The need for e-SAF in Scandinavia

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SAS Aviation Insights
No. 6 | 2026

Preface

The transformation of aviation toward a more sustainable future is accelerating. As an industry, we are entering a new era where cleaner energy sources are no longer optional but fundamental to long-term competitiveness and climate responsibility. The introduction of the e-SAF RefuelEU Aviation blending mandate in 2030 marks a decisive step in this transition, setting clear expectations for the deployment of e-Sustainable Aviation Fuel (e-SAF) across Europe.

This transformation is far greater than the aviation industry. Recent events have shown the imperative of creating energy independence from fossil fuel. As EU Energy Commissioner Dan Jørgensen rightly stated recently when presenting the AccelerateEU initiative: “This must be a wake-up call and a turning point – when Europe steps away from fossil fuel dependence, and steps towards clean energy autonomy.”

Because now it is more obvious than ever – clean energy means security. And the full value chain from producing renewable electricity, transporting it and refining it to jet fuel and other fuel types is the very core of the European clean industrial ambitions.

Understanding the cost implications of this shift is essential. E-SAF holds significant potential to reduce lifecycle emissions and strengthen Europe’s leadership in sustainable aviation, but it also presents substantial financial and operational challenges. As this report shows, the emerging supply chain, evolving regulatory framework, and the need for new production capacity will all shape the cost of e-SAF in the years ahead.

Our ambition is to contribute to a fact-based dialogue on how the aviation sector can meet climate targets while maintaining connectivity, competitiveness, and growth. Transparent analysis is vital for informed decision-making — across industry, policymakers, and society at large.

I would like to thank everyone who contributed their expertise to this report. By deepening our understanding of the cost drivers and market dynamics of e-SAF, we take an important step toward preparing the sector for the mandate and supporting the investments required for a sustainable future.

Mads Brandstrup Nielsen
Senior Vice President Communication
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Main insights

- The e-SAF blending mandate begins in 2030, creating a requirement for approximately 36,000 tons of e-SAF across the three Scandinavian countries.
- By 2032, this demand increases to more than 60,000 tons.
- When the mandate rises to 5% in 2035, the need reaches around 160,000 tons, growing further to approximately 330,000 tons by 2040.
- This would require the output of one dedicated plant by 2032, increasing to 2–3 plants by 2035 and around 5 plants by 2040.
- The market price of e-SAF will mostly depend on whether the market is short (supply below demand) or long (demand below supply)
- In a short market the e-SAF price will in theory be close to the cost of non-compliance. This could result in a premium price of around €23,000/tons. This can be compared to the normal price of conventional fuel of €700–€750/tons
- Based on a cost price estimated by EASA in 2025, the market price premium in a long market would in a best-case scenario be around €6,000/tons in 2030.
- The total cost of e-SAF in Scandinavia in 2030 will based on the assumptions above be between €225 million and 850 million. This will in 2035 increase to €950–€3,800 million, and €1,850 million–€7,800 million in 2040.
- The cost per passenger in Denmark will be 27–105 DKK in 2030, 104–421 DKK in 2035 and 189–803 DKK in 2040.
- The cost per passenger in Norway will be 28–107 NOK in 2030, 105–424 NOK in 2035 and 190–806 NOK in 2040.
- The cost per passenger in Sweden will be 34–130 SEK in 2030, 129–520 SEK in 2035 and 233–989 SEK in 2040.

Photo credit: Kasper Meldgaard

Background

To achieve net zero aviation by 2050, a combination of technologies will be required. A central element of this transition is the increased use of sustainable aviation fuels (SAF), including several different fuel pathways that are compatible with today's aircraft fleet[1].

Producing sustainable aviation fuels requires a variety of feedstocks. Today, the most widely produced SAF is HEFA (Hydrotreated Esters and Fatty Acids), which is primarily derived from used cooking oil and other waste fats. Additional bio-based pathways also exist, using feedstocks such as agricultural residues, dedicated energy crops, and the renewable fraction of municipal solid waste[2].

Another key SAF production pathway is based on Power-to-Liquid (PtL) technologies. In contrast to bio-based fuels, PtL fuels are produced from renewable electricity, water, and captured CO_2. Electricity and water are first converted into hydrogen via electrolysis. This hydrogen is then combined with CO_2 to produce syngas, which can be refined into aviation fuel either through the Fischer–Tropsch (FT) synthesis route or the Methanol-to-Jet (MtJ) pathway — the latter currently advancing through ASTM D4054 certification[3]. Because PtL fuels do not depend on biomass feedstocks, they represent one of the most scalable long-term options for expanding sustainable aviation fuel production.

Power-to-Liquid (PtL) based SAF is also known as e-SAF, electrofuels, or e-fuels. Under the ReFuelEU Aviation regulation, these fuels are classified as 'Renewable Fuels of Non-Biological Origin' (RFNBOs).

As outlined in the next section, the EU's ReFuelEU Aviation regulation introduces a mandatory e-SAF/RFNBO blending requirement in jet fuel beginning in 2030. This obligation establishes a guaranteed market for these fuels and provides a more stable foundation for investments in new e-SAF production capacity. The growth of this emerging sector also offers an opportunity for regions and countries to stimulate economic activity and create new high-quality jobs.

Developing e-SAF production in Scandinavia provides several additional advantages. It offers the aviation sector closer access to fuel supplies, lowering transport-related costs and emissions. It also enhances regional supply security, giving Scandinavian airlines and airports greater certainty and resilience in fuel delivery.

This report estimates the future demand for e-SAF in Scandinavia based on projected jet fuel uplift in the region over the coming years. It also assesses the potential cost implications for both airlines and per passenger.

The cost impact on airlines and passengers will depend heavily on the price of e-SAF, which in turn relies on the development of sufficient production capacity and a competitive market capable of delivering cost-effective supply. A well-functioning market is essential to ensure prices that support the continued growth of the aviation sector. It is important to note that no Final Investment Decisions (FIDs) have yet been made for any e-SAF projects in Europe, underscoring the early stage of market development.

[1] At present, aircraft can use up to 50% Sustainable Aviation Fuel (SAF), but this limit is expected to increase in the future. Achieving higher blend levels will require adjustments to the engines.
[2] Produced with Alcohol to Jet (AtJ) and Biomass Gasification with Fischer-Tropsch (Gas+FT)
[3] Source: EASA What are Sustainable Aviation Fuels? | EASA

What is RefuelEU Aviation?

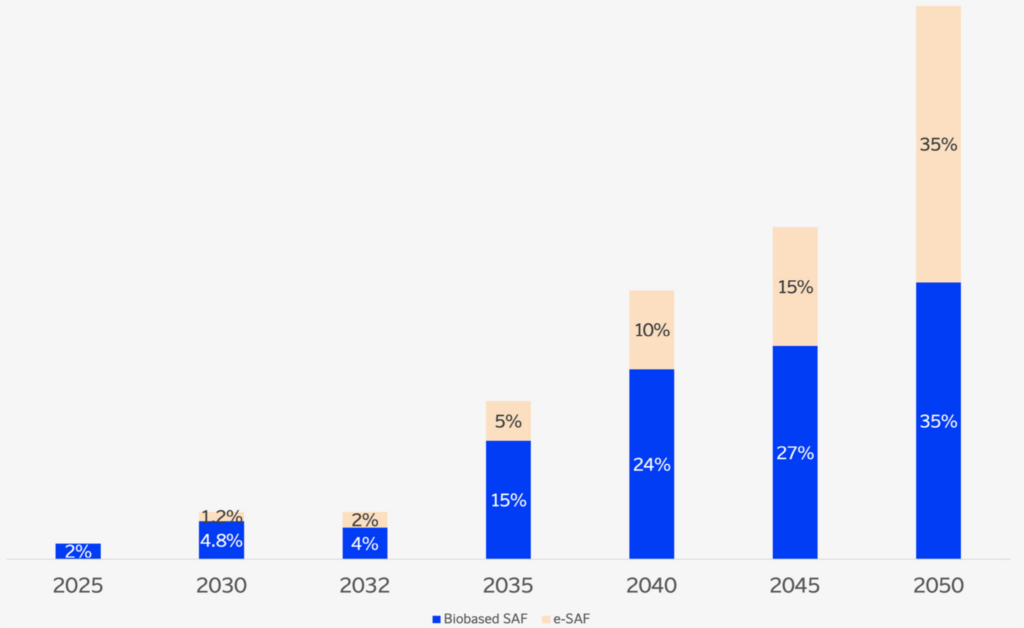
RefuelEU Aviation[4] sets out specific compliance requirements for different parts of the aviation value chain:

- Fuel suppliers: Requirements to deliver minimum blend of SAF and e-SAF to Union Airports[5].
- Airports: Union airports are required to facilitate access to SAF by the time the physical supply obligation kicks in for fuel suppliers in 2035
- Aircraft operators: Are required by ReFuelEU to uplift a minimum of 90% of their annual aviation fuel needs from EU airports within scope.

This report examines the fuel supplier-side requirements of the regulation from a Scandinavian perspective.

The fuel suppliers are required to deliver the following blends of SAF and e-SAF into jet fuel:

Figure 1. RefuelEU Aviation SAF blending mandates



Source: Own estimate

The dedicated e-SAF sub-mandate begins in 2030 at 1.2%, rising to 2% in 2032 and 5% in 2035. The regulation reaches its final target in 2050, requiring a 35% blend of bio-based SAF and a 35% blend of e-SAF.

Until 31 December 2034, a flexibility period applies. During this time, aviation fuel suppliers may average their SAF deliveries across all Union airports they serve in order to meet the minimum blending requirements. In practice, this allows suppliers to concentrate their SAF volumes at one or more airports if this is operationally or logistically more efficient.

The regulation establishes penalties for non-compliance. If a fuel supplier fails to meet the required blending levels, they are subject to a penalty equal to at least twice the price difference between conventional fuel and the respective SAF type. In addition, suppliers must still compensate for the shortfall by meeting the missed obligation in the following year. Member States are required to enforce these provisions, and revenues from penalties must be earmarked for funds that support SAF development.

The EU has allocated 20 million aviation ETS allowances to support SAF purchases from 1 January 2024 to 31 December 2030. The most commonly used SAF pathway today — HEFA — can receive support covering 50% of the price difference between conventional jet fuel and SAF, based on annual average price levels estimated by EASA (European Union Aviation Safety Agency). Once e-SAF enters the market, it will be eligible for support covering 95% of the price differential. The 20 million allowances are expected to be exhausted by 2027–2028, after which the EU may decide whether to extend the support scheme. For the purposes of this report, it is assumed that the support scheme will not be continued beyond its current allocation.

[4] See regulation here: Regulation - EU - 2023/2405 - EN - EUR-Lex

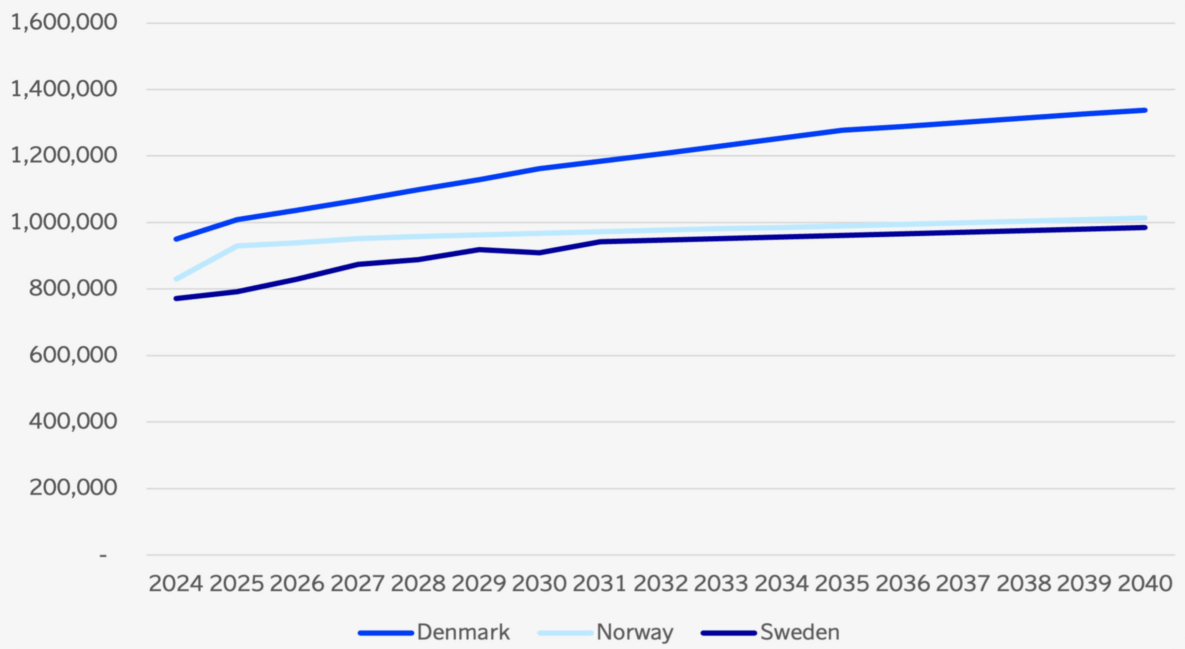
[5] Union airports are all airports with a passenger traffic of ≥ 800,000 per year or ≥ 100,000 tons freight throughput.

Needed e-SAF volume in Scandinavia from 2030

In this report, the Scandinavian e-SAF need is defined as the volume of jet fuel uplifted within the three Scandinavian countries. Alternatively, the definition could be based on fuel consumption by airlines registered in Scandinavia.

A jet fuel consumption forecast has been developed using projections of passenger volumes and fuel use per passenger for each of the three countries. A detailed description of the methodology is provided in the appendices.

Figure 2. Jet fuel consumption per year (tons)

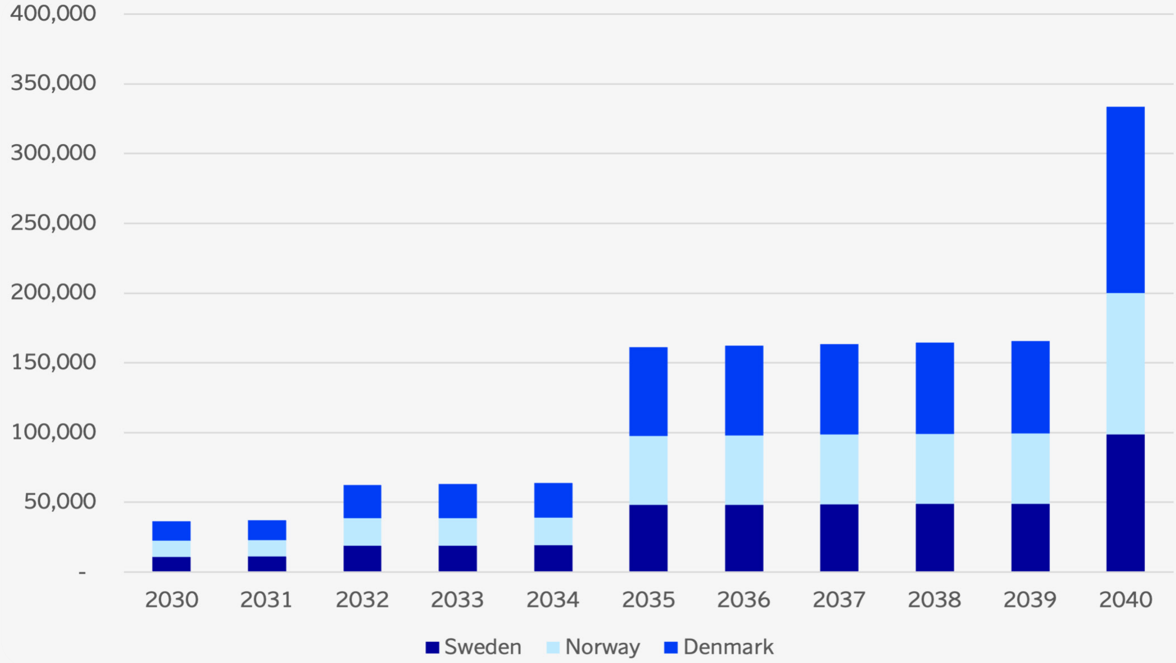


Source: Own estimate

In total, jet fuel demand in Scandinavia is projected to reach 3.0 million tons in 2030 and 3.3 million tons in 2040[6].

Applying the EU blending-mandate percentages to these volumes allows the corresponding e-SAF requirements to be estimated as follows:

Figure 3. Need for e-SAF in Scandinavia (tons)



Source: Own estimate

The blending mandate begins in 2030, creating a requirement for approximately 36,000 tons of e-SAF across the three Scandinavian countries. By 2032, this demand increases to more than 60,000 tons. When the mandate rises to 5% in 2035, the need reaches around 160,000 tons, growing further to approximately 330,000 tons by 2040.

Current expectations suggest that future e-SAF production facilities will have an average annual capacity of 60,000–70,000 tons. Based on this, Scandinavia would require the output of one dedicated plant by 2032, increasing to 2–3 plants by 2035 and around 5 plants by 2040.

Since e-SAF plants located in Scandinavia would not be limited to supplying only the domestic market, the total potential for production could be even greater.

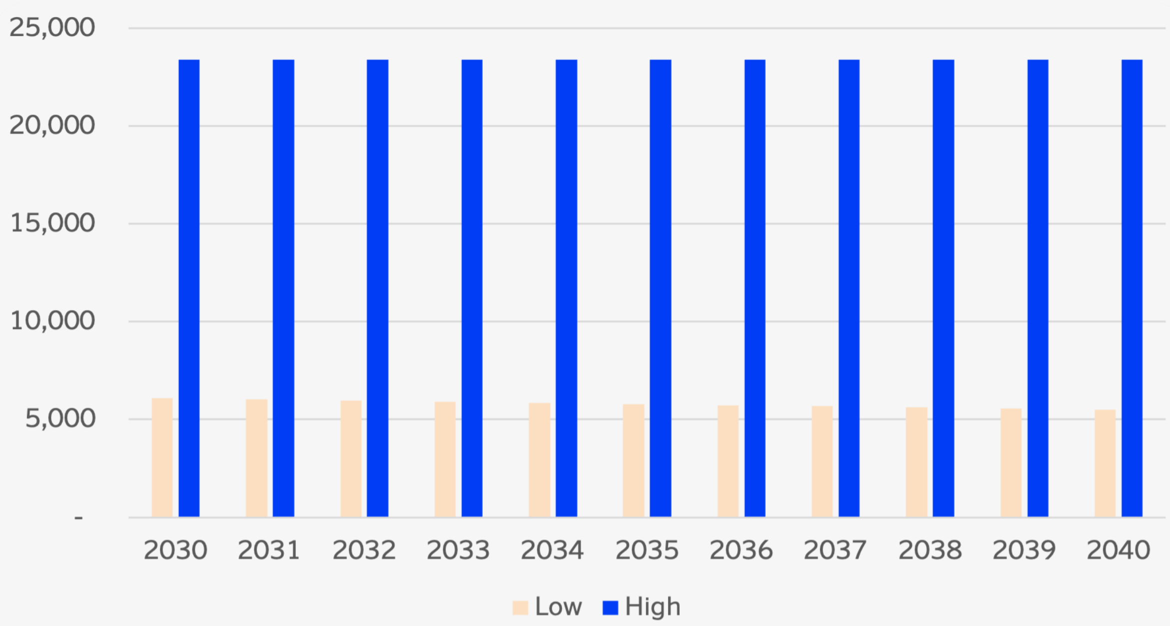
[6] Since not all Scandinavian airports qualify as "Union Airports", RefuelEU covers slightly less fuel.

Possible market price for e-SAF

Forecasting future e-SAF market prices remains challenging, as no commercial-scale e-SAF is currently available and no European e-SAF project has yet reached Final Investment Decision (FID).

As detailed in Appendices 3 and 4, the final market price of e-SAF will depend on a range of underlying factors. To reflect this uncertainty, both high- and low-price scenarios have been developed:

Figure 4. Possible e-SAF market price premium compared to current conventional fuel price (EUR)



Source: Own estimate

The low-price scenario is based on EASA's 2024 low estimate[7], with an assumed annual price reduction of 1% driven by expected efficiency improvements.

The high-price scenario assumes a persistently tight market throughout 2030–2040, with prices approaching the regulatory penalty level[8] plus the cost for next year's mandate. See appendix 3 and 4 for details.

In a short market, there is a theoretical risk that e-SAF prices could rise sharply — potentially triple each year — until supply catches up. This mechanism is described in Appendix 5. However, this report assumes that such extreme price dynamics will not occur. This may be due to potential regulatory adjustments, insufficient publicly available market prices for EASA to calculate reliable averages, or a substantial share of e-SAF being sold under long-term off-take

[7] EASA (2025)

[8] Based on the high penalty indicated by Germany Germany plans €17,000/t e-SAF penalty | Latest Market News. It is assumed that off-takers are ready to buy e-SAF for 10% below this price, as there are costs connected to receiving the e-SAF.

Possible e-SAF cost for Scandinavian aviation

The cost of e-SAF for Scandinavian aviation is estimated by multiplying the required e-SAF volumes by the low- and high-price scenarios.

Table 1. e-SAF cost for Scandinavia

Million euro		2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Total Scandinavia	**Low**	**222**	**224**	**373**	**373**	**374**	**934**	**931**	**928**	**925**	**921**	**1,837**
	High	**853**	**870**	**1,465**	**1,480**	**1,495**	**3,777**	**3,802**	**3,827**	**3,852**	**3,878**	**7,808**
Denmark	Low	85	86	144	145	147	370	369	369	369	369	737
	High	326	332	565	575	586	1,494	1,508	1,522	1,537	1,551	3,132
Norway	Low	71	70	116	116	115	287	285	283	282	280	558
	High	272	273	457	459	461	1,158	1,164	1,169	1,175	1,180	2,371
Sweden	Low	66	68	113	112	112	278	277	275	274	272	542
	High	255	264	443	445	447	1,124	1,130	1,135	1,141	1,147	2,305

Source: Own estimate

The blending mandate takes effect in 2030 with an estimated total cost of €225–850 million. This increases further in 2032 as the mandate rises, reaching €375–1,500 million.

It should be noted that the bio-SAF mandate also increases over this period, adding additional costs that are not included in these figures.

This assessment does not incorporate the e-SAF support scheme currently funded through revenues from the aviation ETS. In a long market (= sufficient supply of e-SAF to fulfil the mandate), a prolonged support scheme could decrease the cost shown below in the low scenario.

By dividing the total cost by the projected number of passengers, the potential additional average cost per passenger can be estimated as follows:

Table 2. e-SAF additional average cost per passenger in Denmark

DKK	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Low	27	27	44	43	42	104	102	100	98	96	189
High	105	105	173	171	170	421	417	413	409	405	803

Source: Own estimate

By 2032, the additional average cost per passenger in Denmark is estimated to range from 44 to 173 DKK — potentially heavily exceeding the current average Danish passenger tax of 70 DKK. The cost increases further to 104–421 DKK in 2035, and to 189–803 DKK by 2040.

Table 3. e-SAF additional average cost per passenger in Norway

NOK	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Low	28	27	45	44	43	105	103	101	99	97	190
High	107	106	175	173	171	424	420	415	411	407	806

Source: Own estimate

In Norway, the additional average cost per passenger is estimated to range from 28 to 107 NOK in 2030. This rises to 105–424 NOK in 2035 and 190–806 NOK in 2040.

Table 4. e-SAF additional average cost per passenger in Sweden

SEK	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Low	34	33	55	54	52	129	126	124	121	119	233
High	130	130	214	212	210	520	515	510	505	500	989

Source: Own estimate

In Sweden, the additional average cost per passenger is estimated to range from 34 to 130 SEK in 2030. This increases to 129–520 SEK in 2035 and 233–989 SEK in 2040.

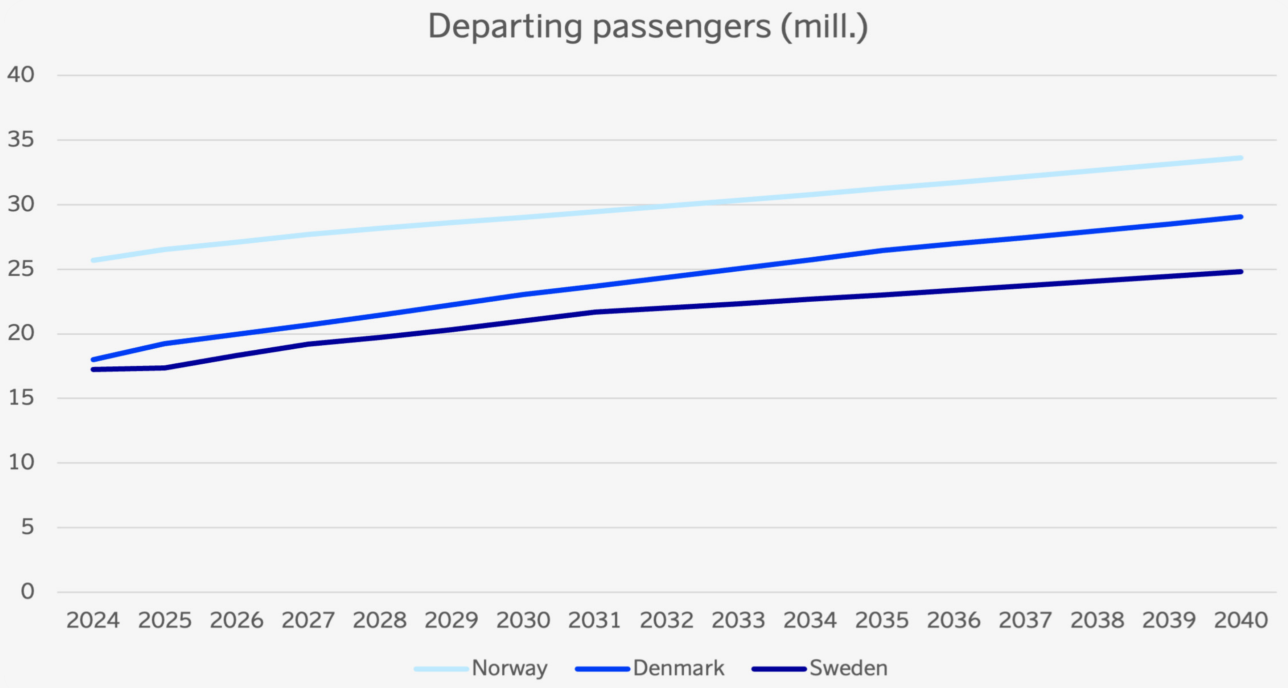
Appendix 1. Passenger forecast in the three Scandinavian countries

To estimate the future demand for e-SAF, total jet fuel consumption beyond 2030 must first be forecasted. The following methodology is applied:

- Denmark: A passenger forecast has been developed based on historical trends and SAS's growth strategy at Copenhagen Airport, projecting an increase from 19 million departing passengers in 2025 to 29 million in 2040. Forecasts of fuel use per passenger have also been applied, declining from 52 litres per passenger in 2025 to 46 litres in 2040.

- Norway: Jet fuel demand is projected using GDP forecasts from SSB combined with the historical Passenger-to-GDP elasticity of 1.1.

- Sweden: For 2015–2031, projections are based on the Transportstyrelsen forecast. From 2031 to 2040, an annual growth rate of 1.7% is assumed.



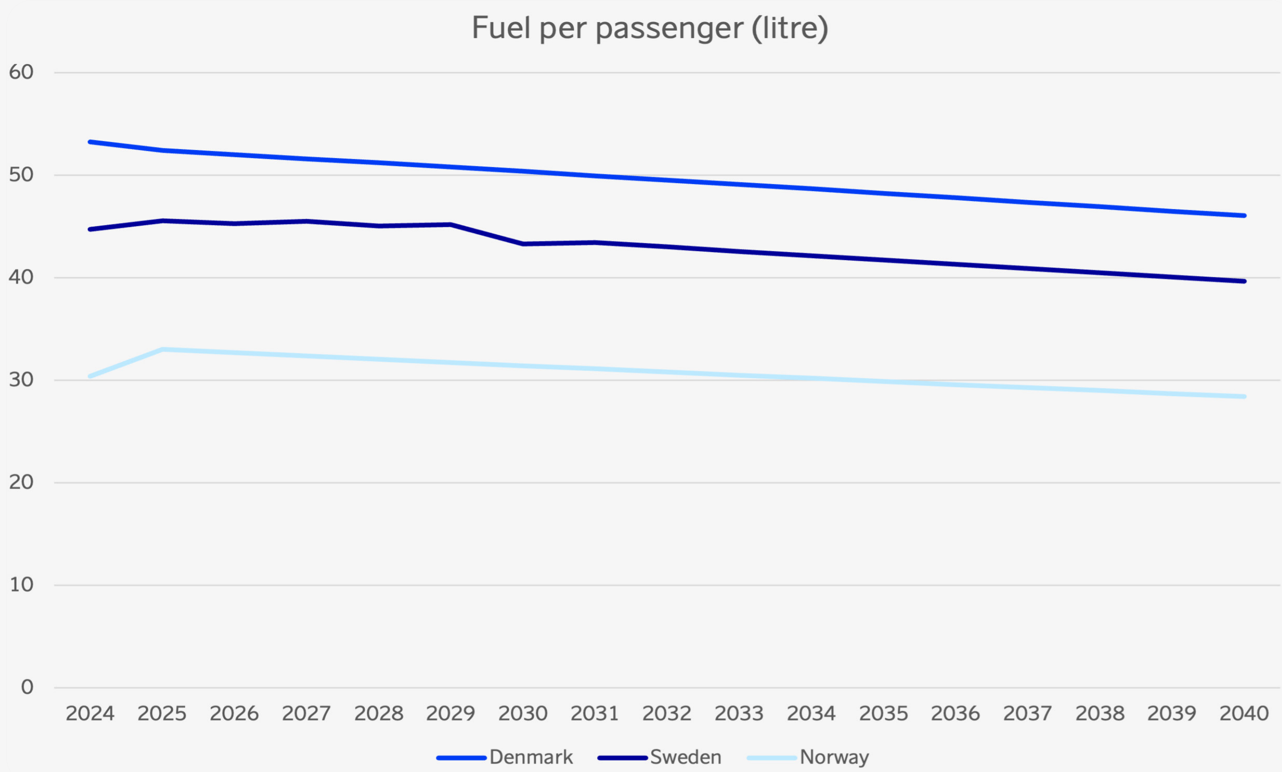
Source: Own estimate

It should be noted that these passenger forecasts are subject to uncertainty. Actual passenger numbers may vary due to shifts in market conditions, geopolitical developments, and other external factors.

Appendix 2. Forecast of fuel per passenger

An overall annual reduction of 1% in fuel consumption per passenger is assumed for all countries[9].

This represents a relatively conservative assumption, given that historical improvements have averaged around 1.7% per year[10].



Source: Own estimate

Fuel consumption per passenger is highest in Denmark due to the largest share of long-haul flights, while Norway shows the lowest value because of its high proportion of domestic traffic.

[9] For Sweden Transportstyrelsen's fuel forecast 2025-31 is used.
[10] Aviation - IEA

Appendix 3. Estimating the possible market price of e-SAF in 2030

The production cost of e-SAF will depend on several key factors, including:

- The price of renewable electricity
- The cost of CO_2 feedstock
- The cost of freshwater
- Capital expenditure (CAPEX) for constructing the facility
- Overall plant efficiency
- Financing and capital costs
- Transportation and logistics costs

However, the final market price will also be shaped by broader market conditions, including:

- Whether the market is short or long — a short market occurs when e-SAF supply is insufficient to meet the mandated blending requirement
- The extent to which fuel suppliers enter into long-term off-take agreements, which can lock in prices for a defined period
- The level of penalties associated with non-compliance, which influences the maximum price suppliers are willing to pay

As no Final Investment Decisions (FIDs) have yet been taken for any European e-SAF projects, there is a substantial risk that the market will be 'short' when the blending mandate comes into effect in 2030. Meeting the EU-wide requirement will demand approximately 552,000 tons of e-SAF in all of EU/EEA in 2030, implying that around eight new e-SAF production facilities would need to be operational by that time to avoid a supply shortage. By 2035, this requirement would rise to more than 35 facilities.

Under the current regulation, penalties for non-compliance must be at least twice the price difference between conventional fuel and e-SAF. Germany has already proposed a penalty level of €17,000 per tons, even though EASA's price estimates indicate that the minimum penalty required under the regulation would be €13,922 per tons.

Suppliers must still compensate for the shortfall by meeting the missed obligation in the following year. It is stated in the regulation that double penalty must be avoided. In a short market lasting for more than one year, this must result in the total cost of non-compliance to be the penalty for the first year equal double the price premium, plus one time the price difference in year two[11]. In total three times the price premium.

In a short market, fuel suppliers are expected to be willing to pay a price just below the penalty level, as doing so reduces their overall compliance costs. In practice, a willingness to pay around 10–15% below the penalty is anticipated, reflecting the additional handling and operational costs associated with receiving and using e-SAF.

[11] Article 12.5 from RefuelEU regulation 2023/2405

If a short market in 2030 is the most likely outcome, the free-market price of the limited e-SAF available is expected to approach the cost of non-compliance. If EASA calculates a similar production-based price for e-SAF in 2029, this will correspond to €7,695 per tons. Under the low- and high-price scenarios, the resulting market premium relative to conventional fuel would range from €6,086 to €8,671 per tons.

For this analysis, the low-price scenario assumes that the market is long and that e-SAF trades at EASA's low estimate of €6,820 per tons — equivalent to a price premium of 6,086 per tons compared with conventional fuel. In the high-price scenario, it is assumed that the market price will be 10% below the cost of non-compliance, resulting in a price of €23,300 per tons.

This assessment does not incorporate the e-SAF support scheme currently funded through revenues from the aviation ETS. Such a support scheme would make it even more attractive to buy the scarce volume of e-SAF in a short market resulting in an even higher market price.

In a short market, there is a theoretical risk that e-SAF prices could rise sharply — potentially triple each year — until supply catches up. This mechanism is described in Appendix 5. However, this report assumes that such extreme price dynamics will not occur. This may be due to potential regulatory adjustments, insufficient publicly available market prices for EASA to calculate reliable averages, or a substantial share of e-SAF being sold under long-term off-take agreements.

Appendix 4. Estimating the possible market price of e-SAF from 2031

Beyond 2030, several price trajectories are possible, largely depending on whether the market remains short or becomes long.

In the low-price scenario, it is assumed that the market is long and that the 2030 low price declines by 1% annually due to efficiency improvements. Actual reductions could be higher, but this will depend, among other factors, on the development of renewable electricity prices. This scenario also assumes that the substantial increase in demand in 2035 and 2040 does not put upward pressure on prices because supply grows in parallel.

In the high-price scenario, it is assumed that the market remains short throughout the entire period until 2040, keeping e-SAF prices close to the cost of non-compliance. The penalty level proposed by Germany of €17,000/tons is used as the worst-case benchmark in this scenario.

Photo credit: Michael Kidmose

Appendix 5. e-SAF price doubling effect

There is a substantial risk that the e-SAF market will be short for an unknown period of time after 2030. In this case, the free market price of e-SAF will in theory be close to the cost of non-compliance as explained above. The cost of non-compliance equals roughly three times the price difference between conventional fuel and e-SAF.

In year 1 the market price could thereby be €23,000/tons. In year 2 this will be the basis for the penalties in that particular year — equal to 3 times 23,000 = €69,000/tons. In year 3 it will be three times €69,000/tons continuing until the market is not short anymore.

To conclude, the current RefuelEU Aviation regulation has this built-in mechanism, as the penalty level is based on the market price the year before. And the market price should end up close to the cost of non-compliance in a short market.

It is not likely that this scenario will occur in reality, as EU and the member states cannot accept this kind of price development. There exist different factors that can remove or limit this effect:

- EU decide to change the regulation, so the penalty is not linked to the market price anymore. In the UK for example, the penalty for non-compliance is a politically decided fixed amount.
- There are not enough e-SAF transactions on the free market for the Pricing Reporting Agencies[12] to determine the market price.
- Many e-SAF users have signed individual off-take agreements that fix the prices.

[12] Currently are the following agencies used by EASA: Argus Media (Argus), S&P Global Commodity Insights (Platts) and General Index (GX). See EASA (2025-2).

References

- EASA (2025-1): 2024 Aviation Fuels Reference Prices for ReFuelEU Aviation
- EASA (2025-2): Methodology document - EASA Reference Prices for RFEUA Eligible Aviation Fuels