetting Scheme for International Aviation (CORSIA).....	25
4.3	EU regulation of relevance for common Nordic initiatives.....	27
5	Perspectives for sustainable aviation in the Nordics	33
5.1	Current national policies for sustainable aviation	33
5.2	Nordic initiatives dealing with sustainable aviation fuels.....	38
5.3	Electric aviation	39
5.4	Possibilities for Nordic cooperation on electric aircraft.....	46
6	Assessment of potential Nordic policy measures for sustainable aviation fuels	48
6.1	Blending mandate and CO ₂ -reduction requirements.....	49
6.2	Taxation of aviation	55
6.3	Comparative impact assessment of the policy measures.....	59
	References	68
	Appendix A: In depth interviews and consultations	82
	Appendix B: Initiatives to promote sustainable aviation in the Nordics.....	88
B.1	Policy oriented stakeholder initiatives for sustainable aviation.....	88
B.2	Initiatives to promote sustainable aviation fuels.....	89
B.3	Research and development initiatives on sustainable aviation fuel	91
B.4	Initiatives and research projects on electric aviation.....	92
	Appendix C: Calculation model for policy analyses	98
	Appendix D: Routes shorter than 200 km within and between the Nordic countries	102

Terms and abbreviations

Advanced biofuel: biofuel following specific criteria, various definitions are applied. According to the Renewables Directive, advanced biofuels are; mostly cellulosic and lingo-cellulosic materials that cannot be processed with first generation biofuel technologies.

Additionality: Carbon offsets should lead to additional projects that otherwise would not take place.

Aircraft: a vehicle that is able to fly by gaining support from the air.

Airplane: An aircraft with fixed wings.

ASK: Available Seat Kilometres = Seat supply x flight kilometres.

Biofuel: fuel based on biologic materials.

Bio jet fuel: jet fuel coming from biologic materials, including forest residues (cellulosic biofuel), plant oils, algae, organic waste.

Cabotage: Transport of goods or passengers between two places in the same country by a transport operator from another country

CIS: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Uzbekistan.

CO₂: Carbon dioxide.

CO₂e: CO₂-equivalents, a summary of measures where all GHG's are converted to CO₂e with their relative GHG-

CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation.

DAC: Direct Air Capture of CO₂

EEA: European Economic Area = EU + Norway + Iceland + Lichtenstein.

E-fuels: or electro fuels, or synthetic fuels: fuels where all or a significant share of the energy content stems from electricity based on renewable energy power to X (PtX).

E-jet fuel: E-fuels that can replace fossil jet fuel. Other terms: power-to-jet (PtJ).

EU: European Union.

Eurocontrol: The European Organisation for the Safety of Air Navigation

ETS: Emission Trading Scheme, EU's regulatory system for tradeable CO₂ emission permits.

GHG-emissions: Greenhouse gas emissions; both CO₂ and non-CO₂ emissions.

HEFA: Hydrogenated Esters and Fatty Acids, types of biofuels.

HVO: Hydrogenated Vegetable Oils.

IATA: International Air Transport Association.

ICAO: International Civil Aviation Organization.

IEA: International Energy Agency.

ILUC: Indirect land use change.

Long-haul flights: Flights longer than 4,000 km.

LULUCF: Land use, land use change and forestry

Medium-haul flights: Flights between 1,500 km and 4,000 km.

The Nordics: Short for the Nordic countries Denmark, Finland, Iceland, Norway and Sweden.

PJ: Petajoule = 1 million gigajoule (GJ) = 1 billion megajoule (MJ).

PSO: Public Service Obligation, a term used for services which are provided under public sector regulation, typically with financial support. Also linked to Public Procurement Agreement (PPA)

RD&D: Research, Development and Demonstration

RTK: Revenue Tons Kilometers.

SAF: Sustainable aviation fuels.

Short-haul flights: Flights shorter than 1,500 km.

Seat supply: Number of seats summed over a set of flights.

T&E: the non-governmental organization (NGO) Transport and the Environment.

TRL: Technology Readiness Stage, a method for estimating the maturity of technologies

VAT: Value added tax.

Summary and conclusions

Globally, aviation accounts for a modest share of World total greenhouse gas (GHG) emissions from today's energy use. However, air transport has been rapidly increasing and many other sectors are expected to reduce their emissions. Hence, aviation's share of global emissions can be foreseen to rise and will constitute a significant part of the problem unless strong counteracting initiatives are taken. However, regarding aviation, efforts have so far been limited, although aerospace industry has achieved significant technological improvements of aircraft energy efficiency over the past decades.

The Nordic countries all have high ambitions to become more environmentally sustainable. January 2019, the Nordic Prime ministers signed "*Declaration on Nordic Carbon Neutrality*", committing their countries to strengthen mutual cooperation to attain carbon neutrality domestically. The declaration emphasizes decarbonization of the transport sector. The aim of this report is to examine challenges and opportunities for increased Nordic cooperation with regards to increasing sustainability of aviation and, based on evaluation of alternative options, propose common policy measures.

Current situation

All Nordic countries have plans for national GHG reduction toward 2030 and climate neutrality by 2050 or earlier. Only Sweden and Finland have reduction targets for the transport sector and none of the Nordics have specific targets for aviation. However, some economic measures with environmental purposes are implemented:

- **Norway** has a blending mandate for 0.5% advanced biofuels as of 2019. There are plans to increase it to 30% toward 2030, but this is not yet translated into legislation.
- **Sweden and Norway** have passenger taxes. The rates per departing passenger are: 76.5 NOK (7.8 EUR) and 62 SEK (5.9 EUR) for domestic and EEA¹ destinations; 204 NOK and 260 or 416 SEK for longer routes.
- **Norway** has a fuel tax on domestic flights with a rate equivalent to about 55 EUR / tonne CO₂.

On the other hand, all Nordic countries have a reduced or zero VAT rate on domestic trips. In addition, all flights within the European Economic Area (EEA) are regulated by the EU Emission Trading System. The system de facto implies a price on CO₂-emissions from aviation, although airlines receive tradeable allowances covering a certain level of emissions from their flights per year. The market price is about 25 EUR per tonne CO₂ (August 2020). This level is far lower than national estimates of the marginal CO₂ abatement costs to achieve the emission targets in the Nordics, in particular if we only look at contributions from the transport sector. The climate impact of these emissions is, moreover, estimated to be significantly larger than for surface emissions when flying in high altitudes due to contrails from fuel burn and other complex atmospheric chemical reactions. The total effect is uncertain but can add up to a more than doubling of the CO₂-effect.

International aviation is subject to many international conventions and agreements as well as EU regulations that in practice limit what measures can be applied, although the exact interpretation is debated. International aviation is not subject to VAT and fuel taxes have to be bilaterally agreed.

¹ EEA = European Economic Area = EU + Norway, Iceland and Lichtenstein.

Pathways to sustainable aviation

Although the need for significant reduction of the climate impact from aviation is politically recognized, the ultra-high mobility generated by air transport is also widely considered an important and highly valued factor in many people's lifestyle in the Nordics. Hence, in the political mainstream, curbing air travel by strong demand side measures, strong enough to stop aviation growth, is not considered an attractive path to significantly reducing the GHG emissions from aviation. Alternative pathways to significant reductions are to:

- pursue continued energy efficiency improvements and/or
- replace fossil jet fuel with alternative energy sources with lower lifecycle GHG emissions

recognizing that this can also increase costs and ticket prices and thereby reduce air travel.

Over the next two decades, achievable fuel efficiency improvements for new conventional aircraft are estimated to be at best about 40%, and air traffic management is expected to be able to generate another 5–10%. Adding that the significant GHG reductions required from aviation to reach the long-term targets implies that a major share of the reductions will expectedly have to come from replacing fossil energy with low-carbon alternatives.

Sustainable Aviation Fuels

A straight-forward approach is to replace fossil jet fuel with what is termed *sustainable aviation fuel* (SAF). SAF encompasses various fuels with very low lifecycle GHG emissions. However, high altitude effects will still be an issue. SAFs have to be certified as sustainable and, in particular, for safety and performance by independent third-party bodies. Six production pathways are currently certified with blending levels up to 50%, but levels are expected to be higher in the future.

Today, all SAF production pathways are far more expensive than fossil jet fuel. This is the main reason why current demand for SAF is insignificant compared to the total aviation fuel consumption and supply is considered scarce or unstable. Only about 0.05% of jet fuel used in the EU is SAF. It is mainly biofuel produced from waste oil and animal fat residues as feedstock, which is not scalable to significant shares of total aviation fuel demand. The largest volumes of biofuels are today used in other transport modes, predominantly road transport and are to a wide extent produced on a basis which can also be used for SAF. The sustainability of using food and feed crops as feedstock for fuel production is increasingly questioned, as there are severe risks of deforestation and other indirect land use change (ILUC) impacts. Biofuels that use waste and residues from agriculture or forestry as feedstock are considered more sustainable. A crucial issue is therefore which sustainability criteria biofuels must match to be labelled as SAF, especially regarding the origin of the feedstock.

Anyway, biomass for energy purposes will undoubtedly be a scarce resource over the next decades, in particular in a global perspective, but the scarcity will most likely also play out in a Nordic context. In early phases of the transformation, where SAF will only constitute a smaller share of total fuel consumption, this might not be an issue. However, full phase out of fossil fuels in aviation solely based on biofuels might be challenging, due to the availability of biomass that can be used sustainably. Therefore, the required biomass might come at a very high cost needed to divert it from other applications. Thus, aviation also needs other sources of sustainable jet fuel, and the currently promising alternative is *electro-jet fuels* or e-jet fuels.

Sustainable e-jet fuels are synthetic kerosene made by extracting hydrogen from water through electrolysis. The energy used for this process should come from renewable based electricity. The hydrogen is subsequently converted into e-fuels. The process requires carbon which can come from biomass, including forest or agriculture residues, or from CO₂ captured from point sources or from the air (Direct Air Capture). The life cycle GHG emissions are very low compared to fossil jet fuel but the energy loss in the production pathway is significant. A main advantage of e-jet fuel is that renewable based electricity is not considered globally limited in the same way as biomass. The big challenge

with e-fuels is the costs, due to the large amount of renewable energy needed to produce it and the technical development needed to commercialize it. Costs estimates for e-fuels vary widely but are generally expected to decrease over the next decade.

Direct combustion of liquid hydrogen (LH₂) in turbines is an alternative pathway which has a considerably lower energy loss compared to e-jet fuels because liquefaction by cooling is less energy demanding than the conversion process from hydrogen to a hydrocarbon liquid fuel. However, hydrogen-based propulsion technology is still at a very low technology readiness level (TRL).

Electrification

Electric propulsion combined with battery storage has recently gained intense attention as an alternative to liquid fuel. The background is the last decades' dramatic development in battery technologies which is expected to continue with higher energy intensity at significantly lower production costs as well as remarkable reduction in costs of solar and wind energy-based electricity.

The energy efficiency of electric motors is higher than for combustion engines and energy costs per MJ is lower for electricity than for jet fuel. In addition, local emissions can be eliminated, and noise nuisance significantly reduced.

Still, the main barrier is energy intensity (kWh per kg) of batteries. Future development in this area will be decisive for the role of battery-electric aircraft. Battery storage is essential for electrification to be a genuine alternative that circumvents the challenges described for SAF. The main disadvantage of batteries is their weight, which is a much bigger challenge for aviation than for surface transport. The energy density of the batteries needs to be increased significantly, but with the current rate of innovation this appears likely to be achieved within the next 5–10 years.

Electric aviation comprises various types of aircraft technologies that use electric motors for propulsion. The propulsion system may be labelled battery electric or hydrogen electric depending on the energy storage. The latter use fuel cells to convert hydrogen to electric power. Hybrid-electric aircraft where one of the fuel-burning engines are replaced by an electric motor can be a first step toward 'pure' electrification.

Expectations from the manufacturers of electric airplanes and others on the timeline of the introduction of electric airplanes vary widely, with optimistic views expecting it to be before 2030 for small aircraft for short distances.

GHG reductions potential for Sustainable aviation fuels and electrification

Electrification holds significant potentials in coming years, in particular for small aircraft at short to medium distances. Over the next couple of decades, electric aircraft could possibly obtain significant market shares in some parts of the short distance market depending on further technological development and cost reductions as well as political commitment. Irrespective of the timeline, battery-electric aircraft will initially probably be most competitive:

- on routes with very short distances where cruise speed is less important and
- in sparsely populated regions, where passenger volumes are very small

Such routes could be existing services on Public service obligation (PSO) routes operated with subsidies or routes to one of the many existing small airfields without services today. This would also open up for significantly improved mobility in remote areas, which could be particularly interesting in the Nordics.

On the other hand, it is considered unlikely that fully electrified aircraft relying on battery stored energy will have any significance in scheduled operations on medium to long distances within the next two (or perhaps even three) decades. Taking into account medium to long flight distances' heavy share of total energy consumption, it seems fair to conclude that:

- SAF will be the dominant option for replacing fossil jet fuel toward 2030. Adding slow replacing rates of airplanes due to long service life SAF will most likely also be by far the main contributor to carbon neutral aviation toward 2050 in combination with expected strong progress in energy efficiency.²
- However, the market readiness for both advanced SAF and electric propulsion is currently relatively low and intensified efforts in RD&D is needed for both SAF and electrification to reach maturity.

Progress toward sustainable aviation can be accelerated through political and financial support. Irrespective of considerations about SAF versus batteries as energy carrier, clear signals of political commitment can contribute to reassure investors and other stakeholders without favouring one of these technological paths over the other. At a strategic level this could be done by formulating:

A common Nordic vision for sustainable aviation backed by an ambitious joint target for the share of renewable energy in aviation by 2030.

In addition, Nordic cooperation, e.g. by a joint funding scheme, is likely to have potential gains beyond the sum of unilateral initiatives.

Strategies for promoting sustainable aviation fuels

Uncertainty is high about what will turn out as the preferred SAF solution(s) due to insufficient knowledge about sustainability, resource availability and full-scale production for the alternative production pathways. Technology readiness levels (TRL) are very different for the various pathways, but currently both already certified SAFs and new bio-jet fuel, as well as e-jet fuel, are potential outcomes and in the longer term – possibly also hydrogen.

For SAF to constitute a significant share of Nordic jet fuel consumption in 2030 the following considerations should be taken into account:

- Even with expected price reductions, the social costs of GHG-reductions are likely to be high for all SAFs compared to the costs of many available GHG reductions in other sectors. This means that bringing SAF to the market in significant quantities requires targeted political aviation initiatives, in addition to cross-sectoral measures such as the EU Emission Trading System or an economy wide CO₂e-tax, which are generally held as cost-effective economic instruments to achieve overall national and EU-wide reduction targets.
- The strategy behind targeted policy measures for promoting SAF should be to reduce investors' risk by establishing economically attractive and stable framework conditions for a time horizon until at least 2030, rather than to push for use of high SAF volumes in the short term. This will be essential to bring on large scale production plants, which is necessary to bring down unit costs and increase production volumes to a scale with impact. A harmonised Nordic policy framework can make a difference, because the total Nordic consumption of jet fuel is more than four times that of any single Nordic country.
- A political commitment to implement a certain share of SAF in 2030 can create a strong and reliable long-term demand. Starting at very low levels and increasing progressively toward e.g. 30%³ in 2030 can allow for a gradual ramp up of supply based on large scale production.

² Hydrogen is a less developed alternative which has not been considered in this report. The energy density by weight is higher than for (other) SAF or fossil jet fuel, but the challenges include that energy density by volume of liquid hydrogen is only about one fourth (McKinsey 2020).

³ A target of about 30% is currently on the political agenda in Denmark, Norway, Sweden and Finland.

Direct regulation and taxes toward sustainable aviation

This report considers five policy measures which have all been part of the public debate about policies to reduce the climate impact of aviation:

• **Blending mandate** • **CO₂e reduction requirement** • **SAF fund** • **Fuel tax** • **Passenger tax**

Two approaches are applied to assess the policy measures:

- A quantitative approach where the size of the impacts on ticket prices, air travel demand, CO₂-emissions and tax revenue will be estimated based on simplified model calculations.
- A more qualitative approach based on literature reviews and with more principal arguments.

This section draws up the conclusions from the analyses which are subsequently in the next section summarized in a table with a comparative assessment of the relative advantages and disadvantages of each measure on twelve indicators.

Blending mandate, CO₂-equivalent reduction requirement or a SAF fund?

Political measures can ensure a certain amount of SAF by direct regulation either as a

- **blending mandate** requiring that SAF constitute a certain share of total jet fuel consumption, or a
- **CO₂ reduction requirement** setting a limit on CO₂e-emission per MJ fuel consumed.

Raising the share or lowering the limit over time can achieve a gradual phase-in toward a target level, e.g. 30% in 2030.

The two measures are in practice rather similar depending on the criteria for SAFs which are allowed for to fulfil a blending mandate. In mutual comparison both measures have advantages and disadvantages:

- A CO₂e reduction requirement has the advantage over SAF blending mandate in that it gives an incentive to use more expensive SAFs with lower lifecycle emissions if operators' costs per litre can be compensated by meeting the requirement with a lower blending rate. The disadvantage is that the administrative costs to documentation, control and audit are higher.
- An administratively simpler, but less efficient alternative is to confine a blending mandate to advanced SAF. This will secure a high level of sustainability of the SAF but it will not necessarily minimize the GHG abatement costs. We consider a harmonized Nordic approach to be more important than the choice between a (advanced) SAF blending and CO₂ reduction requirement.
- Both a SAF blending mandate and a CO₂e reduction requirement are likely to increase airlines' fuel costs significantly if the SAF share is to increase toward 30% in 2030 given current price expectations. This will create severe risks of climate leakage through much stronger tankering incentives for airlines.
- Any regulation that increases airlines' fuel price will also amplify the already strong existing incentives to reduce fuel use and thereby GHG emissions. This might, in principle, lead to higher occupancy rates, extra seats in the aircraft, lower cruise speed, and/or other operational energy efficiency improvements, and not least choosing more fuel-efficient aircraft when reinvesting or advancing such reinvestments⁴.
- A requirement or mandate should be levied on the fuel supplier, as in road transport, to be administratively most efficient, as they are quite few in number. To allow for maximal logistic

⁴ In principle also to develop more fuel-efficient new aircraft. But in reality, the effect will be insignificant if confined to a solely Nordic effort, due to the countries' small share of world aviation market.

flexibility, the fulfilment criteria should cover total annual sales as is the case for the road sector blending mandate.

- Uncertainties about the persistence of political commitment can be perceived as a severe risk by potential investors. Hence, a politically adopted target for the SAF share in 2030 might not be sufficiently stable framework conditions for the required investments described above.

An alternative to direct regulation is what is here called a **SAF fund**, i.e. allocating financial means for compensating the additional cost of SAF for replacing a certain volume of jet fuel. As for direct regulation, a gradual phase-in toward a target level, e.g. 30% in 2030, can be designed.

- A main advantage of a SAF fund is that it will eliminate the above-mentioned incentives to tankering by cancelling out the price differential “at the pump” between SAF-blended and fossil jet fuel, provided that the financing mechanism of the SAF fund is not directly related to the fuel price.
- Tendering of long termed purchasing or price guarantee contracts can be a strong tool to secure market demand and thereby lower investors' risks. The additional benefits of a joint Nordic SAF fund initiative will probably be very similar to those of a blending mandate or a CO₂e reduction requirement.
- There are several options for the detailed design of the market creation mechanisms of a SAF fund. Pros and cons, including legal aspects, of various designs should be investigated in further detail, including whether to combine a SAF fund with a blending mandate.
- A SAF fund can be financed by Government budgets, but more likely from aviation taxes or payments from a polluter-pays-principle. Only fuel related taxes will give rise to the tankering issues of SAF blending and CO₂e reduction requirements.

Taxes for stimulating or financing sustainable aviation

An appropriate taxation approach to stricter regulation of climate impacts from aviation is complicated because of constraints from existing EU regulation and international agreements.

A carbon-based fuel tax is in principle an attractive instrument to secure cost-effective CO₂e-reduction, both across and within sectors, in particular if implemented on a global, or at least European, scale. In practice, there are several issues related to implementing aviation fuel taxes, in particular on international flights:

- The smaller the region covered by the fuel tax, the bigger the issues of climate leakages by tankering and unfair competition will be.
- A common Nordic initiative to implement a fuel tax will reduce these unwanted effects of leakage as compared to a unilateral national implementation.
- EU regulation and international agreements limit the scope for a Nordic carbon-based fuel tax initiative. The juridical issues are complicated and subject to differing interpretations. Nevertheless, it seems safe to conclude that non-domestic fuel taxes on aviation will have to be bilaterally agreed. Therefore, a joint Nordic initiative will in the first place have to be restricted to flights within the Nordics.
- The added value of a bilaterally agreed fuel tax policy within the Nordics is additional coverage of 10% all CO₂-emissions. This is because flights within the Nordics account for about 30% of all jet fuel consumption and related CO₂-emissions from the Nordics, and two thirds of these emissions (about 20% of the total) would also be covered by unilateral taxes.
- A common Nordic implementation of aviation fuel taxes can subsequently be a platform for negotiating bilateral agreements on harmonized fuel taxes with neighbouring countries, such as Germany, the Netherlands and the United Kingdom. Such agreements could even be stepping stones toward a common European CO₂e tax on aviation fuels which would increase the beneficial climate impacts significantly and could also minimise the leakage effects of the

fuel tax. An alternative approach could be a radical reform of the EU ETS that would raise the price of emission allowances significantly.

- Finally, a carbon-based fuel tax can warrant a shift to SAF, but it is difficult to design a gradual phase-in: The tax should be high enough to match the price premium to make it profitable for airlines to substitute jet fuel with SAF. But then full shift to SAF will be more advantageous and airlines will, whether they shift to SAF or not, bear the full cost premium on all fuel consumption at once.

A passenger tax is a rather blunt instrument for promoting sustainable aviation in comparison with the previous measures. It only creates GHG reduction via demand side incentives to reduce the number of air trips.

- The clear advantage of a passenger tax is that it avoids the issues of climate leakage from tankering incentives by measures that increases fuel costs.
- To the extent that a passenger tax can be differentiated according to distance, it can be more closely related to CO₂ emissions per trip and hence create a stronger incentive to reduce longer trips and thereby GHG-emissions. Similar arguments hold for differentiating the passenger tax according to aircraft specific fuel efficiency per seat.
- International agreements and EU legislation limit the options for differentiating passenger taxes. Interpretation of the scope for national possibilities to differentiate passenger taxes within EEA is disputed. Still, no European countries that have implemented passenger taxes have differentiated their rates between destinations within the EA, but higher rates for other destinations are common.

Comparative impact assessment of five of policy measures

This section gives an overall comparative assessment of the policy measures using twelve indicators:

- **Overall CO₂ impact:** To what extent can a joint Nordic implementation contribute to significant reductions of CO₂-emissions from domestic and international air travel from the Nordics?
- **Flights outside the Nordics:** Can the policy measure be imposed on flights to destinations to the rest of the EEA and the rest of the world?
- **Reducing demand** by fewer and shorter trips?
- **More fuel-efficient operations**, including more passengers per flight, energy optimizing speed, flight route and altitude, use and by energy efficient aircraft etc.?
- **Using (more) sustainable fuels:** Does the policy measure promote use of SAF and give incentives to prefer fuels with lower life cycle GHG emissions?
- **Market creation for SAF:** Will the policy measure guarantee a demand for SAF that will enable economics of scale and competition driven cost reductions?
- **Avoid leakage risks:** Can the policy measure avoid creation of or reduce incentives to tankering or to shifting operations to airports outside the Nordics with lower fuel prices?
- **Government budget revenue:** Does the policy measure have a net positive impact on Government revenue that can be used to promote sustainable aviation or other purposes?
- **Polluter-Pays-Principle:** Does the policy measure secure that social costs to prevent or remedy GHG-effects are financed by liable producer or consumer?
- **Cost effectiveness:** Does the policy measure give adequate incentives to choose or develop solutions that minimize the social costs of the reduction?
- **Administrative burden:** Are costs to the aviation industry, the regulatory body and the air travellers' airlines to administrate the regulation ignorable or small compared to achieved effect?
- **International regulation compliance:** Is it certain that the policy measure is uncomplicated to implement in a Nordic context without conflicting with EU regulation or international conventions and agreements?

The comparison is summarized in the in Figure 1.1. The scores 'YES', 'yes', 'no', and 'NO' are to be interpreted as an assessment of relative ranking among the five policy instruments – 'YES' in capital letters being the highest ranked, to 'NO' in capital letters being the lowest. The ranking is extracted from the analyses above and not derived from exact criteria. Hence, refinements of the scores can be debated.

Figure 1.1 Comparative assessment of five policy measures for sustainable aviation

Assessment of measure with regard to:	SAF blending requirement	CO ₂ e reduction requirement	SAF Fund	Fuel tax	Passenger tax
Overall CO ₂ -reduction impact	YES	YES	YES	yes	yes
Flights to outside the Nordics	YES	YES	YES	NO	YES
Reducing demand: Fewer trips Shorter distance	yes	yes	NO	YES	YES yes
Fuel efficient operations ⁽¹⁾	yes	yes	NO	YES	NO
Using (more) sustainable fuels	yes	YES	YES	yes	NO
Market creation for SAF	yes	yes	YES	no	NO
Avoid leakage risks ⁽²⁾	NO	NO	YES	no	yes
Government budget revenue	no	no	NO	yes	YES
Polluter-pays-principle	yes	YES	NO	YES	yes
Cost effectiveness	NO	no	yes	YES	NO
Administrative burden minimised	no	NO	yes	no	yes
International regulation compliance	YES	YES	yes	yes	YES

(1) Including occupancy rate, cruise speed, etc.

(2) Tankering or displacing operations abroad. The leakage risk is less for a fuel tax than for a SAF blending and CO₂ reduction requirement because the fuel tax is assumed to be imposed only for flights within the Nordics.

The overall picture from the figure is that the counts of 'YES'/'yes'/'no'/'NO' are not that different across policy measures. Although some indicators can be said to be more important than others, none of the policy measures stand out as either clearly advantageous or the opposite.

Passenger taxes will only reduce CO₂-emissions through lower demand. Hence, rates have to be unrealistically high to result in significant CO₂ reduction. The same applies to fuel taxes unless they are set high enough to eliminate the cost premium of SAF. In addition, a common Nordic fuel tax regime will only apply to flights within the Nordics, which will reduce the total demand driven reductions with two thirds, cf. above.

Significant CO₂ reductions will require a blending or CO₂ reduction requirement or a SAF fund, as these measures can be designed to secure a substantial use of SAF, even if implemented by the Nordics alone.

By increasing fuel costs, the two measures based on requirements will at the same time indirectly give (some) incentives for travellers to reduce travel demand and for airlines to improve energy efficiency of operations. However, this effect is a "double-edged sword" as the increased fuel costs at the same time creates risks of leakage effects.

Both the enhanced incentives to reduce fuel consumption and the risk of leakage is avoided by the SAF fund that eliminates the cost premium of the SAF. The main disadvantage of a SAF fund is that it demands funding, which in the table is assumed to be financed by the Government budget, - to illustrate its pure form. This will of course have costs elsewhere in society and thereby violates the fairness of the 'Polluter-Pays-Principle'.

Combining a SAF fund with an earmarked passenger tax

Both the financing and polluter-pays-principle issues with a SAF fund can be addressed by combining it with a tax at a rate that generates a revenue of the estimated size to finance the price premium of SAF at the targeted share, e.g. 30% of total jet fuel volumes. If a fuel tax is chosen as the financing mechanism in a combined measure it can, as mentioned, only be levied on internal Nordic flights. Hence, to finance 30% SAF for all flights it has to be rather high. This will result in a quite distortive tax differential between internal Nordic and extra-Nordic flights. A passenger tax can be levied on all flights and set at higher rates outside to destinations outside the EEA to reflect the higher GHG impact of these long-haul flights. This might reduce long-haul trips or shift them to shorter distances and thereby reduce GHG-emissions. Hence, it will be more in accordance with the 'polluter-pays-principle' than a fuel tax confined to flights within the Nordics.

Taxes will have to be implemented in national legislation, and this could be mirrored in parallel national SAF funds with harmonized setups. Still, a joint Nordic fund with unified tendering processes for greater volumes of SAF will have a stronger signaling effect.

Figure 1.2 presents an assessment of a combined SAF fund and a passenger tax along the same lines as for the single measures in Table 1.1. It appears that the combined measures generally have positive ratings on the twelve indicators, because one measure in many cases compensates for the disadvantage of the other. Only one negative rating stands out: The combined measure does not create incentives to more fuel-efficient operations. However, as mentioned above, this is the unavoidable downside of avoiding risks of leakage from increasing fuel costs at Nordic instead of an EEA or global level.

Given that a main reason for a combined measure is that the passenger tax is meant to establish a fair and feasible way of financing the extra costs of SAF compared to fossil jet fuel it makes sense to set the level of the passenger tax and the SAF share so as to obtain a revenue that approximately balances the total extra fuel costs.

Figure 1.2 Assessment of SAF fund & earmarked passenger tax

Assessment of measure with regard to:	SAF fund & Passenger tax
Overall CO ₂ -reduction impact	YES
Flights to outside the Nordics	YES
Reducing demand: Fewer trips Shorter distance	YES yes
Fuel efficient operations ⁽¹⁾	NO
Using (more) sustainable fuels	YES
Market creation for SAF	YES
Avoid leakage risks ⁽²⁾	yes
Government budget revenue	yes
Polluter-pays-principle	yes
Cost effectiveness	yes
Administrative burden minimised	yes
International regulation compliance	yes

Note: To be compared with Table 1.1

It turns out from model calculations that these criteria might be fulfilled with a 30% SAF share and a common Nordic passenger tax with rates corresponding to the average of the current Norwegian and Swedish passenger tax rates. Based on model calculations it is estimated that this scenario will lead to

- a passenger tax revenue of slightly more than 1 bill. EUR per year;
- extra fuel costs of about a little less than 1 bill. EUR per year; and that
- the common Nordic passenger tax amounts to about 4% of ticket prices on average.

Again it should be stressed that these figures and, hence, the relationship between the SAF share and the required tax rates depends heavily on the assumptions, and in particular the forecasted price premium of SAF compared fossil jet fuel price. This relationship will be strongly influenced by the future costs of EU ETS allowances. Depending on the price development of the allowances they fully or partially substitute passenger taxes for flights within EEA.

Main policy recommendations for promotion of SAF

To conclude, the above considerations leads to the following overall recommendations for the types of policy measures that are required and appropriate for promotion of SAF:

- Supply-side measures with a long-term perspective are needed to promote sustainable aviation. In a 2030 perspective, this will in practice mean pushing for a gradual increase to significantly higher share of SAF of total jet fuel consumption.
- Demand-side measures in terms of increased taxation can remedy excessive air travel from under-taxation of aviation both with respect to its climate impact and to other modes of transportation, in particular road transport. However, national or Nordic taxes alone are not likely to lead to a profound leap forward toward sustainable aviation over the next decade under existing international regulation.
- A combination of establishing a SAF fund and a passenger tax or payment on all aviation might both minimise carbon leakage from tankering and provide financing mechanism for the additional costs of a significant share of SAF in total jet fuel consumption.
- A joint Nordic policy framework consisting of a joint Nordic (or parallel national) SAF fund financed by harmonised Nordic passenger taxes or payments will enhance efforts to create significant and stable volumes of demand for SAF towards 2030. Such long-term demand commitments will enhance opportunities for large scale production by reducing investor risks.

Finally, when deciding on common Nordic initiatives for sustainable aviation the global dimension of climate change should be recalled. Reductions of GHG emissions stemming from Nordic aviation contribute little to the overall climate impact of global aviation. This is not to say that common Nordic initiatives are not essential, on the contrary. But arguably, the most significant overall impact might be via its influence on European and international climate change policies. The exact design of a common Nordic policy framework should also take into account how this influence can be maximized.

Initiatives to accelerate innovation in electric aviation

Electric propulsion can contribute to more sustainable aviation in two ways:

- Firstly, by higher energy efficiency of electric motors compared to conventional combustion engines.
- Secondly, by battery storage of electricity based on renewable energy.

Battery storage is essential for electrification to be a genuine alternative to SAF that avoids the challenges described above for SAF. The main disadvantage of batteries is their weight, which is a much bigger challenge for aviation than for surface transport. Hybrid-electric aircraft where one of the engines are replaced by an electric motor and SAF combined with hydrogen fuels cells can be first steps toward 'pure' electrification (i.e. 100% battery energy storage).

The relatively low technology readiness level (TRL) of airplanes with electric propulsion means that it can be politically difficult to credibly commit to stable long-termed framework condition in general at the current stage of maturity where high uncertainty prevails.

- Political initiatives should focus primarily on measures that can encourage and financially support RD&D and accelerate innovation. This could include programmes for Nordic cooperation, experience exchange etc.
- Widespread market creation in line with the strategy for SAF described above appear to be premature until higher levels of TRL is reached.
- Nordic cooperation to promote electric aviation should target short routes up to about 500 km. Toward 2030 this is most likely the only segment where electric airplanes will have potential. This includes some of the most travelled Nordic routes, but most will be domestic
- Very short routes (<200 km) will be most suitable for the earliest demonstration projects. An agreement on financial support for parallel demonstration projects in all or several Nordic countries could be part of a common vision. All countries have suitable routes, but about two thirds of the very short routes are Norwegian due to the country's challenging geography with fjords and mountains which hampers surface transport.

Over the next decade, certified electric airplanes will predominantly be small; with up to 9 or 19 seats for certification reasons. This means that additional staff costs and other operational costs per passenger will be higher than today. This will counteract and possibly more than outweigh the potential cost savings on propulsion energy and technically lower maintenance demands. In that case, commercial operations will require political subvention.

- Clear signals of political commitment to financial support that can reduce risks and secure viable business cases for electrified routes are crucial to attract operators in the early phases.
- The financial implications of securing viable business cases for operating electric airplanes on a limited number of short routes are manageable. Many levers can be pulled to support operators willing to invest in electric aviation, for example:
 - Environmental zero emission criteria in tendering of selected routes with public support
 - Providing the necessary charging infrastructure in relevant airports
 - Removing or reducing operators' financial risks of investment in through "pool purchasing" electric airplanes, e.g. by buying the aircraft and leasing it to the operator for the contracting period
 - Passenger tax exemption for electric aircraft or similar economic support
 - Harmonizing standards for electric airplanes, e.g.
 - common charging standards
 - common security standards
 - prioritising joint efforts on standardisations in international fora

Several of these initiatives will be strengthened through a joint Nordic approach.

How to finance initiatives to promote electric aviation is basically a matter of political prioritisation. However, one solution that springs to mind is the combination of a SAF fund and passenger taxes. Extra finances to support developing electric aviation as well can be provided by phasing in common passenger taxes faster than the financial needs for the gradually increasing SAF share of fuels.

Next steps

This report has outlined overall recommendations for a joint Nordic approach to promoting more sustainable aviation in the Nordics. If the Nordic countries agree to move forward in line with the suggested approach next steps in the preparation of specific and joint initiatives could be to:

- Conduct a juridical assessment of alternative models for construction of a Nordic or parallel National SAF fund(s), in particular which financing mechanisms that would be in accordance with the EU's state aid regulation.
- Elaborate the detailed design of the financial support mechanism of a SAF fund, including sustainability criteria for eligibility of SAF.
- Nationally implemented and harmonized passenger taxes in each Nordic country, taking into consideration the size and structure of existing and expected passenger taxes in neighbouring European countries.
- Politically adopt a common Nordic commitment to pursue the potentials of electric aviation
- Finance a common Nordic research and innovation programme for SAF and electric propulsion
- Form a united position in EU and international fora pleading for EU-wide GHG taxation of fossil jet fuel or alternatively a wider scope for national implementation of distance-based passenger taxes.

1 Introduction

1.1 Strong growth in aviation and its emissions

Air transport of persons and goods has been steadily increasing with on average high growth rates in most part of world, including the Nordic countries. Globally, commercial aviation counts for around 2.4% of the global total greenhouse gas (GHG) emissions from energy use (Graver et al., 2019). In the EU, the aviation sector in 2016 was responsible for 3.6% of total GHG emissions (EEA et al., 2019, p. 8).

The substantial increase in aviation has caused large growth in the aviation sector's total GHG emissions globally, despite significant improvements in the energy efficiency of airplanes in the last decades (Ministry of Transport, 2019). The climate impact of emissions in high altitudes is, moreover, significantly larger than for surface emissions due to contributions to e.g. cirrus cloud formation, condensation trails, emissions of soot and aerosols, when flying in high altitudes (e.g. IPCC, 1999; McKinsey, 2020; Aamaas & Peters, 2017).

Aviation is, moreover, also a source of local pollution, such as nitrogen oxides (NO_x) emissions and ultrafine particles (e.g. Keuken et al., 2015), and it also leads to significant local noise nuisance (Basner et al., 2017; Krog et al., 2017), in particular around airports (EEA et al., 2019). Poor air quality is an important cause of premature deaths and ill health in Europe and elsewhere (European Environment Agency, 2019; Khreis et al., 2019). However, it seems that aviation's impact on local particle pollution in at least some of the Nordic countries is rather modest, like at Oslo Airport, other Norwegian airports and at the Stockholm Airport (Avinor, 2020b; Krog et al., 2017; Swedavia Airports, 2020a).

Estimates of growth in international air transport over the next decades vary, but the general expectation is that aviation is expected to continue to grow at a rapid pace. The International Civil Aviation Organization (ICAO), estimates that aviation will increase 3.3 times measured in revenue tonne kilometers (RTK). Fuel consumption will, depending on the scenario, increase by 2.2–3.1 times in 2045 compared to 2015 (ICAO, 2019b). Increases in aviation are closely connected to economic growth, and the largest growth of aviation in the next two decades is expected to be in the Asia-Pacific area (Boeing, 2019; IATA, 2018b).

Thus, if measures are not implemented, growth in aviation seriously increases the sector's contribution to global warming (EEA et al., 2019). Estimates of aviation's share of the world's remaining carbon budget are uncertain. The share of the remaining carbon budget is most likely going to increase, if the growth continues, because other sectors are reducing their GHG emissions (see e.g. Carbon Brief, 2016; McKinsey, 2020).

Aviation has also grown substantially within the European Union (EU) and the European Economic Area (EEA) in the last decades, up until the Covid-19 crisis hit the area. Aviation traffic in Europe has been expected to grow by 50% from 2012 to 2035 (European Commission, 2015, p. 9). Total airline activity in Europe, accounts for around 27% of total global airline activity and 25% of airline fuel consumption, excluding Russia and the rest of CIS⁵ (Strand, 2019).

⁵ Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan and Uzbekistan.

1.2 A regulatory gap in international aviation

In other words, aviation has created important societal benefits, being a crucial factor in our long-distance mobility, but the downside is significant external costs in terms of contributions to climate change as well as other environmental impacts. The fact that there is almost no taxation of international aviation outside Europe, although a considerable share of the climate impact from aviation comes from medium and long-distance flights, suggests that additional measures are required to reduce these costs (Pirlot & Wolff, 2017; Schuknecht, 2019; Strand, 2019).

It has, so far, proven very hard to obtain international agreements on global standards that reduce aviation emissions in the next years and decades to levels that are compatible with the targets in the Paris agreement. International aviation is, for example, not subject to value added tax (VAT) or fuel charges (Amsterdam Economics & CE Delft, 2019). This has been intended policy from the side of ICAO (Pirlot & Wolff, 2017, Interviews 2020), as they have opted to develop aviation internationally to the largest extent possible. The lack of VAT in international transport is attributed to the fact that most goods are taxed either in the country where they are produced or consumed, and thus, international aviation and other international transport is excluded (Pirlot & Wolff, 2017).

In Europe, the EU Emissions Trading System has since 2012 applied to aviation within the European Economic Area. However, to date, most emission allowances have been given for free. In addition, some European countries have implemented passenger taxes, but many countries also either charge a low or even zero VAT rate on domestic flights (Amsterdam Economics & CE Delft, 2019; Faber & Huigen, 2018; Strand, 2019).

Comparison of fairness of operating conditions across for different modes of transport is, however, not straight forward: As the aviation industry itself points out, aviation pays fully for its own infrastructure, the airports, while for example the railways do not fully pay for railway stations or the railway lines (Pirlot & Wolff, 2017, Interviews, 2020). In road transport many parts of the network access are offered for free. Some countries have road user charges. All EEA countries have fuel taxes which can finance the infrastructure and cover at least some of the other external costs of related to driving.

1.3 Ambitious goals for GHG reductions in the Nordic countries

The Nordic countries Denmark, Finland, Iceland, Norway, and Sweden have all committed to becoming climate neutral within the next two or three decades and they all have high ambitions to become more environmentally sustainable (e.g. Danish Government, 2018; Karlsen, 2017; Ministry for the Environment and Natural Resources, 2018; Ministry of Finance, 2019; Ministry of the Environment, 2018). This is also the case for the transport sector: Sweden is at the forefront regarding using biofuels in road transport. Norway is leading internationally in electrification of cars and ferries.

The Nordic countries, the Nordics for short, have a long history of cooperation. For example, they created the Swan ecolabel. Norway and Sweden launched the world's first international electricity market, NordPool, which today also includes the other Nordic countries (except Iceland) and the Baltic states. Sweden and Norway launched the world's first international market for trade of green certificates to support the production of renewable energy. The Nordics also led the development in creating standards for telecommunication: NMT and GSM.

In January 2019, the Nordic Prime Ministers signed "Declaration on Nordic Carbon Neutrality", committing their countries to strengthening mutual cooperation to attain carbon neutrality domestically. The declaration emphasizes decarbonization of the transport sector, such as through

shifting between transport modes, enhancing energy efficiency, electrifying various transport modes, and using sustainable renewable fuels (Sipilä et al., 2019).

The aim of this report is to examine the opportunities for increased Nordic cooperation with regards to increasing sustainability of aviation and based on evaluation of alternative options propose common Nordic policy measures.

1.4 Strategies to reduce emissions from aviation

It is generally recognized that the ultra-high mobility generated by air transport is perceived as an important and highly valued factor in the lifestyle among the wealthy in the world, and is a crucial contributor to the benefits of globalization, including extensive international trade (see European Commission, 2015). Curbing air travel by strong demand-side measures that could stop aviation growth is seen by some as a necessity. In the political mainstream, however, this is not considered an attractive path to significantly reduce GHG from aviation. This is, of course, not an either-or situation, as a cost-efficient climate policy for aviation may very well include policies that *both* reduce GHG emissions per trip *and* incentivize customers to drop the least important trips, choose alternative modes of transportation or to choose destinations nearby.

A wide range of political measures can be used to reduce GHG emissions from aviation. All measures will in principle function through one or more of the following three sub-divided factors:

- Reduced air transport (passenger and tonne kilometers)
- Energy efficiency improvements, by:
 - More passengers or freight per flight
 - Air traffic management and operations
 - Less fuel-consuming types of airplanes among existing types
 - Technological development of aircraft and engines
- Replacing fossil jet fuel by energy carriers with lesser climate impact, through:
 - Fuels with lower life cycle GHG emissions
 - Electric propulsion instead of combustion engines

In the last decades, the average GHG emissions per passenger or tons per kilometer have declined significantly, mainly through energy efficiency improvements (IEA, 2020; McKinsey, 2020). For example, in Norway from 1998 to 2018, gradual improvements have been achieved adding up to more than a 50% reduction in CO₂ emissions per passenger kilometer for the two largest airlines. Emissions have declined from 196 gCO₂/km to 83.5 gCO₂/km. These airlines, SAS and Norwegian, together cover more than 70% of the airline passengers in Norway (Ministry of Transport, 2019).

Over the next two decades, fuel efficiency improvements for new conventional aircraft are estimated to be at best about 40% compared to 2016 by 2034, if “all” cutting-edge fuel-saving technologies are implemented (Kharina et al., 2016). Air traffic management is expected to be able to generate another 5–10% of the potential improvements in the future.⁶ However, this would probably at best just level out the effect of the expected demand growth (Fleming & Lépinay, 2019; ICAO, 2018; McKinsey, 2020). Adding that the significant GHG reductions required from aviation to reach long-term climate targets implies that a major share of the reductions will expectedly have to come from replacing fossil energy with low-carbon alternatives.

⁶ ITF-workshop 24. Feb 2020 [no precise source can be listed due to Chatham House Rules].

1.5 Sustainable aviation fuel (SAF)

As explained above, radical reductions of GHG emissions from aviation requires a shift away from fossil fuels, as there are physical and technical limits to how much can be achieved by fuel efficiency gains. Even though speeding up deployment of fuel saving technologies in new aircraft and development of completely new propulsion systems are crucial in the long run, the short- and medium-term effects will likely be modest due to a number of factors. A main factor is the long economic lifetime of aircraft: A modern aircraft is expected to be in service for two to three decades.

From an operational point of view, the easiest way to significantly improve the sustainability of each journey by airplane in the next years is probably to replace the jet fuel with what is termed *sustainable aviation fuel* (SAF). SAF is a term that encompasses various fuels that have been certified as sustainable according to independent third-party bodies such as Roundtable on Sustainable Biomaterials and certified for safety and performance by American Society for Testing of Materials (ASTM International). There are a number of high-carbon feedstocks that may be used to produce such fuels, including biomass, biogas, animal fat and bio oils (Wormslev & Broberg, 2020). SAFs are termed “drop-in fuels”, as they can be blended in fossil fuels immediately with minimal need for technical changes in the airplanes and other infrastructure. The maximal blending rates of SAFs today is 50% (Wormslev & Broberg, 2020).

Bio-jet fuels

Biomass constitutes an important part of the use of renewable energy in the Nordics, but very little is used in aviation. A number of projects have been launched for producing various types of sustainable aviation fuel (SAF), mostly advanced biofuel, in the Nordics. Market prices for SAF are today high and the production volumes are low (European Commission & DG Move, 2020; Swedish Government, 2019a). For example, only about 0.05% of jet fuel used in the EU is SAF. SAF consumption in 2050 in aviation will only contribute to 2.8% of total aviation fuel consumption in 2050, according to estimates (European Commission & DG Move, 2020, p. 3).

This could change in the future, depending on political commitment and what measures are implemented to increase it (Mortensen et al., 2019; Rambøll, 2017; Wormslev & Broberg, 2020; Wormslev et al., 2016). Various types of support are needed to establish higher production capacities, drive innovation and thus bring down prices:

In the absence of a long-term, stable policy framework with sufficient incentives, the necessary confidence for major investments in SAF production is not provided. Such investments would enable economies of scale in the production and drive production costs down. (European Commission & DG Move, 2020, p. 2).

E-jet fuels

A special type of SAF is *electro-jet fuels* or e-jet fuels (synthetic kerosene) where electricity is used to produce hydrogen (from water) which is subsequently converted to fuels. The process requires carbon which can come from either biomass, including forest residues, or from CO₂ captured from point sources or from the air (DAC). According to some analyses, e-jet fuels are essential to make aviation fuel sustainable in the next decades, because of the globally limited sustainable feedstock potential for biofuels (Energinet, 2019; Mortensen et al., 2019; Wormslev & Broberg, 2020).

However, the big challenge with e-fuels is the costs, due to the large amount of renewable energy needed to produce it and the technical development needed to commercialize it. Cost estimates for e-fuels vary widely. A study found, for example, optimistically that in several scenarios, e-fuels can compete with fossil fuels in 2035 in Denmark (Energinet, 2019). E-fuels will likely be cheaper to

produce sustainably than previously in the next decades anyway, due to the lower cost of producing electricity: Photovoltaic power and onshore wind power are for example likely reaching cost competitiveness with other types of electricity on the global markets in 2020 (IRENA, 2019).

Direct combustion of liquid hydrogen (LH₂) in turbines is an alternative pathway which has a considerably lower energy loss compared to e-jet fuels because liquefaction by cooling is less energy demanding than the conversion process from hydrogen to a hydrocarbon liquid fuel. However, hydrogen-based propulsion technology is still at a very low TRL. Although promising, this alternative is far less mature than both bio-jet fuels and synthetic jet fuels and is therefore also outside the scope of this report. For an updated study of the hydrogen potential strategic overview, see McKinsey (2020).

1.6 Electrification

In the next decades, electrification also holds a lot of potential, at least for short distances. Electric aircraft is here defined as an aircraft that is fitted by one or more electric motors for propulsion (Avinor & Civil Aviation Authority, 2020, p. 50; McKinsey, 2020). Electrification could be a significant contributor to reducing the climate impact of aviation within the Nordics, where there is a large number of routes that are short (Avinor & Civil Aviation Authority, 2020; Roland Berger, 2017, see also Chapter 5.4 and Appendix B.4). Partial electrification, e.g. to launch hybrid electric motors with both combustion engine and electric engines could also help bring down GHG emissions on medium-haul and long-haul routes.

Electricity production in the Nordics is increasingly based on renewable sources and will in the future be close to 100% fossil free. Such electrification also reduces other negative externalities of using liquid fuel in aviation, namely the release of particles and contrails high up in the air, the potential use of crops that could be used for food or other purposes (LULUCF) and the noise from combustion engines. Analyses point in different directions as to when electric and hybrid electric airplanes will be introduced and how quickly they will replace airplanes with conventional and bio-based fuels (e.g. Avinor & Civil Aviation Authority, 2020; Roland Berger, 2017).

Electrification of the aviation sector is, however, challenging, for a number of reasons (Hanano, 2019; Roland Berger, 2017; WSDOT, 2019; Ydersbond & Amundsen, 2019, 2020). The most important issue is likely that the energy density of batteries needs to be significantly higher (at least 500 Wh/kg) than what is the case today (250 Wh/kg for batteries in commercial use to up to over 300 Wh/kg for new innovations) if they are to be used for commercial purposes (Roland Berger, 2017). Another issue is the low technological readiness level (TRL): only one electric airplane, a battery electric two-seater, is so far certified for ordinary flying (in 2020). It is impossible to predict the scale of introduction, and exact timing of introduction of aircraft with this group of propulsion technologies.

1.7 Report structure and scope

The report will focus on aviation in the Nordics, i.e. flights and trips *within and between* the five Nordic countries as well as *to other countries*. Only commercial, scheduled aviation will be considered, and focus will be on passenger transport. With regard to the potential for electric aviation the report will mainly focus on battery electric aircraft whereas hydrogen electric aircraft, i.e. hydrogen energy storage combined with a fuel cell for conversion to electric power, will not be considered due to its very early and uncertain stage of development. The same holds for hydrogen as a sustainable aviation fuel for combustion in turbines.

The next chapter gives an overview of travel patterns in the Nordics in terms of travel volumes within and between the Nordic countries as well as to Europe and the rest of the world. Subsequently, Chapter 3 and 4 give an overview of the international regulatory context and the current Nordic perspectives on sustainable aviation in terms of relevant existing policies and other initiatives with regard to sustainable aviation fuels and electrification. Finally, Chapter 6 analyses and assesses potential Nordic policy measures for promotion of sustainable aviation fuels in Nordic aviation.

Impacts of Covid-19 on this report

The Covid-19 crisis hit international aviation and other economic activity hard from the beginning of 2020 and led to a dramatic and unprecedented decline in the number of flights domestically and internationally (ICAO, 2020a). Several countries, including many countries in the EEA, closed their borders temporarily and launched travel restrictions (e.g. ICAO, 2020a; Isaksen, 2020). This led to an unprecedented economic crisis in the aviation industry. Different countries launched large rescue packages to save their airlines from bankruptcy (e.g. Mikalsen, 2020; Rasmussen, 2020; Trumpy, 2020).

How long this crisis will last is uncertain, and also what kind of consequences it will have for the national, European and international community. For example, if airlines go bankrupt, this may lead to lower competition and higher ticket prices. Moreover, the Covid-19 crisis may have profound long-term implications in terms of reducing passenger demand; Businesses have grown used to communicating via digital platforms rather than meeting in person (Sandberg, 2020), which make them demand less travel by airplane. This development is likely also stimulated by the fact that many businesses, an important customer group, have suffered and are suffering economically, and are thus reducing travel to cut their costs (Interview NEA, 2020).

However, in all previous crises the last decades, passenger volumes have rebounded after 1-2 years, or simply been stable for a period, and subsequently reached previously unprecedented growth levels (Boeing, 2019, p. 17). Probably, the aviation industry will, when the Covid-19 pandemic is over, return to normal business sooner or later, and passenger numbers will continue to increase. Some analysts argue that it may take at least until 2023 before the airlines are back to their passenger numbers pre COVID-19. In some scenarios, the current COVID-19 crisis may have a long-lasting impact on aviation travel demand (Curley et al., 2020). If activity rebounds to expected levels of growth, this will also be the case regarding GHG emissions.

In this study, we will not take into consideration the possible impacts of the Covid-19 crisis. The possible consequences for long-term growth are not assessed to be in an order of magnitude that is likely to influence the *types* of measures that are most suited to promote the transformation of the Nordic aviation sector to sustainability. However, the current crisis might very well influence how fast the measures should be implemented to take into account the weak financial situation of the industry and hence the capability to invest in and adjust to the transformation. The timing and pace of climate policy implementation is not considered in this study.

2 Overview of aviation in the Nordic countries

2.1 Internal and international travel patterns

The potential benefits from joint Nordic policies to promote sustainable aviation depends on the importance of air travel between the Nordic countries compared to total air travel volumes for these countries. Comprehensive data for total passenger volumes are not readily available. However, a good proxy indicator is the "Seat supply". That is: the sum across all flights of the number of seats available. Seat supply in 2019 is shown for each Nordic country with a split on geographical destination segments:

- Domestic: Flights within each country
- Nordic: Flights between Nordic countries
- Europe: Flights to the rest of the Europe
- World: Flights to the rest of the world

Table 3.1 Seat supply from Nordic countries in 2019

To:	From: Denmark (5.8)	(population in mill.) Finland (5.5)	Iceland (0.4)	Norway (5.3)	Sweden (10.1)	Total (27.1)
Domestic (464 km)	3.011.187	4.572.125	379.492	24.534.349	11.089.018	43.586.171
Nordic (693 km)	4.533.809	2.595.233	830.283	4.220.302	4.412.167	16.591.794
Europe (1446km)	13.490.910	7.287.865	2.112.860	10.149.603	12.629.391	45.670.629
World (6245 km)	2.253.201	2.293.167	1.247.102	799.050	1.496.849	8.089.369
Total (1301 km)	23.289.107	16.748.390	4.569.737	39.703.304	29.627.425	113.937.963
	20%	15%	4%	35%	26%	100%

Source: Extracts from OAG-database (<https://www.oag.com/>).

Note: Return flights from outside the Nordics are not included.

In 2019 the overall seat supply was about 114 million seats per annum. The differences in total volumes across the Nordics reflect population size and country area. When correcting for population size, the figure corresponds to 4.2 seats per capita per year, with Iceland and Norway clearly above the rest. For Iceland, it is primarily a high seat supply to Europe, whereas Norway has a high domestic seat supply, most likely due to widespread mountains and fjords, and very long distances, making surface transport more complicated and expensive. Denmark's small size results in a low number of domestic trips because cars and trains are good alternatives. The hub function of Copenhagen Airport results in higher volumes to Europe and the rest of the world. The same is to some extent true for Reykjavik and Helsinki for flights to North America and East Asia, respectively. For Sweden, the regional distribution of flights is close to average for the Nordics.

Short, medium and long haul

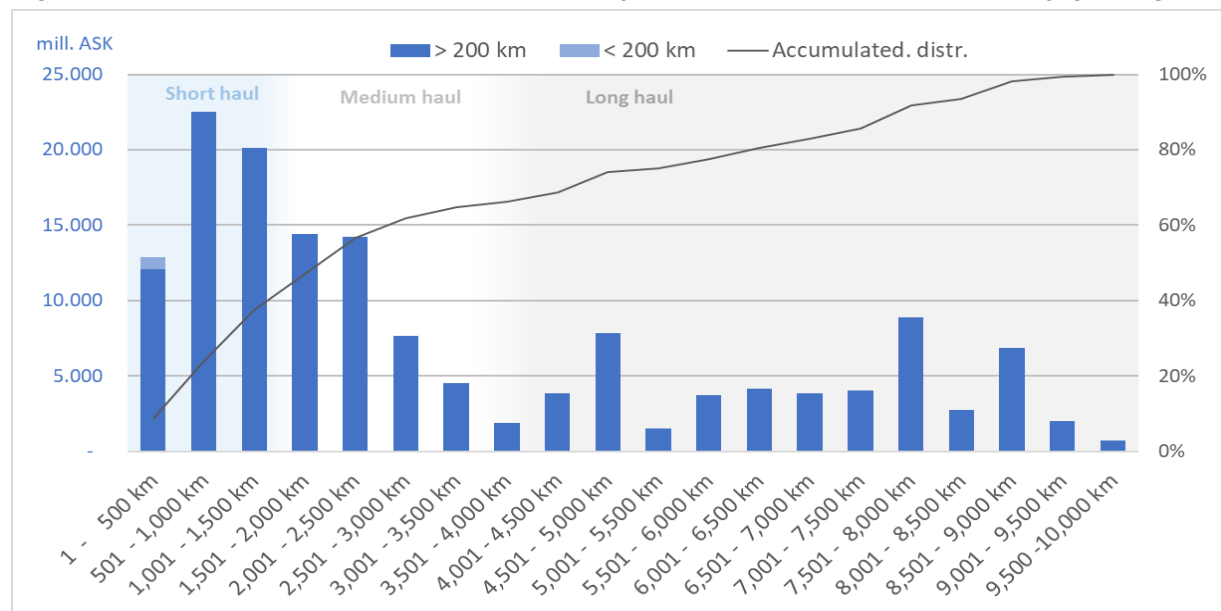
It is common to distinguish flight distances by term short-, medium- and long-haul. There are no commonly agreed, exact definitions of limits between them, but for example Eurocontrol defines medium-haul routes as being between 1,500 and 4,000 km. Taking this definition as departure all domestic and practically all Nordic routes are short -haul, while routes to Europe will be classified as mainly short and medium haul, whereas almost all (direct) flights to the rest of the world will be long haul.

In addition, regional flights are sometimes used for the shortest short-haul routes, typically about one hour or less.

Seat supply is a relatively good indicator for demand for air trips, but for fuel consumption and GHG emissions flight lengths are obviously also important and need to be taken into account. The statistics on *available seat kilometres* (ASK) adds all flight lengths for every seat supplied. However, ASK is not a precise indicator for energy consumption because fuel consumption per seat kilometre varies with distance and other factors.

Figure 3.1 shows ASK distributed on 500 km flight length intervals by the blue bars whereas the accumulated distribution is illustrated by the curve. Long-haul flights (above 4,000 km) constitute a relatively small share of seat supply, but they account for about one third of the total ASK. Short-haul (under 1,500 km), which are the most and frequent, and medium haul (1,500-4,000 km) account for about another third each.

Figure 3.1 Available seat kilometres (ASK) in 2019 from Nordic countries distributed on flight lengths.



Source: Extracts from OAG-database combined with distances from www.gcmap.com.

2.2 Airline market shares

The market structure within each geographical destination segment is also relevant with a view to possible policy instruments for promoting sustainable aviation. Table 3.2 shows the market share in 2019, again measured by seat supply, for all departures from each Nordic country. For the Nordics in total, the figures are split on destination segments. Market shares are shown for Nordic and foreign airlines and airlines with more than 1 million seats supplied are listed individually.

Table 3.2 Market shares in 2019, measured as seat supply with departure from a Nordic airport. Split on departing countries and on destination segments.

From: To:	Denmark Total	Finland Total	Iceland Total	Norway Total	Sweden Total	Total Total	Domestic	Nordic	Europe	World
Totalsum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Nordic Airlines	60%	87%	80%	87%	69%	77%	100%	98%	49%	63%
SAS	34%	4%	3%	38%	35%	30%	40%	49%	16%	15%
Norwegian	18%	12%	3%	34%	19%	22%	27%	22%	19%	10%
Finnair	2%	70%	1%	1%	2%	12%	9%	17%	10%	24%
Wideroe	1%	0%	0%	14%	0%	5%	12%	3%	0%	0%
Braathens Regional	0%	0%	0%	0%	11%	3%	8%	0%	0%	0%
Icelandair	1%	0%	58%	0%	0%	3%	0%	7%	2%	12%
Other Nordic Airlines	5%	0%	15%	0%	1%	2%	4%	1%	0%	3%
Foreign Airlines	40%	13%	20%	13%	31%	23%	0%	2%	51%	37%
Ryanair	7%	0%	0%	2%	5%	3%	0%	0%	9%	0%
Wizz Air	1%	1%	5%	3%	4%	2%	0%	0%	6%	0%
Lufthansa	3%	3%	1%	1%	4%	2%	0%	0%	6%	0%
KLM Royal Dutch Airlines	3%	1%	0%	2%	2%	2%	0%	0%	6%	0%
easyJet	4%	1%	6%	0%	1%	2%	0%	0%	4%	0%
British Airways	2%	0%	1%	1%	2%	1%	0%	0%	3%	0%
Other Foreign Airlines	18%	7%	7%	4%	14%	10%	0%	1%	18%	36%

Source: Extracts from OAG database (<https://www.oag.com/>).

Note: See note to Table 3.1.

Nordic airlines account for 77% of total travel by aviation from the Nordic countries. Domestic travel is completely dominated by national carriers⁷, and within the Nordics their share is 98%. Foreign carriers only have a significant market share for European and World destinations. SAS is the biggest airline, first and foremost in the founding countries of Sweden, Denmark and Norway. However, its market is below 60% in all combinations of country and a destination segment. Finnair is quite dominant within and from Finland, as is Icelandair to and from Iceland (as is Air Iceland Connect within Iceland).

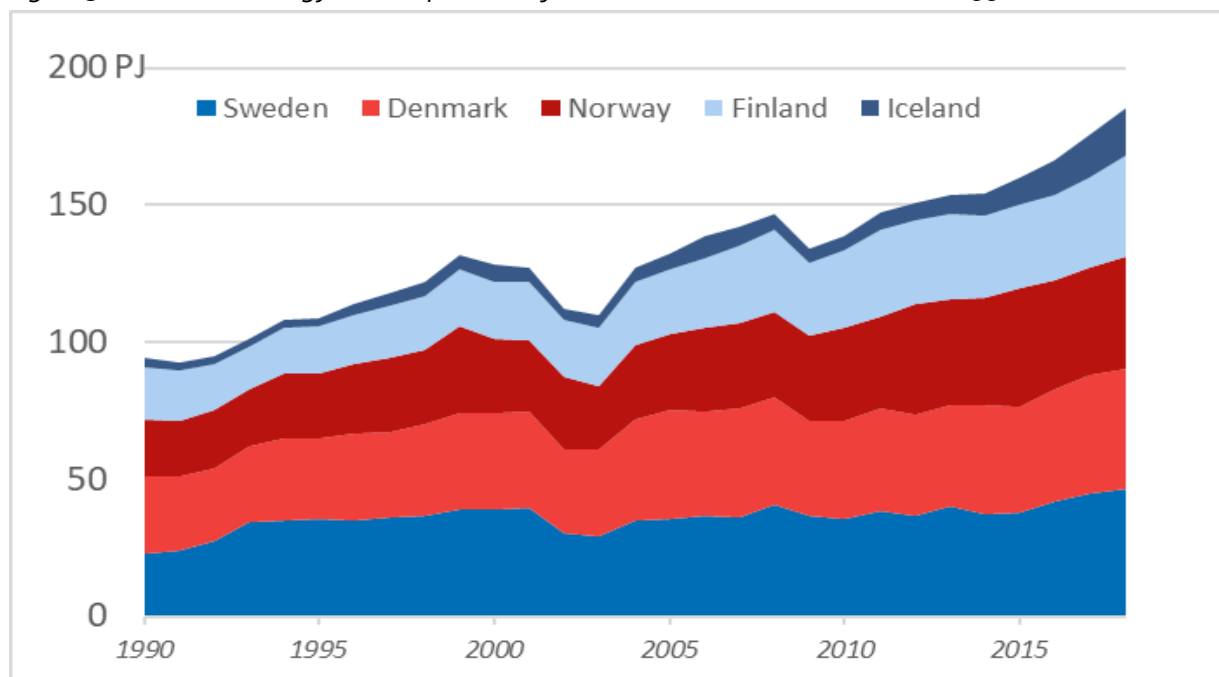
The market to and from Europe is divided almost exactly 50–50 between Nordic and foreign carriers, with higher shares for foreign airlines for Denmark and Sweden, the countries closest to the rest of Europe. For intercontinental routes, Nordic carriers have the 'upper hand' with 63%.

2.3 Future demand for aviation fuel

A Nordic strategy for sustainable aviation does not only imply that production of fuels for sustainability meet certain environmental sustainability criteria for their production. It also must rely on renewable energy sources and production pathways that can provide the SAF in volumes matching the need for gradual phase out of fossil jet fuels to eventually meet full decarbonisation of the aviation sector. This section analyses the expected future demand for jet fuel, whereas section 3.4 investigates volumes of sustainable biomass in the Nordics that can be provided as feedstock for production of the required amounts of SAF.

Propulsion energy for aircraft is currently based almost entirely on fossil jet fuel, i.e. kerosene, fulfilling international fuel standards for use in aviation. Figure 3.2 illustrates that the total energy consumption for aviation has steadily increased in all Nordic countries since 1990, only interrupted by the negative impacts of the 9/11 terror attack in 2001 and the financial crisis in 2008–2009. Average annual growth has been 4.4%, with no tendency towards decreasing growth; rather the contrary.

Figure 3.2 Annual energy consumption (PJ) for aviation in the Nordic countries. 1990–2018.



Source: Eurostat.

⁷ SAS is registered in Sweden, but it is here considered as a national airline in Denmark and Norway as well.

In 2018 jet fuel consumption amounted to 186 PJ, approximately double of that in 1990 in spite of energy efficiency gains of about 40% per revenue passenger kilometre (RPK) (Kharina et. al., 2016). The driving factor has been strong growth in air travel demand, which has surpassed all other modes of transport. Under business as usual air travel demand growth rates are expected to continue to be high, and very high globally, especially in Asia.

However, the need for drastic global reductions in GHG emissions implies that business as usual will not be an option for aviation. Efforts to reduce CO₂ emissions cannot be confined to solely relying on continued or even reinforced improvements in energy efficiency of aircraft and operations. Extensive substitution of fossil jet fuel with low carbon alternatives will be necessary. This will most likely drive up fuel costs more than what can be counterbalanced by continued aircraft energy efficiency improvements. Rising fuel costs will in turn reduce, but most likely not eliminate, the growth in travel demand through the effects on ticket prices.

Overall, we conclude that future demand for aviation fuels will mostly likely be higher than at present (August 2020), although growth will likely be at a slower pace than the past two decades. The special energy requirements in terms a high weight and volume density energy carrier will for at least the next couple of decades maintain air travels' dependency on liquid fuels. Moreover, as aforementioned, it takes time to change the aircraft fleet, and there are also orders for new traditional aircraft that will be delivered in the next years. This means the volumes of SAF needed to significantly decarbonize Nordic aviation must be in the same order of magnitude as today's consumption of fossil jet fuels.

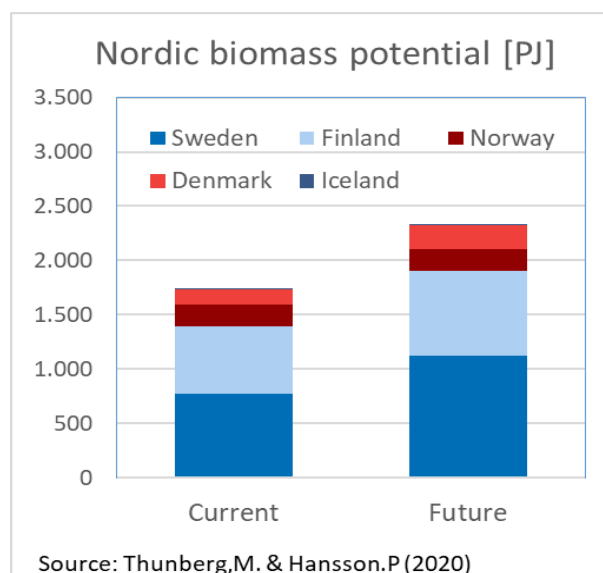
2.4 Biomass potential for sustainable aviation fuels in the Nordics

The two main energy sources for producing SAF at large scale are residual biomass and hydrogen generated from renewable based electricity by electrolysis, also labelled "Power-to-X". Whereas renewable energy sources for producing electricity (e.g. by wind turbines at sea) and, hence, hydrogen are not considered to be limited,⁸ the same is not true for sustainable biomass. Biomass is globally a scarce resource and will in the future increasingly also be needed in other sectors, including other parts of the transport sector, to replace coal, gas and oil. Increased use in aviation will limit the use in another sector. According to one analysis sustainable biomass may only cover somewhat more than 10% of jet fuel demand (Interview consultant, 2020; T&E, 2018). For an ambitious Nordic policy for sustainable aviation to be considered as 'leading by example', it should be justifiable that the chosen path is also sustainable on a global scale. This could be very difficult to verify if substitution of fossil jet fuel with SAFs is predominantly based on imported biofuels or biomass.

Only relying on renewable energy sources that can be provided from within the Nordics/EEA can be a way to secure sustainability for production of bio-jet fuels at a scale that can significantly reduce CO₂-emissions from Nordic aviation. From this perspective it is relevant to get an idea of the potential Nordic biomass potential as feedstock for SAF production in comparison with total jet fuel consumption in the Nordics.

⁸ But the renewables technologies also face sustainability challenges, that have to be dealt with, e.g. with practices used in industries that will supply the metals and minerals (Sovacool et al., 2020).

Tunberg and Hansson (2020) estimates, based on Pöyry 2019, that the total available sustainable biomass for energy in the Nordics is currently about 500 TWh (1700 PJ), and can possibly be raised to about 650 TWh (2300 PJ). Forest biomass accounts for around 70% of the total biomass supply, primarily from Sweden and Finland, and some from Norway. Agro biomass accounts for about 20%, and consists of energy crops, straw, husk, grasses, and manure. Waste delivers the remaining 10%, and includes biological material from consumers (such as municipal solid waste), waste water sludge, cooking oil, and waste from fisheries and slaughter. In Denmark, SAFs may primarily be produced from agro biomass and waste.



For economic reasons, almost all Nordic energy biomass is used as feedstock in the energy and industrial sectors for electricity and heat production. In a long-term perspective, it will be technically and economically feasible to use other renewable energy sources, e.g. solar, wind and hydro power, to replace biomass to an even larger extent than what has been the case so far. Still, aviation will in the future compete for the available resources of sustainable fuels with other applications, e.g. other modes of transport, which will also have to phase out fossil energy. Currently, the costs of utilising biomass for SAF is higher than for many other applications, due to the need for conversion to liquid fuels to fulfil very high safety standards, and due to the fact that production is very small compared to production of biofuel for road transport.

In addition, the figures for biomass potentials cannot be directly compared to the consumption of jet fuel. Only a fraction of the energy is maintained during the conversion of the biomass into liquid fuels. There are significant energy losses and/or heat generation as well as side products from all pathways.

To conclude: While biomass availability in the Nordics might, at first sight, appear abundant compared to current demand for SAF, biomass for energy purposes will undoubtedly be a scarce resource over the next decades. This will in particular be the case globally, not least if aviation continues to grow as expected, but the scarcity will most likely also play out in a Nordic context. This might not be an issue in early phases of the transformation, where SAF will only constitute a smaller share of total fuel consumption. However, full phase out of fossil fuels in aviation solely based on advanced biofuels might be challenged by availability of biomass that can be used sustainably. Therefore, the required biomass might come at a very high cost needed to attract it from other competing applications. Thus, aviation cannot rely on biofuels alone but needs other sources of sustainable energy. The currently promising alternative is e-jet fuel (Interview NISA, 2020; T&E, 2018) and electric propulsion for some applications (see Section 5.4).

The technology readiness levels for electrofuels are currently lower and costs are higher than for advanced biofuels. Still, increasing prices on biomass and cost reductions in power-to-X can indicate that electrofuels will turn out to be an important element in decarbonising aviation because of the limited availability of biomass. This could either be by boosting the energy from biofuels through hydrogenation, or by combining hydrogen and carbon capture from flue gases or from the air. The cost estimates for e-fuels in the coming years vary widely and are very sensitive to assumptions about the price on the electricity input (see Mortensen et al., 2019).

3 Aviation and climate policy: International context

International aviation is heavily regulated by international agreements, conventions, bilateral air service agreements and EU legislation. This complex international regulatory framework imposes strong constraints on many of the possible policy measures that could be implemented as common Nordic policies to effectively promote sustainability of aviation. This chapter therefore gives an overview of the most important aspects.

3.1 Convention on International Civil Aviation, ‘The Chicago Convention’

The Convention on International Civil Aviation, “The Chicago Convention” from 1944 is the legal basis for international civil aviation. Article 24 a) prohibits countries to impose custom duties and charges on fuel used in international aviation that is already onboard the airplane upon arrival, and prohibits against duties on aircrafts on a flight to, from or across a country’s territory (ICAO, 2006, p. 11; United Nations, 1944).

The Chicago Convention is not applicable to domestic aviation, and *only exempts* fuel already onboard on an airplane from taxation (United Nations, 1944). According to legal experts, the Chicago convention does, *not prohibit taxation on fuels to aircraft fueling in a country* (Faber & Huigen, 2018; Pirlot & Wolff, 2017). However, the exemption of fuel on board implies that the attractiveness of fuel taxation is (to some extent) reduced because of the possibilities for evading the fuel tax by tankering (see section 6.1 and 6.2).

3.2 International Civil Aviation Organization (ICAO) and CORSIA

In the Kyoto Treaty of 1997, Annex 1⁹ countries are asked to work on reducing emissions from aviation through ICAO. The successor is the Paris Agreement under the UNFCCC, agreed by most countries in the world, in 2015.¹⁰ The Paris Agreement entered into force in November 2016. Here, aviation is not mentioned, nor ICAO. However, the Paris Agreement calls on all countries and sectors to reduce their emissions to attain the targets of a maximal of 2 degrees Celsius warming and with the aim to attain a maximum of 1.5 degrees global warming by 2050. Emissions from international flights are generally not accounted for in the nationally determined contributions of the participating member states. However, the EU’s 2030 target includes outbound aviation emissions.¹¹

Emissions from international flights are reported every year to UNFCCC by Annex 1 countries, but only domestic flights are included in the national commitments. ICAO has issued many resolutions against the internalisation of environmental costs for the aviation sector and recommends that the members for international air services shall not impose any kind of duty or tax (ICAO, 2016; Pirlot & Wolff, 2017).

⁹ Annex 1 countries are the signatories of the Kyoto Treaty that committed to reduce their GHG emissions through a binding commitment.

¹⁰ The United States is leaving the Paris Agreement in 2020, and some large territories and self-governing regions like Greenland are not part of the agreement. Nicaragua joined the agreement in 2017.

¹¹ <https://www.transportenvironment.org/what-we-do/aviation-and-eu-ets>

In the period from 2009–2016, ICAO created for the first time a fuel efficiency standard for new aircrafts. This standard is to be implemented by its member states from 2020 onwards for new types and from 2028 for new aircrafts of existing types. ICAO has also set an aspirational goal of a global fuel efficiency improvement rate of 2 percent per annum from 2021 to 2050 (Fleming & Lépinay, 2019; ICAO, 2020b; Kharina et al., 2016, p. 2). According to an analysis of various scenarios made for ICAO, the combined impact of improved fuel efficiency and operations under the most optimistic assumptions will be 1.37% per year (Fleming & Lépinay, 2019).

In 2013, ICAO set the target of stabilizing emissions from aviation at the level of 2020 until 2050, i.e. all growth in aviation from 2020 onwards will be carbon neutral. This target is also aspirational (Fleming & Lépinay, 2019). From 2021, the implementation of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) will require airlines to offset increased emissions by buying quotas representing emission reductions in other sectors (ICAO, 2020b, 2020c). In comparison, the aviation industry's own and more ambitious target from 2009 is that airlines should cut their emissions from flight operations by 50% by 2050 compared to the level in 2005 (IATA, 2018a).

CORSIA will have a route-based approach, meaning that emissions from all flights between participating countries are covered by the scheme. Participation in CORSIA will be voluntary. By the end of 2018, 78 states had signed up to participate, including all EU member states. The years 2021–2023 is a pilot phase. The “first phase” of CORSIA is from 2024 to 2027. In the “second phase” from 2027 until 2035, CORSIA participation will be mandatory for most members of the ICAO. Small island states, landlocked countries, countries with little aviation and the least developed countries are exempted (European Parliament, 2019; ICAO, 2020b, 2020c; Norsk klimastiftelse, 2018).

Another key strategy under CORSIA is substituting jet fuel with sustainable aviation fuel. In principle, the sustainability requirements are similar to the EU's second renewables directive (RED 2, for further details about it, see 3.5): “CORSIA eligible fuel should not be made from biomass obtained from land with high carbon stock”. Such lands include primary forests, peat and wetlands, and goes back to how they were used before 2008, before they were converted to other land categories. To ensure that this happens, CORSIA has created independent certification schemes (ICAO, 2019a). Sustainable fuels shall have at least 10% lower GHG emissions than ordinary jet fuel. However, critics claim that: “Given the uncertainties that exist in these calculations, it's therefore possible that alternative fuels used will actually result in emissions equal to, or in excess of, kerosene” (T&E, 2019, p. 4).

However, in reality, the sustainability criteria under EU's renewables directives, RED I and RED II, are much stronger than those of CORSIA. 10 out of 12 of EU's sustainability criteria have been dropped in CORSIA. The only current sustainability criteria in CORSIA are that: a) the sustainable fuel shall have 10% lower emissions than conventional jet fuel in the life cycle, and b) biomass shall not come from areas that have a high biomass stock (Ministry of Transport, 2019, p. 91; T&E, 2019, p. 8). The sustainability criteria 3 to 12 did not pass ICAO Council initially but was referred back to the environmental committee CAEP for further work. However, at ICAO 219th Council session the additional 10 themes were adopted and are now going on State Letter procedure' writes y (personal communication with Swedish Energy Agency, 29 April 2020). The results will be presented at the ICAO Council in November 2020 (Danish ministry of Transport, 28 August 2020).

To prepare for CORSIA, the airlines need to keep track of, verify and report their emissions from 2019 onwards. 2019 and 2020 were to be the baseline years to calculate average CO₂ emissions from international aviation (European Parliament, 2019; ICAO, 2020b), but due to large declines in air traffic in 2020 caused by the Covid-19 pandemic, leading to very skewed results, the baseline will only rely on 2019 data.

This means that the airlines will also not necessarily have to buy carbon offsets, as long as they have not increased their emissions to pre-Covid-19 levels. If the average of the two years is applied as a baseline, the emission limits for the airlines will be very strict, and likely meet harsh resistance from the aviation industry. International Air Transport Association (IATA) has, for example, asked the ICAO council to use only the 2019-level as an average (IATA, 2020).

CORSIA has been strongly criticized by environmental organizations like Transport & Environment (T&E), for a number of reasons:

- First, it does not deal with reducing international aviation emissions directly on the CORSIA covered routes, because the individual airlines can continue to emit as previously for an indefinite amount of time, and then buy offsets for their pollution instead of reducing it. As long as offsetting is cheaper than CO₂-reduction in the aviation sector, airlines will have limited incentive to reduce own emissions (T&E, 2019).
- Second, participation is voluntary until 2027. A state may decline to participate hereafter through filing a reservation. For the states not wanting to participate, CORSIA has no enforcement mechanisms (T&E, 2019).
- Third, critics, including researchers, claim that CORSIA does not necessarily deliver reduced GHG emissions within the aviation sector, it will mainly provide revenues to various types of green projects. Buying offsets from such projects will be significantly cheaper than implementing other measures. The projects should be 'additional', which means that they would not be established without the buying of offsets. This is difficult to prove in practise (Bergskaug, 2020; Interview consultant, 2020; T&E, 2019). The critics seem to be backed by research: German Öko Institut has evaluated the first 14 carbon offsetting programs for eligibility under CORSIA and conclude:¹²

The evaluation shows that the degree to which the applicants satisfy the ICAO requirements differs substantially. Some applicants hardly met any of the requirements and may not even be considered carbon-offsetting programs. However, there are also notable differences in relation to specific criteria

(Schneider et al., 2019, p. 5).

- Fourth, it seems to be an unresolved issue how to avoid double counting, i.e. that the offsetting projects both count toward their country's GHG emissions reduction targets and the host country of an airlines' targets. If this is not hindered, it could result in states setting weaker targets so that they can sell potential overachievements as offsets. Thus, rules to avoid this situation need to be developed, according to T&E (2019). Another risk is that targets are not specified in certain sectors of a country so that projects there can be used as offsetting projects for international financing provided through the CORSIA (T&E, 2019).

3.3 EU regulation of relevance for common Nordic initiatives

EU's Single Aviation Market

Since 1996, all member state airlines have unlimited cabotage rights in other member states, i.e. unlimited rights to also operate their business within other member states' territorial borders. EU's Single Aviation Market means that all member states have "the nine freedoms of the air". This includes the right of foreign airlines to offer flights on domestic routes. Investors may invest freely in airlines across the EU (European Commission, 2015).

VAT is not levied on international aviation to and from EEA countries. Passenger taxes are implemented in Austria, Belgium, Ireland, Italy, France, Germany, the Netherlands, Norway, Sweden

¹² Due to this, from 2021, international credits will not any longer be allowed to use in the EU ETS.

and United Kingdom (Amsterdam economics & CE Delft, 2019; Faber & Huigen, 2018). If an EEA country introduces passenger taxes, they have to be uniform for the whole EEA area (e.g. Faber & Huigen, 2018).

EU Emissions Trading System (EU ETS)

EU Emissions Trading System (EU ETS) outlines that within the sectors that are covered by it, emissions are to be reduced by 43% in the period from 2020 to 2030, compared to 2005. The amount of quotas/emission allowances is reduced by 2.2% every year (called *the linear reduction factor*). A business within the included sectors polluting more than the emission allowances that it has been issued, has to either reduce its emissions or buy emission allowances from other businesses covered by the EU ETS, while a business pollutes less than its allowances can sell them. The idea of this market driven system is that the yearly reduction will be made by industries and companies where it is cheapest and thereby minimize the total reduction costs of achieving the reduction set out by the linear reduction factor.

The economic crisis starting in 2008–2009 created a large oversupply of EU ETS allowances, leading to very low allowance prices for several years. The price of an allowance was around 3 Euros per tonne CO₂ at the lowest in periods between 2016–2017 before the system was reformed in November 2017 (Ministry of Transport, 2019). It is currently (August 2020) around 25 Euros a tonne CO₂ (Ember, 2020).

As a consequence of the allowance surplus, 900 million emission allowances were ‘back-loaded’ from the EU ETS in 2014–2016 to increase the emission allowance prices and transferred to a Market Stability Reserve, which began operating in 2019. The Market Stability Reserve (MSR) improves the system’s resilience to major shocks by adjusting the supply of allowances to be auctioned each year (European Commission, 2020e).

Aviation within the EU and European Economic Area (EEA) was included in the EU ETS from 2012. Only CO₂ emissions are targeted by EU ETS, and not the climate impact from contrails etc. All flights within the European Economic Area are regulated by the EU ETS. However, most emissions allowances to the aviation sector in EU ETS, 82%, were from 2013, and are until the end of 2020 (the third EU ETS phase), granted to the airlines for free. Only 15% are auctioned, and the 3% were set aside in a special reserve (European Commission, 200x; Ministry of Transport, 2019; Schuknecht, 2019). From 2012 until 2023, all flights to and from the EU are exempted from the EU ETS. After this, the situation will be reviewed.

The EU ETS has led to reduced GHG emissions from aviation in Europe by 17 million tonnes yearly, according to the European Commission (2020g)¹³. Nevertheless, CO₂ and NO_x emissions from aviation in the EU have grown significantly from 2012 onwards (EEA et al., 2019 p. 25).

The aviation industry currently receives a higher amount of free allowances than the other industries included in the third phase: Power generators do not receive any free allowances, while the manufacturing industry in 2013 received 80% free allowances, which was gradually reduced to 30% in 2020 (European Commission, 2020d).

From 2012 until 2020, the airline operators have been granted the same number of EU ETS emission allowances, meaning that all additional emissions would have to be covered by airlines’ buying of EU ETS quotas at auction or from the market (European Commission, 2018). From 2021 until 2030, in the fourth EU ETS compliance period, the EU ETS quotas to the aviation sector for intra EEA flights will be reduced by 2.2% per year, i.e. the linear reduction factor in the EU ETS will also be applied to aviation. This will contribute to pushing the price of the ETS emission quotas/allowances upwards.

¹³ Compared to a situation with the ETS.

The current EU legislation on aviation will last until 2023. Dependent on the development of CORSIA, the EU legislation on aviation may be changed after that year (European Commission, 2018). There are different options as to the relationship between EU ETS and CORSIA in the future, and that no option has been chosen yet (Rothenberg, 2019).

Environmental organizations in Europe, like Transport & Environment are highly skeptical to CORSIA's potential effects on EU's GHG emissions: They argue that if CORSIA would be implemented in the EEA instead of EU ETS and other EU legal frameworks that, it would lead to a *significant increase* of GHG emissions from the aviation sector from 2021-2030: increases by 683.8 million tonnes CO₂ (T&E, 2019). The argument is that EU has agreed on total emissions amounting to maximally 111 million tonnes CO₂ from all outbound aviation from EEA airports for the 2030 emissions reduction target. In 2017, total EU emissions were 174 million tonnes CO₂, thus the EU target is requiring a reduction of 36% GHG emissions from 2017–2030 (T&E, 2019).

The Committee on the Environment, Public Health and Food Safety in the European Parliament and the European Commission has asked member states not to accept CORSIA's exclusivity clause in order to protect the EU ETS and keep up the environmental ambitions for aviation within the EEA (Greenair, 2019). EU negotiators have over several years worked to make CORSIA more ambitious, for example that sustainable fuel should be defined as having at least 30% lower GHG emissions than conventional jet fuel (European Commission, 2020g; European Parliament, 2019; Ministry of Transport, 2019).

According to our interviewees, various CORSIA member states have voiced criticism towards the EU ETS in CORSIA and argued that the EU by having EU ETS that includes the aviation sector violate their international commitments. Thus, they have threatened to withdraw from CORSIA (Interviews, 2020).

The Renewables Directive and its update

The EU Renewable Energy Directive (Renewables Directive, RED I) from 2009 includes sustainability criteria for biofuel (Parliament and Council, 2009). In December 2018, a revised version of this directive (RED II) entered into force (Parliament & Council, 2018), and it is to be implemented in 2020, at the latest by June 2021 by the member states individually. By 2030, 32% of all energy consumed and 14% of the energy used in transport must stem from renewable energy sources. 3.5% of the energy in transport shall stem from advanced biofuels, described as fuels based on waste, residues, e-fuels, renewable electricity and recycled carbon (See RED II, Annex IX, part A for a complete list).

In the current RED II, the multiplier¹⁴ for advanced biofuel used in aviation is 1.2, so that the member states may more easily reach the target of 14% renewable energy in transport by use of SAF (European Commission & EU Science Hub, 2019). However, since the member states can implement the RED II directive in a number of ways, the present version does not necessarily impact the production and consumption of SAFs and e-fuels in aviation. Thus, there has been a public hearing where stakeholders have been invited to elaborate on various policy measures to enhance production and consumption of bio jet fuel and e-jet fuels for aviation (European Commission & DG Move, 2020).

To prevent increased demand of renewable energy in the transport sector from having adverse environmental consequences, such as cutting down rain forest to produce palm oil (called indirect land use change, ILUC), both RED I and RED II include sustainability criteria for bioenergy. The member states may only use a certain share of bio energy that are of high risk of ILUC to attain their renewables target in transport. The limits for high ILUC risk bio energy will be gradually stricter:

¹⁴ "The contribution of non-food renewable fuels supplied to these sectors will count 1.2 times their energy content" (European Commission & EU Science Hub, 2019).

“These limits consist of a freeze at 2019 levels for the period 2021–2023, which will gradually decrease from the end of 2023 to zero by 2030”. Bio based energy sources that have been certified to be low ILUC risk are exempted (European Commission & EU Science Hub, 2019).

Still, the EU has been criticized for its biofuel requirements, which as to date are argued to have contributed to the reduction of significant areas of rainforest/wanton deforestation, because much of the bioenergy used in the EU stems from oil made of palm trees and soybean plants planted after rainforests in for example Indonesia have been cut down to provide for such production (Rainforest Foundation & Cerulogy, 2019).¹⁵ Another criticism is that the EU's RED II directive implies that consumption of palm oil will be phased out in the EU by 2030, while there is to date no such phasing out of soybean oil (Rainforest Foundation & Cerulogy, 2019). Critics also claim that implementation of the current version of CORSIA will pose similar risks of adverse consequences as the current RED I and RED II (Ministry of Transport, 2019; Rainforest Foundation & Cerulogy, 2019).

EU's Energy Taxation Directive, Directive 2003/96/EC

The Energy Taxation Directive (Directive 2003/96/EC) establishes the minimum excise duty rates that Member States must apply to energy products for fuel and transport, and electricity. However, commercial aviation is exempt from excise duty. In fact, the Directive prohibits fuel taxation for international flights. Member states can tax aviation fuel used for domestic flights and by means of bilateral agreements, also fuel used in intra-EEA flights¹⁶ (Amsterdam economics & CE Delft, 2019; European Council, 2008; Faber & Huigen, 2018). Norway and Switzerland have domestic aviation fuel charges (T&E & Hemmings, 2019). In addition, some multilateral and most bilateral treaties contain limitations on taxation of fuel (Piriot & Wolff, 2017).

Piriot (2020) comments that the EU's energy tax policy and EU's climate objectives are largely detached from each other and lack consistency. Interaction between the policies have no clear rules, particularly the relationship between the Energy Tax Directive and the EU Emissions Trading System.

A revision of the Energy Taxation Directive (ETD) is planned as part of the European Green Deal. Proposals for a revision will be presented by the European Commission in the second quarter of 2021 (European Commission, 2020b). The revision will also look at the current tax exemptions for aviation and maritime shipping with the aim that the jet fuel price should reflect its environment and health impact (European Commission, 2019a, p. 10).

The ETD revision may open up EU-wide taxation of non-sustainable aviation fuel, which could favor SAF and e-jet fuels. If the exemption for aviation fuel tax for intra-EU and international flights is taken out of the Energy Taxation Directive, the minimum tax would be 33 Eurocents a liter of jet fuel. Foreign airlines from states that the EU has air service agreements with will have to be exempted until the agreements have been renegotiated (Hemmings et al., 2020).¹⁷

Reform of the ETD may, however, be hard to attain, because there are clearly divergent opinions on the matter among member states, and because issues related to tax is subject to unanimous decision making in the Council (Amsterdam economics & CE Delft, 2019; Interview consultant, 2020). With continued unanimity voting, a number of EU member states may block it, namely those with

¹⁵ “Avoiding the direct use of palm oil and soy oil as feedstocks can reduce the likely deforestation impact of alternative fuel policies, but due to the connectivity of global vegetable oil markets, any use of food oils as biofuel feedstock is liable to drive some expansion of tropical oil crops, with associated indirect land use change emissions” (Rainforest Foundation & Cerulogy, 2019).

¹⁶ EU's Excise Duty Directive, Directive 2008/118/EC also applies to energy products, thus also aviation fuels. It states formulates that if there is to be a levy, it has to be demanded at the point of sale, i.e. in the moment of fuelling for flying domestically (European Council, 2008; T&E & Hemmings, 2019).

¹⁷ Assessment by law expert Echard Pache.

peripheral locations, island states, and those that generally are critical to stronger environmental legislation (Amsterdam economics & CE Delft, 2019). There is a suggestion that the voting rules in ETD might be changed to use the ordinary legislative procedure, which requires qualified majority, rather than unanimity voting (European Commission, 2019a, p. 5).

EU's initiative on sustainable aviation fuels

24 March–21 April 2020, there was a public consultation for a roadmap for SAF, Sustainable *aviation fuels* – *ReFuelEU Aviation* organized by the DG Movement in the European Commission. The roadmap deals with how supply and demand of SAF in the EU can be boosted, so as to increase its share of fuel consumption in aviation within EEA. The initiative is part of the work programme for the European Commission and also the Sustainable and Smart Mobility Strategy. The public consultation mentions several measures that may be implemented alone or together with other measures (European Commission & DG Move, 2020, p. 3).¹⁸ These include: SAF blending mandates, revision of the multiplier for aviation in the RED II directive and monitoring of production and use of SAF, develop key performance indicators to assess the effects of SAF policies. The European Commission has planned to adopt the strategy by the fourth quarter of 2020 (European Commission & DG Move, 2020)

The “European Green Deal” proposal

The “European Green Deal” is European Commission’s proposal for Europe to become the first climate neutral continent. It was first presented in December 2019. In January 2020, elements in how to achieve the goal was presented: The European Green Deal Investment Plan and the Just Transition Mechanism. In March 2020, the European Commission proposed a draft for a European Climate Law. Spring 2020, also the European Industrial Strategy was adopted. In May 2020, the Farm to Fork strategy, which aims to make food systems more sustainable, and the EU Biodiversity Strategy for 2030 were presented. July 2020, the EU adopted strategies dealing with energy systems and hydrogen.

The European Green Deal refers to the ambition that that by 2050, the net GHG emissions of the European Union are to be zero, and economic growth is to be further decoupled from resource use. At the same time, economic growth shall be socially inclusive, natural capital shall be protected, conserved and enhanced, and health and well-being of the citizens shall be protected from risks related to the environment (European Commission, 2019a, p. 2).

Concerning the transport sector, including aviation, there needs to be a 90% reduction of GHG emissions by 2050 compared to 1990. “In aviation, work on adopting the Commission’s proposal on a truly Single European Sky will need to restart, as this will help achieve significant reductions in aviation emissions” (European Commission, 2019a, p. 10).

There is an initiative planned to be launched in 2021 on how to implement CORSIA in the EU ETS to be consistent with EU’s targets for 2030. This initiative will also propose that the number of emission allowances to be auctioned for the aviation sector is increased in the EU ETS. Increase of the number of allowances to be auctioned will increase the price on emission permits and, hence, the fuel costs of aviation, since the aviation sector is expected to continue to be net buyer of permits (European Commission, 2019a, pp. 5, 11; 2020h).

¹⁸ This has been called for by the Nordic Initiative for Sustainable Aviation (NISA).

The European Green Deal mentions a number of other topics which may contribute to making aviation more sustainable. Some are previously launched initiatives.

- *Regulation dealing with land use, land use change and forestry.* The European Commission will propose changes by June 2021 (European Commission, 2019a, p. 4). This may impact production of various types of biofuel, including bio jet fuel.
- *Revision of The Energy Taxation Directive*, as mentioned in the previous section above.
- *Support to battery research and innovation*, which may contribute to attaining higher energy density in batteries, an enabler for electric aviation (European Commission, 2019a, p. 9).
- *Air quality* should be improved near airports by tackling the emissions of pollutants by aeroplanes and airport operations (European Commission, 2019a, p. 11). In 2021, a zero-pollution action plan for air, soil and water will be presented (p. 14).
- How production and consumption of sustainable and alternative fuels for transport can be increased (European Commission, 2019a, p. 11). This could impact electric aviation, the production of e-jet fuels, and also the production of bio jet fuel.
- *Forest ecosystems.* “Building on the 2030 biodiversity strategy, the Commission will prepare a new EU forest strategy covering the whole forest cycle and promoting the many services that forests provide” (European Commission, 2019a, p. 13). 20 May 2020, the biodiversity strategy was presented. It outlines that 30% of land areas and 30% of sea areas in Europe shall be protected. Also, more than 3 billion trees shall be planted by 2030 (European Commission, 2020c). When future EU policies are implemented, this may impact how bioenergy from forestry is produced and consumed. This may also impact aviation, as the largest potential for bio jet fuel in the Nordics come from forestry.

The Sustainable and Smart Mobility Strategy will be launched in 2020 (European Commission, 2020a). Summer 2020, there was a hearing on this strategy (European Commission, 2020i). Core features include:

- stimulating the increased use of low zero emission transportation modes,
- boosting the market deployment of new technologies, including the production and use of sustainable fuels, charging and refuelling infrastructure,
- help in changing to low-emission transport modes by transporting passengers and goods by more sustainable means of transport,
- improved energy efficiency in the transport system,
- stimulus for more sustainable consumption through internalizing external costs, like in carbon pricing (EU ETS is in function a type of carbon pricing),
- the agenda for urban and regional mobility will be revised (European Commission, 2020a).

4 Perspectives for sustainable aviation in the Nordics

4.1 Current national policies for sustainable aviation

The Nordic countries Denmark, Finland, Iceland, Norway and Sweden have ambitious climate goals and seek to be an example in achieving a sustainable energy system transformation. They have all committed to becoming climate neutral within the next decades. A number of different strategies and policies have been launched and implemented to attain this (e.g. Danish Government, 2018; Karlsen, 2017; Ministry for the Environment and Natural Resources, 2018; Ministry of Finance, 2019; Ministry of the Environment, 2018). These strategies also target aviation, but there is still a long way to go to make aviation environmentally sustainable.

Denmark¹⁹

Denmark is opting to be an international frontrunner in creating a more sustainable energy system through e.g. reducing GHG emissions, increasing production of renewable energy and enhancing energy efficiency (IEA, 2014; 2019b, p. 239). Denmark has also for a number of years been a promoter of ambitious policies at the EU level (Ydersbond, 2018), including working for higher emissions standards (Danish Government, 2018). In the Summer of 2018, the Danish parliament adopted a new energy agreement. The agreement included 67 million Euros from 2020–2024 to support green transport solutions (IEA, 2019b, p. 231).

Danish climate and energy targets include:

- 2030: 70% reduction in GHG emissions compared to 1990 (Danish Climate Council, 2019). This was agreed upon in December 2019 and is part of the legally binding Danish Climate law, which entered into force June 2020. The emissions reductions are to be attained domestically and comprise both the EU ETS and the non-EU ETS sectors. Denmark is to be climate neutral by the latest in 2050 (Danish Ministry of Climate, 2019). Sectoral plans to attain the target for 2030 are presented during 2020. Political negotiations about a national climate strategy for transportation, including aviation, toward 2030 take place in autumn 2020.
- 2030: 55% of energy consumption shall stem from renewable energy sources, 100% of the electricity shall stem from renewable energy sources, and 90% of the district heating shall stem from sources other than coal, oil and gas (Danish Ministry of Climate, 2018, p. 2).

Commercial aviation does not pay energy taxes and there are no passenger taxes in aviation. In addition, aviation is by and large de facto exempted from the uniform VAT rate of 25%. A passenger tax of 75 DKK, regardless of travel length, was operational in Denmark from 1997–2007.²⁰ It was charged for all departures from Danish airports, i.e. for domestic return trips. The tax was charged on both in- and outbound flights, while only one way for international flights. Persons travelling in small airplanes with 10 passengers or less, transit/transfer passengers, children less than 2 years old and aviation personnel on duty, were exempted (Ministry of Taxation, 2005).

¹⁹ These sections are partially based on Ydersbond (2019).

²⁰ For certain routes with dependence on air transport the tax was only 50%.

Finland

Finland has, like Sweden, a large bioenergy industry that is particularly related to the country's large forests (see Section 3.4). Finland has reduced their GHG emissions by 21% compared to the level in 1990 (Sanna Marin's Government, 2019). In 2015, the Finnish Parliament decided on The Climate Change Act, a framework for cost efficient long-term planning and monitoring of climate policy in Finland (MEAEF, 2017). The targets are that within:

- 2020: 38% of all energy produced shall come from renewable energy. This target was attained already in 2014 (MEAEF, 2017).
- 2030: More than 50% of the energy produced shall come from renewable energy sources (MEAEF, 2017, pp. 24, 28).
- 2030: Coal shall be phased out of the energy production (MEAEF, 2017, p. 34).
- 2030: Finland shall halve the use of imported oil and increase the use of renewable energy for fuel to 30% (MEAEF, 2017, p. 57).
- 2030: Reduce transport GHG emissions by minimum 50% compared to 2005 (Sanna Marin's Government, 2019).
- 2030: 30% of the fuel used in aviation shall be bio-jet fuel (Sanna Marin's Government, 2019, p. 121).
- Within the end of the 2020's, Finland shall be 55% self-supplied with energy through increased production of renewable energy and improved energy efficiency (MEAEF, 2017, p. 33).
- 2035: Finland in 2019 set the target to become carbon neutral within 2035 and have negative emissions thereafter. Finland aims to be the first fossil free country in the world (Sanna Marin's Government, 2019, pp. 34, 35).

Finland's national policies that may make aviation more sustainable:

- 1) Passengers pay a value added tax on domestic flights (The Barents Observer, 2019). Passenger transport has a reduced tax rate, and is taxed by 10%, compared to 24%, which is the standard VAT rate (Ministry of Finance, 2020).
- 2) Finland will work internationally in the EU and in other international organizations to reduce GHG emissions from aviation (Sanna Marin's Government, 2019, p. 121).

In 2018, Finnish Transport Safety Agency launched a report called *State Action Plan of Finland. International Aviation CO₂ emissions*. This action plan mentions all existing initiatives at the time for making aviation in Finland more sustainable, but does not seem to provide concrete recommendations about how aviation can become more sustainable through new national measures (Finnish Transport Safety Agency, 2018).

Autumn 2019, more than 50 000 persons signed a campaign to introduce passenger taxes in Finland. Thus, the case was to be voted over in the Finnish Parliament April-May 2020, but it seems to have been delayed until June 2020. Two political parties are positive, while the rest seem to be negative to a passenger tax, because they fear that it will be detrimental to the country's tourism industry (Lentovero, 2020, personal correspondence, 2020).

Iceland

Iceland has a very high share of renewable energy in their total energy consumption. In 2015, 84% of the primary energy use came from renewable energy sources, while the rest came from fossil fuels. This is the highest share of renewable energy in domestic energy consumption in the EEA. Almost all space heating, 99%, and electricity, 99.9% comes from hydro power and geothermal heat and power (EEA, 2019b; Government of Iceland, 2018, pp. 20–21; MENR, 2018).

In 2018, the Government of Iceland launched a new climate action plan for the period from 2018-2030. Here, the main points are to phase out fossil fuels in transport and improve carbon sequestration by restoring woodlands and wetlands, revegetate areas and plant trees. Iceland's general carbon tax covers all fossil fuels (Government of Iceland, 2018). Tourism has increased a lot the last years. Almost all these tourists came by airplane. The increased tourism has stimulated the tourism industry significantly (MENR, 2018).

Iceland's climate and energy targets include:

- 2030: Contribute to EUs target of 40% reduction of GHG emissions.
- 2040: Iceland is to be carbon neutral (Government of Iceland, 2020).

As a member of EEA, Iceland is similar to the other Nordic countries also implementing EU legislation regarding aviation, including participating in the EU ETS (Government of Iceland, 2018). Similar to the other Nordic countries, Iceland is also a member of the free route airspace over Northern Europe and the EU project Single European Sky (SES) (Samgöngustofa, 2018). Some pieces of national legislation contribute to enhancing demand for aviation, and thus increase GHG emissions. This includes that Iceland, similar to Norway, offers duty free shopping for travels to and from the EEA area (Ministry of Transport, 2019). Iceland's policies to make aviation more sustainable, or that have this as an effect:

- 1) There is a VAT on domestic travel by airplane, at 11% (Skatturinn, 2020).

Norway

Norway has the last decades aimed to be an international frontrunner regarding reduction of GHG emissions. Norway has the largest share of electric cars and electric ferries internationally and has one of the highest shares of renewable energy in total energy consumption in Europe. Norway has after Iceland the highest share of renewable energy in its final energy consumption. In 2017, it was 70.8% (EEA, 2019b), and also close to 100% renewable electricity. Norway is also an important contributor to the EU's energy security in being a large exporter of oil and not least gas (European Commission, 2020f).

The targets are that within:

- 2020: Attain total GHG emissions of maximally 47.5 million tonnes CO₂ in 2020 in the Climate Agreement (Klimaforliket) made by the Norwegian Parliament in 2015. Attaining this target seems likely today, if the trend in GHG reductions from 2019 continue in 2020 (SSB, 2020). However, parts of the reduction in GHG emissions in 2019 come from the temporary closure of an oil refinery (NTB, 2020).
- 2020: Attain a share of renewable energy in consumption of 67.5%. This target was first attained in 2014 (Øvrebø, 2016).
- 2030: Reduce national GHG emissions by 40% compared to 1990. This is a main point in the Norwegian Climate Law (Ministry of Climate and Environment, 2018).
- Norway has committed to reducing emissions by between 50 and 55% within 2030, Norwegian authorities notified to the UN early in 2020 (Ministry of Climate and Environment, 2020; Solvang et al., 2020). This is Norway's nationally determined contribution to the Paris agreement.
- 2040: State owned airport operator Avinor has stated a vision that all domestic aviation shall be electrified.
- 2050: Cut GHG emissions by 80–95% compared to 1990 and become a low emissions society.

Norway has implemented a number of policies to make aviation more sustainable:

- 1) Blending criteria for biofuel: from 2019 and until 2030, Norway will gradually increase the content of biofuel in aviation, starting at 0.5% *advanced bio-jet fuel in 2020 for all aviation jet fuel*, except for the jet fuel used in defense (Ministry of Transport, 2019).²¹
- 2) Passenger tax: was re-launched in Norway summer 2016. There was also a passenger tax from 1978 until 2002. From 2016–2019, the fee was NOK 80 per passenger. From 2019 onwards, it was changed so that it was NOK 75 for travels where the destination country's capital is less than 2500 km away from Oslo, and NOK 200 for travels where the destination country's capital is farther than 2500 km away from Oslo (Ministry of Transport, 2019).
- 3) There is VAT on tax for domestic aviation (Ministry of Transport, 2019). After the Covid-19 pandemic hit, the Norwegian government decided that this fee should be temporarily lifted, and that it would not exist from 1 January 2020 until 31 October 2020.
- 4) Personal transport, including domestic aviation, pays a VAT of 12% compared to the 25% rate for most other consumables.
- 5) There is a CO₂ tax for domestic aviation, and in 2019, it was NOK 510 per tonne CO₂ (Ministry of Transport, 2019). In 2019, the CO₂ tax was NOK 1.30 /liter, and in 2020, the CO₂ tax is NOK 1.39 /liter jet fuel for domestic aviation (Norwegian Government, 2020).

Some pieces of national legislation contribute to increasing the demand of aviation, and thus increase GHG emissions. This includes that Norway, similar to Iceland, offers duty free shopping for travels to and from the EEA area as long as the passenger has been at least 24 hours abroad and carries goods with a value lower than NOK 6000 (Ministry of Transport, 2019). This is not the case for the EU member states, which dropped this rule for travels within the EU area in 1999.

In 2019, a Norwegian governmental report, *Fra statussymbol til allemannseie – norsk luftfart i forandring*, launched a number of **recommendations** to make aviation in Norway more sustainable (Ministry of Transport, 2019). They include:

- Creation of a national Norwegian aviation strategy.
- Norway should aim towards making both EU ETS and CORSIA more ambitious in relation to reducing GHG emissions from aviation.
- Since aviation in a global business, environmental measures that have an economically detrimental influence on Norwegian aviation stakeholders in particular should be avoided.
- Work together with EU for very strict criteria for what can be classified as sustainable aviation fuels in ICAO.
- Work for a funding solution similar to that of the Norwegian NO_x fund to stimulate the increased production and use of SAF and environmentally friendly technologies.
- Norway should be a promoter of electric and other low and zero emission aviation technologies internationally, and also be an arena for development and early introduction of airplanes with such technologies.
- Demands for low and zero emission technologies in the public service obligation routes (PSO-routes) is a desirable strategy. The same is true for early signalling of benefits with regard to taxes and fees.
- Work for an EEA-wide system of environmental taxation of aviation that complements the EU ETS.

²¹ In the national transport programme from 2019–2029, the suggestion was to start with 1% sustainable bio jet fuel and end up with 30% in 2030. This is also the target set by the Norwegian Parliament and Avinor (Avinor 2017; Ministry of Transport, 2019). The target equates to 400 million liters advanced bio jet fuel annually (Avinor 2017).

- Challenge the EUs state aid guidelines in order to be able to stimulate the increased production and use of advanced SAF.
- Consider various strategies to reduce demand for aviation.

Sweden

Sweden intends to be an international frontrunner and show that “a fossil free world is possible” (Ministry of Finance, 2019). This includes reduction of GHG emissions, production of renewable energy and improvement of energy efficiency. Sweden is also internationally a frontrunner in these domains (CAN Europe, 2018). Sweden has a large bioenergy industry, which has been stimulated by Sweden’s transport policy (Ericsson et al., 2004; Ydersbond, 2014) and probably also has influenced Sweden’s transport policy.

Sweden has climate targets, a climate law and a climate council (IEA, 2019a, 2019b; Swedish Government, 2019c). The targets are that within:

- 2020: Reduce GHG emissions significantly and use 50% renewable energy according to EU commitments in the climate and energy package. Sweden has over fulfilled its obligations for producing renewable energy and met the target of 50% already in 2012 (Sweden.se, 2019). GHG emissions have been reduced significantly (EEA, 2019a; Martiniussen, 2019).
- 2030: GHG emissions from all transport except domestic aviation will be reduced by 70% compared to 2010 (Ministry of the Environment and Energy, 2017).
- 2030: Emissions in Sweden covered by the EU Effort Sharing Decision shall be reduced by at least 63% compared to 1990 (Ministry of the Environment and Energy, 2017).
- 2040: All power production shall be renewable (Swedish Government, 2016).
- 2045: Sweden shall become carbon neutral, and after that have negative GHG emissions. This is part of the Swedish climate law from 2018 (Swedish Government, 2019c).

The Swedish government is promoting a fuel tax on aviation within the EU (Morgan, 2020). Swedish national policies to make aviation more sustainable or that has the capacity to do so:

- 1) Passenger tax/fee: From spring 2018 with differentiated taxes depending on the length of the trip: SEK 62/ 260 / 416 (Swedish Tax Agency, 2020).
- 2) The VAT on personal transport, including domestic aviation, in Sweden, is 6%, compared to 25% on most consumption.

In the January agreement (*Januariöverenskommelsen*) from 2019, several measures to reduce the climate impact of aviation were agreed. It includes that Sweden shall take the international lead in stopping international laws that prohibit taxation of jet fuels. There shall be mandatory blending of renewable fuels. High blending of renewable fuels shall be economically incentivized. A new CO₂-reduction tax shall be created and replace the current passenger fees. Start- and landing fees for environmental purposes shall be discussed (Swedish Government, 2019b).

In 2019, a Swedish governmental committee report SOU 2019: 11, *Biojet för flyget*, launched a number of recommendations about how to make aviation in Sweden more sustainable (Swedish Government, 2019a). Central **recommendations** are:

- The All-Party Committee on Environmental Objectives should be asked to establish targets for reduced GHG emissions from aviation. The official target should be that there is fossil free aviation within 2045. This means that the energy for the aircraft is to be 100% renewable and have low life cycle emissions.
- To have obligations for reducing GHG emissions for the airlines, starting with a target, 0.8%, that corresponds to blending approximately 1% of the volume in 2021 to be bio-jet fuel. The target will be increased so that there is a reduction level of 27%, which corresponds to approximately 30% of the volume to be bio-jet fuel in 2030.

- Governmental central purchasing agreements (*ramavtalen*) should include the option to purchase bio-jet fuel.
- The Swedish Armed Forces should buy bio-jet fuel for the same volume as they use for flying airplanes in Sweden. They and The Swedish Defence Material Administration should be given the task to study the preconditions for domestic production and use of bio-jet fuel for their sector in Sweden.
- The Swedish Energy Agency should analyse whether there is a need for investment and operating support for production of bio-jet fuels that are produced with new technologies and thus cannot compete in fulfilling the reduction obligation for the airlines.
- The Swedish Consumer Agency will be given the task to develop a declaration for the sustainability of long-haul flights.
- There shall be an enquiry into whether increased transportation by using night trains can become an alternative to travel by aircraft.

Overview of national policies

Table 5.1: Overview of national target and policies influencing aviation sustainability.

	Denmark	Finland	Iceland	Norway	Sweden
GHG reduction target for transport	2030-plan to be launched in 2020	50% in 2030 (2005 = 100)			70% in 2030 (2010 = 100)
GHG reduction target for aviation					
Blending mandate		Proposal: 30% biofuel in 2030		0.5% adv. biofuel 2019 → Plan: To be increased → 2030	Suggestion: 1% → 30% from 2021 to 2030
Passenger tax				EEA: NOK 75 Other: NOK 200	EEA: SEK 62 Medium: SEK 260 Long: SEK 416
CO₂/Fuel tax on domestic trips				NOK 1.39 per liter jet fuel	
VAT on domestic trips	Exemption: 0%	Reduced rate: 10%	Reduced rate: 11%	Reduced rate: 12%	Reduced rate: 6%

4.2 Nordic initiatives dealing with sustainable aviation fuels

In addition to the above implemented policies and official plans there is a large number of initiatives and development projects dealing with sustainable aviation fuels in the Nordics. Most of them seem to aim to stimulate its increased production and use. An increasing number of projects also deal with e-fuels. Many different types of stakeholders are involved, including airline customers, the airlines, the airport operators, business interest organizations, businesses and research organizations. Appendix B.2 and B.3 present a non-exhaustive overview of concrete initiatives and projects dealing with SAF. A description of Danish and Swedish research projects regarding bio-jet fuel is also presented in Wormslev and Broberg (2020).

An increasing number of initiatives are targeted at the airline customers so that they personally, or their organizations, can help in creating a market for bio-jet fuel through paying extra for their tickets. This include initiatives by the airlines Braathens Regional Airlines (BRA), Finnair, SAS and Widerøe, and also the Swedish initiative Fly Green Fund. The airport operators Avinor, Swedavia, Swedish Regional Airports, and Copenhagen Airports are all working to enable the airlines to fuel with bio-jet fuel and offer this at their airports.

A number of policy related initiatives have been launched in the Nordic countries to create a market for bio-jet fuel and thus make aviation more sustainable. This includes initiatives by Nordic Energy Research, Nordic Innovation and Nordic Initiative for Sustainable Aviation (NISA) at the Nordic level, and a number of initiatives within each Nordic state. Here is a short presentation of some notable policy initiatives.

In Denmark, *Luftfartens Klimapartnerskab* was formed by the Danish Government. It includes a group of core stakeholders, including the main airlines, Copenhagen airport NISA, the Danish Aviation Association, and others. They were asked to present their recommendations on how aviation could contribute to reaching the Danish climate goals. The partnership launched their final report in May 2020. Here, they recommend that the sector establish an independently governed climate fund for promoting production and use of SAF in combination with a blending mandate of 30% within 2030. The fund should collect a passenger fee which should finance the price difference between fossil jet fuel and SAF. See also Appendix b.2.

Similarly, the main business organization for aviation in Norway, NHO Luftfart, has since 2017 recommended the establishment of a climate fund, similar to the already existing NO_x-fund, to stimulate the increased production and use of SAF through using the, to this fund. This fund should also bridge the price gap between SAF and fossil based jet fuel by using the revenue from the current Norwegian passenger fee and the proposed CO₂ tax. Alternatively, the revenue to the fund could be paid by airlines that get tax exemptions in other fields, as is the case with the NO_x-fund.

In Sweden, the organization Fossil Free Aviation 2045 works to make aviation in Sweden fossil free within 2045. This includes projects and stakeholders working on bio-jet fuel, but also deals with electrification of aviation.

4.3 Electric aviation

Electric aviation is a term used for various types of aircraft that are using electric motors for propulsion. The propulsion system may be labelled battery electric or hydrogen electric depending on the energy storage. The latter use fuel cells to convert hydrogen to electric power. Hybrid airplanes combines fuel burning engine(s) and electric motors. There is uncertainty about what kind(s) of energy storage will have the largest potential, and multi-billion investments are made by various stakeholders in aircraft with the different propulsion technologies (e.g. Sørensen, 2020). This sub-chapter will predominantly focus on battery electric aircraft, as they are seen to hold the largest potential in the next decades for the Nordic countries.

Electrification of aviation is seen to have a number of environmental benefits, in particular lower emissions of CO₂, local air pollutants, and noise. Introduction of fully electric aircraft will have very positive environmental impacts, particularly if the electricity is based on renewable energy (Schäfer et al., 2019, p. 160). In comparison, all SAFs will have emissions of local pollutants and due to upstream GHG emissions currently produced SAFs are not climate neutral. Hydrogen electric aircraft only emit water vapor but have significant challenges in terms of on-board storage. In general, the technology for hydrogen electric aircraft is not yet close to mature (Scott, 2019; Sørensen, 2020).

Battery electric aircraft offer a number of advantages. Electricity is produced in large and increasing quantities, and electricity from renewable sources are today produced at competitive prices (IRENA, 2019). In addition, propulsion by electric motors are more energy-efficient than jet or turbo-prop engines (Roland Berger, 2017).

The largest barrier to battery electric aircraft is the energy density of batteries. The energy density of batteries needs to be significantly higher than what it is today. Today, very good batteries in commercial use have around 250 Wh/kg. These are for example used in the car Tesla model 3.

Batteries at innovation stage today have more than 300 Wh/kg (Wang, 2019). Similar batteries can be used in battery electric aircraft, but the energy density needs to be increased to at least 500 Wh/kg to be suitable for aviation (Roland Berger, 2017).

The speed of innovation and how quickly new battery products will be launched is hard to predict. With the multi-billion efforts in battery research and development around the world, it is generally believed that future batteries will have significantly higher energy densities than the ones of 2020. With the current rate of innovation, Tesla's collaborator Maxwell is expected to deliver batteries with 500 Wh/kg by 2027 (Wang, 2019). Still, the energy density advantage of jet fuel is 6–8 times larger (Roland Berger, 2017, p. 17).

A second major issue might be that there is limited supply of the minerals that are needed for producing batteries, like lithium and cobalt (Carstens & Hesthammer, 2019; European Commission, 2019b). This challenge pertains to all kinds of battery electric modes of travel in the future. Battery manufacturers and research institutions are working to produce batteries that use less or none of these minerals to mitigate the problem.

Time available for charging an aircraft may also be a barrier, as ordinary passenger aircraft normally have a short stopping time at airports to optimize capacity utilization and thereby reduce capital costs invested in the aircraft. Therefore, it is an important challenge to charge the batteries quickly. However, the speed of charging and the charging infrastructure is steadily improving, allowing for charging at higher speeds. Here, battery electric aircraft benefit from the development of charging solutions for other modes of transport. Swapping of batteries is an opportunity, although it adds capital costs to extra batteries (Roland Berger, 2017).

A further challenge is that it also takes time to develop new security procedures and certification procedures for battery electric aircraft and other types of electric aircraft (Hanano, 2019; WSDOT, 2019, interviews 2020). Moreover, joint standards for charging also need to be developed.

Timeline of introduction of electric aircraft

10 June 2020, the first electric airplane, the two-seater Pipistrel Velis Electro, was certified by the European Union Aviation Safety Agency (EASA) for pilot training (EASA, 2020). It can only fly short distances. Thus, they are primarily suited for purposes like pilot training, sightseeing and as air taxis. Several other manufacturers are developing electric airplanes, including Heart Aerospace, Bye Aerospace, Eviation and Wright Electric.

The pace of scaling up production of the various types of aircraft with battery electric motors, including passenger airplanes, is uncertain. Moreover, even if competitive battery electric passenger aircraft were on the market it would take significant time to replace the fleet of aircraft, because the service life of commercial aircraft is typically 20–30 years. Further, airlines' replacement of aircraft involves a long-term planning process. Many airlines will at a given point in time have large binding orders reaching many years ahead for airplanes with combustion engines.

Expectations from the manufacturers of electric airplanes and others on the timeline of the introduction of electric airplanes vary widely. As with other technologies that are in development, the timeline of the introduction depends on a number of factors, including the level of financial resources put into the research and development projects, that research and development programs are stable and long-term, that various central stakeholders engage to have them launched, and that there are beneficial economic framework conditions to introduce the new products to the market once they are available (i.e. cross the so-called 'technological valley of death').

Several of our informants were optimistic about fixed wing battery electric airplanes²² being launched for passenger transport before 2030, while some were highly sceptical if this will be the case within this time frame (Interviews, 2020). Aviation manufacturers like Eviation and Heart Automotive aim to launch electric airplanes used for passenger transport within the early 2020's. Norwegian NOU 2019:22, note that: "Signals from the aviation manufacturers imply that the electrified airplanes can be introduced in commercial routes within the period 2025–2030" (Ministry of Transport, 2019, p. 87).²³

Nordic initiatives dealing with electric aviation

All Nordic countries apart from Iceland seem to have initiatives dealing with electric aviation. Particularly in Sweden and in Norway, there is considerable public attention as well as political support for this. Unlike for SAF, where there are already small quantities on the market today, the initiatives here deal with various aspects around developing electric aircraft. Initiatives include for example market analyses, technological development, testing, and development of business models. Appendices B.4 presents various initiatives and projects dealing with electric aviation in the Nordic countries in detail.

Several stakeholders involved in initiatives regarding SAF also work with introduction of electric airplanes. Airport operators Avinor, Swedavia, Swedish Regional Airports and Finavia all work on projects dealing with electric aviation. Airlines which participate in networks or have their own projects include: Air Greenland, Braathens Regional Airlines, Finnair, Icelandair, SAS and Widerøe. Research institutions involved in various projects on electric aviation include Research institute of Sweden (RISE), SINTEF, and the University of Tromsø.

The Nordics also have aircraft manufacturers that have launched or aim to launch various types of electric aircraft. So far, these are in the prototype stage or earlier. This includes Norwegian Equator Aircraft for small sea airplanes, Swedish Katla Aero for small battery electric aircraft, and Swedish Heart Aerospace for a 19-seater battery electric aircraft. Moreover, Rolls Royce electrical Norway and Widerøe collaborate in developing electric passenger airplanes.

The number of cross Nordic initiatives dealing with electric aviation in one way or another is increasing (Interviews, 2020). A prominent example is The Nordic Network for Electric Aviation (NEA). Ongoing Nordic research projects include Green Flyway between Norwegian and Swedish stakeholders and Finding Innovations to Accelerate Implementation of Electric Regional Aviation (FAIR) between Finnish and Swedish stakeholders. SAS (regarded as a Nordic airline) and Airbus collaborate in gaining knowledge about opportunities and challenges for electric aviation in passenger transport.

Future costs of operating battery electric aircraft

Battery electric aircraft

Prices and costs are essential keywords in the aircraft manufacturers' and others' interest in battery electric airplanes. The business case for electric aircraft essentially rests upon 3 pillars (Hanano, 2019):

²² This is a relevant distinction, as electric aircraft may not have fixed wings, but rather propels, like with electric vertical take-off and landing tools (e-VTOLs).

²³ Our translation.

- Lower operating costs
- Unleashing a new regional travel market
- Ability to meet mandatory carbon emissions standards

As electric motors are much more energy-efficient than combustion engines, and electricity is cheaper, energy costs will, according to most analysts, under normal conditions be lower for electric aircraft than the jet fuel for a similar sized conventional aircraft. In addition, electric motors are much simpler than combustion engines, and thus probably need significantly less maintenance, which also will save costs (Interviews, 2020).

A main component that drives expenses is the battery for battery electric airplanes. The battery currently used in electric airplanes has similar properties or are the same as batteries used in electric vehicles. Battery costs per kWh storage for cars has dropped significantly the last years, and is expected to continue to fall (BloombergNEF, 2020).

If production of electric aircraft takes off to volumes that allow for economies of scale, they could possibly end up being less costly to produce than similar conventional aircraft at some point in time. Thus, the electric aircraft could be cheaper to buy, fuel and maintain than a similar sized conventional aircraft in the long(er) term (Interviews, 2020).

At the end of the day, the key question for airlines is their total operating costs. Apart from having shorter range, the first types of electric airplanes for commercial traffic are expected have up to 9 or 19 seats, which is much smaller than typical aircraft used even on short distance scheduled services today. Therefore, on routes with passenger volumes high enough to obtain normal occupation rates for conventional aircraft personnel cost per passenger will likely be significantly higher for the battery electric airplanes, and probably to an extent that cannot be outweighed by the above mentioned operational cost savings.

These considerations indicate that battery electric aircraft will initially probably be most competitive at routes with

- very short distance routes where cruise speed is less important and
- sparsely populated regions, where passenger volumes are very small

Such routes could be existing services operated with public subsidies (PSO-routes) or routes to one of the many existing small airfields without services today. This would also open up for significantly improved mobility in remote areas, which could be particularly interesting in the Nordics.

The Nordics as a test bed for electric aviation

Several factors point toward the Nordics being a well-suited region for early introduction of electric airplanes. Here are some main reasons:

- In Norway and Sweden, a substantial number of airports have short fields for take-off and landing, which thus are suitable for electric airplanes, which need shorter runways than conventional airplanes (Nilsen, 2019).
- There are a number of routes in the Nordics with few passengers that are subsidized by the public (public service obligation routes, PSO routes). This is a good fit since the first fully electric airplanes will likely be small and thus carry few passengers.
- The Nordics have a large number of islands, coastal areas, and remote areas. Several of these are more accessible by airplane than by other modes of transport. Many of these routes are

short with limited number of passengers, which make them suitable for the early electric airplanes (see the next section).

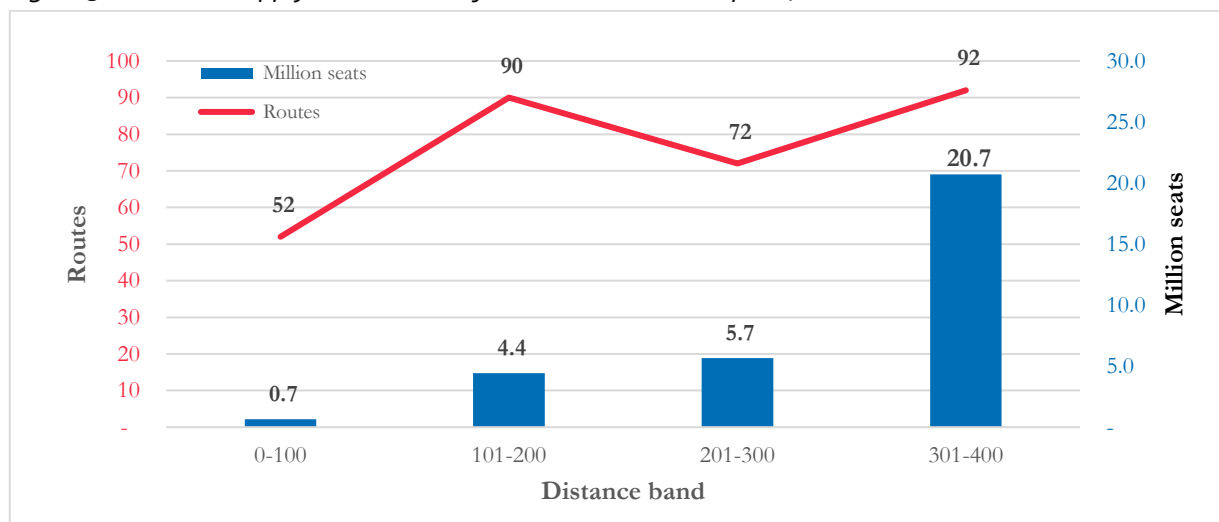
- There is a large number of routes within and between the Nordic countries that are short. These routes are described in detail in below and in Appendix D.
- Electricity prices in the Nordic spot market are usually relatively low in an EU context (AleaSoft Energy Forecasting, 2019). This strengthens the energy cost advantage for battery electric airplanes compared to similar sized conventional ones.
- The Nordic countries have high and increasing share of electricity based on renewable energy sources (EEA, 2019b; Wikipedia, 2020). Iceland's and Norway's electricity production is already close to, or 100% renewable, while Denmark and Sweden are likely to achieve similar level for to renewable or fossil free electricity production in the future in (see also Ch. 4). This strongly contributes to making the lifecycle emissions of electric aircraft low, c.f Schäfer et al. (2019).
- Support for electric aviation appears to be strong in the Nordics.
 - Nordic governments seem generally positive to electric aviation.
 - Several Nordic airlines and airport operators are pushing strongly for public financial support for introducing electric airplanes, e.g. Widerøe, SAS, Danish Air Transport, Swedavia, Swedish Regional Airports, and Avinor (Avinor, 2019a; Avinor & Civil Aviation Authority, 2020; Hegnar.no, 2019; Lorentzen, 2019c; SAS, 2019c; Siemens, 2019a).
 - A number of Nordic companies and institutions are already involved in developing battery electric airplanes, charging infrastructure and batteries, like Fortum, Heart Aerospace, Northvolt and Rolls Royce (Rønningsbakk, 2018; Svensson, 2019, Interviews, 2020).

Short routes within and between the Nordics for potential electrification

The first electric airplanes will likely fly short(er) routes because of the limited ranges of their batteries and the strong safety criteria for carrying extra capacity of energy for flying. Therefore, routes and traffic volumes of flights up to 400 kilometers are identified to assess the initial market for introducing electric airplanes.

Figure 5.1 shows the scheduled capacity and number of routes for short flights within the Nordics in 2019. Flights with a distance up to 200 kilometers accounted for 5.1 million seats (4% of total) on 142 routes (counting both directions). Including distances up to 400 kilometers adds another 164 routes with 26.4 million seats (together 23% of total seat supply, cf. Table 3.1).

Figure 5.1: Seats supply and number of routes at distances up to 400 km within the Nordics.



Source: Extract from the OAG-database (<https://www.oag.com/>).

The shorter/shortest routes will most likely be electrified first. For example, at present, there is a Norwegian initiative that relates to the establishment of electric flights between Stavanger and Bergen (distance: 160 kilometers) by 2023–2025. This route had a total scheduled capacity in 2019 of almost 700,000 seats. See also Appendix B for a more detailed description of this project.

The by far largest number of origin airports and destination pairs with routes that are equal to or shorter than 200 kilometers is in Norway, with 36 origin airports and 100 destination pairs, see Table 5.2 below. In Sweden, there are 12 origin airports and 15 destination pairs, in Iceland there are 4 origin airports and 5 destination pairs, in Finland there are 8 origin airports and 14 destination pairs, and in Denmark, there are 7 origin airports and 11 destination pairs. For detailed list of routes, see Appendix D.

Therefore, there are numerous existing routes which can be served by electric airplanes. The by far largest potential is in Norway with about two thirds of the total routes, flights and seat supply below 200 km, see Table 5.2. Norway is followed by Denmark with 0.8 million seats, Finland with about 0.65 million seats, Sweden with circa 0.5 million seats, and Iceland with approximately 0.02 million seats.

Table 5.2 also shows that the average number of seats supplied per flight is between 50-70 for all countries apart from Iceland. This implies that providing the same seat supply will increase the number of flights with 9- or 19-seater aircraft about three or six times.

Table 5.2 Total network for destination pairs with less than 200 km distance

From:	Denmark	Finland	Iceland	Sweden	Norway	Total
Total seats 2019	813,178	653,587	19,460	507,149	3,277,198	5,270,572
Total flights 2019	11,502	8,978	1,028	7,386	60,522	89,416
Average seats per flight	71	73	19	69	54	59
Origin Airports	7	8	4	12	36	67
Routes (Destin.pairs)	11	14	5	15	100	145

Note: For a comprehensive list of existing routes under 200 km, see Appendix D.

When considering the potential for electric aviation for reducing fossil jet fuel consumption and CO₂-emissions it should be recognized that the short trips share is significantly less than their share of trips or seat supply. For distribution on flight lengths available seat kilometres (ASK) is a relatively good proxy to fuel consumption. Flights under 200 km only account for about 0.5% and flights under 500 km for only about 9% of total ASK from the Nordics²⁴. Hence, this relatively small share sets rather narrow limits to the potential for total GHG reductions from Nordic aviation during the coming decade. However, if we only compare with *domestic* aviation, the only part which counts in international climate GHG reduction commitments, the shares are about 4% and 64% for flights under 200 and 400 km.

Finally, there are a number of airports in the Nordic countries that are located close to each other, where there is little or no traffic today between them because of insufficient demand, and where routes with small, electric airplanes would make sense economically to establish. This could enable for example new business collaborations, shortening peoples' work travels, and testing out the technology. Examples are these routes within and between the Nordic countries: Gothenburg–Åland, Gothenburg–Ålborg, Østersund–Trondheim, Aalborg–Esbjerg, Odense–Århus, Copenhagen–Odense, Karlstad–Oslo, Skellefteå–Vasa, and Umeå–Vaasa (Interviews, 2020). The Nordic Network for Electric Aviation (NEA) thinks this will be the case from the very beginning when electric aircraft are introduced to the commercial market for passenger transport (Interview NEA, 2020).

²⁴ Based on the data behind Figure 3.1.

Infrastructure needs for introducing electric aviation

Introducing electric airplanes requires establishment of charging infrastructure at the airports. In addition, various ground operations are expanding and are increasingly electrified to reduce local pollution and GHG-emissions. This means that the total electricity demand at the airports will increase irrespectively of whether electric aircraft are introduced or not. This implies that the electricity grid to and within the airports may need to be upgraded at some time in the future. The infrastructure within the airports likely needs upgrading and establishment of charging infrastructure in the next decades to establish the opportunity of charging multiple aircraft at high effects simultaneously. Moreover, battery charging at very high effects may require development of new charging solutions to enable short ground times for each airplane (Interview RISE, 2020; Interview NEA, 2020).

Opportunities for regional growth and collaboration

Our interviewees emphasized that new routes, enabled by the introduction of electric airplanes, may create opportunities for new (Interviews, 2020):

- cultural and business collaboration
- travel patterns for work and holidays and new logistics routes
- cross-border health and education cooperation
- tourism activities

New routes can also be established, as aforementioned, to remote places and where there are no routes today, or routes with very few passengers, and connect the different regions in the Nordic countries closer together. Cheaper and faster travelling may also make it more attractive to live in, and visit, very remote places. This opens up the possibility for new collaboration within culture, business, health, education, and for enabling new travel patterns for work and holidays. Electric airplanes could also help established businesses to collaborate on logistic tasks (Interviews, 2020).

Moreover, with more direct routes, and substitution of road, to some extent rail, and boat transport with transport by airplane, people will have faster travels, particularly to remote areas. Electric airplanes could lead to introduction of more regional mini-hub airports, as electric aircrafts can take off at shorter landing fields and make less noise, enabling airports closer to where people live. This could allow for more direct short routes which could be envisaged as an integral part of a mobility-as-a-service system (Interviews, 2020).

Since electric airplanes are very silent, they are expected also to be useful for night-time flying, such as for logistics purposes like bringing high-value goods with low weight. Night-time flying opens up for improved economy of each aircraft and also for flying without a pilot, as the airplanes, which are expected to be able to operate also autonomously in the long term, can have an extended use by being e.g. mainly used for passenger transport with a pilot during the day and logistics purposes, without a pilot, during the night. This would likely make electric airplanes (even) more economically beneficial in the long term, when they have reached market maturity and mass production (Interviews, 2020).

With cheaper travelling, this could also attract tourists abroad even more to the Nordics, and also enable new travel patterns for them. Travel by electric aircraft could be a part of so-called eco-tourism. Because of the low level of noise/sound they make, they are likely also useful for flying to tourism sites where conventional airplanes are regarded as a nuisance. Thus, this opens up new guiding business opportunities for the tourism industry (Interviews, 2020).

Electric routes could also contribute to signalling that the Nordic region is also in the context of aviation a progressive zero-emission region with attractive businesses. Electrification initiatives could lead to generation of knowledge and contribute to creating solutions that could be scaled up, new working places in the service industry and elsewhere. With the creation of a market for electric

airplanes, the international and Nordic manufacturers of aircraft, and their suppliers, like component manufacturers, could benefit (Avinor & Civil Aviation Authority, 2020; Interview Aircontact Group, 2020; Interview Widerøe, 2020).

The whole “ecosystem” around aircraft could develop new business opportunities and build competence from introducing electric aircraft. This “ecosystem” includes: the national ministries for communication, training of pilots, technicians, cabin personnel, aircraft maintenance, reparation of components, logistics businesses, cleaning of aircraft, ground handling, electricity delivery, delivery of charging infrastructure, and sub-contractors of the aviation manufacturers and flight financing stakeholders (banks and leasing companies) (Interview Aircontact Group, 2020).

Stable political support is also considered essential for faster introduction of electric aircraft. An important issue here, is that if the Nordics are early at signaling that there will be political support for introducing electric airplanes in the form of, for example, beneficial economic operating conditions, this may lead aircraft manufacturers to adapt aircraft to be well suited for the Nordic market to use it as an international test bed (Avinor & Civil Aviation Authority, 2020; Interview Widerøe, 2020). This has been the case with certain electric car models, which have been developed to suit the Norwegian car customers’ needs, as Norway has the largest density of electric cars in the world (Interview Widerøe, 2020). This chance of may not appear later, as per 2020 there are a large number of projects developing electric aircraft around the world. Many of these do not necessarily have the Nordic market as a main motivating factor, as it may be deemed to be too small.

Thus, the introduction of electric airplanes could, in addition to reducing GHG emissions and stimulating the expansion of a new technology on the world market, stimulate the creation of new work places in the airplane industry in the Nordics, among component manufacturers, in the service industries, in the tourism industry, enable faster travel, and be helpful also for various types of businesses, for public health providers and for education institutions (Avinor, 2020b; El-fly AS, 2020; Interviews Aircontact Group, 2020; Heart Aerospace, 2020; SINTEF Digital, 2020; Widerøe, 2020).

4.4 Possibilities for Nordic cooperation on electric aircraft

Nordic collaboration for electric aviation could be developed in several ways, as there are several needs to be covered to stimulate such an introduction. Keywords here are joint Nordic:

- political targets and strategies
- financing of research and development and other initiatives to enable electric airplanes
- beneficial economic operating conditions
- standards for charging standards and safety standards
- work towards the EU and ICAO
- procurement of new direct flight routes for electric aviation between the Nordic countries

A joint Nordic vision with political targets for e.g. 2025 and 2030 on the introduction of electric airplanes could by a signaling effect encourage various stakeholders working on electric aviation. Such targets could, for example, be targets to introduce electric aircraft in ordinary passenger traffic, to stimulate a significant increase in use of electric airplanes, and to stimulate technological development, develop joint safety standards and to develop joint Nordic charging standards with the aim of contributing to creating European/global charging standards.

Since the technology is new, development of Nordic charging standards and safety standards is likely very helpful for airlines, airplane manufacturers and others.

The political support must be stable, and e.g. 1–2 decades, to signalize to the manufacturers of electric aircraft that there is a market in the Nordics. This is important, because it takes about a

decade for conventional airplanes and significant economic investments for a new aircraft to achieve certification. Certification appears to be one of the big challenges for electric aircraft. Also, new standards for certification need to be developed. EASA and others work to develop a scheme where it may take shorter time than the conventional decade.

Targets would need to be followed up by concrete and binding Nordic strategies, and stable funding, to ensure that the chance would be as high as possible that the targets would be reached. Such strategies could include developing joint Nordic incentive schemes for electric aviation so that electric aircraft have economically beneficial operating conditions. This could be achieved through for example joint Nordic tax exemptions or reductions on landing fees, VAT exceptions, exemptions or reduction of passenger fees, exemption for electricity tax in ordinary traffic, and financing of charging infrastructure. Implementation of such measures could be combined with raising taxes of fees on non-sustainable aviation.

Beneficial economic operating conditions could contribute to making the tickets for electric airplanes cheaper than the tickets for conventional airplanes. Cheaper tickets may be needed initially, as there is a high risk that a significant number of passengers could be skeptical to electric aircraft due to the fact that the technology is new (correspondence, Aircontact Group). However, it may also be the case that 'green' customer groups have a willingness to pay higher prices for the flight tickets (Han, Lee, Chua, & Kim, 2019; Han, Yu, & Kim, 2019; Interview NEA, 2020).

The Nordic countries could also help with support schemes when airlines opt to buy/acquire electric airplanes, such as purchase support, loan guarantees, or simply buying electric airplanes themselves, and then letting different airlines use them. Financing of research, development and demonstration, and financing of networks where knowledge from the various projects is spread, could also be essential to help electric airplanes take off (Interviews, 2020). The financing of these incentives could come from different sources, including a sustainable aviation fund (such a fund will be discussed further in detail in Chapters 5 and 6). The key point is that there needs to be a guarantee that the electric aircraft will receive beneficial economic operating conditions and be incentivized for a prolonged period²⁵.

The Nordic countries can also promote electric aviation at the EU and European level by a Pan-European collaboration in order to create large enough a market particularly for the large airplane manufacturers to prioritize it. The topic could be put on the European agenda, as part of a European Green Deal and also as part of the recovery packages to stimulate economic development in the wake of the Covid-19 crisis. Working on the European level could also include a push for electric aviation to be included to a higher extent in different European research programs (Interviews 2020).

²⁵ There will be a Swedish report dealing with how to create more sustainable aviation through innovation, with electric aircraft and bio jet fuel as topics.

5 Assessment of potential Nordic policy measures for sustainable aviation fuels

Air travel is mobile by nature with the dominant part being international. Unilateral regulation is therefore vulnerable to airlines' and travellers' options to shift their activities to other countries to avoid the jurisdiction of the regulating country. Therefore, cross-boundary international agreements are the ideal approach for most kinds of regulation of aviation. Historically, these agreements have concentrated on technical standards and market regulations aiming at securing fair competition on international routes. However, international conventions with widespread participation is complicated and time consuming to get in place, and even more difficult to change due to a number of reasons, summed up as conflicting interests and free-rider issues. Consequently, accelerated transformation of the aviation sector to higher sustainability via international agreements like CORSIA is today, at best, a very slow strategy.

Unilateral national regulation to reduce aviation's CO₂ emissions that increase operation costs for airlines, will create incentives to avoid the inferred costs by shifting activities abroad. Imposing standards or taxes could be unfair if the same standards or taxes are not imposed on all, as it would make the affected stakeholders less competitive.

[...] aviation taxation has proven to result in substantial substitution effects of travel demand, both to other modes of transport and to foreign airports where no or lower taxes apply (Amsterdam economics & CE Delft, 2019, p. 13).

For example, if fuel taxes are implemented by one nation alone it will become more attractive to choose hubs or tank fuel in neighbouring countries when possible. Therefore, national regulation creates significant risk of *CO₂ leakage* for certain activities, i.e. that initiatives to reduce national emissions are partly or fully offset by increased emissions abroad. Such leakage may also lead to national economic losses due to distorted competition.

This dilemma can, at least partly, be solved by regional agreements. The leakage and distortionary problems are primarily related to international flights and domestic flights where an airport on the other side of the border is a relevant alternative. Hence, if the country or a group of countries with common regulation is big enough, or remote from other regions, the share of travel affected by the cross-boundary challenges can be ignorable, or acceptable, compared to the intended beneficial effects on the far majority of the travel volumes.

An EU-driven agreement for EEA would probably be a sufficiently large region, as 25% of all air travel energy consumption is related to trips internally in Europe (Strand, 2019). The Nordic countries constitute a geographically large sub-region of Europe where internal Nordic flights will not really be subject to the boundary challenges. A common Nordic policy will, as mentioned in the introduction, have an effect in itself, but can also be viewed as a frontrunner initiative that can pave the way for a EU/EEA wide regulation.

This chapter examines the potentials and challenges for common Nordic policy measures for promoting less carbon intensive aviation. The focus will be on joint Nordic policy measures for enhanced use of SAF, environmental taxation, and on joint initiatives to prepare for and facilitate initial steps in electric aviation.

5.1 Blending mandate and CO₂-reduction requirements

Energy efficiency improvements of aircraft and operations are commonly agreed to be important elements in reaching the political level of ambition in the Nordics for climate impact reductions from aviation. However, it is also clear that attaining significant reductions in GHG emissions will require very significant reductions in the CO₂ emissions from the fuel burn by substituting fossil jet fuel with SAF on a scale far beyond the 0.5% blending implemented in Norway from 2020.

Chapter 4 showed that a 30% target for SAF's share of fuel for all (both domestic and international) commercial fuel consumption by 2030 is on the political agenda in four of the five Nordic countries. It has been adopted politically in Finland and Norway and put forward by high-level advisory boards in Denmark and Sweden. This section takes this level of ambition and time horizon as point of departure for analysing a common Nordic policy framework for stimulating the use of SAF. However, the results and conclusions are indicative for other targets as well.

Certification and sustainability criteria

Aviation fuels are subject to strict international technical standards because of the high level of safety precautions in aviation. In practice, this means that the production pathways have to be certified by ASTM International. Six production pathways are currently certified with blending levels up to 50% (see Table 6.1). Several others are in process for certification, including HEFA+ a high-quality biodiesel (HVO) with a higher freezing point than HEFA (Hydro processed Fatty Acid Esters and Free Fatty Acid) which will limit the blending percentage to 10–15%.²⁶ The Swedish Government, 2019a expects that the maximum allowed blending level over time will reach 100%. Hence, it is not likely to be an important barrier for relevant timelines for extensive use of SAF. This is likely to also be the case for other SAFs, including e-jet fuels.²⁷

Table 6.1 SAF production pathways certified by ASTM (American Society for Testing of Materials), Ultimo 2019

Production Pathway		Max. Blend	Feedstock
FT-SPK Fischer-Tropsch Synthetic Paraffinic Kerosene	[2009]	50%	Biomass
FT-SPK/A Fischer-Tropsch Synthetic Paraffinic Kerosene	[2015]	50%	Biomass
HEFA Hydro processed Fatty Acid Esters and Free Fatty Acid	[2011]	50%	Lipid feedstock
HFS-SIP Hydroprocessing of Ferm. Sugars – Synthetic Iso-Paraffinic kerosene	[2014]	10%	Sugars
ATJ-SPK Alcohol-to-Jet Synthetic Paraffinic Kerosene	[20016/2018]	50%	Alcohol
Co-processing	[2018]	5%	Lipidic

Sources: Wormslev and Broberg (2020, p. 8) and Swedish Government (2019a, p. 118).

A crucial issue is the sustainability criteria which biofuels must match to be labelled as SAF, especially with regard to the origin of the feedstock. Strict and clear criteria are essential, as past experience so far has been that the least expensive biofuels have been based on crops. The sustainability of using crops as feedstock for fuel production is increasingly questioned, as there are severe risks of indirect land use change (ILUC) impacts, c.f. discussions in section 4.3. The CO₂e reduction potential of replacing fossil jet fuel with SAF varies significantly across production pathways because of upstream emissions, in particular those associated with the feed stock.

²⁶ For a technical overview of the global status of SAF see Wormslev and Broberg (2020), Chapter 2.

²⁷ E-fuels processed through a Fischer Tropsch technology are certified today.

Hence, for biofuels to be allowed to fulfil a blending mandate it should be politically decided whether to:

- rely on the general sustainability criteria in EU Renewable Energy Directive II, which appears to be the case in the recommendations in (Swedish Government, 2019a), or
- the mandate be narrowed down to biofuels produced from feedstocks in Annex IX of the directive, i.e. *advanced biofuels* (Part A) and HEFA based on waste oil or animal fat residues (Part B), as in the Norwegian blending mandate as in the adopted Norwegian blending regulation.

Electro-jet fuels produced by wind, solar and water-based power will typically have low upstream emissions and should be allowed to fulfil a blending mandate, which is also recommended by Swedish Government (2019a, p. 11).²⁸

Costs of SAF compared to fossil jet fuel

Biofuels are today only used in very small quantities in commercial aviation because of very high production costs and, hence, availability compared to fossil jet fuel. HEFA will probably be the aviation industry's first choice of SAF to fulfil a blending mandate, at least in the short term, because HEFA is currently the most economically viable bio-jet fuel and the only bio-jet fuel which is actually produced in significant quantities (Swedish Government, 2019a p. 113). However, the scalability of HEFA is very limited if it should be based on waste oil and animal fat as feedstock, because the available amounts of these resources are more or less fixed and very low compared to the volumes needed for SAF to constitute a significant share of aviation fuel consumption. In addition, available resources are to a large extent already exploited today as feedstock for biodiesel (HVO), which is cheaper to produce than bio-jet fuel²⁹. Finally, increasing the scale of production from today's plant size is not considered to lead to significant further cost reductions for HEFA.

In a Nordic perspective, **bio-jet fuel** production pathways based on lignin feedstock from forest residues have a potential in terms volumes in the orders of magnitude required to match a substantial use of SAF in the long run in the Nordics. These sources can be supplemented by straw and manure from agriculture and organic contents in municipal waste (see section 3.4). For several advanced biofuels production pathways technologies are known, but either not used for SAF or not in full-scale production. There is great uncertainty about which technology will be the most efficient, and the manufacturing prices are high. For advanced SAF the production costs per litre is currently significantly higher than for the HEFA, and capital costs are higher, meaning longer payback period. In addition, great uncertainty prevails about which technology will turn out to be the most efficient in the future. All in all, this implies that risks are very high for potential investors.

E-jet fuels are today at a lower technology readiness level. The individual technology components are known, but not in a complete set-up. Commercial production requires high capital expenditures. The estimated costs per litre is currently high, even for full scale production, but it is expected that implementing commercial production will decrease costs through lower wind/solar based electricity costs and learning curve effects. However, estimates for future costs are very uncertain as they are very dependent on price expectations for not only wind/solar power, but also on the side products (heat and hydrocarbons).

²⁸ See p. 188. The report also states the European Commission will before the end of 2021 come up with how to calculate life cycle emissions for e-fuels (page 117).

²⁹ If certified HEFA+ will be simpler and cheaper to produce than HEFA. It could increase the volumes significantly compared to current production of HEFA and also increase potentially available volumes, (although still not for significant shares) for aviation. However, it would still be competing with the road sector which already uses all practically all available resources from waste oil and animal fat. See Pavlenko, N. et al, 2018.

Based on the review of several recent Nordic reports³⁰, we draw the following conclusions about the costs for various SAFs with a view to formulating common Nordic policy framework that can stimulate use of sustainable aviation fuels in the Nordics:

- HEFA is apparently the economically least costly bio-jet fuel today, at least if we account for investors' risks related to heavy capital investments of large-scale production of the alternatives. It is the only SAF in production today, and it is expected to dominate the market in the short term.
- If feedstock for HEFA (or HEFA+) is restricted to waste oil and animal fat, to meet to strict sustainability criteria, limited feedstock availability will impede production volumes required for significant levels of blending for Nordic or even global aviation.
- Advanced bio- and e-jet fuels are more expensive than HEFA. Production costs are closely related to prices on feedstock and sustainable electricity. In addition, the costs of e-jet fuels are fundamentally tied the prices and market outlets of co-products in terms of other biofuels and surplus heat.
- Large-scale production is necessary to minimize costs of SAF production, but high capital costs and uncertainty about future prices makes investment risky.
- Currently, the price of SAF is more than twice the price of fossil jet fuel and in many cases several times higher. In 2030 SAF production costs in an order of magnitude around twice the price of fossil jet fuel might be reached with large-scale production.
- In a highly competitive air travel market this makes the increase in fuel costs prohibitive for commercial production under current regulatory conditions.
- Market creation at a significant scale is necessary to overcome these barriers by measures than can significantly reduce the supply side risks and generate a demand for SAF in spite of the added fuel costs.
- Reaching SAF use in the Nordics in the order of magnitude of 30% of total commercial fuel consumption warrants an early and credible announcement, and gradual phase-in to allow suppliers to develop production capacity with minimum costs.

Finally, it should be stressed that challenges of uncertainties about the future costs of SAF also apply to world market prices on fossil jet fuel, and on top of this future increases in the costs of emission allowances under the EU emission trading system, as a higher and higher share is auctioned and less given for free based on historical emissions.

Regulatory mandating gradual phasing-in of SAF

Policy measures to achieve blending of SAF can be designed by at least four different approaches:

1. Blending mandate
2. CO₂-reduction requirement, taking into account differences in lifecycle CO₂e- emissions for various SAFs
3. SAF fund, financed either from Government budget or from ear-marked taxes or passenger payments
4. Fuel taxes differentiated according to lifecycle CO₂e-emissions

This section investigates at 1.2. and 3., while 4. is considered in section 6.2. along with passenger taxes, which will *not* give incentives to use SAF.

³⁰ Ramboll 2017, Nisa et al. 2019, Rainforest Foundation 2019, Pavlenko, 2019, DBL 2020, Swedish Government, 2019a, Miljødirektoratet et al. 2018.

Blending mandate

A blending mandate means that regulation demands that a minimum percentage of the jet fuel sold is SAF from a list of fuels that are certified according to their production pathways. The liability for fulfilment and responsibility for documentation lie on the supplier not the airline. Typically, the blending mandate applies to all fuel sold during the year and across all airports to give flexibility to suppliers in terms of when and where to blend how much. As long as the required blending percentage is low the requirement can be met by blending in a slightly higher percentage in a few airports with high volumes and thereby reduce costs. In addition, suppliers are given flexibility to fulfil the requirement as a branch or in groups together, or in groups with option for negotiating the allocation of the blending across suppliers.

The set-up above is the most common approach for regulation of blending of biofuels in road transport. It is also the approach taken in the Norwegian blending mandate for SAF. From a regulatory approach, it is simple, and the administrative costs are low. Originally, the Norwegian Government proposed a 1% blending of biofuels fulfilling the RED II sustainability criteria, but Norway ended up with a 0.5% advanced biofuel blending mandate (RED II Annex IX Part A & B).

CO₂e-reduction requirement

A disadvantage of a blending mandate is that it does not incentivize using a SAF production pathway, and in particular a feedstock, with low life cycle CO₂e-emissions among the alternative options that are accepted for meeting the blending criteria. Such an incentive can be implemented by weight factors similar to the RED II criteria for fulfilling the 2030 targets for renewable energy. However, a more stringent way is to replace the blending criteria with a requirement for reduction of the weighted average CO₂e-emissions per MJ of jet fuel taking into account the lifecycle emissions of both the fossil jet fuel and the SAF share. Also in this case, the SAF should fulfil general sustainability criteria (see Section 4.3). Assessment of lifecycle emissions is an extremely complicated and demanding process. However, the practical implementation of the regulation can follow the detailed and comprehensive set-up in RED II. Still, the administrative costs will probably be higher for a CO₂e-reduction requirement than for a blending mandate.

The inquiry *Biojet för flyget* (SOU 2019:11) recommended a gradual introduction of a CO₂e-reduction requirement with a slow start to allow production to ramp up and reach 27% in 2030. According to the inquiry this level will correspond to a volume share of 30% based on expectations that lifecycle emissions from bio-jet fuel will decrease from 16.0 to 8.9 g CO₂e per MJ bio-jet fuel. For comparison, 89 g CO₂e per MJ is used for fossil jet fuel. The inquiry recommends that certified e-jet fuels are allowed for in the CO₂e reduction requirement, provided that they are based on renewable energy and carbon feedstock.

Table 1 Reduction levels, presumed LCA emissions and estimated volume ratios			
Year	Reduction level	Presumed LCA-emissions bio-jet fuel (gCO₂/MJ)	Estimated volume ratios
2021	0,8	16,0	1
2022	1,7	14,2	2
2023	2,6	12,5	3
2024	3,5	10,7	4
2025	4,5	8,9	5
2026	7,2	8,9	8
2027	10,8	8,9	12
2028	15,3	8,9	17
2029	20,7	8,9	23
2030	27	8,9	30
The Inquiry's own estimates.			

Source: Swedish Government, 2019 a, p. 32.

Tankering can result in 'Climate Leakage'

Production costs for SAF will undoubtedly be significantly higher than for fossil jet fuel towards 2030. Measures that will mandate use of SAF will increase fuel costs in a country or region, such as the Nordics, will create an incentive to tactical fuelling for flights in and out of the country/region. Tactical fuelling, or "tinkering", means that airlines try to minimise fuel costs by refuelling where the price is low if possible. This is also taking place today because of differences in prices across airports, typically with higher costs in remote areas. Tankering will reduce the positive climate effects of mandating SAF in two ways:

- Firstly, and most important, because it will shift fuel consumption from SAF-blended fuel to pure fossil fuel.
- Secondly, the aircraft will have to carry more fuel which in turn increases fuel consumption.

However, the latter effect also increases fuel costs for the airline and reduces the incentives for tankering.

The impacts of the tankering issue can be quite different for short and long-haul:

- *For short-haul flights*, the leakage problem of tankering can be significant for high blending shares. SOU2019:11 has assessed that the fuel price differential has to be at least 5-10% if tankering should be profitable for flights to Europe, and that this will not be the case until the SAF content reaches about 5%. If airlines have a certain willingness-to-pay for SAF for branding reasons, this will increase the tipping point accordingly.
- *For long-haul flights*, possibilities for tankering will be very limited simply because the fuel tank capacity is fully utilised. If the fuel price differential is high enough it can lead to stop-overs for refuelling in neighbouring countries with lower fuel costs, but more likely the consequence will be fewer direct intercontinental flights from the Nordics.

Regulatory mandating

High capital costs and uncertainties about costs and future demand are among the serious barriers to commercialising some of the SAF pathways with the highest potential in the Nordics. These investors' risks are amplified by a gradual phase-in of a blending or reduction requirement with low shares for the first years to allow production to ramp up.

The clear policy support signalled in a gradual requirement, phasing-in over ten years, can be discounted heavily by investors who are uncertain whether this support will exist for the duration of the project's lifetime, which can range from 15 to 25 years. Hence, there is a clear risk that some of the most promising long-term pathways will not be brought to market even by a blending/reduction requirement (Swedish Government, 2019a; Pavlenko et al. 2019).

State grants and loan grantees up front can be a mechanism to reduce these perceived risks. Such measures are most suitable in demonstration and pilot phases of technological development and can conflict with EU regulation for state aid when a market is established, in particular under a blending/reduction requirement. The Swedish Inquiry assesses that this will be the case if fulfilment of the required blending/reduction is incentivised by a high non-compliance tax as in their proposal. (Swedish Government, 2019a)

An alternative measure is to establish a fund that can generate a demand for SAF or a certain subset living up to stricter sustainability criteria by financing the additional costs. Such a funding mechanism will be similar to the principles in the Danish PSO scheme (Danish Climate Council, 2016) for renewable energy and the Norwegian NO_x fund. The Climate Partnership for Aviation in Denmark in 2020, and NHO Luftfart have put forward such funding mechanisms for Denmark and Norway with some differences (Luftfartens Klimapartnerskab, 2020; Norsk klimastiftelse, 2018; Rambøll, 2017). The details can be designed in numerous different ways and should be carefully elaborated, i.e. to comply with EU state aid regulation. It is beyond the scope of this report to delve into these details.

A fund can generate a demand for SAF

In brief, a SAF fund can establish a demand mechanism by public procurement in various forms, e.g. as a kind of "Contract for Difference" program where potential producers bid in an auction for a minimum price floor (Pavlenko et al. 2019).

The fund guarantees that producers will be able to sell their fuel for that minimum price floor by "topping up" the price differential when market price is below the winning price floor. The volumes under the contract can be limited to match the financial resources in the fund but should be big enough to allow for exploiting economies of scales.

A long-term stable framework is essential. Contracts should have a lead time for delivery to start 3–4 years into the future to give potential producers time to establish production facilities, and contracts should last for extended periods (e.g. 10 years) to provide sufficiently secure revenues for investors and thereby reducing the risk on their investment.

The size of fund and hence the need for financing will depend on both the price differential between the contractual minimum price and the expected market price for the SAF as well as the level of ambition for SAF blending. However, it is important to note that the willingness to pay and, hence the demand, for SAF will also depend on the future development of the oil price, including the price of the emission permits in the EU Emission Trading System, both of which are expected to rise toward 2030. A price increase on fossil fuel will undoubtedly increase the demand and thereby price for biomass as energy feedstock which will in turn also probably increase the costs of producing SAF.

The fund can be financed either by Government budgets or from a polluter-pays-principle by earmarked taxes on aviation. Advantages and disadvantages of fuel taxes and passenger taxes are described in the next section.

5.2 Taxation of aviation

Basic economic principles of environmental taxation states that a tax should be levied as close to the source of the problem as possible and should reflect the marginal social costs per unit of the emissions creating negative externalities for the environment. However, designing a suitable environmental tax to reduce the climate impacts of aviation is a complex matter. The decision of how design the tax and the size of the tax has to take into account other national and international economic instruments as well as lack of such measures.

Ignoring administrative and legal barriers there are at least three clear-cut economic arguments for some kind of national taxation of aviation in the Nordics:

- International flights are exempted from Value Added Tax (VAT) and domestic flights pay reduced or no VAT. This can be considered as a de-facto subsidy that distorts the relative price of flight tickets compared to other private consumption (including travelling to the same destination by car), which is in general subject to VAT. This leads to higher consumption of air travel, and the result is higher CO₂ emissions since air travel is significantly more CO₂ intensive than average consumption.
- The price on emission allowances of the EU Emission Trading Scheme acts like a CO₂ tax. However, the current level (August 2020) of about 25 EUR per tonne CO₂ is far lower than national estimates of the marginal CO₂ abatement costs to achieve the emission targets in the Nordics, in particular if we only look at contributions from the transport sector. Hence, the issue of double taxation can be refuted. In addition, flights in and out of the EEA zone are not comprised by the ETS.
- The climate effects of flights are under some circumstances significantly higher than the effect from CO₂-emissions, especially in high altitudes. The impact is most severe for long distances. Contrails from fuel burn in high altitudes and other complex atmospheric chemical reactions can lead to a more than doubling of the CO₂-effect. The scientific understanding of the effect is not robust and the estimates of the effects are highly uncertain.

In addition, neighbourhoods close to airports are severely exposed to noise nuisances and aircraft contribute to local regional air pollution, which could also warrant environmental taxation. All in all, aviation is significantly lower taxed than road transport, having significant fuel taxes as well as vehicle taxes in the Nordics. Compared to alternative modes of collective transport, e.g. buses and railways, aviation has a significantly higher climate impact for the same distance.

Further, taxes on aviation will generate a fiscal revenue, which can be justified from the “polluter-pays-principle” and could be used to finance initiatives to promote sustainable aviation, e.g. by supporting research/development or market introduction of SAF.

Unilateral versus common Nordic taxation

The current low-tax regime on aviation is supported by a number of interacting national, European and global rules and agreements, as described in Chapter 3. The origin of many of these regulations are recognition of the mutual benefits of creating common regulations and fair competition between countries. However, today they also act as unwarranted barriers for countries with ambitions to be first movers in promoting sustainable aviation. Compliance with the international framework conditions as well as the disadvantages of acting alone have to be taken into account in how to choose the best available national and joint Nordic policies for reducing GHG impacts from Nordic air travel.

Some of the possible negative side effects from stricter national regulation are CO₂ leakage to neighbouring countries, strain on the competitiveness of Nordic airlines, tourism impacts from higher travel costs and other possible wider economic impacts from aviation's contribution to

connectivity³¹. However, a harmonised Nordic initiative will probably reduce the negative impacts, because the options for substituting to other countries with lower levels of taxation will be fewer.

If a tax is imposed by a country on departures from that country, the tax revenue will partly be paid by citizens from the destination countries because the price will presumably increase on return tickets bought in both countries. This incidence effect creates an incentive for countries to make bilateral agreements, or form multi-country coalitions, such as a common Nordic initiative, to impose the taxes in order to obtain a balanced sharing of the tax revenue.

Fuel tax

A fuel tax directly targets CO₂-emissions because the emissions are directly determined by the volumes of fuel burned, and as such a jet fuel tax reflects in principle an “ideal” tax on the externalities of climate change. If implemented globally it imposes appropriate short- and long-term incentives on air travellers, fuel suppliers, airlines and aircraft producers to:

- reduce excessive travel via higher ticket prices
- encourage energy-optimised flight operations and maximise capacity utilisation
- stimulate usage and development of low carbon fuels
- buy and develop fuel-efficient aircraft or alternative propulsion technology

SAF, or more precisely the CO₂ reduction of a given SAF, should not be subject to a CO₂-based fuel tax whether in pure use or as a blended share of the jet fuel.

A unilateral or common Nordic implementation of a fuel tax would only have negligible technology driving effects for fuel-efficient or electric aircraft because of the countries' insignificant share of aviation world market.

Further the leakage effects, first of all in terms of tankering, but also shifting hub activities abroad as described above, might significantly reduce the CO₂ reduction impact of a fuel tax. The size of the leakage effect will depend on the size of the fuel tax, as it increases the fuel costs differential to neighbouring countries proportionately. A bigger leakage will therefore also increase the tax evasion and thereby erode some of the additional revenue effect from higher fuel taxes.

At first sight, the leakage effect will be equal to the effect of a similar cost increase from a blending mandate for SAF. However, the leakage effect might actually be smaller, because the airlines / travellers will most likely have some willingness to pay for using SAF which will counteract the incentives to evade the blending mandate but not the fuel tax.

³¹ These economic effects of taxes on aviation is discussed in more detail in Hemmings et al. (2020), Chapter 5. One of these is tourism impacts. Here it should be noted that they go both ways: Both ingoing and outgoing tourist trips are affected negatively if travel abroad is reduced and further, that reduced outbound tourist trips will most likely be substituted to a great extent by domestic demand in the same sectors. The net effect on the economy is likely to be positive if the tax implementing countries are net importers of tourism, i.e. their citizens spend more abroad than the tourists they receive. If so, as is probably the case for the Nordics, taxing aviation might actually benefit the domestic tourism industry.

In practice, EU regulation limits fuel taxes to routes covered by bilateral fuel tax agreements (see box)³². The possibilities for tankering are significantly reduced for destination countries that have a fuel tax of the same size. If so, only aircraft coming from a non-covered route to serve a route between or within the two countries can take advantage of tankering. Therefore, the leakage effect would be less under a common Nordic initiative compared to national implementation, as tankering opportunities will diminish with the size of the geographical area and the number of routes covered in both ends.

If a common Nordic CO₂-based fuel tax is high enough it can make up for the price premium on SAF and make SAF cheaper for airlines than fossil jet fuel. This will in principle make the fuel demand under the tax regime shift fully to SAF³³, provided that the supply is sufficiently elastic. Distinguishing between taxed sales for Nordic and domestic flights and untaxed sales for international flights adds administrative costs but is clearly feasible and corresponds to the current situation for domestic flights in Norway and in USA.

From a global climate change perspective, the most significant impact of a common Nordic decision on fuel taxes on internal Nordic flights could be the possible influence on the political process within the EU in connection with revision of the Energy Tax Directive. A united Nordic position with an actual implementation of an intra-Nordic fuel tax could contribute to pave the way for comprising EEA-internal aviation on an equal footing with other sectors in terms of energy taxation.

However, with small populations and only three out of five countries being EU members the Nordics' influence should not be exaggerated. A joint Nordic implementation can also be seen as a stepping stone for extending bilateral agreements to neighbouring countries and thereby enhancing influence on European policy. On the other hand, this 'international negotiation strength' perspective rather points toward a passenger tax: For example, Germany, United Kingdom and Austria in addition to Norway and Sweden have already implemented this measure. Arguably, it would therefore be easier to agree on.

A Nordic jet fuel tax regime and EU-regulation

The main challenge for a fuel tax as pivotal instrument for promoting sustainable aviation is that it is unlikely to be implemented at a close to global scale in the foreseeable future. An EEA-wide measure could at least partly create the same incentives. This could for example be done by abolishing the intra-EEA flights' exemption from the EU energy tax directive's minimum tax rate of 33 EUR-cents per litre (about 130 EUR per tonne CO₂e) as suggested by T & E (2020). Alternatively, renewed interventions in the ETS could increase the quota price equivalently from the current level of about 25 EUR per tonne. A report to the European Commission found that a general 33 EUR-cents tax per litre would cut European aviation emissions by 11%.

The European Commission has announced its intention to revise the Energy Tax Directive, i.a. with a view to addressing the exemption for jet fuel. However, at present, adoption of a revised directive requires unanimity, and political support from all member states to such a revision is far from secured.

The 2003-revision of the Energy Tax Directive allowed for bilateral intra-EEA jet fuel taxation between two or more member states. Hence, a common Nordic taxation policy is an option. In practice, there are some juridical complications with third party carriers that account for an insignificant market share within the Nordics.

CE Delft (2019b) judges that this can be handled by a *de minimi* exemption.

³² CE Delft (2018) Section 6.3.1 challenges the general belief that fuel taxes can only be levied by bilateral agreements if the fuel tax is differentiated according to life cycle carbon emissions.

³³ This is feasible even with a technical maximum blending rate of 50%, because fossil fuel and SAF will in practice be handled in the same supply infrastructure where the allocation of SAF for the Nordic market and fossil fuel for international flights is handled by a 'green certificate' scheme in line with the electricity market.

Passenger tax

A passenger or ticket³⁴ tax is a rather blunt way to internalise the climate impacts of aviation: Of the four advantages listed above for fuel taxes it only incentivises fewer air trips, and does not contribute to improved fuel efficiency or use of SAF.

However, technically a passenger tax can be differentiated several ways to make it “mimic” a fuel tax to partially obtain the same incentives. Most importantly, a passenger tax could be increased with trip length, preferably in combination with the specific fuel efficiency of the aircraft trip length. The dilemma is that the more sophisticated the tax is, the more complicated it will be to administer and comply with. A simpler alternative could be a per flight tax based on the maximum take-off weight of the aircraft (or the number of seats) and distance flown.

So far, no European countries have implemented a per-flight tax in any of the numerous various designs that could be superior to a passenger tax in terms of more directly regulating the climate change impact of aviation. It was the preferred model of the UK government in 2008, but it was not implemented because of legal concerns in relation to international agreements and EU regulation, and the same consideration was behind the German aviation tax (Faber & Huigen, 2018 p. 23). In general, a study examining European court trials concludes, in relation to possible designs of aviation taxes, that:

Aviation taxes may be legally challenged when there is a 'direct and inseverable link between the quantity of fuel held or consumed by an aircraft and the pecuniary burden on the aircraft's operator' (Faber & Huigen, 2018 p. 28).

The above conclusion also prevents passenger taxes differentiated by distance within the EU/EEA if we (realistically) set aside bilaterally agreed passenger taxes. This is in line with the fact that no EEA countries have implemented passenger taxes that differ between European destinations, but several countries have significantly higher rates for distance bands exceeding distances of destinations within EEA.

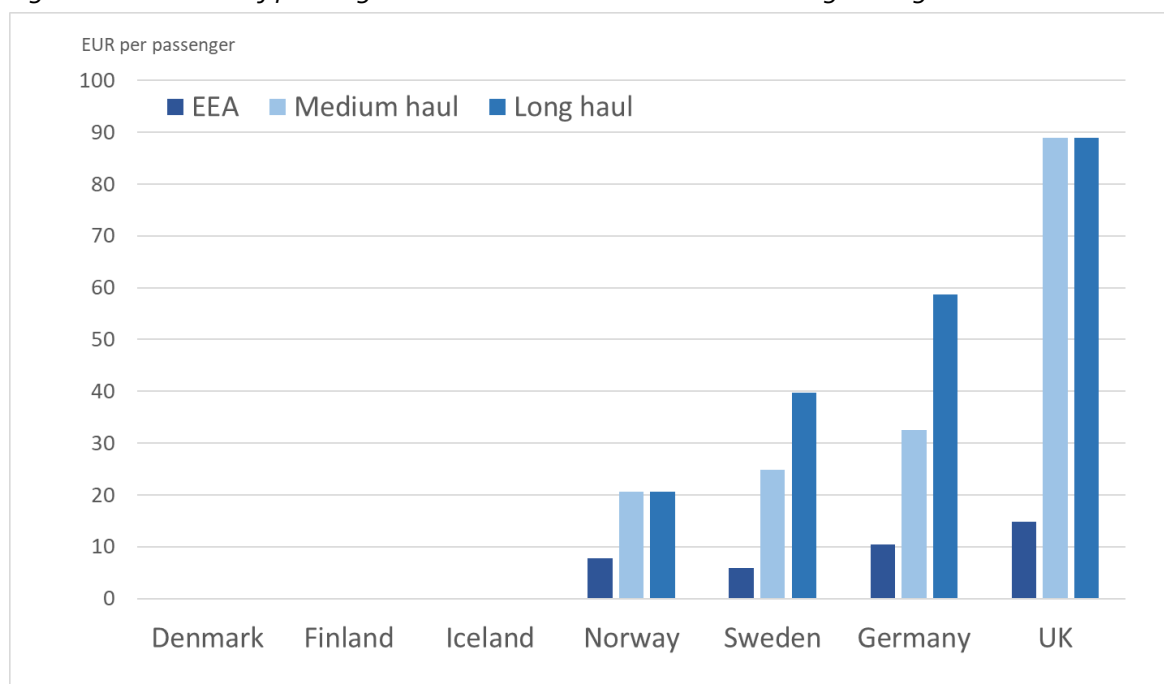
An important advantage of a passenger tax over a fuel tax is that it does not create an incentive to evade the tax by tankering because does not give rise to added fuel costs. The advantage is twofold:

- Firstly, no climate leakage effects in terms of extra fuel use to exploit the tankering possibilities as described in section 6.1.
- Secondly, erosion of the tax revenue by evasion is prevented.

In addition, the administration and enforcement of a passenger tax is simple, if it is implemented with a uniform tax for internal European flights and distance bands for long-haul flights. Administrative simplicity is also an argument for a unified Nordic approach and indeed also for taking into consideration the size and structure of existing and expected passenger taxes in neighbouring European countries.

³⁴ A ticket tax has basically the same properties as a passenger tax and the distinction between the two is the administrative setup, although not always clear. A ticket tax is levied on the sale of the tickets whereas a passenger tax is levied on the airlines on their number of departing passengers. Transit passengers are typically exempted from a passenger tax in order to avoid the distortion of taxing stop-over passengers twice and thereby creating disincentives to the network benefits created by the operational advantages of having major airports with hub functions. On the other hand, the passenger tax that takes into account distance should be levied on OD passengers irrespectively of a stop-over to take into account the full length of the trip.

Figure 6.1 Overview of passenger taxes in the Nordics and selected neighboring countries.



Note 1: Medium and long-haul definitions vary across countries but are in all cases outside EEA.

Note 2: Other EU countries with passenger taxes: Austria, France, Italy.

Source: (Amsterdam Economics & CE Delft 2019, p. 20-21).

5.3 Comparative impact assessment of the policy measures

This section gives a comparative impact assessment of the types of policy measures analysed in section 6.1 and 6.2. The impact assessment will be conducted in two steps:

- In the next subsection, quantitative impacts on a set of key figures are estimated. The purpose is to give an order of magnitude of the effects and compare them across the alternative policy measures. Hence, simplified model calculations are used.
- The subsequent subsection gives an overall assessment of the relative advantages and disadvantages of each policy measure taking into account the quantitative impact analyses as well as the more qualitative and literature review-based findings in section 6.1 and 6.2.

Effects on air travel demand and GHG emissions

Quantitative impacts for four rather specific policy scenarios are presented to illustrate the impacts of a blending mandate, a SAF fund, fuel tax and a passenger tax. A scenario has not been set up specifically for a **CO₂ reduction requirement** because it works in a similar way as the blending mandate. The main difference will be that the CO₂-reduction requirement will potentially give a more cost effectively *global* CO₂ reduction per substituted litre fossil fuel. This will be the case if it turns out to be cheaper to fulfil the reduction requirement by substituting less fossil jet fuel with SAF with lower life cycle emissions but with a higher price premium per litre.

Four alternative policy scenarios

- (A) **Blending mandate of 30% SAF** in jet fuel for all scheduled departures from Nordic airports.
- (B) **SAF fund** financed by Government budget to pay the price differential between SAF and fossil jet fuel for **30%** of total Nordic jet fuel volumes.
- (C) **Fuel tax** on fossil jet fuel for all scheduled departures from Nordic airports to **Nordic destinations** at a rate corresponding to the Energy Tax Directive's minimum tax on fuels. This would be equivalent to **0.33 EUR per litre** fossil jet fuel or 130 EUR per tonne CO₂.
- (D) **Passenger taxes of 10.43 / 58.63 EUR per passenger** for all trips to EEA countries and to the rest of the world. This would be similar to the 2020 level of the German passenger tax³⁵ (ignoring the medium haul tax rate at 32.57 EUR for simplicity).

Focus will be on comparing the yearly impact on five key figures:

- Ticket prices (% change)
- Air travel demand (% change)
- CO₂ emissions (% change) in terms of reduced fossil jet fuel use^{36, 37}
- Government revenues (mill. EUR) changes, including revenue from current national aviation taxes
- Total extra fuel costs (mill. EUR) from replacing fossil jet fuel by SAF

for each four concrete examples of policy measures (A) to (D). An early announced gradual phase-in toward 2030 is recommended (see chapter 1), but for analytical purposes we only look at a situation with a full phase-in and after supply and demand have fully adapted to the changes.

Summary of assumptions for the calculations

The calculations use 2019 air travel volumes and patterns and assume that the rates set up in scenario (A) to (D) are applied in all Nordic countries and replace all current national aviation measures. As an example: In the case of a 30% Nordic blending mandate passenger taxes, the CO₂ tax and the advanced biofuel blending rate of 0.5% tax is cancelled in Norway and so forth. The reported changes in Government revenues are the total revenues (exclusive of VAT) from the common Nordic policies, thus not deducting revenue losses from existing measures that are cancelled. Also, possible leakage effects from tankering etc. are not taken into account in the calculations.

Further, prices of 0.57 and 1.14 EUR per litre for fossil jet fuel and SAF is assumed in line with the assumptions for 2030 in Swedish Government, 2019a. The same source assumes 71.5 g CO₂ fuel burn emissions per litre fossil fuel and assuming upstream emissions of 17,5 and 8.9 gram CO₂e per litre fossil jet fuel and SAF. These assumptions imply an *implicit CO₂ price of about 225 EUR per tonne CO₂ or 200 EUR per tonne CO₂ if upstream emissions of both fuel types are taken into account.*

³⁵ Bloomberg (2020).

³⁶ Emission increases caused by substitution to other modes of transport is ignored.

³⁷ If upstream emissions are taken into account the absolute CO₂-reduction will be slightly higher, but percentage reductions slightly less (not taking possible ILUC effects into account, see section 6.1).

Table 6.2 Assumptions about price and CO₂-emissions from fossil jet fuel and SAF.

2030		Fossil jet fuel	SAF
Fuel costs	(EUR per litre)	0.57	1.14
excl. VAT and tax			
CO₂ e-emissions	(g per MJ)	89.0	8.9
- Fuel burn		71.0	0.0
- Up stream		17.5	8.9

Source: Swedish Government, 2019a, 22 p. 325 and 330.

Demand changes are calculated using price elasticities ranging between -0.7 and -0.4 and assuming a pass-on rate of 100% of increases in airlines operating costs including taxes. A main challenge in estimating the impacts of the policy scenarios is to reliably estimate representative ticket prices for various types of routes as prices are well-known to be very volatile and to vary significantly with passenger volumes, level of competition, time to departure and time of year and many other factors. Further details about input data and calculation model is described in Appendix C.

Results

Table 6.3 below gives a comparative overview of the calculations for the four scenarios and splits the effects on domestic flights, flights to other Nordic countries, to rest of Europe and to the rest of the world.

Table 6.3 Comparison of the impact of four alternative policy scenarios

Nordic Policy measure	Ticket price change (%)	Demand change (%)	CO ₂ -emissions (%)	Tax revenue (bill. EUR)	Extra fuel costs (bill. EUR)
(A) Blending requirement	0%	0%	-30%	-	0,95
(B) SAF fund	-6%	4%	-27%	-	0,99
(C) CO₂-based fuel tax	1%	0%	0%	0,82	-
(D) Passenger tax	4%	-2%	-2%	1,69	-
(A) Blending requirement - 30%					
Total	0%	0%	-30%	-	0,95
Domestic	-5%	4%	-27%	-	0,31
Nordic	3%	-2%	-31%	-	0,14
Europe	3%	-2%	-31%	-	0,36
World	2%	-1%	-31%	-	0,14
(B) SAF fund - 30%					
Total	-6%	4%	-27%	-	0,99
Domestic	-11%	9%	-24%	-	0,32
Nordic	-5%	3%	-28%	-	0,15
Europe	-2%	1%	-29%	-	0,37
World	-2%	1%	-30%	-	0,15
(C) CO₂-based fuel tax - 0,33 EUR / litre					
Total	1%	0%	0%	0,82	-
Domestic	1%	0%	0%	0,56	-
Nordic	9%	-5%	-5%	0,26	-
Europe	-2%	1%	1%	-	-
World	-2%	1%	1%	-	-
(D) Passenger tax - 10,43 / 58,63 EUR					
Total	4%	-2%	-2%	1,69	-
Domestic	3%	-2%	-2%	0,67	-
Nordic	8%	-5%	-5%	0,25	-
Europe	4%	-2%	-2%	0,38	-
World	9%	-3%	-3%	0,39	-

Source: Own calculations based on calculation model described in Appendix C.

- (A) The scenario with a **blending mandate of 30% SAF** for all flights from the Nordics results in a reduced jet fuel consumption and CO₂-reduction of 30%. The increased fuel costs incurred on airlines result in higher ticket prices, for all routes but domestic flight. For these flights increased fuel costs are more than counterweighted by the cancelling of the passenger taxes and the Norwegian CO₂-tax. Consequently, the total demand effect is close to zero, even though the total fuel costs are increased by about 1 billion EUR per year by the assumed double price of SAF compared to fossil jet fuel.
- (B) The scenario with a **SAF fund** which generates the same share of SAF as the **30% blending mandate** for all flights from the Nordics will only result in a 27% decrease of total CO₂-emissions. This is because the additional fuel costs are financed by Government budgets so that the cancelling of national policies leads to a 5% decrease on average for ticket prices for flights to all regions and a 4% demand increase. In particular, the price on domestic flights is reduced by 10% on average across the Nordics. These figures can (If we reverse the sign) also be interpreted as the total combined effect of the current passenger taxes in Sweden, Norway and Finland, the CO₂-tax on domestic routes in Norway and the 0,5% blending mandate in Norway. If the current national policies were maintained, the demand effects

would have been zero because the added fuel costs are paid by the SAF fund financed by subsidies from the Government budget.

- (C) The scenario with a **CO₂-based fuel tax** corresponding to **0.33 EUR per litre** results in a rather limited CO₂-reduction. The tax leads to more than a 50% increase in the fuel price, but the tax is confined to internal Nordic flights which only account for about 30% of total CO₂ emissions from Nordic aviation³⁸. The effect is also dampened by the cancelling of the existing Norwegian and Swedish passenger taxes. However, if the tax approaches the assumed price premium of 0.57 EUR per litre for SAF (225 EUR per tonne CO₂) fuel demand will shift toward SAF and thereby lead to significantly higher CO₂-reductions provided that SAF supply can catch up without price increases. This also illustrates the fact that the effects of a fuel tax at a certain level are very sensitive to the future prices of both fossil jet fuel and SAF. The rate of 0.33 EUR per litre for intra-Nordics flights is estimated to raise ticket prices for Nordic and domestic flights by 9% and 1% and to generate a revenue of about 0.8 billion EUR per year.
- (D) Finally, scenario (D) has a common **passenger tax at 10.43 EUR** per departing passenger for flights within EEA and **58.63 EUR** per passenger to destinations outside EEA. The rates are set to illustrate the impacts of a level corresponding to the rates for 2020, which are 50-100% higher than the average of the Norwegian and Swedish levels (see Figure 6.1). As for the fuel tax scenario the passenger tax scenario results in significantly lower CO₂-reductions than for scenario (A) and (B), both directly targeting the replacement of fossil jet fuel by SAF. But with a CO₂-reduction of a little less than 3% the effect is four times higher than for the fuel tax. This is primarily because a general demand reduction is achieved by levying the passenger tax on all flights instead of the fuel tax only on internal Nordic flights. If the passenger taxes were maintained at current levels in Scenario (C) along with the introduction of the fuel tax the demand reduction and CO₂ effect of the two scenarios would be of similar size. The revenue from a common passenger tax at German rates would result in a revenue of about 1,7 bill. EUR per year. As opposed to fuel taxes, higher passenger tax rates will not pave the way for substituting fossil fuel with SAF. The CO₂ reduction effect will still only stem from reduced demand due to higher ticket prices.

All four policy scenarios are characterized by quite significant increases in use of SAF or high levels of taxation, although in some cases off-set by reduced national taxation. In all cases the average net increase in ticket price is below 5% on average for all trips. The highest increases are 9% and 8% for Nordic trips in the two taxation scenarios (C) CO₂-based fuel tax and (D) Passenger tax. For the blending requirement and fuel tax scenarios (A) and (C) the fuel costs' share of the ticket price is a decisive factor. This is typically small for shorter domestic trips (19% in our data) and on average about 25% for all flights from the Nordics³⁹. However, the share varies very much across routes because of the previously mentioned big variations in ticket prices, passenger numbers, competitive situation, low-cost carrier share, etc.

To conclude, the two taxation scenarios do not reach CO₂-reductions anyway near the two SAF blending scenarios. For fuel taxes, the restricted application to only flights within Nordics means that CO₂ reductions similar to the ones obtained by blending cannot be obtained by air travel demand reductions, but only by a tax that is high enough to make shifting to SAF attractive for airlines. This cannot be achieved by a passenger tax which can only reduce CO₂-emissions by lower air travel demand. But even a passenger tax corresponding to about three times the current German passenger tax, or about four times the Swedish and Norwegian tax, would only lead to a CO₂-reduction of about 20% through reduced demand.

³⁸ Own estimate based on model calculations (See appendix C).

³⁹ Worldwide 23.7% in 2019 (according to the Statista database accessed 25-05-2020), which corresponds very well with our data: 24.1% in 2019.

Assessment of advantages and disadvantages of policy initiatives

This section gives an overall comparative assessment of the five policy measures. The qualitative assessment of the advantages and disadvantages of the various policy measures in section 6.1 and 6.2 and the quantitative analyses of the effects on costs, ticket prices, air travel, CO₂ emissions in subsection above are summarized in the following indicators:

- **Overall CO₂ impact:** To what extent can a joint Nordic implementation contribute to significant reductions of CO₂-emissions from domestic and international air travel from the Nordics?
- **Flights outside the Nordics:** Can the policy measure be imposed on flights to destinations to the rest of the EEA and the rest of the world?
- **Reducing demand** by fewer and shorter trips?
- **More fuel-efficient operations,** including more passengers per flight, energy optimizing speed, flight route and altitude, and use of energy efficient aircraft etc.
- **Using (more) sustainable fuels:** Does the policy measure promote use SAF and give incentives to prefer fuels with lower life cycle GHG emissions?
- **Market creation for SAF:** Will the policy measure guarantee a demand for SAF that will enable economics of scale and competition driven cost reductions?
- **Avoid leakage risks:** Can the policy measure avoid creation of or reduce incentives to tankering or to shifting operations to airports outside the Nordics with lower fuel prices?
- **Government budget revenue:** Does the policy measure have a net positive impact on Government revenue that can be used for promoting sustainable aviation or other purposes?
- **Polluter-Pays-Principle:** Does the policy measure ensure that social costs to prevent or remedy GHG-effects are financed by liable producer or consumer?
- **Cost effectiveness:** Does the policy measure give adequate incentives to choose or develop solutions that minimize the social costs of the reduction?
- **Administrative burden:** Are costs to the aviation industry, the regulatory body and the air travellers' airlines to administrate the regulation ignorable or small compared to achieved effect?
- **International regulation compliance:** Is it certain that the policy measure is uncomplicated to implement in a Nordic context without conflicting with EU regulation or international conventions and agreements?

The comparison is summarized in the table below. The scores 'YES', 'yes', 'no', and 'NO' are to be interpreted as an assessment of relative ranking among the five policy instruments. The ranking is extracted from the analyses above and not derived from exact criteria. Hence, refinements of the scores can be debated.

Figure 6.2.a Comparative assessment of five policy measures for sustainable aviation

Assessment of measure with regard to:	SAF blending requirement	CO ₂ e reduction requirement	SAF Fund	Fuel tax	Passenger tax
Overall CO ₂ -reduction impact	YES	YES	YES	yes	yes
Flights to outside the Nordics	YES	YES	YES	NO	YES
Reducing demand: Fewer trips Shorter distance	yes	yes	NO	YES	YES yes
Fuel efficient operations (1)	yes	yes	NO	YES	NO
Using (more) sustainable fuels	yes	YES	YES	yes	NO
Market creation for SAF	yes	yes	YES	no	NO
Avoid leakage risks (2)	NO	NO	YES	no	yes
Government budget revenue	no	no	NO	yes	YES
Polluter-pays-principle	yes	YES	NO	YES	yes
Cost effectiveness	NO	no	yes	YES	NO
Administrative burden minimised	no	NO	yes	no	yes
International regulation compliance	YES	YES	yes	yes	YES

(1) Including occupancy rate, cruise speed, etc.

(2) Tankering or displacing operations abroad. The leakage risk is less for a fuel tax than for a SAF blending and CO₂ reduction requirement because the fuel tax is assumed to be imposed only for flights within the Nordics.

The overall picture from Figure 6.2.a is that the numbers of YES/yes/no/NO are not that different across policy measures. Although some indicators can be said to be more important than others, none of the policy measures stands out as either clearly advantageous or the opposite.

Passenger taxes, in general, as well as fuel taxes, implemented by the Nordics alone, will not be able to contribute significantly to GHG reductions from air travel to destinations outside the Nordics, which constitute about two thirds of the GHG emissions from total Nordic civil aviation. This would require a blending or CO₂ reduction requirement or a SAF fund, as these measures can be designed to secure a substantial use of SAF, even if implemented by the Nordics alone.

By increasing fuel costs, the two requirements will at the same time indirectly give (some) incentives for travellers to reduce travel demand and for airlines to improve energy efficiency of operations. However, this effect is a 'double-edged sword' as the increased fuel costs at the same time creates risks of leakage effects.

Both the enhanced incentives to reduce fuel consumption and the risk of leakage is avoided by the SAF fund that eliminates the cost premium of SAF. The main disadvantage of a SAF fund is that it demands funding, which is here assumed to be financed by the Government budget, to illustrate its pure form. This will of course incur costs elsewhere in society and thereby undermine the fairness of the "polluter-pays-principle".

Combining a SAF fund with an earmarked passenger tax

Both the financing and polluter-pays-principle issues with a SAF fund can be addressed by combining it with a tax at a rate that generates a revenue matching the estimated size to finance the price premium of SAF at the targeted share, e.g. 30% of total jet fuel volumes. If a fuel tax is chosen as a financing mechanism in a combined measure it can, as mentioned, only be levied on internal Nordic flights. Hence, to finance 30% SAF for all flights the fuel tax has to be rather high, about a doubling of the rate in Scenario (C). This will result in a quite distortive tax differential between internal Nordic and extra-Nordic flights. A passenger tax can be levied on all flights and set at higher rates outside EEA to reflect the higher GHG impact of these long-haul flights. This might reduce long-haul trips or shift them to shorter distances and thereby reduce GHG-emissions. Hence, it will be more in accordance with the 'polluter-pays-principle' than a fuel tax confined to flights within the Nordics.

The financing tax will have to be implemented in national legislation. This could be mirrored in parallel national SAF funds with harmonized set ups. Still, a joint Nordic fund with unified tendering processes for greater volumes of SAF will have a stronger signaling effect.

Figure 6.2.b gives an assessment of a combined SAF fund and a passenger tax along the same lines as for the single measures in Table 6.4.a. It appears that the combined measures generally have positive ratings on the twelve indicators, because one measure in many cases compensates for the disadvantage of the other. Only one negative rating stands out: The combined measure does not create incentives to more fuel-efficient operations. However, as mentioned above, this is the unavoidable downside of avoiding risks of leakage from increasing fuel costs at Nordic instead of a EEA or global level.

Given that a main reason for a combined measure is that the passenger tax is meant to establish a fair and feasible way of financing the extra costs of SAF compared to fossil jet fuel, it makes sense to set the level of the passenger tax and the SAF share so as to obtain a revenue that approximately balances the total extra fuel costs.⁴⁰

It turns out from the calculations that these criteria might be fulfilled with a 30% SAF share and a common Nordic passenger tax with rates corresponding to the average of the current Norwegian and Swedish passenger tax rates. Using the same assumptions for other parameters as above we estimate:

- a passenger tax revenue of slightly more than 1 bill. EUR per year,⁴¹
- extra fuel costs slightly less than 1 bill. EUR per year; and that
- the common Nordic passenger tax amounts to about a 4% of ticket prices on average

Again it should be stressed that these figures and, hence, the relationship between the SAF share and the required tax rates depends heavily on the assumptions, and in particular the forecasted price premium of SAF compared fossil jet fuel price. This relationship will be strongly influenced by the future costs of EU ETS allowances. Depending on the price development of the allowances they fully or partially substitute passenger taxes for flights within EEA.

Table 6.4 below presents the results of the combined scenario in comparison with the overall results from the previous scenarios (A) – (D).

Figure 6.2.b Assessment of SAF fund & earmarked passenger tax

Assessment of measure with regard to:	SAF fund & Passenger tax
Overall CO ₂ -reduction impact	YES
Flights to outside the Nordics	YES
Reducing demand: Fewer trips	YES
Shorter distance	yes
Fuel efficient operations (1)	NO
Using (more) sustainable fuels	YES
Market creation for SAF	YES
Avoid leakage risks (2)	yes
Government budget revenue	yes
Polluter-pays-principle	yes
Cost effectiveness	yes
Administrative burden minimised	yes
International regulation compliance	yes

Note: To be compared with Figure 6.2.a

⁴⁰ An argument for a passenger tax which gives a higher revenue than needed for financing the price premium of SAF could be that a passenger tax should also finance support mechanism for promoting development of emerging propulsion technologies such as electrification. Alternatively, such a revenue could also be raised by phasing-in the passenger tax faster than the SAF share of total fuel consumption.

⁴¹ These figures the full revenue from the tax, i.e. the lost revenue from the discontinuation of current Swedish and Norwegian taxation is not deducted.

Table 6.4 Impact of a combined SAF fund combined with an earmarked passenger tax scenario compared to the four alternative single measure scenarios.

Nordic Policy measure	Ticket price change (%)	Demand change (%)	CO ₂ -emissions (%)	Tax revenue (bill. EUR)	Extra fuel costs (bill. EUR)
(A) Blending requirement	0%	0%	-30%	-	0,95
(B) SAF fund	-6%	4%	-27%	-	0,99
(C) CO₂-based fuel tax	1%	0%	0%	0,82	-
(D) Passenger tax	4%	-2%	-2%	1,69	-
SAF fund & Passenger tax	1%	0%	-30%	1,08	0,95
SAF fund & Passenger tax - 30% & 6.84 / 30.18 EUR					
Total	1%	0%	-30%	1,08	0,95
Domestic	-2%	1%	-29%	0,45	0,30
Nordic	4%	-2%	-32%	0,17	0,14
Europe	2%	-1%	-31%	0,25	0,36
World	4%	-1%	-31%	0,20	0,14

Source: Table 6.3 and additional own calculations based on calculation model described in Appendix C.

The first thing to notice from Table 6.4 is that the combined SAF fund and passenger tax scenario will increase in the ticket prices by only 1% on average⁴² which will hardly have any impact on demand total travel demand. The total effect on CO₂-emissions in the table therefore correspond almost exactly to the reduction of the use of fossil jet fuel, because upstream emissions are ignored here for both fossil jet fuel and the blended in SAF.

Because the various current national policies are assumed to be replaced by the common Nordic initiative the price changes vary between the countries. More detailed results shows that ticket prices will:

- increase about 5% in Denmark, Iceland and Finland which have (hardly) any cost inducing policies today,
- decrease 4% in Norway where the CO₂-tax on domestic flights and the 0.5% blending mandate is cancelled,
- increase about 1% in Sweden where the existing national passenger tax is replaced by the new common Nordic passenger tax.

The design of the passenger tax implies that the highest percentage increases in ticket prices will be for Nordic and intercontinental travel. If we look at the revenue from the passenger tax about 40% will come from domestic trips which are short, but many and have the same tax per passenger as other EEA trips. In comparison, the last column in the table shows that the domestic trips only account for a third of the added fuel costs (which are not passed on to airlines and passengers because of the SAF fund). This implies that domestic passengers subsidise the extra fuel costs on the on average longer European flights, but this is unavoidable as long as the passenger tax rate has to be the same within EEA.

⁴² Recall that the passenger tax replaces the existing aviation taxes in Norway and Sweden.

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Appendices

Appendix A: In depth interviews and consultations

Method

Anonymous interviews with experts have been carried out on digital services like Skype, Zoom, Teams and by phone. The informants have been chosen based on beforehand knowledge, as well as tips from various persons about who to contact. Various persons regarded to hold key insights were interviewed initially. On electric aviation, the Nordic airlines, the airport operators, persons working with projects related to electric aviation, and firms working with technology development were contacted. The list of interviews is presented in Appendix A.

Initially, we were to hold workshops where we could test out our preliminary considerations for policy options. Due to safety reasons and travel restrictions caused by Covid-19, this strategy was not feasible. Thus, stakeholders like aviation industry associations, researchers, airport operators and people representing other organizations with key insights were contacted. The interview guides were sent beforehand, and the persons who were asked to provide comments to our preliminary considerations were sent a note with some key points in advance of the interviews. The interview guide and an example of an information letter is attached in online appendices. The interviewees were given the chance to check all information related to the interview and their organization before the final publication. The interview guides for electric aviation and for policy options are presented below.

Consultation with other knowledgeable stakeholders

Throughout the process, the authors have been, and will be, given feedback from the steering group, consisting of e.g. the Danish Ministry of the Climate, Energy and Utilities, and the Swedish Environment Agency. The authors have also consulted with knowledgeable persons in e.g. the aviation industry to get feedback on what are the best conceptualization of various issues.

List of interviews

Electrification and policy recommendations

- Aircontact Group, 28 May 2020 (email)
- Avinor, 28 May 2020 (Teams)
- El-fly AS, 27 May 2020 (Teams)
- Heart Automotive, 29 May 2020 (phone)
- Nordic Network for Electric Aviation, 4 June 2020 (2 interviewees) (Teams)
- RISE, 15 June 2020 (email)
- SAS, 22 June 2020 (Teams)
- SINTEF Digital, 29 May 2020 (Teams)
- Swedavia, 3 June 2020 (email)
- University of Tromsø – School of Aviation, 5 June 2020 (phone)
- Widerøe, 2 June 2020 (phone)

Blending criteria, passenger fees, CO₂ taxes and policy recommendations

- Avinor, 29 April 2020 and 3 June 2020
- NHO Luftfart, 28 April 2020 and 3 June 2020
- NIRAS, 26 May 2020
- NISA, 2 June 2020
- Rosetta Investment and Advisory Services SPRL, 1 April 2020
- Transport and Environment, 24 April 2020
- Transportföretagen, 4 June 2020

Letter of information to the interviewees

Would you like to participate in the research project; *“Nordic Sustainable Aviation”?*

This is a question to you about participating in the research project Nordic Sustainable Aviation. Here, the purpose is to enquire into how to make the aviation in the Nordic countries more sustainable through introducing for example joint Nordic blend-in requirements for biofuel, or supporting electric airplanes. Here, we will inform you about the targets for the project and what participation will imply for you. The research project is carried out by The Institute of Transport Economics (TØI). The funding comes from Nordic Energy Research, who is following up the project on behalf of the Danish presidency of the Nordic Council of Ministers.

Purpose

The target with the research project is: 1) to publish a report and an easy-to-read information letter/summary, and: 2) present recommendations about how to make aviation in the Nordic countries more sustainable through the implementation of joint Nordic policies at the meeting of the Nordic Council of Ministers in October 2020.

Why we contact you

We contact you because of your profound competence on the issue of sustainability and aviation, and we would like to hear your reflections on electrification of the aviation sector, aviation biofuel, passenger fees, fuel taxes, etc. We are basing our interview requests on our existing knowledge, as well as publicly available information about which persons hold which positions in the organizations that we regard to be the most relevant.

The information from the project may be used for other purposes in the future, including as background data for studies on related questions. The information may also be used to publications in peer reviewed articles in research journals, for analyses to international outlets like Energypost (www.energypost.eu), and for publication for TØIs guidance in how to achieve better energy and environment solutions in Tiltakskatalogen (<https://www.tiltak.no/>).

What participation means for you

Participation means that you are participating in an in-depth research interview in spring/summer 2020. It will last 45-60 minutes and be carried out in Zoom (or Skype, Teams or by phone).

It is voluntary to participate

Participation is voluntary. If you choose to participate, you can at any moment withdraw your consent without giving a reason for this. All the personal data that we have gathered will then be deleted. It will have no negative consequences for you if you decide not to participate or later decide to withdraw.

If you consent, the interview guide will be sent to you.

How we store your data

We will only use the data for the purposes described in this text. All data will be confidentially treated and in line with the rules for treatment of personal data. The interview will be recorded and notes will be taken from it. Data that are sensitive, such as the sound recording, will be deleted when the project is over. Before the report is published, you will have the chance to read through and comment on all issues related to the interview and your organization, and see it in the context of the complete report.

What happens with the data after the research project is ended?

The data will be anonymized when the project is finished, which likely will happen in October 2020. Then, the interview notes will be stored anonymously, while the sound recordings will be deleted.

Your rights

As long as you can be identified in the data, you have the right to:

- See which personal data about you that are registered and have a copy of these data
- Have personal data of you corrected
- Have personal data about you deleted
- You may complain to the Norwegian Data Protection Authority

What gives us the permission to treat personal data about you?

We do this based on your consent. The Norwegian Centre for Research Data (NSD) has assessed the project and found that it is in line with the GDPR rules.

How can I find out more?

If you have questions about the study or want to find out more about your rights, please contact:

- The Institute of Transport Economics, by Inga Margrete Ydersbond, imy@toi.no, +47 92019154. Project leader: Niels Buus Kristensen, nbk@toi.no, +45 22929481.
- Our GDPR official: Gro Østlie, gro@toi.no, +47 91619347

If you have questions regarding NSDs evaluation of the project, please contact:

- NSD – Norwegian Centre for Research Data AS, email (personverntjenester@nsd.no) or at phone number: +47 55 58 21 17.

Kind regards,

Inga Margrete Ydersbond
Project manager
Senior researcher

Niels Buus Kristensen
Project leader
Research leader

Declaration of consent

I have received and understood the information about the project *Nordic Sustainable Aviation* and have had the chance to ask questions. I consent to:

- ☐ Participate in an in-depth research interview

I consent that my data will be stored until the project is ended.

(Signed by project participant, date)

Interview guide for electric aviation in the Nordic countries

Your business'/organizations' initiatives and research projects

- 1) Which initiatives and research projects has your business/organization regarding electric airplanes (e-planes)?
- 2) What types of electric airplanes are you working with?
- 3) What kind of results has the initiatives/ research projects had so far? What have you achieved? If you have published reports, evaluations, etc., please send them to us.
- 4) What kind of initiatives and research projects about electric airplanes will you have in the time to come?

Routes for electric airplanes

- 5) Which routes do you think that first should have electric airplanes a) within your country? and b) between the Nordic countries?
- 6) Why exactly these routes?
- 7) What are the most important preconditions for airlines to use an electric airplane on a route between the Nordic countries?
- 8) What are the success criteria?
- 9) And the potential barriers?

Infrastructure needs

- 10) What kind of infrastructure needs need to be covered in order to have fully electric or hybrid routes within, and between, the Nordic countries?
- 11) What kind of infrastructure needs does your business need to have covered to use an electric airplane with 19 seats in 2025?

Regional development

- 12) If there is an electric airplane with 19 seats in 2025, how will this influence the opportunities to increased Nordic collaboration and business development?
- 13) What is needed for electric aviation to give development opportunities to various regions in the Nordic countries? Development opportunities could, for example, be growth in various businesses, increased business collaboration, establishment of new businesses, cultural collaboration, etc.

Nordic collaboration about electric aviation

- 14) What may a potential Nordic collaboration about electric aviation look like?
- 15) What kind of Nordic projects could promote the introduction of electric airplanes?
- 16) What do you think is needed within this field?
- 17) What could the Nordic Council of Ministers contribute with?
- 18) What would eventual barriers to Nordic collaboration on electric aviation?

The time scale for introduction of electric aviation

- 19) How are the opportunities for introducing electric airplanes with 9 and 19 seats during the 2020s? And during the 2030s?
- 20) If there are electric airplanes with 19 seats in 2025 that can fly ranges up to 400 kilometers, how does this influence your business? And the flight market in which it operates? For which routes would you then use electric airplanes?
- 21) When do you think large electric passenger airplanes will be launched?
- 22) If there are large passenger airplanes in 2030, how would it influence your market? What would you do with it?

General

- 23) To which degree does the crisis caused by Covid-19 influence your projects regarding sustainable aviation?
- 24) What do you think aviation in your country in 10 years will look like? And in 20 years? And 20 years?

Interview guide Nordic Sustainable Aviation (example for interview with Transport & Environment)

Introduction

- 1) What are the most important ways one could make aviation more sustainable, as you view it, in terms of changing the framework conditions for the airlines in the EU/EEA?

The new T&E study

- 2) What are the main conclusions from the T&E study that you mentioned in your email?
- 3) When will this study be published, do you think?
- 4) What has been your role in this study?

Policy measures

- 5) What would enable the introduction of a CO₂-tax on all departing airplanes from a country within EEA? Or is that impossible due to the Chicago Convention?
- 6) What do you think about the suggestions for: a) joint Nordic blend-in requirements for biofuel, - if you think that it is a good idea, how high should they be? Norway at the moment has a criterion of 1% biofuel. This will be raised to 30% within 2030. b) joint Nordic passenger taxes/fees – today, Norway and Sweden have passenger taxes/fees, c) joint Nordic CO₂-taxes/GHG reduction criteria?
- 7) Is there really enough bio energy available for producing large amounts of sustainable aviation biofuel in the Nordic countries?
- 8) So far, only a few biofuels have been environmentally certified, according to a report from Wormslev et al. in NIRAS from 2020, among them biofuel coming from used frying oil. Production is low, and the prices for biofuel are high globally. What is needed to ramp up production of aviation biofuel in the Nordic countries? What kind of such production is desirable from an environmental point of view?

Various relevant issues

- 9) What is your view on e-fuels?
- 10) T&E writes in its' comments to a European Green Deal that it has a vision of: "Carbon pricing and fuel taxes that puts a stop to aviation emissions growth while airlines are required to start using cleaner fuels." What is needed to make this happen in the EU?
- 11) In T&E's comment to the corona crisis and potential bailout of the aviation industry, a key message is that the airlines, in order to get help, should use synthetic kerosene and waste-based biofuel more. What would make this happen?

Joint Nordic policies

- 12) How could the Nordic countries be frontrunners and inspire other countries/EU to make aviation more sustainable?
- 13) What steps do you think would need to be taken to introduce such joint Nordic policies in a successful way?
- 14) Would there be additional issues to consider, now with the airlines struggling economically due to the corona virus?
- 15) What do you think the Nordic countries should do to become international frontrunners regarding electric aviation? What can be done to speed up the development and introduce routes with electric airplanes? How far are we from having routes with electric airplanes today?

Follow up

- 16) Are you interested in commenting on our draft report later?

Appendix B: Initiatives to promote sustainable aviation in the Nordics

B.1 Policy oriented stakeholder initiatives for sustainable aviation

Nordic initiatives

Nordic Energy Research has organized several activities related to increasing the use of SAF, including organizing several conferences and workshops and commissioning and publishing research on the topic.

Nordic Innovation is financing various activities related to making aviation more sustainable, including commissioning research and financing activities like Nordic Network for Electric Aviation.

Nordic Initiative for Sustainable Aviation is a Nordic organization that works for making the aviation industry more sustainable, particularly in regard to making the fuel more sustainable. Members are: Air Greenland, Airbus, Atlantic Airways, Avinor, Boeing, Copenhagen Airports, Brancheforeningen Dansk Luftfart, Finavia, Finnish Transport Safety Agency (Trafi), Finnair, International Air Transport Association (IATA), Icelandair, Isavia, Ministry of Transport and Communications of Finland, NHO Luftfart, SAS, SkyNRG, Svenska Flygbranschen, Föreningen Svenska Flyg, Swedavia, Swedish Transport Agency, Trafikstyrelsen (Danish Transport Authority), Sunclass Airlines (Interview NISA, 2020; Nordic Initiative for Sustainable Aviation, 2020).

Denmark

Danish Aviation Association (*Brancheforeningen Dansk Luftfart*, BDL) has argued for a carbon fund/climate fund to support production of sustainable aviation fuel, to be supported via the airlines' ticket price, and it is intended to bring in DKK 250–300 million yearly. From 2020, their members will CO₂-compensate all inland aviation in Denmark, which is limited compared to that of Sweden, Norway and Finland in number, c.f. Ch. 2. Their target is that Danish aviation at the very latest in 2050 is carbon neutral (BDL, 2019; SAS, 2019a).

Luftfartens klimapartnerskab: In November 2019 the Danish Government asked a group of core stakeholders including the main airlines, Copenhagen Airport, NISA, the Danish Aviation Association, and others to join the so called Luftfartens Klimapartnerskab. The aim was to present their view on how aviation could contribute to reach the Danish climate goals. May 2020 the group presented their report (Luftfartens Klimapartnerskab, 2020). The report aims at a 30% of CO₂ emission in 2030 as compared to 2017. As the optimal measure the report recommended a global CO₂-tax on aviation, or a European CO₂ tax on aviation as a minimum solution. Denmark shall work internationally for such a tax.

However, until this is implemented, they recommend that the aviation industry voluntarily establish a non-governmental climate fund (*Luftfartens Klimafond*), to be financed via passenger fees. The fund shall finance the additional fuel costs of a SAF blending mandate reaching 30% in 2030. The fund is suggested to be funded by a passenger fee of, for example, 20–30 Danish kroner from the passengers departing from Danish airports, which according to their estimations will lead to an income of 500 million Danish kroner. This climate fund shall be used for environmental purposes, like creating demand for sustainable aviation fuels and thus make this production be scaled up. The fund will pay for the difference between the cost of SAF and conventional jet fuel, so that there will be scaled up solutions for production, distribution and purchasing of SAF. The climate fund should promote Danish solutions, and thereby contribute to creating new work places, and collaboration between the various sectors, like aviation, waste and agriculture. They also plead for a national plan for green electricity and carbon capture and storage (CCS) (Luftfartens Klimapartnerskab, 2020).

Finland

Autumn 2019, more than 50,000 Finnish citizens signed a petition where they asked for a Finnish aviation passenger tax in order to increase the costs of travel by aviation and also to use the revenue for environmental purposes. That means that the Finnish parliament has to consider the case (Teivainen, 2019).

Norway

A representative from the Norwegian Business Association Aviation branch (*NHO Luftfart*) has voiced the view that there should be established a CO₂-fund for bio-jet fuel, modelled after the successful Norwegian NOx-fund, so that the speed of innovation in biofuel production and the commercial production of biofuel in Norway could be established (Norsk klimastiftelse, 2018; Rambøll, 2017). The target of the fund is to bridge the gap between the price of conventional jet fuel and sustainable aviation fuel.

Since the current CO₂-tax does not sufficient to cover the extra costs of SAF, the fund should also be financed via the Norwegian passenger tax. Alternatively, the organization could be similar to the current Norwegian NOx-fund. This would imply that the airlines would not have to pay a certain tax if they instead paid a certain amount of money to a privately organized fund for the industry, which could be used to finance sustainable aviation projects (Rambøll, 2017).

Blending criteria for biofuel will also create a market, but also, without additional measures, drive up the costs for the airlines significantly. Regardless of the solution chosen, a criterion would be that the aviation fuel is sustainably produced and not be detrimental for example for food production (Interview NHO Luftfart I, 2020; Rambøll, 2017). The whole aviation industry in Norway has supported this initiative (Interview Avinor 3, 2020). See Chapter 8 for further discussion and elaboration about a CO₂/sustainable aviation fund.

Sweden

The interest organization Fossil Free Sweden together with the interest organization Föreningen Svenskt Flyg in 2018 created a plan for how to make aviation in Sweden more sustainable. Here, they also launch two targets:

- 2030: All domestic air travel shall be fossil free (Föreningen Svenskt Flyg & Fossilfritt Sverige, 2018).
- 2045: Fossil free international aviation departing from Sweden in 2045 (Föreningen Svenskt Flyg & Fossilfritt Sverige, 2018).

Fossil Free Aviation 2045: Their target is to create a Swedish national platform to enable aviation in Sweden to be fossil free by 2045. They aim to achieve collaboration, sharing of knowledge, and synergies between established research institutions and stakeholders working with innovation. Stakeholders for the whole value chain/ecosystem to create fossil free flights are included in the network.

Partners: SAS, Swedavia and RISE (Founders) in addition to flyresor.se, Westander, Södra, Afry, NISA, Mälardalen Högskola, Svenska miljöinstitutet (IVL), KLM, European Flight Service (EFS), Cowi, BRA, Bioshare, BIO4ENERGY, Östersund kommun and Neste.

B.2 Initiatives to promote sustainable aviation fuels

Initiatives aimed at passengers

Braathens Regional Airlines /BRA (Sweden) write that they offset GHG emissions for all their flights. This is included in the ticket price. The airline customers may also contribute extra to use bio-jet fuel and other means of emissions reduction through paying 300 Swedish kroner extra. Braathens Regional Airlines also offset emissions for the rest of their operations (Braathens Regional Airlines, 2020; Dahl, 2019).

Fly Green Fund (Sweden): Partners are Swedish airport operator Swedavia and SRF (Swedish Regional airports). The founders are Karlstad Airport, SkyNRG, Nordic Initiative for Sustainable Aviation (NISA). Here, airline customers may pay an amount to support the increased use of bio-jet fuels in Sweden. 75% of the revenue goes to the purchase and delivery of sustainable aviation fuels. 25% of the revenue goes to market development and supporting initiatives that contribute to increased market demand and local production of sustainable aviation fuels in Sweden (Fly Green Fund, 2020; Interview NEA, 2020).

Finnair (Finland): The GHG emissions from the corporate customers will be offset from 1. September 2020. Corporate customers will in the future also have the opportunity to reduce their climate footprint through the

increased use of biofuel. Their target is to reduce GHG emissions by 50% from the 2019-level by 2025 (Finnair, 2020a). By 2045, Finnair aims to be carbon neutral. The airline has also partnered with biofuel producer Neste to increase the bio-jet fuel production in Finland and increase its share of sustainable aviation fuel (Finnair, 2020b; News Now Staff, 2020). In 2011, Finnair was the second international airline to operate flights using biofuel (Finnish Transport Safety Agency, 2018).

Icelandair (Iceland): Here, passengers may offset GHG emissions by paying extra to support projects for reducing GHG emissions by paying for tree planting to compensate for their GHG emissions (Icelandair, 2020).

Norwegian (Norway): Passengers may offset emissions of greenhouse gases by paying extra. The revenue goes to various climate projects approved by the UN, such as renewable energy projects (Norwegian, 2020).

SAS (Scandinavian): Youth tickets and tickets bought through the Eurobonus programme are automatically climate compensated (Bergskaug, 2020). Customers can, since summer 2019, buy bio-jet fuel comparable to 20 minutes flight time, and may multiply this to pay for the total flight time (SAS, 2020). SAS' target is that 17% of its fuel is bio-jet fuel by 2030 (Euractiv, 2019).

Widerøe (Norway): lets the customers buy bio-jet fuel when they order tickets (Hjørnevik, 2020).

Initiatives aimed at airlines

Avinor (the state-owned operator of most of the Norwegian commercial airports, operates a total of 46 airports in Norway). In 2016 and 2017, Avinor together with AirBP and several airlines launched blending of biofuel in their airports, amounting to 1,25 million litres, or 0.1% of all jet fuel sold in 2016 in Norway. The first airport was Oslo Airport Gardermoen. In 2017, the scheme was expanded and also included to include Bergen Airport Flesland. This year, there was very limited availability of bio-jet fuel, so only 125 000 liters were blended in. There was also limited volumes sold in 2018. Oslo Airport was the first airport to offer bio-jet fuel on a regular basis and offer jet fuel with bio-jet fuel to all airlines fueling there (Avinor, 2020a; Miljødirektoratet, Avinor, & Luftfartstilsynet, 2018, p. 4).

For the period 2013–2022, Avinor set aside 100 million NOK for measurements and projects to the introduction of bio-jet fuel in Norway. Together with airlines and the Federation of Norwegian Aviation Industries (NHO Luftfart), Avinor has explored the potential for establishing the large-scale production of biofuels for aviation using biomass from the Norwegian forestry industry. The conclusion is that this can be realised between 2020 and 2025. Jet biofuel can also be imported from abroad. Avinor has worked with a number of stakeholders on the production of jet biofuel for aviation in Norway. In addition, Avinor supports several research projects related to this, including in collaboration with SINTEF, BI Norwegian Business School, and the Norwegian University of Life Sciences (Interview Avinor 3, 2020).

The sustainable aviation fuel has come from different sources and producers, including hydroprocessed esters and fatty acids (HEFA) produced by Finnish Neste based on camelina oil produced in Spain supported by the EU project Itaka, and HEFA based on used cooking oil (UCO) produced by World Fuels in California and brought to Norway by ship (Interview Avinor 3, 2020). Their target is that 30% of the aviation fuel in 2030 shall be advanced biofuel.

Swedavia (the largest Swedish airport operator, operates 10 airports in Sweden): was the first airport operator to offer bio-jet fuel to airlines that had been stored at the airport. Swedavia has since 2016 bought bio-jet fuel amounting to the same as the fuel for their employees' flights for business reasons. This amount has been 450 tonnes a year. Now, Swedavia will increase its purchase to 560 tonnes bio-jet fuel yearly. The remaining 110 tonnes of bio-jet fuel will be used by other businesses. Swedavia has set the target that within 2025, 5% of the fuel is to be fossil free (Swedavia, 2019). In 2019, eight Swedavia operated airports in Sweden supplied bio-jet fuel to the airlines.

Sveriges regionala flygplatser (Swedish regional airports), include Karlstad Airport. Karlstad airport was the first in the world, in 2014, to deliver bio-jet fuel in the same chain of logistics as the fossil jet fuel (Interview NEA, 2020).

Copenhagen Airports (CPH, Denmark's largest airport): aims to be emissions free by 2030 (Copenhagen Airport, 2019). The customers of SAS can choose to fly and reduce emissions by the use of bio-jet fuel tanked at CPH, as well as other airports in Scandinavia (SAS, 2019b).

B.3 Research and development initiatives on sustainable aviation fuel

International projects with Nordic partners

The Roundtable on Sustainable Biomaterials (RSB) The Nordic members of RSB includes: Neste, QuantaFuel, UPM-Kymmene Corporation, Eco-1, Maersk, SAS Tech AB.

Revofuel: <https://www.sekab.com/en/products-services/product/rewofuel/>

Denmark

As an agricultural country with strong engineering expertise, a number of projects regarding producing various types of sustainable bio energy fuels and electrofuels have been launched.

Maersk, DSV Panalpina, DFDS, Ørsted, SAS and Copenhagen Airports. Maersk, DSV Panalpina, DFDS, Ørsted, SAS and Copenhagen Airports have joined forces in a partnership that will build a hydrogen plant in the metropolitan area as early as 2023. The factory will be fully expanded by 2030 to supply more than 250,000 tonnes of sustainable fuel for ships, aircraft and road traffic (Friis, Svansø, & Hansen, 2020; Maritime Denmark, 2020).

EUDP (a Danish Energy Technology Development and Demonstration Program), Power2Met. *Partners:* GreenHydrogen, Aalborg University, Integrate ApS, Process Engineering A/S, Cemtec Fonden, Holtec Automatic – Nord A/S, Lillegården el A/S, Drivkraft Denmark, Rockwool A/S, NGF Nature Energy Biogas A/S and E.ON Denmark A/S.

Innovation Fund Denmark, SYNFUEL project. *Partners:* Danmarks Tekniske Universitet (DTU), Aalborg University, Haldor Topsøe A/S, Chalmers University of Technology, Ørsted A/S, Energinet, Institut National des Sciences Appliquées (INSA), Technische Universität Berlin, Northwestern University, Chinese Academy of Science, MIT and AVL GmbH.

Smart airports. *Partners:* NISA, Copenhagen Airports, SAS, Teknologisk Institut, IATA, RSB and more. This project is funded under EU Horizon 2020 and will look at the development of e-fuels and hydrogen, handling and development of SAF in airport, prepare the airport for electric aircraft, digitalization and electrification of ground activities in airport (Interview NISA, 2020).

Future Liquid Aviation Biofuels Based on Ethers for Gas Turbine Engines (FLABBERGAST). *Partners:* DTU, Copenhagen University, Aalborg University, NOVOZYMES A/S, Cumulus Bio ApS, Niels Clauson-Kaas A/S, Airbus Operations Ltd., RWTH Aachen and Lawrence Berkeley National Laboratory (US).

Finland

Neste has planned to expand its capacity for production of sustainable aviation fuel.

<https://www.neste.com/products/all-products/aviation>

Finnair and Neste cooperate in helping Finnair to increase its share of SAFs. Link:

[https://www.biofuelsdigest.com/bdigest/2020/03/05/finnair-neste-partner-to-reduce-CO₂-footprint-of-flying-with-sustainable-aviation-fuels/](https://www.biofuelsdigest.com/bdigest/2020/03/05/finnair-neste-partner-to-reduce-CO2-footprint-of-flying-with-sustainable-aviation-fuels/)

St1 looking at starting a SAF production, (Finnish based Nordic Oy, production plant in Gothenburg) see:

<https://www.st1.com/st1-constructs-a-biorefinery-to-produce-renewable-diesel-and-jet-fuel>

Norway

QuantaFuel: <https://kommunikasjon.ntb.no/pressemelding/inngar-samarbeid-om-produksjon-av-baerekraftig-jet-biofuel?publisherId=17421123&releaseId=17866725>

Biozin (sells to Preem) <https://www.dn.no/energi/biozin-holding/thomas-skadal/biodrivstoff/satser-milliarder-pa-biodrivstoff/2-1-485602>

Silva (Statkraft and Södra): <https://www.statkraft.no/om-statkraft/hvor-vi-har-virksomhet/norge/silva-green-fuel/>

Bio4Fuels: <https://www.nmbu.no/fakultet/kbm/forskning/bio4fuels>

Sweden

Flying on forest residues in Småland, Sweden. *Partners:* Södra, KLM, Växjö Kommun, Småland Airport, Fores, Research Institutes of Sweden (RISE), Luleå University of Technology, Växjö Energi, SkyNRG.

Validation and demonstration of forest-based bio-jet fuel. *Partners:* Luleå University of Technology, RISE, SkyNRG, INERATEC, SCHMIDTSCHESCHACK | ARVOS, Smurfit Kappa, Sveaskog, Svebio, SAS, BRA and Fly Green Fund.

Green hydrogen and electrofuels in Sweden. *Partners:* Nouryon, RISE, Södra and BillerudKorsnäs.

Partnership Fossilfria Flygtransporter. *Partners:* SAS, Swedavia and RISE.

Green hydrogen and electrofuels in Sweden. *Partners:* Nouryon, RISE, Södra and BillerudKorsnäs.

Large scale Bio-Electro-Jet fuel production integration at CPH-plant in Östersund. *Partners:* IVL, Universities of Lund and Chalmers, NISA, Jämtkraft in Östersund, FGF (financed by Energimyndigheten).

Forestry 2 Jet. <https://www.ri.se/sv/vad-vi-gor/projekt/forestry-2-jet>

Grøn Flygplats. <https://www.flygplatser.se/de-regionala-flygplatsernas-miljoarbete/gron-flygplats/>

Overview of other projects:

<http://www.energimyndigheten.se/nyhetsarkiv/2019/nya-forskningsprojekt-ska-bidra-till-mer-hallbart-bransle-for-flyg/>

<http://www.energimyndigheten.se/nyhetsarkiv/2018/11-forskningsprojekt-ska-bidra-till-att-na-ett-fossilfritt-flyg/>

B.4 Initiatives and research projects on electric aviation

The Nordics

The Nordic Network for Electric Aviation (NEA). Participants in NEA are: Avinor, Finavia, Swedavia, Swedish Regional Airports, Copenhagen Airports, Air Greenland, Braathens Regional Airlines, Finnair, Heart Aerospace, Icelandair, SAS, El-fly AS, Green Flyway, Nordic Initiative for Sustainable Aviation (NISA), Nordic Innovation, SAS, Green Flyway and RISE.

This network has four main targets: 1) to standardize the infrastructure for electric airplanes in the Nordic countries, 2) develop business models for regional direct routes between the Nordic countries, 3) develop aircraft technology to meet the weather needs in the Nordics, 4) create a platform for European and global collaboration. The network is funded by Nordic Innovation (NEA, 2020). Their first meeting was held in Östersund in Sweden, December 2019.

Green Flyway is a project between Avinor, the Røros Region, Østersund Municipality, SINTEF Digital, and Swedish partners like Swedavia Airports. The project leaders are Næringsshagen in Røros and Østersund Municipality, while the research partner is SINTEF Digital. They will establish a testing arena for electric aviation, autonomous aircraft (drones), and aircraft control on the route between Røros and Østersund/Åre. This is a little trafficked area. The project is open to all types of electric aircraft, and the project leaders are in dialogue with various developers and manufacturers of electric airplanes (Interview SINTEF Digital, 2020). The winter coldness of the area is regarded as useful, as drones and electric aircraft also needs to be tested under very cold conditions, as batteries have shorter ranges during low temperatures. Green Flyway is supported by EU-funding through an Interreg programme, and also receives Norwegian funding (Avinor, 2019b; Interreg.no, 2020; Jære, 2020).

Finding Innovations to Accelerate Implementation of Electric Regional Aviation (FAIR) is an EU -, nationally and regionally funded project regarding electric aircraft in the Kvarken region in Sweden (Region of Västerbotten) and Finland (Region of Österbotten). The Kvarken Council is coordinating the project. Aims: to gain knowledge about the opportunities of electric aircraft, to enhance the introduction of electric aircraft and start cross border innovation processes. First, there will be a market analysis to describe the regional effects. There will then be a mapping of what is necessary to introduce electric aircraft early in the region. Third, there will be development of new services, products and business models to create added value of the technology both for the private and the public sectors. Partners/receivers of funding are Kvarkenrådet, Umeå University, Vasa University, BioFuel Region, RISE, and Region Västerbotten (Kvarkenrådet & Merenkurkun neuvosto, 2020).

SAS and Airbus collaborate to create electric airplanes. They will have a joint research project to enhance their knowledge about the opportunities and challenges for electric aviation in commercial passenger traffic (SAS, 2019c). Their collaboration continues as previously despite the Covid-19 crisis. They are looking at the specifications about electric airplanes that Airbus could produce, like range, weight, time and ground handling time (Interview SAS, 2020).

SAS, in addition to participating in NEA and collaborating with Airbus, also carries out other activities related to electric airplanes. This including supporting Heart Aerospace through having given them a letter of support and providing them with insight about rules and regulations and other things that are important. SAS is also in dialogue with other Star Alliance partners with similar travel patterns about electric aviation, like partners in Canada and New Zealand. As regards concrete technologies for electric/electrified airplanes, SAS is technology neutral. In the future, SAS will rather accelerate their work with electric airplanes than reduce it. For them, the airplanes' sizes and capacities will decide when they can be used after they have been certified. Then envision that they can use airplanes with 50–70 seats and larger when they have been certified, and could need 30–40 airplanes of this size in the future (Interview SAS, 2020).

Denmark

Copenhagen airport would like to see electric airplanes using their facilities. The previously mentioned Smart Airports project includes that the airport must be prepared to handle and be able to charge future electric aircraft (Interview NISA, 2020).

In the fall 2019, **NISA**, together with the Engineering Association, Danish Aviation and Copenhagen Airports planned an electric aircraft seminar for the fall 2019. In combination, a Danish electric aircraft initiative was prepared, including the identification of possible routes, cooperation in the Øresund region, Danish and Nordic technology stakeholders. The initiative postponed due to Covid-19, - expected to be initiated in autumn 2020 (Interview NISA, 2020).

The Climate Partnership for Aviation includes electric aircraft as part of the long-term plan, i.e. mainly after 2030 to reduce the climate impact. (Interview NISA, 2020).

Finland

Helsinki Electric Aviation Association is sponsored by Finavia and Fortum, and is testing a small electric airplane of the type Pipistrel Alpha Electro (Rønningsbakk, 2018). They have arranged conferences and events on the topic of electric and other types of sustainable aviation (MAF, 2020). The organization works with different technologies, including an electric/hybrid powerline, an electric/hybrid seaplane, an electric/hybrid skydiving plane, and is also involved Kvarken area electric passenger airplane study (Interview Helsinki Electric Aviation Association, 2020).

Finavia has started testing flying with small electric airplanes, similar to Avinor (Rønningsbakk, 2018).

Norway

Equator Aircraft is a Norwegian company developing small two-seater hybrid-electric sea airplanes. They have received funding from small investors. They participate in a research project called Flightsmart together with Maritime Robotics, SINTEF and NTNU on developing the technology: automation, a sophisticated and minimalist user interface and aerodynamic cooling (Dalløkken, 2018). Equator Aircraft also collaborate with the Danish company Nordic Seaplanes in developing electric aircraft for passenger transport. The latter company operate commercial sea plane routes between Copenhagen and Aarhus. In the future, they want to have larger aircraft that can fly commercial routes. They think that these aircraft can replace helicopters and other small conventional airplanes. The project is supported by Kjeller Innovation (Bay, 2019).

The world's first fully electric commercial passenger route? Avinor, Sparebanken Vest, Berg-Hansen, Aircontact Group and the Business organization in the Stavanger Region (*Næringsforeningen i Stavanger-regionen*) collaborate to set up the first commercial fully electric passenger route in the World between Stavanger and Bergen. They have established a company called Start Norge AS to achieve this. Their first target was to achieve this within 2023. However, they aim to achieve this as soon as possible, in light of what kind of electric airplanes suitable for passenger transport is available (Interview Aircontact Group, 2020).⁴³ A study is commissioned to map the opportunities and challenges by introducing electric airplanes between Stavanger and Bergen. They await the results of this study before conducting further work in the project, as to if the passenger number is large enough, the distance works for electric airplanes, the airports may be able to contribute with the needed infrastructure, and that local business is interested and motivated to contribute to a sustainable change. Their target is to contribute with financing of the airplanes so that the financial risk of the airlines of acquiring electric airplanes is reduced. Aircontact group also envisions that they can take part in the establishment of support functions for electric aviation in the next years. The project collaborators are open to different types of technologies regarding electric airplanes (Interview Aircontact Group, 2020). There is hard competition to be the world's first all-electric route, and it may well be, that the first all-electric route will be established in Vancouver (Reuters, 2020) or at the Orkney Islands (Sigler, 2019).

Avinor: Stavanger Airport and Bergen Airport are preparing for electric aviation, and plan to install charging infrastructure for electric airplanes (NTB, 2019b). Avinor will contribute with the necessary infrastructure once the electric airplanes are in place (Avinor, 2020b).

Elnett21 is a project where they install charging infrastructure, solar panels, battery storage and work with smart electricity use. They are working on micro grids. The area involves Risavika harbor, Stavanger airport (Sola), Sola and Forus Næringspark. Partners are Avinor, Forus Næringspark, Lyse Elnett, Smartly and Stavangerregionen Havn (Elnett21, 2020).

⁴³ Personal communication with Aircontact Group, 2020. See also Norum (2020).

Widerøe and Rolls-Royce Electrical Norway collaborate on developing electric airplanes. They signed an agreement about research collaboration in 2019 (Rolls-Royce, 2019). Rolls Royce delivers the jet turbines to airplane manufacturer Airbus.

Widerøe's internal project, Project Zero, aims to introduce electric airplanes in Widerøe's fleet within 2030. More than 30 airplanes, their Dash 8 fleet, are to be changed within 2030, and Widerøe has set the target to have launched commercial zero emission routes within this year. The project is supported by Innovation Norway (Dalløkken, 2019b; Rolls-Royce, 2019). The current crisis caused by COVID-19 has made Widerøe signal that their target for at least one zero emission route within 2030 *may* have to be postponed. However, the target is still to electrify at least one route within 2030 (Norum, 2020). Widerøe works with different types of electric airplanes, including battery electric, serial hybrid (two motors, with hydrogen fuel cells and gas turbines) and parallel hybrid (combustion engine motor and an electric motor) (Interview Widerøe, 2020).

Rolls-Royce Electrical Norway and Airbus collaborate on developing electric aircraft. Rolls-Royce in 2019 bought Siemens' e-aircraft department, eAviation, located in Munich and Erlangen in Germany and in Budapest in Hungary (Dalløkken, 2019b; Siemens, 2019c; Svensson, 2019). Siemens' target was to have hybrid electric aircraft with a range of 1000 kilometers within 2030. This will, according to their representatives, suffice to cover 2/3 of all destinations that are directly attainable from Gardermoen by airplane (Siemens, 2019b).

Rolls-Royce has a technology department located in Trondheim where a staff of around 50 persons work on developing electric motors and propulsion systems for aviation (Lorentzen, 2019c). Their target is to become the leading supplier of electric and hybrid electric airplane motors (Siemens, 2019c). Rolls-Royce is also developing the electric motor for the luxury commuter aircraft Eviation Alice, which may carry 9 passengers and a staff of 2 (Eviation, 2019; Rolls-Royce, 2019/2020). The aircraft Alice is currently under certification by the Federal Aviation Administration, and the same is the case for Bye Aerospace's e-flyer.

Rolls-Royce Electrical Norway and Airbus collaborated to create the first hybrid electric aircraft in the E-Fan X project. The last phase of this project was cancelled spring 2020. However, Rolls Royce will continue to test the electric motors that it has developed and work on further technology development (Excell, 2020; Norum, 2020).

OSM aviation in 2019 launched an order of 60 electric airplanes from Bye Aerospace, to be used for pilot training in their training schools in the United States, Norway and Sweden. These are to be delivered from the end of 2021. Advantages with these airplanes include very low operating costs, low noise, zero emissions, high speed and good performance at high altitudes (Dalløkken, 2019a; Lorentzen, 2019a).

El-Fly AS (Elfly AS), located in Bergen, also launched an order of 18 small electric aircraft from Bye Aerospace in 2019, to be used for commercial operations, like training of pilots or other purposes, like tourist sightseeing, air taxiing or for flight clubs (El-fly AS, 2020; Lorentzen, 2019b). They want to stimulate so that electric airplanes are used as early as possible.

Avinor, the operator of most Norwegian airports, has been working on electric aviation since 2010. In 2015, the Norsk Luftsportforbund and Avinor started collaborating on electric aviation. In 2016, Avinor organized an environmental conference Zerokonferansen, where Airbus presented their work on electric aviation. Avinor also participate in or has launched a number of other initiatives and projects. Their interest is all types of electric airplanes with fixed wings (as opposed to rotors) that may be used for the Norwegian short-haul airports, primarily with airplanes with 19 seats or upwards. The airport operator is also, together with Norsk Luftsportforbund, is testing to fly with small electric airplanes of the type Pipistrel Alpha Electro. This airplane has been used in various airplane shows in Norway before it had an accident and had to be repaired (Avinor, 2020b).

Avinor has contributed to setting electrification of aviation on the public agenda in Norway in numerous ways. The company has set the target that all domestic aviation is to be electric within 2040, and that the GHG emissions from domestic aviation will be reduced with 80% within this year. To stimulate electrification, Avinor has promised that small electric airplanes will be free of charges and receive free electricity at their airports until 2025. To prepare for electric aircraft, Avinor is the first half of 2020 mapping the existing

electricity infrastructure at all their airports in order to prepare for future electrification of the aircraft (Avinor, 2020b).

Avinor and the Norwegian Civil Aviation Authority (Luftfartstilsynet) March 2020 launched a report where they suggest how electric airplanes can be introduced to commercial aviation (Avinor & Civil Aviation Authority, 2020). Here, they recommend that “Norway should be one of the main areas in the world for the electrification of air travel”, Avinor CEO Dag Falk-Petersen note. This may be attained via development, testing and using electrified aircraft early (CAA Norway, 2020).

They recommend that objectives set by the government should be that: a) by 2030, the first electrified aircraft (i.e. fully electric or hybrid electric) should carry passengers in ordinary scheduled routes, b) within 2030, all inland aviation transport within Norway should have electrified aircraft. To attain these targets, many measures are needed. These include incentives for technology development, support for investments, and beneficial operating conditions. Technology development could be attained via establishing an international test center for electric aviation in Norway, and an international cooperation forum (CAA Norway, 2020).

Investment support could include for example support schemes when airlines are purchasing new airplanes. The same is the case for schemes to establish aircraft charging infrastructure. Light aircraft should have an exception for VAT. To make electric aviation attractive for the ordinary customers, the ticket prices must be cheaper than the tickets for flying with ordinary airplanes. This can be achieved, for example, by VAT exception or reduction until 2040 on passenger aircraft, exemption or reduction of the passenger tax until 2040, lower take off charges at Avinor’s airports, and reduction of the electricity tax for electric airplanes in ordinary traffic (CAA Norway, 2020). Their report is on a public hearing until August 2020. Link: **The Norwegian Civil Aviation Authority, Avinor, Widerøe, Safran, Airbus, Leonardo/ATR, and EASA** on collaborate the topic electric aviation in a high-level task force. By summer 2020, they write that they will launch a roadmap for “innovation related to zero and low-emission regional aircraft” (CAA Norway, 2020).

Avinor and SINTEF in 2020 signed an agreement to collaborate on electric airplanes, efficient, secure and sustainable aviation. The collaboration will include participating in joint research projects, that employees will have the chance to work at each other’s places, and that research results are commercialized (SINTEF, 2020).

The University of Tromsø (UiT) has acquired two electric airplanes of the type Pipistrel Alpha Electro for research purposes. Their branch University of Tromsø School of Aviation (UTSA) collaborates with the research center Arctic Centre for Sustainable Energy (ARC) in making aviation as sustainable as possible. They want to test the battery capacity of their electric airplanes and how they are to fly. However, so far, they have not been flown a single time, because they await the certification of the Norwegian Civil Aviation Authority, expecting it by the end of June 2020. The electricity fueling the airplanes are primarily created by the university’s own solar cell panels, and they have 100 square meters of solar panels to generate electricity. This may also be helpful in discovering the opportunities for local generation and energy storage at other airports for electric aviation, as there are large surfaces where solar panels may be installed (Interview UiT flight school, 2020).

UiT flight school is the only public flight school in Norway. In the future, they want to use the electric airplanes in their pilot training and want to have them introduced as early as possible after they have received ordinary certification (Interview UiT flight school, 2020; NTB, 2019a; Wangen, 2018). One hour of flying with a conventional little airplane, like their Cessna 182 demands 40–50 liters of jet fuel and thus costs about 700 NOK per flight hour. With an electric airplane like Pipistrel, the energy cost per hour could be reduced to 20 NOK or less. In addition, the electric airplanes are much cheaper to maintain. The Cessna 182 needs a good round of maintenance every 50th flight hour, while the electric small airplanes need maintenance every 100th flight hour, and then will need very small adjustments. UiT flight school will also start the world’s first master study within aviation, with a particular focus on electric aviation (Interview UiT flight school, 2020).

The Norwegian political parties: Electric aviation receives broad political support in Norway. February 2020, Centre Party representatives launched an initiative in the Norwegian Parliament regarding improvement of the aviation offer from the Norwegian short-haul airports. This included measures that would stimulate the introduction of electric airplanes in Norway: changing the fees to stimulate the development and introduction of electric airplanes and making the airports ready for electric airplanes (Stortinget, 2020). The case was

debated in the Norwegian Parliament on 26 May 2020, and their requests were turned down (Stortinget, 2020).

This does *not* imply that there is little interest in the topic. The government wanted a thorough discussion of the issue in relation to the national transport plan. The last government and the current government have had electrification of aviation in their platforms, and also asked Avinor and the Norwegian Civil Aviation Administration to create a program for the introduction of electric aircraft.

Sweden

Electric Aviation in Sweden (ELISE): is funded by the Swedish innovation agency Vinnova. They are, according to their own web page, building an electric aircraft in collaboration with a number of universities and other research institutions and the Civil Aviation Administration (Elise, 2020). Aircraft manufacturer Heart Aerospace is also a member.

Swedavia Airports launched a strategy for electric aviation February 2020. All 10 airports they operate shall be made ready to have electric commercial routes within 2025. Swedavia works for fossil free domestic aviation within 2030. They are also a participant in the aforementioned Green Flyway project. The testing of drones and electric airplanes between Røros and Öresund is planned to start autumn 2020. Umeå airport is participating in a project where they assess the opportunities for electric aviation between Finland and Sweden (Swedavia Airports, 2020b).

Swedish Regional Airports, by member Skellefteå Airport, have strategies for electric aircraft. It is made ready to have electric airplanes there for testing (Flyg24Nyheter, 2020; Interview NEA, 2020).

Heart Aerospace is developing a 19-seater battery electric aircraft, to travel 400 kilometers, and aims to have it launched within 2025 (Heart Aerospace, 2019). 19 seat airlines are not subject to the same certification criteria as aircraft with more than 20 seats and are thus simpler to certify. A number of Nordic airlines have signed letter of intents, amounting to 127 airplanes altogether. 2/3 of their funding is from private investors and 1/3 of the funding is from public agencies. Heart Aerospace works with a number of research and innovation projects. Their aircraft uses a traditional aluminum frame. The motor and other systems, they design themselves, and have subcontractors as suppliers. The largest cost of developing the airplane is to achieve certification, and this is a very costly process (Interview Heart Aerospace, 2020). They say that the COVID-19 crisis has delayed some of their equipment suppliers, and that they thus are some months behind schedule (Norum, 2020).

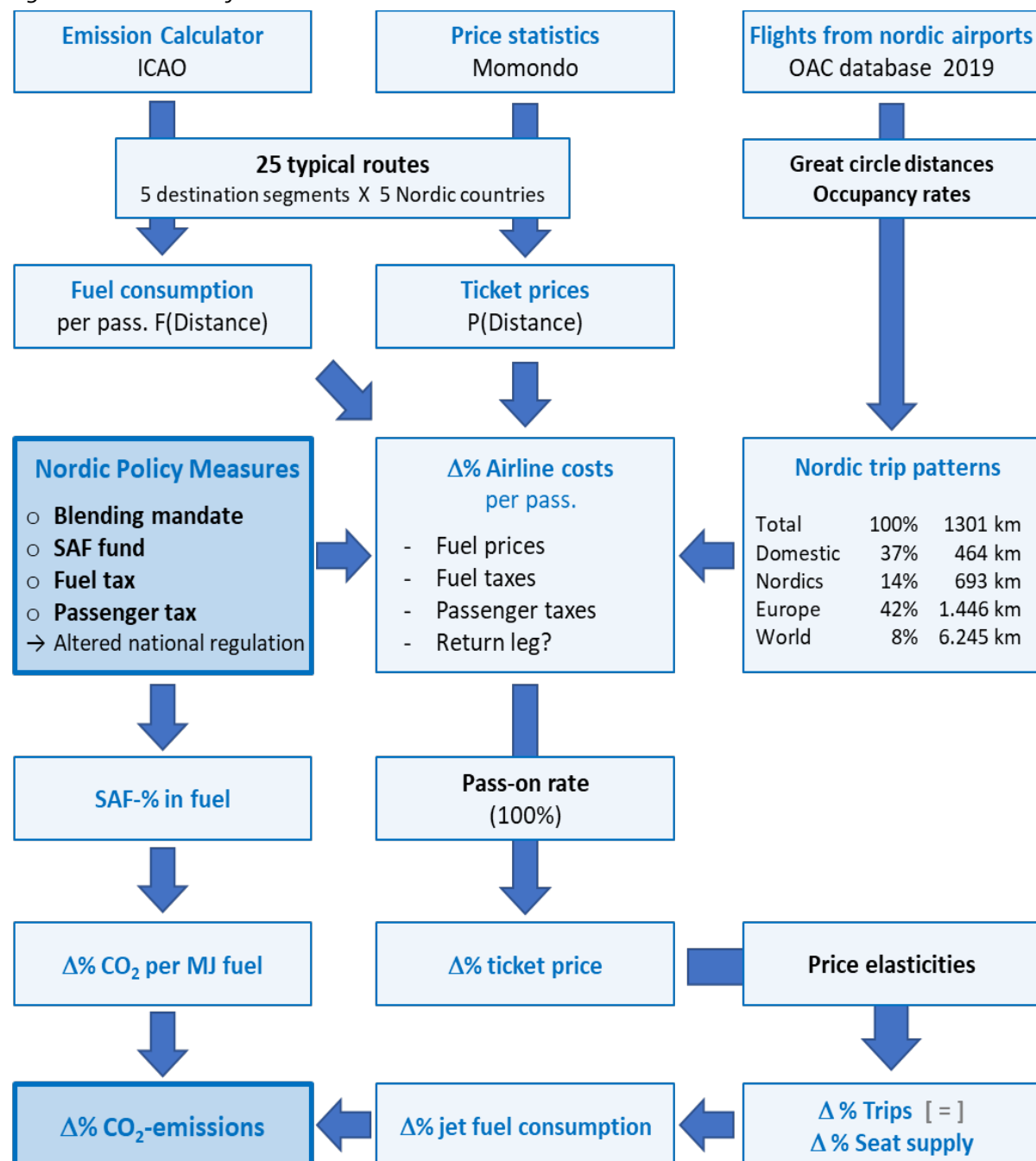
Katla Aero is developing small battery electric airplanes. Their aircraft can be manned, unmanned, and carry up to two passengers or 200 kilos (Katla Aero, 2020).

Research Institute of Sweden (RISE) is participating in a number of projects on electric aviation, including ELISE, NEA and FAIR. Recently, they launched an internally financed strategic initiative on electric aviation. Here, anybody within the organization that is interested in the topic may meet and creates a link to the ongoing external projects. The initiative, called Electric Flight Systems, aims to address not only the development of the actual airplanes, but also to take a holistic research approach on the possibilities and challenges associated with a systematic introduction of electric aviation in the overall transportation ecosystem (Interview RISE, 2020).

Appendix C: Calculation model for policy analyses

This appendix documents the calculation model which has been developed for quantitative assessment of the impact of alternative Nordic policy scenarios in section 6.3. Figure C.1 below presents overview of the main input and the causal structure.

Figure C.1 Overview of the model structure.



Note: Δ% = percentage change

Model structure

The above data on the Nordic air trip pattern and fuel consumption per passenger is used to calculate the impacts on airlines' operation costs per passenger from the introduction of common Nordic measures. Assumptions about prices for fossil jet fuel and SAF and CO₂ emissions per litre fuel follows (Swedish Government, 2019a) for 2030:

2030	Fossil jet fuel	SAF
Fuel costs (EUR per litre) excl. VAT and tax	0.57	1.14
CO₂e-emissions (g per MJ)	89.0	8.9
- Fuel burn	71.0	0.0
- Upstream	17.5	8.9

The change in the ticket price is calculated by assuming a **long-term pass-on rate of 100% of cost changes**, also in line with (Swedish Government, 2019a).

The Nordic policy measures are assumed to replace the existing Swedish and Norwegian passenger taxes, the Norwegian CO₂-tax on domestic flights and blending mandate. The cancellation of existing national policies means that the *net cost change* will be different across the Nordic countries. Therefore, costs changes and demand effects are calculated separately for departures from each country.

For Nordic trips the situation is even more complicated: We make the plausible, simplifying assumption that all tickets are bought as return trips. This implies that costs, and hence, ticket prices are affected on both legs the Nordic measures as well as the cancellation of the national policies. Consequently, the ticket price change will depend on both the Nordic origin country and the Nordic destination.

	Domestic	Nordic	Europe	World	Total
Demand-Price elasticities	-0.7	-0.6	-0.5	-0.4	-0.6

Finally, the model is based on the following implicit assumptions:

- Demand changes will lead to some substitution to other modes of transport. This is in particular the case for shorter trips which is reflected in the differences in demand elasticities across segments. Any emissions from these alternative modes is ignored but they will counteract the changes reported here for aviation.
- Airlines will minimise their operational costs and only use SAF if the price per MJ is lower than for jet fuel including taxes and emission allowances. And when this is the case, they will replace all jet fuel with SAF.
- Occupancy rates as well as choice of aircraft and other operational parameters are assumed to be unaffected by policy induced cost changes. This means that airlines' adaption to demand changes are taken by number of flights alone.

Input data

Flights from Nordic airports. Aircraft type with seat number from all Nordic airports in 2019 are extracted from the OAC-database and aggregated to total seat supply to four regional destination segments:

Domestic:	Flights within each Nordic country
Nordic:	Flights to other Nordic countries
Europe:	Flights to the rest of the Europe
World:	Flights to the rest of the world

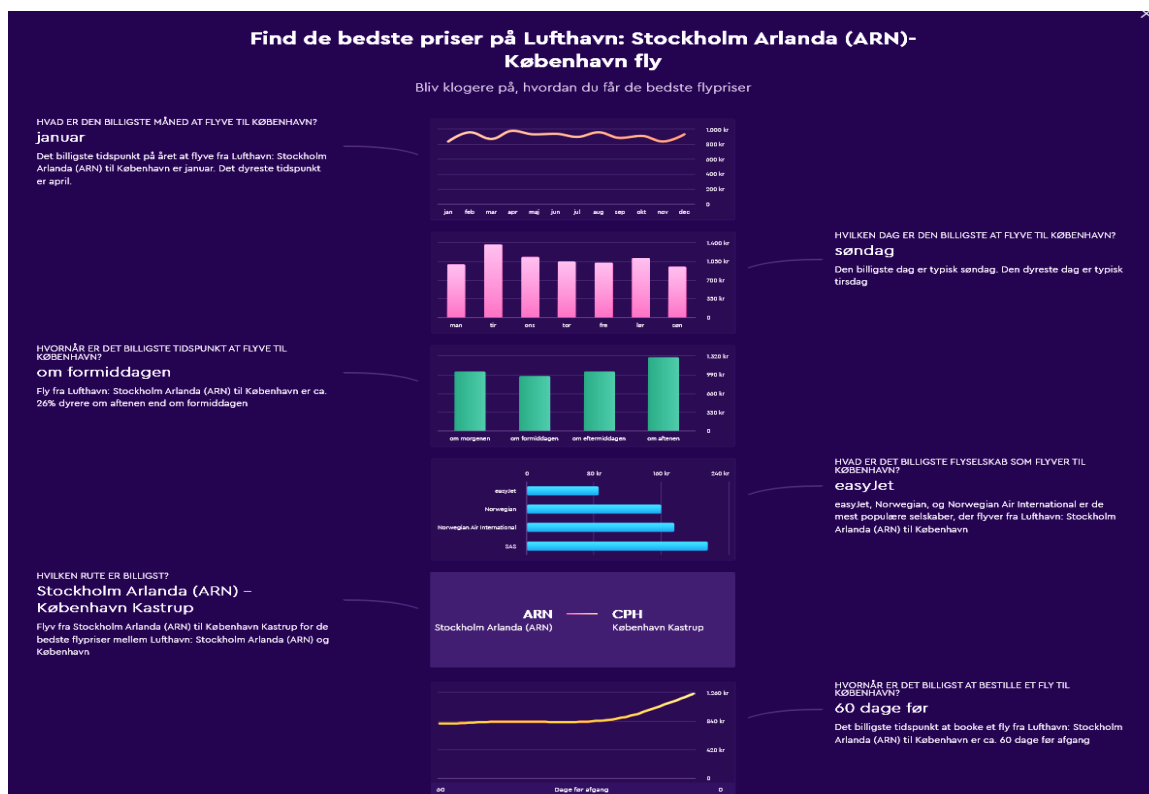
The seat supply data are described in Chapter 2. In addition, great circle distances for each flight from (www.gcmap.com) is used to generate available seat kilometres (ASK) for the same destination segments. Average distances for each destination segments are calculated by dividing Seat supply by ASK. The

distribution of seat supply is converted to passengers across regional destination segments by assuming the following occupancy rates across segments:

	Domestic	Nordic	Europe	World	Total
Occupancy rates	75%	75%	82%	85%	79%

Price statistics. Comprehensive price statistics for flight tickets is not readily available. Instead, we have used statistics from Momondo by taking the average of the highest and the lowest monthly prices. For Iceland no statistics were available do to too few observations. Instead prices five months ahead (i.e. September 2020) were used. Data were extracted mid-April 2020.

Figure B.2 Price statistics from Momondo



Source: <https://www.momondo.dk/travel-smart> March 2020

All currencies conversions use interbank currency exchange rates 31. Dec-19⁴⁴.

⁴⁴ <https://www.ofx.com/en-au/forex-news/historical-exchange-rates/yearly-average-rates/>

25 typical routes. A set of 25 specific routes has been chosen for further analyses of the implications of common Nordic policy framework for promoting sustainable aviation. This approach is preferred to averages or totals for two reasons: Firstly, to simplify quantified impact assessment, and secondly for communicative purposes as concrete examples are easier for the reader to relate to. To minimize the risks of drawing conclusions from results that are significantly dependent on the ad hoc selection of routes, 5 times 5 = 25 routes, are chosen based on the following criteria:

- Five types of routes matching the geographical distinction between the destination segmentation described above:
 1. A high-volume domestic route
 2. A low volume domestic route
 3. A main Nordic route
 4. A frequent European route
 5. A direct intercontinental route
- All five types of routes are for each of the five Nordic countries

Both high and low volume domestic routes are included to get both main routes often served by single aisle jets (typically A320/B737 with 123–209 seats) and short routes with less demand served by smaller turboprops (<100 seats). In addition, the selection of routes also has taken into account to achieve a spread of distances within each regional destination segments.

Emission calculator. The ICAO emission calculator is used to calculate average fuel consumption per passenger for the 25 typical routes. The emission calculator takes into account the distribution of aircraft for each route. As for ticket prices the 25 observations of fuel consumption and distance are used to estimate a functional relationship $F(\text{distance})$ between flight distance and typical fuel consumption per passenger. $F(\text{distance})$ is then applied to calculate average fuel consumption for each of the four regional destination segments.

Denmark		km
1. København - Bornholm		146
2. København - Aalborg		237
3. København - Oslo		515
4. København - London		977
5. København - Los Angeles		9.024
Finland		km
1. Helsinki - Jyväskylä		232
2. Helsinki - Oulu		510
3. Helsinki - København		890
4. Helsinki - Madrid		2.943
5. Helsinki - Tokyo		7.820
Iceland		km
1. Akureiry - Vopnafjörður		146
2. Reykjavik - Akureiry		282
3. Reykjavik - Helsinki		2.441
4. Reykjavik - Berlin		1.894
5. Reykjavik - Boston		3.872
Norway		km
1. Bodø - Leknes		103
2. Oslo - Bergen		323
3. Oslo - Stockholm		383
4. Oslo - Amsterdam		958
5. Oslo - Bangkok		8.665
Sweden		km
1. Stockholm - Visby		222
2. Stockholm - Göteborg		394
3. Stockholm - København		546
4. Stockholm - Bruxelles		1.286
5. Stockholm - New York		6.304

Appendix D: Routes shorter than 200 km within and between the Nordic countries

“EL 9 flights” and “EL 19 flights” means the number of flights that would have been necessary if “Seats 2019” should have been supplied 9 seaters or 19 seaters alone.

Denmark

Airport	Destination	Distance	Seats 2019	Flights 2019	EL 9 flights	EL 19 flights
Aalborg, DK	Aarhus, DK	100	1 184	37	132	62
Aarhus, DK	Goteborg, SE	182	5 248	164	583	276
	Copenhagen, DK	148	155 180	1 799	17 242	8 167
Billund, DK	Esbjerg, DK	45	2 300	49	256	121
Copenhagen, DK	Bornholm, DK	147	3 240	18	360	171
	Sonderborg, DK	196	75 512	1 144	8 390	3 974
	Aarhus, DK	148	155 180	1 799	17 242	8 167
	Bornholm, DK	147	167 322	2 640	18 591	8 806
Esbjerg, DK	Billund, DK	45	2 230	48	248	117
Bornholm, DK	Copenhagen, DK	147	170 270	2 660	18 919	8 962
Sonderborg, DK	Copenhagen, DK	196	75 512	1 144	8 390	3 974
TOTAL POTENTIAL			813 178	11 502	90 353	42 799

Finland

Airport	Destination	Distance	Seats 2019	Flights 2019	EL 9 flights	EL 19 flights
Helsinki, FI	Tampere, FI	143	82 026	1 179	9 114	4 317
	Turku, FI	150	90 914	1 309	10 102	4 785
	Tallinn, EE	101	192 608	2 566	21 401	10 137
Ivalo, FI	Kittila, FI	147	46 619	271	5 180	2 454
Jyvaskyla, FI	Kokkola, FI	195	4 720	67	524	248
Kokkola, FI	Jyvaskyla, FI	195	1 736	25	193	91
Kittila, FI	Ivalo, FI	147	10 311	55	1 146	543
Mariehamn, FI	Turku, FI	138	3 448	102	383	181
	Stockholm, SE	123	7 573	224	841	399
	Turku, FI	138	16 906	244	1 878	890
Turku, FI	Mariehamn, FI	138	23 808	396	2 655	1 263
	Helsinki, FI	150	87 454	1 259	9 717	4 603
Tampere, FI	Helsinki, FI	143	82 016	1 179	9 113	4 317
TOTAL POTENTIAL			650 139	8 876	72 238	34 218

Iceland

Airport	Destination	Distance	Seats 2019	Flights 2019	EL 9 flights	EL 19 flights
Akureyri, IS	Grimsey, IS	100	3 460	184	384	182
	Vopnafjordur, IS	148	4 180	220	464	220
Grimsey, IS	Akureyri, IS	100	3 460	184	384	182
Thorshofn, IS	Akureyri, IS	139	4 180	220	464	220
Vopnafjordur, IS	Thorshofn, IS	60	4 180	220	464	220
TOTAL POTENTIAL			19 460	1 028	2 162	1 024

Sweden

Airport	Destination	Distance	Seats 2019	Flights 2019	EL 9 flights	EL 19 flights
Arvidsjaur, SE	Gallivare, SE	185	46 562	559	5 174	2 451
Stockholm, SE	Mariehamn, FI	123	7 573	224	841	399
	Visby, SE	190	168 151	2 298	18 683	8 850
Gallivare, SE	Arvidsjaur, SE	185	46 562	559	5 174	2 451
Goteborg, SE	Aarhus, DK	182	5 248	164	583	276
Jonkoping, SE	Karlstad, SE	193	4 557	93	506	240
Kalmar, SE	Ronneby/Karlskrona, SE	78	720	8	80	38
Kramfors, SE	Vilhelmina, SE	177	2 200	44	244	116
Karlstad, SE	Jonkoping, SE	193	4 557	93	506	240
Lycksele, SE	Vilhelmina, SE	90	24 450	489	2 717	1 287
Norrkoping, SE	Visby, SE	161	1 008	14	112	53
Visby, SE	Norrkoping, SE	161	1 008	14	112	53
	Stockholm, SE	190	167 903	2 294	18 656	8 837
Vilhelmina, SE	Kramfors, SE	177	2 200	44	244	116
	Lycksele, SE	90	24 450	489	2 717	1 287
TOTAL POTENTIAL			507 149	7 386	56 350	26 692

Norway

Airport	Destination	Distance	Seats 2019	Flights 2019	EL 9 flights	EL 19 flights
Alesund, NO	Kristiansund, NO	107	9 672	248	1 075	509
Alta, NO	Hammerfest, NO	79	4 056	104	451	213
	Sorkjosen, NO	95	9 594	246	1 066	505
	Tromso, NO	174	135 145	1 412	15 016	7 113
Andenes, NO	Harstad/Narvik, NO	92	10 195	249	1 133	537
	Tromso, NO	117	24 138	613	2 682	1 270
Bergen, NO	Haugesund, NO	106	4 200	84	467	221
	Forde, NO	126	12 012	308	1 335	632
	Sogndal, NO	142	23 673	607	2 630	1 246
	Floro, NO	144	58 822	1 506	6 536	3 096
Batsfjord, NO	Stavanger, NO	160	530 502	4101	58 945	27 921
	Vardoe, NO	57	9 750	250	1 083	513
	Vadso, NO	60	9 828	252	1 092	517
	Berlevag, NO	39	11 895	305	1 322	626

	Mehamn, NO	84	12 012	308	1 335	632
Bronnoysund, NO	Sandnessjoen, NO	56	7 438	180	826	391
Bodo, NO	Vaeroy, NO	86	9 390	626	1 043	494
	Rost, NO	101	11 778	302	1 309	620
	Mosjoen, NO	173	23 907	613	2 656	1 258
	Sandnessjoen, NO	169	26 010	617	2 890	1 369
	Harstad/Narvik, NO	167	33 774	833	3 753	1 778
	Mo i Rana, NO	101	38 649	991	4 294	2 034
	Stokmarknes, NO	149	58 032	1 488	6 448	3 054
	Svolvaer, NO	109	61 386	1 574	6 821	3 231
	Leknes, NO	104	81 822	2 098	9 091	4 306
Berlevag, NO	Batsfjord, NO	39	9 750	250	1 083	513
	Vadso, NO	95	9 867	253	1 096	519
	Hammerfest, NO	198	11 895	305	1 322	626
Harstad/Narvik, NO	Andenes, NO	92	12 307	304	1 367	648
	Tromso, NO	160	24 681	610	2 742	1 299
	Bodo, NO	167	32 441	796	3 605	1 707
Forde, NO	Floro, NO	45	8 619	221	958	454
	Bergen, NO	126	14 469	371	1 608	762
Floro, NO	Forde, NO	45	11 037	283	1 226	581
	Bergen, NO	144	59 251	1 517	6 583	3 118
Hasvik, NO	Tromso, NO	152	12 051	309	1 339	634
	Hammerfest, NO	61	21 606	554	2 401	1 137
Haugesund, NO	Bergen, NO	106	4 200	84	467	221
Hammerfest, NO	Berlevag, NO	198	9 750	250	1 083	513
	Mehamn, NO	157	9 906	254	1 101	521
	Hasvik, NO	61	12 012	308	1 335	632
	Honningsvag, NO	92	21 801	559	2 422	1 147
Orsta/Volda, NO	Sandane, NO	39	3 471	89	386	183
	Floro, NO	86	4 095	105	455	216
	Sogndal, NO	128	11 700	300	1 300	616
Honningsvag, NO	Mehamn, NO	67	11 895	305	1 322	626
	Hammerfest, NO	92	31 629	811	3 514	1 665
Kirkenes, NO	Vardoe, NO	83	9 945	255	1 105	523
	Vadso, NO	38	33 150	850	3 683	1 745
Kristiansand, NO	Stavanger, NO	161	17 006	269	1 890	895
	Molde, NO	50	4 956	98	551	261
	Trondheim, NO	160	10 322	261	1 147	543
Leknes, NO	Bodo, NO	104	81 588	2 092	9 065	4 294
Mehamn, NO	Berlevag, NO	47	9 906	254	1 101	521
	Vadso, NO	131	11 817	303	1 313	622
	Honningsvag, NO	67	21 723	557	2 414	1 143
Mosjoen, NO	Mo i Rana, NO	81	1 365	35	152	72
	Bodo, NO	173	23 868	612	2 652	1 256
Mo i Rana, NO	Mosjoen, NO	81	1 365	35	152	72
	Bodo, NO	101	39 936	1 024	4 437	2 102
Namsos, NO	Rorvik, NO	46	13 338	342	1 482	702
	Trondheim, NO	117	31 824	816	3 536	1 675

Rost, NO	Svolvaer, NO	134	11 778	302	1 309	620
	Bodo, NO	101	12 012	308	1 335	632
Rorvik, NO	Trondheim, NO	154	20 943	537	2 327	1 102
	Namsos, NO	46	21 294	546	2 366	1 121
Sandane, NO	Sogndal, NO	93	21 684	556	2 409	1 141
Stokmarknes, NO	Tromso, NO	198	22 308	572	2 479	1 174
	Bodo, NO	149	63 375	1 625	7 042	3 336
Sogndal, NO	Floro, NO	123	3 471	89	386	183
	Orsta/Volda, NO	128	11 661	299	1 296	614
	Bergen, NO	142	23 166	594	2 574	1 219
Sorkjosen, NO	Sandane, NO	93	30 771	789	3 419	1 620
	Hammerfest, NO	143	9 789	251	1 088	515
	Tromso, NO	80	23 478	602	2 609	1 236
Sandnessjoen, NO	Bronnoysund, NO	56	2 301	59	256	121
	Rorvik, NO	139	5 616	144	624	296
	Bodo, NO	169	24 299	605	2 700	1 279
Stavanger, NO	Kristiansand, NO	161	21 060	270	2 340	1 108
	Bergen, NO	160	551 887	4 234	61 321	29 047
Svolvaer, NO	Stokmarknes, NO	40	5 850	150	650	308
	Rost, NO	134	12 012	308	1 335	632
	Bodo, NO	109	55 575	1 425	6 175	2 925
Tromso, NO	Hasvik, NO	152	21 645	555	2 405	1 139
	Stokmarknes, NO	198	21 801	559	2 422	1 147
	Sorkjosen, NO	80	23 673	607	2 630	1 246
	Andenes, NO	117	24 105	613	2 678	1 269
	Harstad/Narvik, NO	160	25 460	628	2 829	1 340
Trondheim, NO	Alta, NO	174	148 712	1 761	16 524	7 827
	Kristiansund, NO	160	600	12	67	32
	Rorvik, NO	154	23 283	597	2 587	1 225
	Namsos, NO	117	23 907	613	2 656	1 258
Vardoe, NO	Vadso, NO	56	9 711	249	1 079	511
	Kirkenes, NO	83	11 973	307	1 330	630
	Batsfjord, NO	57	21 762	558	2 418	1 145
Vadso, NO	Mehamn, NO	131	9 633	247	1 070	507
	Batsfjord, NO	60	11 934	306	1 326	628
	Vardoe, NO	56	23 673	607	2 630	1 246
	Kirkenes, NO	38	33 384	856	3 709	1 757
	Bodo, NO	86	9 390	626	1 043	494
TOTAL POTENTIAL			3 277 198	60 522	364 133	172 484