Summary

Accelerating the phase in of electric aircraft in Norway

Possible societal impacts and policy instruments

TØI Report 1851/2021
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Oslo 2021 137 pages Norwegian language

Given the ambitious climate goals set by Norwegian authorities, and given the desire to maintain current air travel activity, one of the solutions for achieving the goal may be to start replacing conventional aircraft with zero-emission aircraft over the next ten years. With an attempt to speed up the phasing in of electric planes on a route in Norway, the Bergen–Stavanger (BGO–SVG) seems like a promising case. The report concludes that investing in a demonstration case for electric planes between Bergen and Stavanger can be expected to have greater net benefits than not investing.

In several international agreements, the Norwegian authorities have committed to drastic emission cuts and have also set national targets for such cuts. We assume that the Norwegian authorities have intentions to comply with these obligations. It is an important premise for the entire report that current and future governments should keep their promises of emission cuts.

To achieve the ambitious climate goals Norway, with sustained travel activity, it is proposed to start replacing conventional aircraft with zero-emission aircraft over the next ten years. For Norway, battery-electric electric aircraft seems as a promising zero-emission option.

With an attempt to speed up the phasing in of electric planes on a route in Norway, the Bergen–Stavanger (BGO–SVG) seems like a promising case, for several reasons:

1) Short distance – only 160 kilometers by air (considering that first generation battery electric aircraft are estimated to have approximately 350–400 km of efficient range)
2) Relatively large customer base – approx. 550 000 passengers annually
3) Aircraft are highly competitive in terms of time – the options take a long time

Given that electric planes are being phased in on the Bergen–Stavanger route, experience will be invested in infrastructure and experience will be gained earlier than would otherwise have been the case. It is reasonable to expect that this will lead to the phasing in of electric planes elsewhere in the country, and perhaps also in other countries, will begin earlier, compared to what will force its way sooner or later due to increasingly tight climate policies both nationally and internationally. Exactly how much earlier phasing in of electric aircraft in ordinary passenger transport will begin if an electric flight BGO–SVG is established, and whether there would be any difference in the phase-in rate is impossible to establish. What we can do is try to concrete a plausible reference scenario and a plausible acceleration scenario, and to make some rough calculations based on that.

We base ourselves on the objectives set by Avinor and the Civil Aviation Authority (2020): 1) By 2030, the first ordinary domestic scheduled flights will be electrified. 2) By 2040, all civil domestic aviation in Norway will be electrified, reducing greenhouse gas emissions by at least 80% compared to 2020.

If emissions trends in domestic aviation are flat through the 2020s, and 80% of emission cuts are to be made through the phasing in of electric aircraft in 10 years, the average reduction rate in the years 2030–2040 must be about 13.5% per year. If there are no successful demonstrations with electric planes in the 2020s, the phasing in of electric planes from 2030 onwards seems very optimistic.

Thus, in the reference scenario, in the absence of a successful demonstration case, the phasing in of electric planes is expected to begin in 2035, with a 13.5% reduction in greenhouse gas emissions per year thereby. Compared to Norwegian aviation's 2019 emissions, emissions in 2040 will thus be 58% lower, not 80%, which is the target.

In the acceleration scenario, we assume that the first experiences with electric aircraft on the BGO–SVG route will be successful and that players in the domestic aviation market will start the same phasing in of electric aircraft as in the reference scenario, but 5 years earlier, i.e. in 2030. The phase-in rate in the acceleration scenario is also assumed to be identical to that in the reference scenario, with an annual emission reduction rate of 13.5%.

The implications of these assumptions are that over the period from the time the phase-in begins in the reference scenario to the phasing-in would have been completed in this scenario, the acceleration scenario will in total entail reduced greenhouse gas emissions equivalent to 5 years of emissions from the entire domestic aviation sector before the phasing in of electric planes. With the continuation of the emission level from the years before the pandemic, this will correspond to approximately 6 million tons CO_2 equivalents ($MtCO_2e$).

How will travelers and businesses perceive such an alternative with electric aircraft?

A sample of transport users traveling between Bergen and Stavanger (in the period 2019–2021) have been asked about travel activity, attitudes and preferences for a future electric plane option on this route. This sample of 1,000 people is expected to reflect the views of the underlying population of transport users between the Bergen area and the Stavanger area.

The majority of the sample is positive about a future electric plane alternative. The negative effect of an increase in flight time of 10 minutes, on the willingness to choose the electric option, was relatively small. Respondents under the age of 30 were most positive about electric planes as a future transport option between Bergen and Stavanger, while those over the age of 50 were the least positive.

The majority who took a positive approach to electric planes as an alternative mode of transport between Bergen and Stavanger will not necessarily be willing to pay more for an electric plane alternative than for a conventional aircraft. This is to be expected, as many have economic conditions as the main factor for why they choose one transport option over another. However, some respondents express a high willingness to pay. Among those who were positive about electric planes, we get an estimated average willingness to pay a price increase up to 20 per cent for electric planes per se. However, the majority of those who initially make a positive approach to flying electric planes are *not willing* to pay more to travel by electric plane than to travel on other aircraft.

In the minority who set themselves negatively or undecided to electric planes as an alternative mode of transport between Bergen and Stavanger, a share will probably be "tempted" with a lower price to travel by electric plane rather than with other aircraft. Nevertheless, even with a 90% relative price reduction, i.e. price reduction in an electric plane ticket BGO–SVG compared to a plane ticket with an ordinary aircraft SVG-BGO, about half will not choose the electric plane option. The average compensation requirement for passengers will thus be large – we estimate a willingness to pay for electric planes is 60-70 per cent lower than for conventional aircraft.

If we look at the entire sample in context, the positive as well as the negative/undecided, we will find that (a weighted) average willingness to pay is barely higher than 0%. If travelers *are* *given the choice* between electric and conventional aircraft, those with a higher willingness to pay for electric planes will be able to self-select themselves for electric planes. We expect this, all else being equal, will contribute to an improvement in travelers' consumer benefit.

We also conducted a survey for 16 businesses in the Bergen area and the Stavanger area. The main finding from this survey points to a positive attitude towards the development of an electric flight route on this route. The biggest challenge is to document and convince this business market that electric flights are safe and hassle-free, to have electric flight safety approved as a safe mode of transport by, as well as to clarify positive environmental effects.

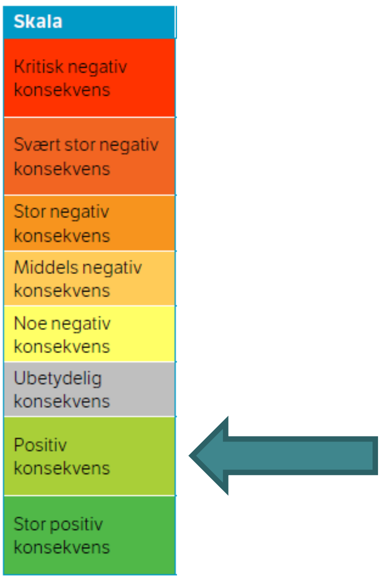
Main conclusion

Since the development of electric planes is at such an early stage, there are major challenges in value the cost effects and benefits of an accelerated phasing in of electric planes in Norway. Therefore, the cost-benefit analysis is more qualitative than is usual in e.g. road development, and it is presented as a so-called multi-criteria analysis, with both priced and non-priced effects.

The multi criteria analysis is summarized in Chapter 8. We assess the magnitude of the valued environmental benefits, as well as the number and magnitude of the non-priced positive effects, against the number and magnitude of the non-priced costs and negative effects. We follow the guidance from the Norwegian Public Roads Administration (2018) on how to place the net effect on the scale from Critical negative consequence to Great positive consequence.

We conclude that initiating the SVG–BGO2025 demonstration case, which will significantly increase the likelihood of realizing the acceleration scenario rather than the reference scenario, can be expected to have:

Positive consequence – The option will be better than the reference option



In other words, we expect that investing in a demonstration case for electric planes between Bergen and Stavanger will have greater net benefit than not investing. This is the report's main conclusion.

Table S.2: Multi-criteria table with sources in parentheses.

Nyttekomponent	Valuation (present value)/ assessment of non-priced effects
Emission cuts CO_2 and NO_X from the SVG–BGO2025 demonstration chapter (Chapter . 5)	Up to NOK 2 million
Emission cuts CO_2 in acceleration scenario (Ch. .5)	Up to NOK 13,670 million
Cuts in other climate effects in the acceleration scenario (Chapter . 5)	Up to NOK 10,940 million
Emission cuts NO_X in the acceleration scenario (Chapter . 5)	Up to NOK 323 million
Insurance against worst case future climate action costs (Chapter 7)	++/+++
Insurance against a lack of political will and the ability to set the necessary carbon price in Norway (Chapter 7)	++/+++
Benefits from noise reduction – reduced health costs and land-value capture (Chapter 7)	+
Electric aviation is an immature technology and there is little experience on commercial routes, so there will be a need for RD&D. Successful demonstration and faster upscaling can help to faster create a market for zero-emission technologies globally. (Chapter 7)	+/++
Benefits for future electric flights from other airports – network benefits (Chapter 7)	+
Extended toolbox for regional policy, which can also reduce the need for investments in road and railways (Chapter 7)	+/++
Increase in consumer surplus (Chapters 4 and 7)	0/+
Cost component (and negative benefits)	**Assessment of non-priced effects**
Additional costs when shifting to electric aircraft from conventional aircraft in the demonstration case (Chapter 7)	-
Additional costs related to five years accelerated phasing in of electric aircraft (Chapter 7)	---
Additional costs related to five years accelerated the construction of charging infrastructure (Chapter 7.)	--
Cost of public funds (Chapter 7)	-/--
More polluting use of resources in the production of electric aircraft (Chapter 7)	-

A larger study at a later date with more knowledge and experience with the growing electric aircraft sector may provide a more concrete presentation of net benefits. The conclusion of the multi criteria analysis, on the other hand, provides a basis for initiating measures that actively support the advancement of zero-emission aircraft and/or make conventional flights more expensive.

An important caveat to the conclusion is that even if a SVG-BGO2025 demonstration case is initiated, there is no guarantee that all the reviewed benefits from an acceleration scenario will be realized. There is always a risk that you may be left with more on the cost side and less on the benefit side. On the other hand, uncertainty can also pull in the opposite direction. There is also the possibility that the net benefit effect will be even greater than outlined here, if, for example, the technology development of electric planes and the necessary infrastructure goes faster than expected.

Advantages and disadvantages for the business sector in Norway in general and in the Bergen–Stavanger region especially by accelerated phasing in of electric planes

Many of the players in the aviation ecosystem believe that they can benefit from a green transition where different types of electric aircraft are increasingly being used. For example, they argue that electric airlines will be able to help support green tourism, sustainable work trips and new business opportunities for companies developing technology. Industry players also believe that electric planes will make it faster and cheaper to transport time-critical goods to and from near and far areas, compared to trucks. Representatives of many small towns and villages that currently have short-haul airports envision that passenger routes by electric plane can help to provide better conditions for the business community and society there, because in the long term it can result in more departures and lower prices for the transport of people and goods, as well as more tourism.

In the small aircraft segment, where small electric planes will be able to have the same number of seats as a conventional small aircraft, the players expect electric planes to have cost advantages in the form of lower energy costs, without losing scale advantages. On short distances, the players envision that electric planes could constitute a type of "taxi bus", especially based on electric sea planes that can serve towns and cities close to water, thus making electric planes extra useful for business travelers with a high willingness to pay and tight schedules. A market for electric planes "on demand" may also open up for a market segment with high ability to pay.

The players believe that investment in electric planes on the Bergen–Stavanger route in particular can help the Norwegian aviation sector, airlines and the supplier industry to achieve niches in the electrified aviation market internationally as well. The argument is that this can be achieved by giving the various actors in the "ecosystem" around air transport early expertise and making early investments in different types of infrastructure that can later be scaled up, such as charging and maintenance infrastructure. The players believe that different companies in the area will benefit from cooperation around the technology that can give rise to value-added industry cluster effects.

The agents we have interviewed indicate that the biggest winners in a large-scale introduction of electric aircraft will be the business sector in the regions that have electric flights and the operators of electric planes. If electric planes are significantly subsidized, some of the travelers may also receive lower generalized costs, meaning that those who already fly will receive lower ticket costs (which more than compensate for any increased flight time) and those who can switch from car/train/ferry/bus to aircraft will also be expected to have reduced travel time to their destinations. The groups that may lose out on the acceleration/subsidy of electric planes are operators of train, ferry and bus lines that receive competition from electric planes, including those who prefer trains/ferries/buses if the route is reduced/removed. Conventional aviation fuel suppliers will also face additional challenges.

Instruments for expedited phasing in of electric planes in Norway in general and between Stavanger and Bergen in particular

In order to accelerate the phasing in of immature technologies such as electric aircraft technologies, concrete, overarching political objectives, with associated specific strategies at the national level, and preferably also Nordic and European levels, will first need to be established. Such objectives must be enshrined in management strategies such as the National Transport Plan, the Government's climate plans, and the future planned aviation strategy. At the Nordic level, it may be necessary that such objectives are enshrined in the plans of the Nordic Council of Ministers. In Norway, as of 2021, national targets for electrification of aviation are not adopted. One possibility is that the Norwegian authorities are making the targets that Avinor and the Civil Aviation Authority have already proposed to national targets.

The fact that specific national targets are set for the accelerated phasing in of electric aircraft in Norway may in itself be important for achieving targets nationally. But it is likely to give a strong political boost if the Nordic governments *together* create common goals and strategies for electrification of aviation than if only one of the countries does. If the Nordic countries can point to an expedited phasing in of electric aviation, it can be expected to inspire the setting of similar goals for electric aviation at EU level.

The accelerated investment in electric aircraft requires, among other things, that it must pay for the airlines to operate electric aircraft, and that the manufacturers of electric passenger aircraft feel confident that there is a future market for them, so that they invest the resources needed to go through the demanding process of getting the electric planes certified and developing the technology further after the certification.

Norwegian electric car policy has shown that significant tax exemptions can help speed up the use of battery-based alternatives. Economic instruments to *support* the operation of electric planes may include exempting electric planes from taxes such as passenger duty, starting fees and landing fees in Norwegian, Nordic and possibly also European levels for a phase-in period up to 2040. Exemption from value added tax on tickets for zero-emission aircraft until 2040 is another measure that the informants believed would be important.

Economic instruments that support *the procurement* of electric planes may lie in the state, via Enova, Innovation Norway or others, providing[3] support for the purchase of new electric planes, or possibly buying new electric planes and lending them to airlines. These may be solutions that make it easier for airlines to invest in this new technology at an early stage.

The interviewed agents were very positive about *a combination of instruments*, such as requirements for electric planes on public service air routes in combination with investment support, residual value guarantees and increased contract length. [4]*Charging infrastructure* for battery-electric aircraft was also something the interviewees believed could need financial support, as it is a significant acquisition cost to establish such charging infrastructure at the country's airports.

In addition to supportive instruments, the profitability of electric aircraft will also depend on the tax pressure on conventional aircraft. A restructuring of the policy instruments to stimulate the development and use of low- and zero-emission aircraft may be an opportunity to address some of the existing bias in the use of taxes in aviation, including the under-taxation of flights into and out of the EU-ETS area. The Norwegian air passenger tax for travel out of Europe is significantly lower than the emission cost of such flights, with the current valuation of CO_2emissions, which means that longer flights are favored to a much greater extent than relatively short journeys within Europe. This is economically inefficient. In other words, there is good reason to consider increasing air passenger tax for travel out of Europe, so that there is more consistency between the private incentives and society's. The recommendations of the *Nordic Sustainable Aviation* report on imposing the fee for travel out of Europe at the German level (approx. 58 Euro) will some way on the way remedy this bias. Increased tax revenue for the use of conventional aircraft may be considered to finance instruments to stimulate low- and zero-emission aircraft, for example through a climate fund (ideally at the Nordic level). Earmarking the revenue to stimulate green technologies can contribute to an increase in acceptance of taxes.

A Norwegian/Nordic climate fund can be used to develop different climate solutions in the air travel sector, be it through payment of the difference between conventional aviation fuel and advanced biofuels/e-fuels, or through stimulating electrification. The fund may also be used to stimulate research and innovation to reduce greenhouse gas emissions from aviation

[3] As with their zero-emission fund.

[4] Means commitment to public services.

and possibly also support the surrounding commercial activity of air transport. The fund could also be used to finance an innovation center for electric aircraft, as proposed by Avinor, the Civil Aviation Authority, SINTEF and the Federation of Norwegian Industries.

Recommendations

Given that the Norwegian authorities wish to focus on expedited phasing in of electric aircraft in Norway, the following points may be relevant:

- **National targets** for emission cuts in the aviation sector and for phasing in zero-emission aircraft will provide the most important policy framework for speeding up the transition. The objectives proposed by Avinor and the Civil Aviation Authority (2020) may form the basis for such national goals.
- If the planned aviation strategy signals that the **carbon tax** for domestic aviation will continue to rise after 2030, in line with a carbon price path necessary to comply with the Paris Agreement, then it will strengthen aviation's own incentive for transitioning.
- Another shift in favour of the competitiveness of electric planes is **the exemption from air passenger duty for zero-emission aircraft** over an extended period of time. The tax is also partly motivated by climate change considerations. The detailed regulation of this (including how to stay within the rules on public funding) must be investigated further.
- Applied national CO_2-values imply **increasing air passenger duty for flights out of Europe for conventional aircraft**, so that the ticket price should better coincide with theCO_2-costs incurred (as has been the case for flights within Europe before the pandemic). This is also recommended in *Nordic Sustainable Aviation.*
- It can be considered to use the tax revenue from the air passenger tax to fund a **climate fund** for aviation, either nationally or perhaps preferably at the Nordic level. Such a fund could be used to support the measures that provide the most emission cuts and technology development for the money. This may be in biofuels, electrification, including support for both procurement and operations, as well as research and development. It may also include an innovation center for electric aircraft. The detailed regulation of this may need to be investigated further.
- Public support for **the development of charging infrastructure** for electric aircraft at Norwegian airports provides network benefits, so it is also relevant to consider as measures to accelerate the phase-in. The detailed regulation of this may need to be investigated further.
- Another element is the **emission requirements set by the aviation authorities for the FOT routes** (public service routes); where strict requirements can increase the pace of new technology phasing in. The aviation authorities should thoroughly follow up the experiences made with this new technology. The detailed regulation of this may need to be investigated further.
- We find that accelerated phasing in of electric planes through a successful demonstration case for the Bergen–Stavanger route is expected to have a positive net benefits. This could imply **public support for such a demonstration case**-including public funding of the charging infrastructure.

