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Nordic measures to promote sustainable aviation fuels

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Abstract

Decarbonising transportation is necessary to reach long-termed climate goals and Nordic countries have committed themselves to be ambitious and lead the way. Finding technically feasible and economically viable solutions for aviation is among the most difficult challenges. This paper examines opportunities for increased Nordic cooperation to promote use of sustainable aviation fuels. Pros and cons of implementing each of five policy instruments in a Nordic context are analyzed and their impacts in terms of impact on air travel, CO_2-emissions and Government budget are estimated.

The paper concludes that the most suitable common Nordic policy for significant CO_2 reductions from air travel is to announce a gradually increasing blend-in share of sustainable fuels toward 2030 backed by establishing a Nordic fund that will compensate the price premium compared to fossil fuels. The fund should be financed by common earmarked passenger taxes for all departing flights from the Nordics.

Introduction

With the Paris Agreement adopted in December 2015 at the 21st Conference of the Parties to the UNFCCC 195 countries agreed to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels". As a follow-up IPPC published the report *Global Warming of 1.5°C* in October 2018 strongly illustrating that this will require global carbon neutrality by mid-century. Recently, the sixth assessment report (IPCC 2021) has reinforced the evidence from climate science that human activities are the main driver behind observed and projected climate changes. According to United Nations countries representing more than 65 per cent of harmful greenhouse gasses and more than 70 per cent of the world economy have committed to achieve net zero emissions by the middle of the century (UN Secretary General 2020).

The Nordic countries wants to pursue this goal ambitiously and lead by example. This is expressed in *Declaration on Carbon Neutrality* signed by the Prime Ministers in December 2019. The declaration stresses the need for and commitment to intensified cooperation, and it highlights transport as an important common Nordic challenge in the fight to reduce greenhouse gas emissions. Aviation is arguably one of the most challenging sectors to decarbonise and the fact that aviation is a global industry where EU frameworks as well as global agreements and conventions restrict the options for Nordic policy.

This paper investigates various options for common Nordic regulatory initiatives to reduce carbon emissions from air travel within the Nordics and abroad with a view to promote long-termed sustainable aviation in the longer term. Advantages and shortcomings of alternative measures are compared. The paper presents a subset of the results from the report *Nordic Sustainable Aviation* commissioned by the Nordic Council of Ministers and published by Nordic Energy Research in 2020 (Ydersbond et.al. 2020).

Pathways to sustainable aviation

It is more than difficult to envisage that the Nordics can live up to the Paris Agreement without opting for radical reductions in greenhouse gas (GHG) emissions from aviation, especially if concerns about the potentially even more damaging (although very uncertain) non-CO_2 impacts from 'net-NO_x' and cirrus contrails are considered (EASA 2020). Further, business-as-usual projections estimates significant increases in air travel over next decades compared to the level before the Covid-19 pandemic which will amplify the need for emission reductions.

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 political mainstream, curbing air travel by demand side measures strong enough to stop aviation growth or even limit it to significantly below pre-pandemic levels is not considered an attractive path to significantly reducing the GHG emissions from aviation. In fact, relying primarily on demand reducing measures to achieve GHG reduction in the order of magnitude required over the next couple of decades will in practice imply abandoning air travel for the population at large.

Alternative pathways to significant reductions are thus to:

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

recognizing that these pathways 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% (Kharina et al., 2016), and air traffic management is expected to be able to generate another 5–10%. This means that efficiency improvements will globally only be able to offset slightly more than the effect of expected demand growth (International Transport Forum, 2021). Hence, attaining radical GHG emission reductions will imply that a major share of the reductions will expectedly have to come from replacing fossil energy with low-carbon alternatives.

In the long run new propulsion technologies could possibly fully decarbonise aviation using renewable energy based on electricity as energy source. **Battery electric** aircraft is an emerging technology with significant potentials in coming years, in particular for small aircraft at short distances of up to 500 - 1000 km accounting for only 9 - 24% of total seat kilometers departing from Nordic airports (see Figure 1 below). For longer distances fully electric aircraft relying on battery stored energy will probably not have any significance in scheduled operations within the next two or three decades (Ydersbond et.al., 2020). For these as well as short distances **hydrogen** produced from electricity by electrolysis might be the carbon-free propulsion energy of the future. But the technology is at a very early stage and commercial aircraft could probably not enter into service until beyond 2035. Moreover, even when hydrogen aircraft are certified and ready to market it would at least a decade before they would constitute a significant share of the fleet. The replacement rate of commercial aircraft is typically slow, because the service life is typically 20–30 year and 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.

A technologically more straight-forward approach is to replace fossil jet fuel with **sustainable aviation fuel (SAF)**. SAF encompasses various fuels with very no or low lifecycle GHG emissions. SAF could be *advanced biofuels* based on conversion of biomass residues to liquids or *synthetic e-fuels* produced by combining hydrogen from hydrolysis with a carbon source, either from biomass or captured CO_2.

Considering battery-electric aircraft's limited potential in terms of share of passenger kilometers and, hence, aviation's total energy consumption, and the long time horizon before hydrogen aircraft could gain significant market shares majority of total passenger kilometers over the next three decades will most likely be provided by conventional propulsion technology. Hence, it seems fair to presume that

> *replacing the fossil jetfuel by SAF appear to be the predominant option for decarbonising aviation toward 2050 supported by expectedly strong progress in energy efficiency.*

Currently, the market for SAF is immature. The produced volumes are insignificant compared the total consumption of jetfuel with a main constraint being that the price is several times higher than fossil jetfuel. 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. However, other production pathways based on alternative feedstock with much higher volume potentials are available, but their technology readiness levels (TRL) are low and costs are currently high, although economies of scale and technological maturity can most likely reduce costs. Still, SAF will probably maintain a considerable cost premium per liter compared to fossil jetfuel at least in the short and medium term. Therefore, political intervention to promote SAF is required for it to substitute fossil fuel to any significant extent.

International and EU legislation as a framework condition for Nordic initiatives

Aviation's comparative advantage compared to other modes is by nature at long distances and, hence, also cross boundary trips. This calls for regulatiotory measures by international standards and agreements to secure effectiveness, fair competition and avoid evasion of regulatory measures. International aviation has since its infancy been subject to many international agreements, including certification procedures for aircraft and fuels for obvious safety reasons. These international agreements act as a framework condition which to some extent limits additional common Nordic initiatives or reduces their de facto effectiveness.

The Convention on International Civil Aviation, '*The Chicago Convention*', from 1944 is the legal basis for international civil aviation (ICAO, 2006). The convention's 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). The Chicago Convention does not prohibit taxation on fuels to aircraft fueling in a country (Faber & Huigen, 2018). 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 i.e., carrying excess fuel in order to reduce or eliminate refueling at its destination in order to avoid higher fuel prices for example due to taxation (see below). In addition, some several multilateral and bilateral treaties contain limitations on aviation fuel taxation (Pirlot & Wolff, 2017).

EU's Energy Taxation Directive (Directive 2003/96/EC) establishes minimum excise duty rates that Member States must apply to energy products, including transportation fuels. However, commercial aviation is exempted. In fact, the Directive prohibits fuel taxation for international flights. Member states can only tax aviation fuel used for domestic flights or by means of bilateral agreements, (Amsterdam economics & CE Delft, 2019; European Council, 2008; Faber & Huigen, 2018), the latter being relevant for common Nordic initiatives.

The European Commission's climate package '*Fit for55*' released in July 2021 includes a proposal for a revised Energy Taxation Directive(European Commission 2021). The proposal revokes the exemption for aviation which will imply a tax on fossil jetfuel for European flights based on energy content be introduced linearly over a transitional period of 10 years from 2023, corresponding to minimum tax rates applicable to road transport fuels. However, adoption will require unanimous approval by the Member States.

Aviation within the EU and European Economic Area (EEA) has been included in the EU Emission Trading System (ETS) since 2012. Only CO_2 emissions are targeted by EU ETS, and not the climate impact from contrails etc.[1] All airlines operating in Europe, European and non-European alike, are required allowances against their emissions from intra-European flights. So far, airlines have received tradeable allowances for free covering a substantial share of emissions from their flights per year. The '*Fit for 55*' package also proposes amending the EU ETS to align with the global ICAO CORSIA offsetting scheme and to phase out free emission allowances for aviation (European Commission, 2021a).

However, even if the Energy Taxation Directive revision is adopted the economic incentives of the gradually increasing minimum tax rate combined with the currently low, yet rising, market price of the CO_2-emission allowances[2] will not most likely not for many years induce initiation of the required transformation of aviation to zero or low GHG emission technologies, including SAF. The expected price premium will still outmatch the savings from the fossil fuel tax and emission allowances.

The '*RefuelEU Aviation'* proposal (European Comission, 2021c), released as a part of the '*Fit for 55*' package, might introduce significant use of SAF, although at a slow pace. The proposal sets up an EU-wide SAF blending mandate on aviation fuel suppliers for a minimum volume percentage of SAF in the fuel supply. The minimum rate is proposed to start at 2% in 2025, rising to 5% in 2030 and 20% in 2035 and further on to 32%, 38% and 63% in 2040, 2045 and 2050, and hence still leaving 37% for fossil fuel in the year when EU has committed to be climate neutral[3].

Current situation in the Nordics

Regulatory measures

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

- **Blending mandate:** 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.
- **Passenger taxes:** Sweden and Norway have passenger taxes. 2020-rates per departing passenger are:
  - for domestic and EEA destinations: 76.5 NOK (7.5 EUR) and   62 SEK (6 EUR);
  - for longer routes: 204 NOK (20 EUR) and 260 or 416 SEK (25 or 40 EUR).
- **Fuel taxes:** Norway has a fuel tax on domestic flights with a rate equivalent to about 55 EUR/tonne CO_2.

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[1] The climate impact of aircraft emissions is 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 CO_2-effect.

[2] The current market price of emission allowances is about 50 EUR per ton CO_2 (August 2021). This level is far lower than national estimates of the marginal CO_2 abatement costs to achieve the emission targets in the Nordics, in particular if we only look at contributions from the transport sector.

[3] Synthetic e-fuels or hydrogen is required to constitute an increasing share from 0.7% in 2030 of total fuel volumes to 28% in 2050.

In, addition, intra-EU/EEA flights are as mentioned above subject to the EU ETS. Working in the opposite direction, international aviation is in general not subject to VAT and all Nordic countries have a reduced or zero VAT rate on domestic trips.

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 [464 km]
- **Nordic:** Flights between Nordic countries [693 km]
- **Europe:** Flights to the rest of the Europe [1,446 km]
- **World:** Flights to the rest of the world [6,245 km]

The distances shown in brackets is the seat-weighted average distance within each destination segment based on extracts from OAG-database combined with distances from www.gcmap.com. The table below shows the travel patterns from each of the Nordic countries to the four destination segments based on extracts from the OAG-database.

Table 1 Seat supply from Nordic countries in 2019 (in millions - apart from per capita figures)

	Denmark	Finland	Iceland	Norway	Sweden	Total
Domestic	3.0	4.6	0.4	24.5	11.1	43.6 (38%)
Nordic	4.5	2.6	0.8	4.2	4.4	16.6 (15%)
Europe	13,5	7.3	2.1	10.1	12.6	45.7 (40%)
World	2.3	2.3	1.2	0.8	1.5	8.1 (7%)
Total	**23.3** (20%)	**16.7** (15%)	**4.6** (4%)	**39.7** (35%)	**29.6** (26%)	**113.9** (100%)
Per capita Population (mill.)	4.0 5.8	3.0 5.5	11.5 0.4	7.5 5.3	2.9 10.1	4.2 27.1

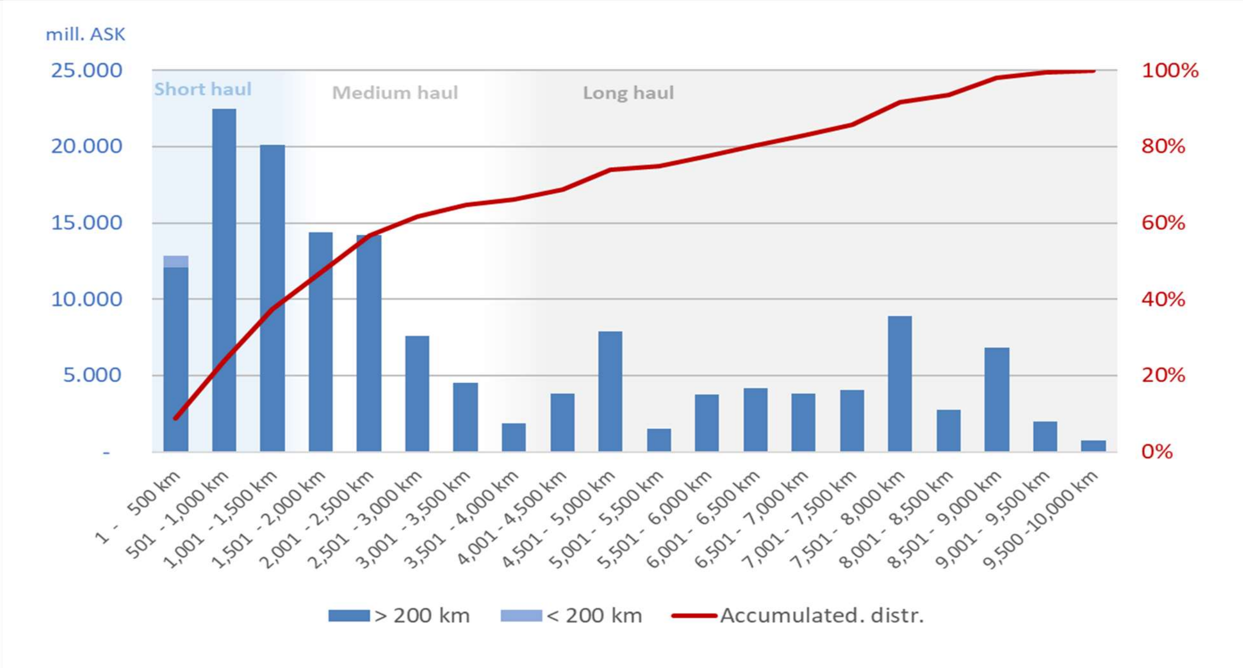
Source: Extracts from OAG-database (https://www.oag.com/).

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, distances and geographical conditions. 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.

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 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

Figure 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.

Analysis of policy measures to promote sustainable aviation

The introduction to this paper argued that the predominant path to decarbonising aviation will be to replace fossil jetfuel with SAF at least for the next decades. This section examines opportunities for increased Nordic cooperation to promote use of sustainable aviation fuels for flights departing from airports in the Nordics.

A common Nordic policy for promoting SAF

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. This paper does not consider alternative pathways but merely take as a point of departure that a zero- or low-carbon alternative to fossil jetfuel can technically be provided and that 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 prevailing EU Emission Trading System or an economy wide CO_2e-tax on all GHG. Such measures are generally held as cost-effective economic instruments to achieve overall national and EU-wide reduction targets. Hence, additional initiatives to obtain a significant SAF share of Nordic jet fuel consumption over the next decade will not necessarily be a cost-effective contribution to achieve nationally committed reduction targets in 2030. Rather the primary rationale for such initiatives would be to accelerate the long-termed transition to more sustainable aviation which is one of the most challenging sectors to decarbonize and a necessary element of the path toward carbon neutrality in 2050.

A political commitment to implement a certain share of SAF in 2030 can create supplier confidence in a strong and reliable long-term demand. A harmonised Nordic policy framework can make a difference because the total Nordic consumption of jet fuel is by far more than that of any single Nordic country. This could reduce investors' risk by establishing economically attractive and stable framework conditions for a time horizon that allow for depreciation of the significant financial investment in large scale production plants, which is necessary to bring down unit costs and increase production volumes to a scale with impact. Early announcement of the scheme and starting at very low levels and increasing progressively toward e.g. 30% in 2030 rather than to pushing for high SAF volumes in the short term can allow for a gradual ramp up of supply based on large scale production.

Direct regulation and/or taxation?

Depending on the future development of the EU ETS quota price replacing fossil jet fuel with SAF will expectedly imply considerable additional operational costs at least for many years ahead. A significant SAF share of total aviation energy consumption will therefore demand very concrete policy measures. A key question is which measures are most suitable to overcome this barrier.

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** requiring that SAF constitute a certain share of jet fuel consumption. Strict and clear sustainability criteria for eligibility of SAF are essential.
- **CO_2e reduction requirement** which works in a similar way as the blending mandate. But instead of requiring a certain volume share of SAF it sets an upper limit to the GHG emission per MJ fuel. This means that the blending percentage depends on the lifecycle emissions of the various types of SAF and their alternative production pathways.
- **SAF fund** financed by Government budgets to pay the price differential between SAF and fossil jet fuel for a certain share % of total Nordic jet fuel volumes.
- **Fuel tax on fossil jet fuel** for all scheduled departures from Nordic airports to Nordic destinations as EU legislation only allow for fuel taxation for international flights by means of bilateral agreements.
- **Passenger tax** for all trips both domestic, to EEA countries and to the rest of the world. Transit passengers exempted to treat direct flights and stop-over flight equally.

A comparative impact assessment of the five policy measures is conducted by coming two approaches:

- *Firstly, a quantitative approach* where the size of the impacts on ticket prices, air travel demand, CO_2-emissions and tax revenue will be estimated based on simplified model calculations.
- *Secondly, a more qualitative approach* based on literature reviews and 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.

Effects on air travel demand, GHG emissions and costs

Four scenarios are set up for model calculation to illustrate the impacts of each of the policy measures. A scenario has not been set up specifically for a CO_2 reduction requirement because it works in a similar way as the blending mandate. The main difference would be that the CO_2-reduction requirement will potentially give a more cost effectively global CO_2 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. However, since the paper does not distinguish between different types of SAF and, hence, not cost variations among them model calculations of the impacts will not differ from the blending mandate scenario.

Table 2 – Calibration of the policy measures in the model calculations

(A)	**Blending mandate** (or **CO_2e reduction requirement**) for the fuel use on all flights from Nordic airports		**30%**
(B)	**SAF fund** financing the cost premium for the same volumes of SAF as for (A)		**30%**
(C)	**Fuel tax** on all fuel used for flights from all Nordic airports to Nordic destinations		**0.33 EUR/litre**
(D)	**Passenger tax** on all passengers on flights from Nordic airports	Domestic and to EEA: The rest of the world:	**10.43 EUR/pass.** **58.63 EUR/pass.**

A blending share of 30% has been chosen to reflect the level of ambition which has been put forward by stakeholders in several Nordic countries. A fossil fuel tax of 0.33 EUR per litre is indicative of the long term implications of the EU Commission's proposal for a revised Energy Taxation Directive, cf. above. The rate corresponds to 130 EUR per tonne CO_2. The passenger tax rates correspond to the 2020-level of the German passenger tax (Bloomberg, 2020) to outline a situation for regional harmonization and minimum competitive distortion vis-à-vis the largest neighbouring country.

For all measures an early announced gradual phase-in toward 2030 is recommendable to allow for adaptation. 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.

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

- Ticket prices (% change)
- Air travel demand (% change)
- CO_2 emissions (% change) in terms of reduced fossil jet fuel use
- Government revenues (mill. EUR) changes, including revenue from current National aviation taxes
- Total additional fuel costs (mill. EUR) from replacing fossil jet fuel by SAF

Emission increases caused by substitution to other modes of transport is ignored as are upstream emissions. If upstream emissions are taken into account the absolute CO_2e-reduction will be slightly higher, because we expect upstream emissions for SAF to be lower than for fossil jetfuel (see below). Percentage reductions slightly less and fully carbon neutral flights requires that upstream emissions for SAF are zero.

Method

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 CO_2 tax and the advanced biofuel blending rate of 0.5% tax is cancelled in Norway and so forth. 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.

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 but they are considered in the next section dealing with the comparative regulatory assessment.

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 CO_2 fuel burn emissions per litre fossil fuel and assuming upstream emissions of 17.5 and 8.9 gram CO_2e per litre fossil jet fuel and SAF. These assumptions imply an implicit CO_2 price of about 225 EUR per tonne CO_2 or 200 EUR per tonne CO_2 if upstream emissions of both fuel types are taken into account[4].

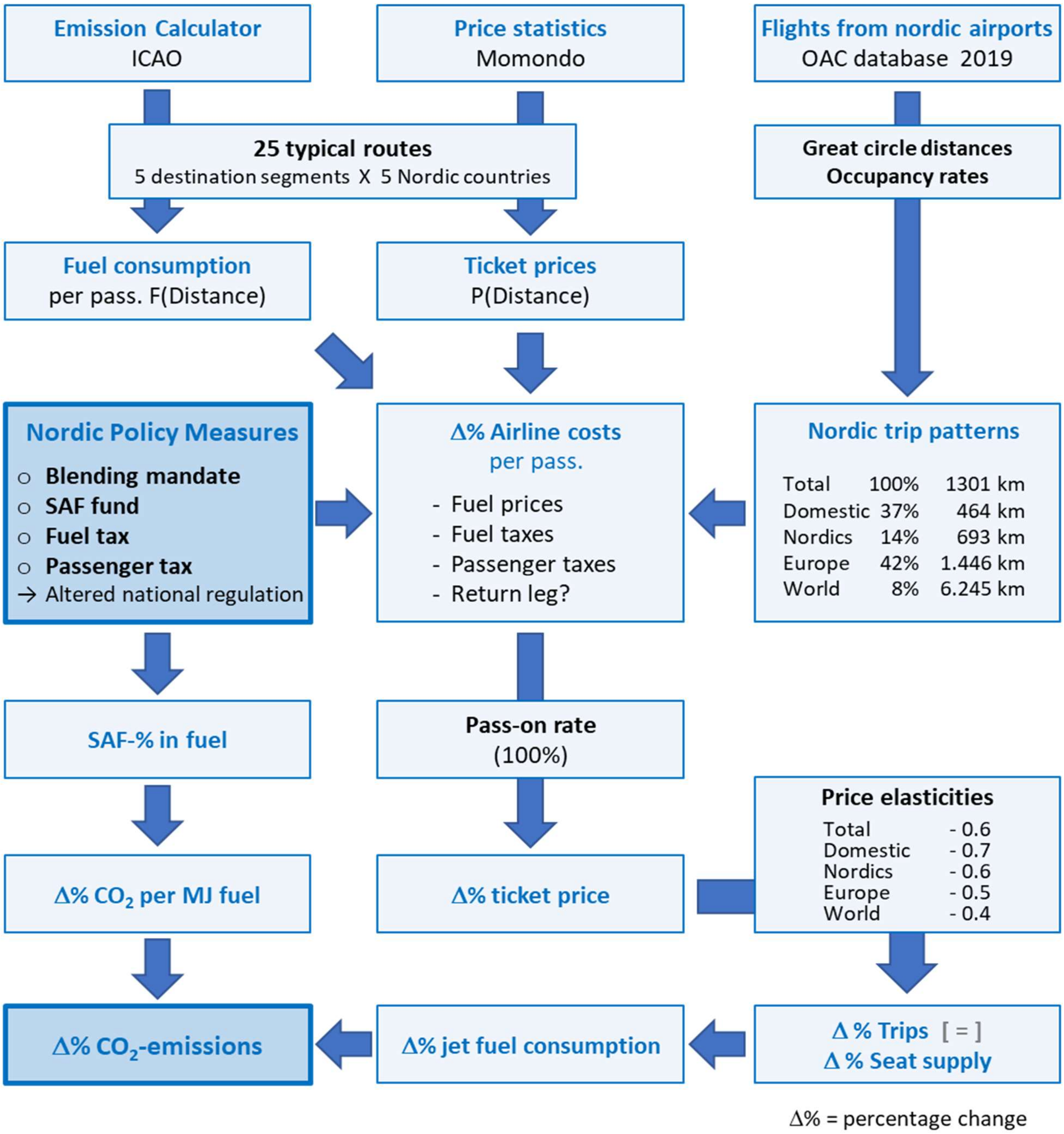
Finally, the model is based on the following implicit assumptions:

- 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 is 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.

[4] For intra-EEA flights the costs of replacing fossil jet fuel with SAF is reduced by savings from the costs for EU ETS permits. For simplicity this is ignored in the calculations. The EU ETS quota price amounted to about 5% of the estimated SAF price at the time of the calculations, whereas the price of SAF is estimated to roughly the double of fossil jet fuel, both being subject to significant uncertainty. Hence, the EU ETS savings is minor to the uncertainty on the price differential between SAF and fossil jet fuel.

An overview of the model used for the calculations is illustrated in the Figure 3.

Figure 3 Diagram representation of the structure of the calculation model



The resulting changes in CO_2 emission are obtained primarily by substituting fossil jet fuel with SAF, but also from demand reduction to the extent that cost increases are reflected in ticket prices. Demand changes are calculated assuming a pass-on rate of 100% of increases in airlines' operating costs including taxes and using literature-based price elasticities. Elasticities are differentiated on destination type ranging from –0.7 for domestic to –0.4 for intercontinental trips which reflect among other things that other modes are better substitutes for shorter distances. A main challenge in estimating demand impacts of the policy scenarios by price elasticities 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 are described in Appendix A.

Results

Table 3 gives a comparative overview of the results of the calculations for the four scenarios. The highlighted (light blue) rows list the total results for all destinations whereas the results below are split on each destination type. The calculated impacts vary significantly across domestic flights, flights to other Nordic countries, to rest of Europe and to the rest of the world.

Table 4 Comparison of the impact of four alternative policy scenarios

Nordic Policy Measure	Ticket price [%]	Demand change [%]	CO_2 emissions [%]	Tax revenue [bill. EUR]	Extra fuel costs [bill. EUR]
(A) Blending requirement [30%]	**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%]	**-6%**	**4%**	**-28%**	**-**	**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) CO_2-based fuel tax [0,33 EUR / litre]	**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]	**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 illustrated in Figure 3.

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. Still, Table 4 shows that for all scenarios 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 scenarios (C) and (D) and 9% for trips to the rest of the world in (D). 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 Nordics[5]. However, the share varies very much across routes because of the

[5] 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.

previously mentioned big variations in ticket prices, passenger numbers, competitive situation, low-cost carrier share, etc.

In addition, Table 4 shows the following results for the individual the scenarios:

(A) The scenario with a blending mandate of 30% SAF for all flights form the Nordics results gives a reduced jet fuel consumption and CO_2 reduction of 30%. The increased fuel costs incurred on airlines results 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 Swedish and Norwegian passenger taxes and the Norwegian CO_2 tax. Consequently, the total Nordic 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 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 CO_2 emissions. This is because the additional fuel costs are financed by Government budgets so that the cancelling of national policies leads to an on average 5% decrease for ticket prices for flights to all regions driving 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 and Norway, the CO_2 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 CO_2-based fuel tax corresponding to 0.33 EUR per litre results in a rather limited CO_2 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 CO_2 emissions from Nordic aviation[6]. 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 CO_2) fuel demand will shift toward SAF and thereby lead to significantly higher CO_2-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, in the passenger tax scenario the common passenger tax at 10.43 EUR per departing passenger for flights within EEA and 58.63 EUR per passenger to destinations outside EEA are 50-100% higher than the average of the Norwegian and Swedish levels. As for the fuel tax scenario the passenger tax scenario results in significantly lower CO_2 reductions than for scenario (A) and (B), both directly targeting replacement of fossil jet fuel by SAF. But with a CO_2 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 CO_2-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 billion EUR per year. As opposed to fuel taxes, higher passenger tax rates will not be pave the way for substituting fossil fuel with SAF. The CO_2 reduction effect will only stem from reduced demand due to higher ticket prices.

[6] Own estimate based on the model calculations.

To conclude …

The two taxation scenarios (C) and (D) do not reach CO_2 reductions anywhere near the 30% and 27% in two SAF blending scenarios (A) and (B). Indeed, it is in practice close to impossible to achieve reductions at that level by increasing the rates of the passenger tax, because it only reduces CO_2 emissions by lowering air travel demand. Even a passenger tax corresponding to about three times average Swedish and Norwegian tax would only lead to a total fuel and CO_2 reduction of about 6%.

If the same tax burden was instead levied as a fossil fuel tax on all flights (and not only within the Nordics) the overall air travel demand reduction would be about the same. The tax rate would amount to 0,585 EUR/litre or 230 EUR per ton CO_2, which would be exactly enough to overcome the price premium for SAF and, hence, make it profitable to replace (all) fossil jet fuel with SAF[7]. This implies that the fuel shift would be the dominant effect overshadowing the demand reduction which merely adds to the reduction to the extent that SAF upstream emissions matters.

However, as a Nordic initiative a fossil fuel tax is an ineffective measure because the EU Energy tax directive in practice confines its application taxes to intra-Nordics flights which only accounts for about one third of the total CO_2 emissions from Nordic aviation.

Regulatory advantages and disadvantages of the policy measures

The previous section estimated the quantitative effect of the four types of policy measures on CO_2 emissions via demand impacts as well as replacement of jet fuel with SAF. This section regulatory advantages and disadvantages in a broader perspective but also taking the quantitative CO_2 effect. A more detailed review is presented in the report Nordic Sustainable Aviation (Ydersbond et.al., 2020).

A blending mandate (A1) can secure substantial use of SAF, even if implemented by the Nordics alone. Measures that will secure substantial use of SAF are necessary to obtain significant CO_2 reductions toward 2030. By increasing fuel costs these measures will at the same time indirectly give (some) incentives to reduce travel demand and save energy. However, as for any regulatory measure that increases airlines' fuel price this effect is a 'two-edged sword' as it at the same time creates risks of ‘tankering’ and other leakage effects such as displacing operations abroad. Any regulatory measure 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 reinvestments

A CO_2 reduction requirement (A2) works in similar way as a blending mandate and a. The main difference will be that the CO_2 reduction requirement will potentially give a more cost effectively global CO_2 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. The disadvantage is that the administrative costs to documentation, control and audit are higher. Typically, a CO_2 reduction requirement (or blending mandate) is levied on fuel suppliers and is not imposed on every litre of fuel but as an average for all fuel delivered during a year from all airports for logistic efficiency reasons.

[7] Fuels for aviation are certified according to strict standards for obvious performance and safety concerns. In 2020 only six production pathways were certified and none of them have a blending level above 50%. But certified blending levels are expected to be significantly higher in the future.

A SAF fund (B) eliminates the cost premium of the SAF and thereby avoids the risk of leakage but also eliminates the incentives to reduce travel and improve energy efficiency. Tendering of long termed purchasing or price guarantee contracts can be a strong tool to secure market demand and thereby lower investors' risks. Such long termed contracts can be particularly relevant to underpin political commitment in early phase of a gradual phase-in scheme with low SAF shares for the first years to allow production to ramp up. A main disadvantage of a SAF fund is that it demands funding, which will of course have costs elsewhere in society and thereby violates the fairness of the 'polluter-pays-principle'.

A fossil fuel tax (C) targets GHG-emissions directly and is therefore considered as an appealing general measure to consistently creating equivalent incentives for cross sectoral cost-effective CO_2 reductions. In aviation a fossil fuel tax creates incentives for travellers to reduce travel demand and for airlines to improve energy efficiency of operations and, in principle, also for shifting to SAF. For a fuel tax to induce significant shares of SAF the rate has to be set high enough to eliminate the cost premium of SAF. If it is lower than that there will be no incentive to substitute fossil jet fuel with SAF. This means that a fossil fuel tax is not a suitable measure to promote a gradual phase in. In addition, the high levels of uncertainty relating to the future price of both fossil jet fuel and, in particular, of SAF complicates fixing the adequate tax rate which eliminates the price premium without being excessively high.

Further, a common Nordic fuel tax regime will only apply to flights within the Nordics due to international legislation. These flights stand for only about one third of total jet fuel consumption, which severely limit the potential of a fuel tax as a Nordic measure for reducing total CO_2 emissions both via SAF substitution and demand driven reductions.

A passenger tax (D) is a rather blunt instrument for promoting sustainable aviation. It will only reduce CO_2 emissions through lower demand and will not create incentives to fuel savings nor use of SAF. Hence, rates have to be unrealistically high to result in a significant CO_2 reduction. A clear advantage of a passenger tax is that it avoids the issues of climate leakage from tankering incentives created by measures that increases fuel costs. The administrative costs are considered relatively low, and it is already implemented in several Nordic and neighbouring countries.

Comparative assessment of the five policy measures

This section gives an overall comparative assessment of the five policy measures. The qualitative assessment of the advantages and disadvantages of the five policy measures above and the quantitative analyses of the effects on costs, ticket prices, air travel, CO2 emissions in the previous section is synthesised into the twelve indicators presented below:

- **Overall CO_2 impact:** To what extent can a joint Nordic implementation contribute to significant reductions of CO_2 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**, incl. 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 legislation or international conventions and agreements?

For each of the twelve indicators the comparison is based on the ordinal scores "YES" > "yes" > "no" > "NO" which are to be interpreted as an assessment of relative ranking internally among the five policy instruments. The ranking is extracted from the analyses presented above and not derived from exact criteria. Hence, refinements of the scores can be debated. The comparison is summarized in the table below.

Figure 4 Comparative assessment of five policy measures for sustainable aviation

Assessment of measure with regard to:	SAF blending requirement (A1)	CO2e reduction requirement (A2)	SAF Fund (B)	Fuel tax (C)	Passenger tax (D)	SAF fund & Passenger tax (B+C)
Overall CO2-reduction impact	YES	YES	YES	yes	yes	YES
Flights to outside the Nordics	YES	YES	YES	NO	YES	YES
Reducing demand: Fewer trips Shorter distance	yes	yes	NO	YES	YES yes	YES yes
Fuel efficient operations (1)	yes	yes	NO	YES	NO	NO
Using (more) sustainable fuels	yes	YES	YES	yes	NO	YES
Market creation for SAF	yes	yes	YES	no	NO	YES
Avoid leakage risks (2)	NO	NO	YES	no	yes	yes
Government budget revenue	no	no	NO	yes	YES	yes
Polluter-pays-principle	yes	YES	NO	YES	yes	yes
Cost effectiveness	NO	no	yes	YES	NO	yes
Administrative burden minimised	no	NO	yes	no	yes	yes
International regulation compliance	YES	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 CO_2 reduction requirement because the fuel tax is assumed to be imposed only for flights within the Nordics.

The overall picture from Figure 4 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 will only reduce CO_2 emissions through lower demand. This implies that rates have to be unrealistically high to result in significant CO_2 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 CO_2 reductions will require a blending or CO_2 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 absent in the case of a SAF fund because it 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 5 presents an assessment of a combined SAF fund and a passenger tax along the same lines as for the single measures in Figure 4. 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. In addition, even with today's fuel costs the incentive to minimize fuel consumption is very significant

Figure 5 Assessment of SAF fund & earmarked passenger tax

Assessment of measure with regard to:		SAF fund & Passenger tax (B+C)
Overall CO2-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 4.

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.

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;
- 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.

The revenue figure is the full revenue from the tax, i.e. the lost revenue from the discontinuation of current Swedish and Norwegian taxation is not deducted. Similarly, average ticket price increase would only be about 1% if we compare with current price level including the existing Swedish and Norwegian taxes, and for domestic trips within Norway ticket price would actually be reduced by about 6% due to the removal of the fuel tax.

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.

Conclusions

Available propulsion technologies and current expectations to technological development in the next decades clearly indicates that replacing a share of fossil jet fuel to sustainable aviation fuels (SAF) is essential if the climate impact of aviation should be significantly reduced toward 2030. In a longer perspective, fully electric aircraft holds potential to contribute on shorter flights and hydrogen powered novel aircraft types might also be developed for longer distances. However, technology readiness levels of alternative propulsion technologies are low. Adding slow replacing rates of airplanes due to long service life replacing the fossil jetfuel by SAF appear to be the predominant option for decarbonising aviation toward 2050 supported by expectedly strong progress in energy efficiency.

Supply-side measures with a long-term perspective are needed to the currently immature market for SAF. Produced volumes are insignificant compared the total consumption of jetfuel with a main constraint being that the price is several times higher than fossil jetfuel. A political commitment to implement a certain share of SAF can reduce investors' risk. An early announcement of a target share in 2030 can establish economically attractive and stable framework conditions for the significant financial investment in large scale production plants, which is necessary to bring down unit costs and increase production volumes to a scale with impact. Starting at very low levels and increasing progressively toward e.g. 30% in 2030 can allow for a gradual ramp up of supply based on large scale production.

Demand-side measures in terms of national or joint Nordic taxes will per se have limited effect. Fuel taxes can only be levied on intra-Nordic flights, and passenger taxes provide no incentive for airlines to reduce fossil jet fuel consumption. For both tax measures the reduced fuel consumption from the induced demand reduction will be small compared to the potential from direct regulatory approaches securing a SAF share of total jet fuel consumption.

A SAF blending mandate and the variant CO_2 reduction requirement are narrow measures targeted at obtaining a certain SAF share and as such effective to reduce CO2 emissions. But they involve a certain risk of evasive airline behaviour in terms of tankering and displacement of operations to airports just outside the area. The disadvantage of this behaviour is bigger the smaller the geographical area covered by the regulatory measure. The '*RefuelEU Aviation'* proposal from the European Commission put forward a gradually increasing blending mandate fo SAF, but at a slow pace with very limited impact on aviation's CO_2 emissions toward, if adopted. A SAF fund can eliminate the incentive to evasive behaviour by compensating the cost premium of SAF for airlines, and the tendering process allows for flexibility to accommodate the suppliers' development of the production capacity in the pathway toward the target set for 2030. The drawback is that a fund requires financing and apparently violates 'polluter-pays-principle'.

Policy recommendations

The paper's overall recommendation for a common Nordic policy to promote a certain SAF-share of total jet fuel consumption is to establish a SAF fund financed by earmarked passenger taxes on all aviation. The combined measure compensates for their individual weaknesses by minimising carbon leakage from tankering and providing a financing mechanism for the additional costs of a significant SAF-share. The scheme should be announced as early as possible and implemented gradually over a decade.

Our model calculations indicate that as an order of magnitude harmonized passenger tax rates for all Nordic countries corresponding to the average of the Norwegian and Swedish levels can finance a SAF fund of 30% of fuel consumption in current Nordic aviation. A harmonised Nordic policy framework can make a difference because the total Nordic consumption of jet fuel is by far more than times that of any single Nordic country. In addition, leakage by evasion by shifting operations is minimized by the large the geographical area covered by the same regulatory measure and the fact that the biggest neighbouring countries Germany and Great Britain also have passenger taxes and at higher rates.

Finally, when deciding on common Nordic initiatives for sustainable aviation the global dimension of climate change should be kept in mind. 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 optimised.

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Appendix A Input data to the calculation model

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

1. **Domestic:** Flights within each Nordic country
2. **Nordic:** Flights to other Nordic countries
3. **Europe:** Flights to the rest of the Europe
4. **World:** Flights to the rest of the world

Passengers and Available Seat Kilometers (ASK). Great circle distances for each flight from www.gcmap.com is used to generated 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 www.momondo.dk by taking the average of the highest and the lowest monthly prices for each of 25 routes (from the sub-page "Prisindsigt" for each route). 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.

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 above:

- 1a. A high-volume domestic route
- 1b. A low volume domestic route
- 2. A main Nordic route
- 3. A frequent European route
- 4. A direct intercontinental route

All five types of routes are for each of the five Nordic countries.

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(distance) between flight distance and typical fuel consumption per passenger. F(distance) is then applied to calculate average fuel consumption for each of the four regional destination segments.