The impact of the traffic charge incentives on Sustainable Aviation Fuel (SAF) use

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The aviation sector has been considered as the most difficult sector to implement sustainability, but the pressure towards emissions reduction has been increasing considerably during the latest years.

This thesis was conducted as a self-commissioned study, reviewing if air traffic charge incentives could support the uptake of Sustainable Aviation Fuels (SAF) in Europe. The theoretical framework consists of basic information regarding SAF production and the economics relating to the energy demand of the aircraft operators.

The research chapter includes the qualitative comparative analysis of several different SAF incentive programmes introduced by various European airport companies for years 2023 – 2024.

The findings are encouraging, many incentive programmes are oversubcribed and can considerably help narrowing the price gap between SAF and fossil jet fuel. However, the aircraft operators should actively participate the traffic charge consultation processes, to ensure that the airport operators offer incentive schemes or modulated traffic charges.

Keywords
Sustainable aviation fuels, emissions, incentives

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1 Introduction

This thesis reviews different incentive mechanisms, linked with the air transport traffic charges, which have been implemented to support the uptake of sustainable aviation fuels (SAF). SAF is one of the most efficient tools to reduce the CO_2 emissions related to commercial aviation. According to International Civil Aviation Organization (ICAO), aviation plays a role supporting the United Nations' Sustainable Development Goals (SDGs), especially SDG 13 Climate Action, having one of the clearest and wide-ranging climate action plans of any industry to reduce CO_2 emissions and is making good progress towards achieving its global climate targets. (International Civil Aviation Organization, Assembly – 40th Session, 2019, 1-3)

Due to limited SAF production and the price premium to the fossil jet fuel, the use of SAF has been very limited so far. Different kinds of incentives are needed to increase the use of SAF.

Promoting SAF uptake during this challenging time requires robust, multi-stakeholder partnerships between governments, airlines, airports, fuel producers, and investors. (Santos et al. 2021)

This thesis follows the development during late 2021 - early 2023, compares various incentive methodologies at different airports and analyse their impact. Additionally, this thesis includes also the basic information regarding the SAF production and related legislation. The results of the thesis could be useful for strategic management purposes by

- the airport companies planning similar traffic charge incentives,
- the aircraft operators planning their SAF use,
- the SAF producers planning their SAF marketing and deliveries,
- other parties interested in air travel / cargo related emission reduction.

This thesis focuses on the near-term future, thus the EU SAF blending mandates, effective as from 2025, are excluded from this thesis.

This thesis is a self-commissioned study, due to the public nature of the thesis.

2 Research design

2.1 Research questions

This thesis is focusing on three research questions:

1. What are currently available traffic charge related incentives encouraging the uptake of sustainable aviation fuels?

2. What is the economic impact of these SAF incentives?

3. What could be the most attracting incentive mechanism from the aircraft operators' viewpoint to increase the use of SAF?

2.2 Research methodology

This thesis is based on a qualitative comparative analysis. In sustainability research, the substance will clearly relate to actions and sustainable outcomes, forming 'how' and 'why' questions. (Franklin and Blyton, 2013)

This research method was chosen for this thesis, because the aim is to understand the phenomenon of sustainable aviation fuel incentives. I wanted to gain insights regarding traffic charge related incentives, because the price difference between sustainable aviation fuel and fossil jet fuel is considerable, and additional incentives are needed to promote the use of SAF.

SAF is not yet a commodity product, thus the market price level transparency does not exist yet. Therefore, this thesis could not be based on a quantitative analysis, thus I decided to conduct qualitative analysis.

According to Sietz et al (2019), qualitative comparative analysis groups cases into sets with similar causal factor configurations. In their paper, four gradients were depicting core aspects of archetype analysis in sustainability research: causality, normativity, space and time. Considering causal mechanism and implicit nature, I considered qualitative comparative analysis useful method for this study.

2.3 Research process

I work as a pricing manager for sustainable aviation fuels, thus the SAF market development during this decade is very familiar to me. I started my research process with literature review of sustainable aviation fuels from information availability viewpoint. After literature review, I planned the data collection: information was primarily gathered from internet, because there are very little other

information sources regarding this ramp-up market product. The aim is to understand real-life phenomena via reviewing some of the incentive mechanisms available in Europe. The SAF market is still in its infancy, thus the research is based on the situation valid in February 2023.

2.4 Analysis

The economic impact analysis is only covering the impact for the aircraft operators and for the airport companies, not indirect impacts, because that would be too complex to handle. During the qualitative comparative analysis, my methods to collect information were observations and text analysis.

2.5 Validity and reliability

The reliability of the research estimates if the results are repeatable. It should be noted that my research findings are relatively time and place specific. In other words, this means that similar research conducted later would most likely produce different results. The literature review as a method examines a few examples and does not even try to produce universally representative results.

The research process is totally repeatable, and I have tried to increase the reliability by adding the original material to the Appendix section for ease of reference.

2.6 Limitations and other considerations

There are some limitations related to this literature review. I have only reviewed incentive policies in Europe, because a different approach has been taken in the US and there are no incentives place yet in the Asia-Pacific region.

The intention of this thesis is to promote the role of the airports in the airline industry related emissions reduction. The infrastructure needed for commercial aviation is paid by the aircraft operators in the form of various traffic charge types: landing, emissions, parking and other charges. Therefore, it can be considered that SAF incentive scheme by an airport company is a pay back to the aircraft operators.

Furthermore, aircraft operators' Scope 1 emissions related to certain flight phases can be considered as Scope 3 emissions for the airport company, thus airports promoting SAF use could be lowering their Scope 3 emissions. Scope 1 emissions are related to organization's own or controlled sources. Scope 3 emissions are not produced by the organization itself, but it is indirectly responsi-

ble for them in its upstream or downstream value chain. Scope 2 emissions are related to the purchase of electricity, steam, heat, or cooling, thus Scope 2 emissions are not considered in this context because jet fuel is not included in these Scope 2 categories.

The airport companies should consider introducing incentive programs, because ReFuelEU Aviation introducing EU-wide SAF blending mandates includes SAF flexibility mechanism. This has been often interpreted to mean that the SAF uplifts could be centralised to certain airports by the aviation fuel distributors for efficiency, economic and supply chain reasons.

Therefore, an additional bonus for the aircraft operators is needed to allocate the SAF use more widely within the European Union, and that should be considered by the airport companies when they plan their emission reduction activities.

Due to an economic impact, strong strategic management is needed to implement incentive programs. Not least because of the strong customer opinions which can be raised during the traffic charge consultation period, because certain customers may not support SAF incentive programmes, especially if they consider that their competitors could benefit more from them.

The thesis ends with the comparison of the incentive mechanisms.

3 Theoretical framework

The aviation sector has been considered as the most difficult sector to implement sustainability, because it is often questioned if environmental sustainability is compatible with financial sustainability. (Abdi et al, 2021)

According to the International Energy Agency (IEA), flight operations activity growth has outpaced fuel efficiency improvements. Between 2000 and 2010 fuel efficiency improved by 2.4% per annum, and by 1.9% from 2010 to 2019, but this is far below the annual passenger demand growth, 5% per year during 2000 and 2019.

If the airline industry would like to align with net zero scenario, where emissions are still generated but they are offset somewhere else, additional improvements such as SAF are required.

3.1 What is SAF?

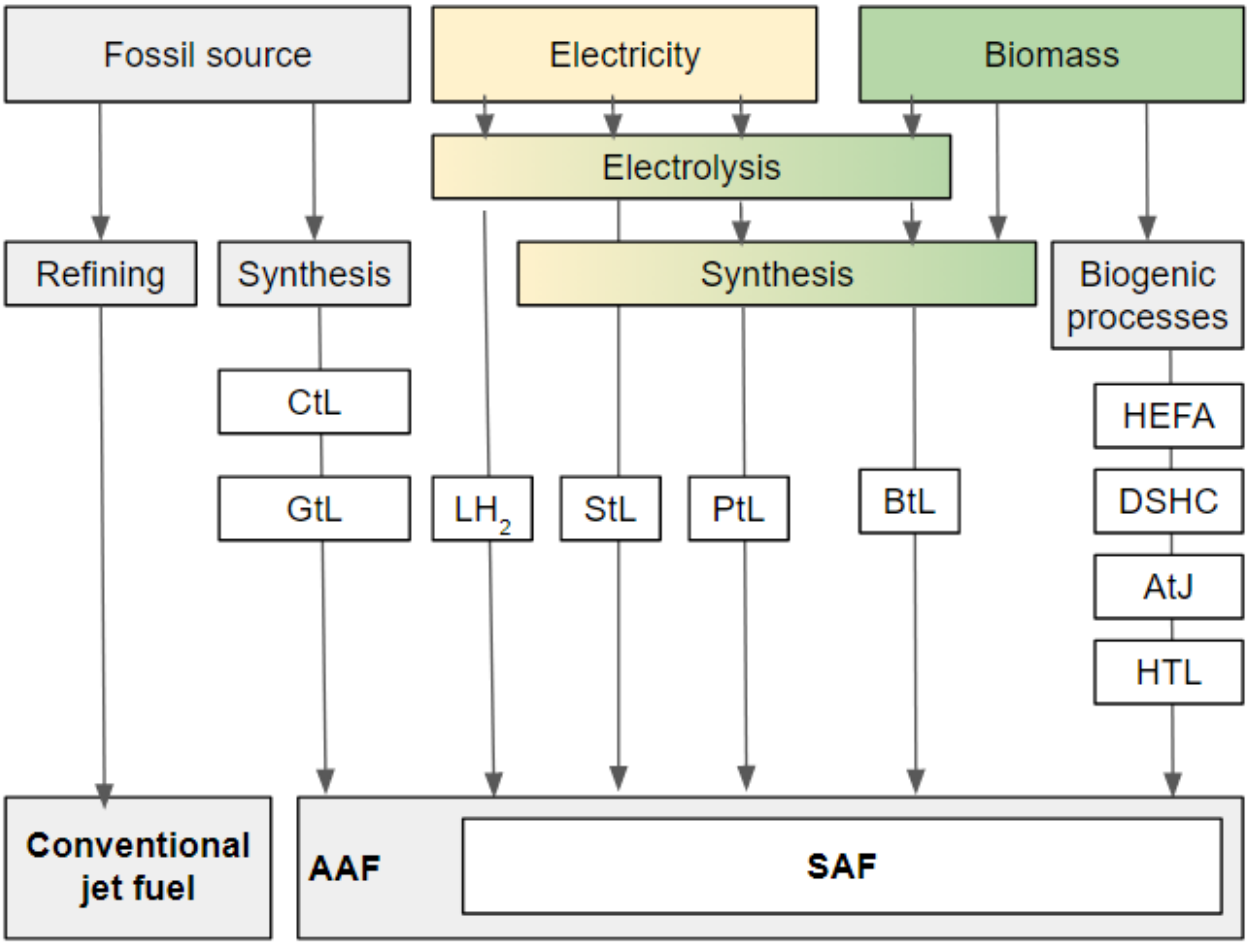
Sustainable alternative fuel, sustainable alternative jet fuel, renewable jet fuel or biojet fuel - several terms have been used to describe aviation fuel, which is not derived from fossil fuels. The International Aviation Transport Association (IATA) prefers the term sustainable aviation fuel, SAF. The use of term 'biofuel' is not recommended, because current technologies allow jet fuel production also from non-biological sources. (International Aviation Transport Association, 2020)

SAF can be produced using different conversion processes, such as Fischer-Tropsch (FT) and Hydroprocessed esters and fatty acids (HEFA).

- SAF is chemically and physically almost identical with conventional jet fuel, thus it is considered as a drop-in solution, because the existing supply infrastructure can be used, and no adaptation is required for the engines or the aircraft fuselage.

The aviation fuel infrastructure at the bigger airports is usually based on the fuel hydrant system, consisting of storage tanks, underground pipeline, pressurised fuel hydrant pits and hydrant dispensers connecting the aircraft fuel tank and the fuel supply line. Considering this, different kind of aviation fuel molecules will mix with each other, and in the future the aircraft are likely to burn multi-blend of JET A-1 and different SAF types. (Oehmichen K, Majer S et al. 2022)

Figure 1. Production pathways for conventional (fossil based) and sustainable aviation fuels. Adapted picture, based on the Factsheet: Übersicht und Einordnung Alternativer Kraftstoffe by Nationale Organisation Wasserstoff-und Brennstoffzellentechnologie GmbH. (Barke A, Bley T et al. 2022)

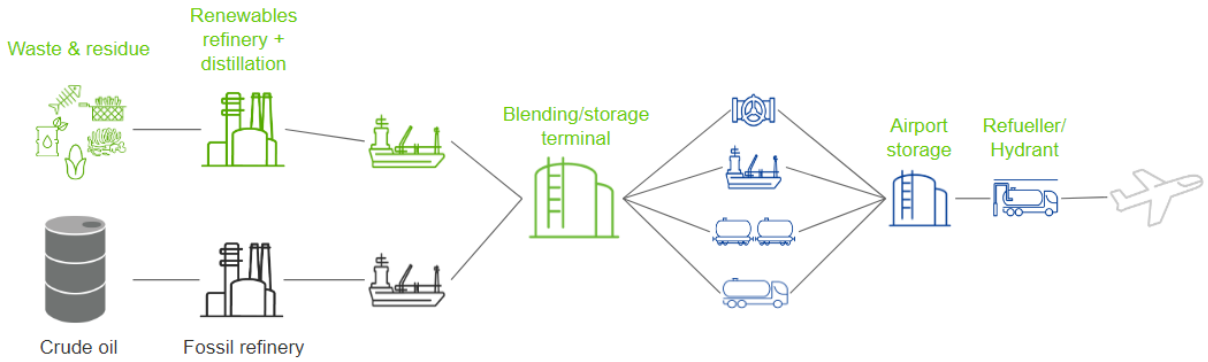


Sustainability in this context is defined as something that can be continually and repeatedly resourced in a manner consistent with economic, social and environmental aims, and conserves an ecological balance by avoiding depletion of natural resources.

3.2 Why SAF reduces emissions?

When biomass is used to develop SAF, the plants absorb CO_2 for growth during photosynthesis in relatively short time scales. The carbon that is then emitted back into the atmosphere during combustion will return to the plants in a closed loop. (International Civil Aviation Organization, 2018)

Figure 2. SAF supply chain compared with fossil jet fuel.

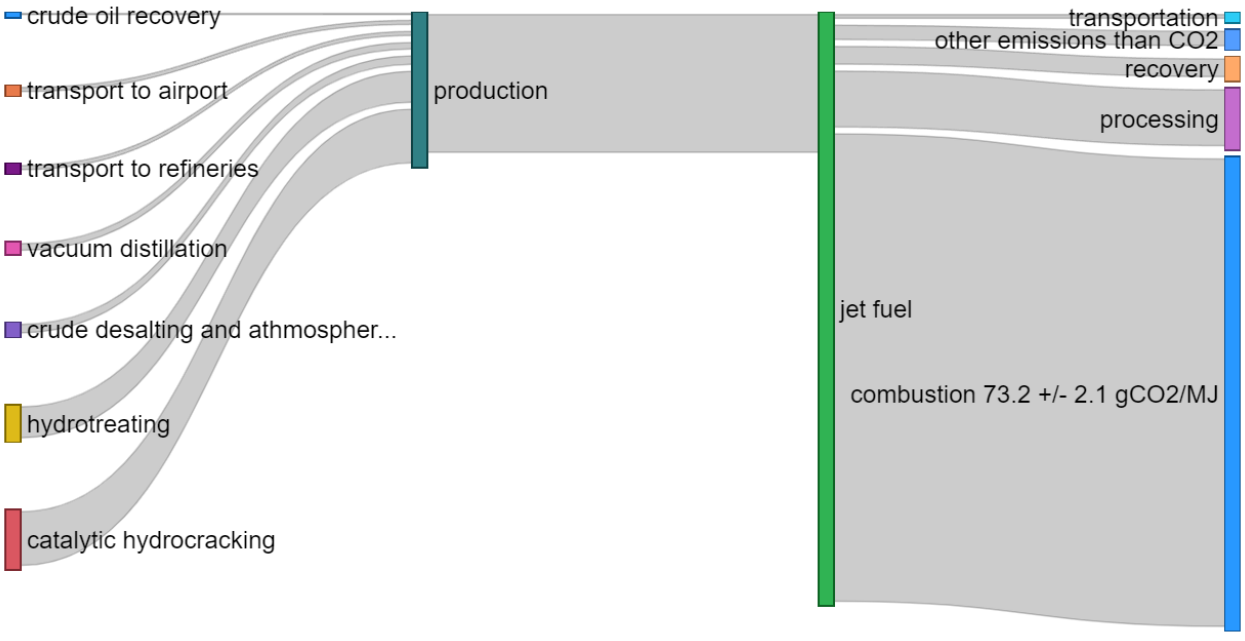


Although the fuel combustion phase could be carbon neutral, the CO_2 emissions are generated during the fuel production, when the fuel is recovered, processed or transported. Therefore, it is vital to calculate the emissions for the full life cycle of the fuel. This is also the reason why most currently used SAF types have CO_2 emission reduction level less than 100%.

The life cycle emissions of fossil jet fuel are explained in the Figure 3, which clearly shows that 84.18% of the CO_2 emissions are related to the fuel combustion phase, i.e. when the aircraft is moving using its own engines.

The life cycle emissions for SAF are similar during the refinery phase, depending on the feedstock and required pre-treatment, and zero for the combustion phase.

Figure 3. Energy and lifecycle GHG emissions of conventional jet fuel, based on the life cycle analysis by Kolosz and Luo (2020).



The fuel specification ASTM D7566 “Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons” describes only the physical characteristics of the fuel. Therefore, the SAF must have a separate, specific sustainability certification, e.g., Round Table on Sustainable Biomaterials (RSB) (International Air Transport Association, 2018).

- The 12 RSB principles cover issues such as human and labour rights and local food security.

- As an additional benefit, SAF contains fewer impurities, thus enabling a reduction in sulphur dioxide and particulate matter emissions. The DLR-NASA study, conducted with Airbus 320 aircraft, provides experimental evidence that burning low aromatic sustainable aviation fuel can result in a 50 to 70% reduction in soot and ice number concentrations and an increase in ice crystal size. (Voigt, Kleine and Sauer, 2021)

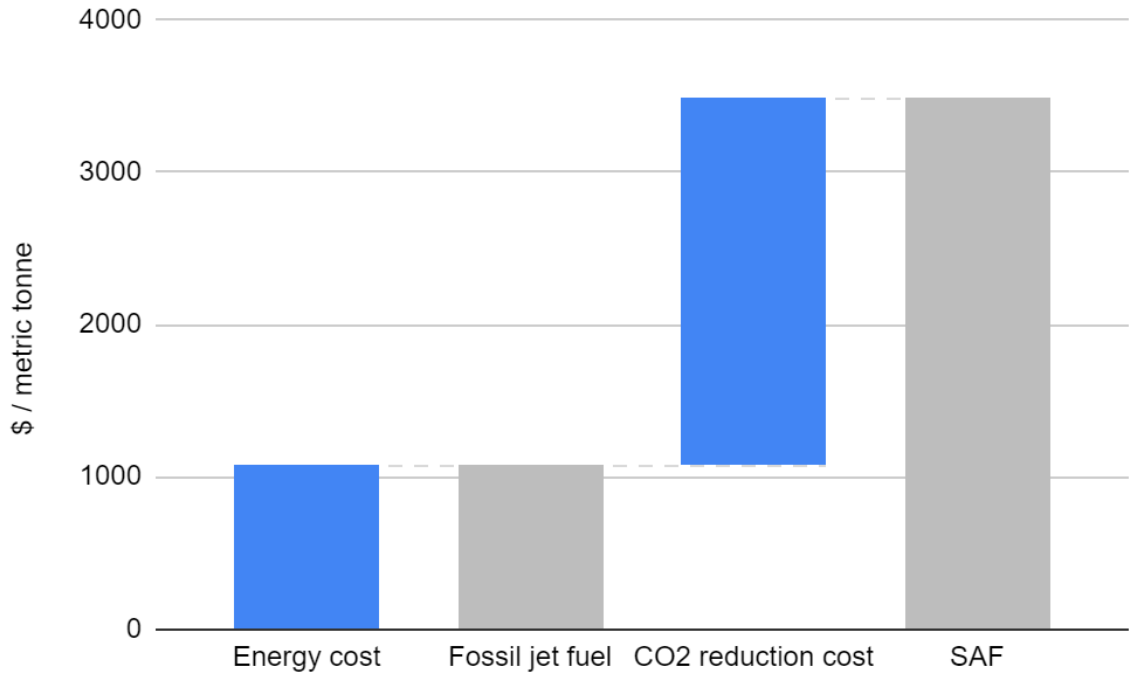
3.3 Economics

SAF is considerably more expensive than fossil jet fuel, mainly due to expensive feedstocks (such as Used Cooking Oil and Animal Fat) but also due to the refinery investment costs. The airlines need to buy energy for their flights in some form, thus the price difference between SAF and fossil jet fuel can be considered as a carbon reduction cost and calculated as $ / tCO_2 reduction.

The price reference agency Argus reported on the argusmedia.com on the 15th August 2022, that the outright price for SAF (Used Cooking Oil) fob ARA range was 3 510.25 $ / metric tonne. On the same day, the fossil jet fuel spot price at the ARA was 1 077 $ / metric tonne, so the price difference was 2 420 $ / metric tonne, or SAF was 3.25 times more expensive than fossil jet fuel. ARA refers to the ports of Amsterdam, Rotterdam, and Antwerp in the Northwest Europe oil refining hub market.

There has been significant volatility in the fossil jet fuel prices, first a price crash due to covid-19 pandemic in March 2020 and the price hike when the war in Ukraine started in late February 2022, and the acceptance of Russian-origin crude oil changed because of the sanctions.

Figure 4. SAF has both energy and CO2 reduction cost.



The Figure 4 above explains that the cost of SAF can be split in two parts:

1. Cost of energy, which is needed for the aircraft movement, this cost is about the same for SAF as for the fossil jet fuel use, small difference is related on the different energy density measured as MJ / fuel kg
2. Cost of the CO_2 reduction, which is the cost differential of SAF and fossil jet fuel, also called price premium, fossil jet fuel has no CO_2 reduction

SAF cost being 3 – 5 times higher than the fossil jet fuel is a challenge for the airlines. Even fossil jet fuel, which is considered affordable energy, can constitute 30 - 50% of the airline operating costs. On the other hand, it can be argued that thanks to technological progress leading to improved fuel efficiency, 'Jevons paradox' has occurred what comes to the commercial aviation. The air fares have been declining since 1990s, and the world passenger air traffic has increased at 5% annual rate.

The EU Emissions Trading System (EU ETS) related costs have increased very quickly during the last two years, buying emission allowances from the auction could mean 30% "fuel surcharge" for the aircraft operators. The emission allowance gives a right to emit one tonne of CO_2, and during the combustion phase each fossil jet fuel metric tonne converts to 3.16 tonnes of CO_2. The EU emission allowance price at the auction market exceeded the level of 100 € in late February 2023.

This price level would mean that burning 1 metric tonne of fossil jet fuel would cost 316 € (over 340 $) for the aircraft operator, increasing the fossil jet fuel use cost substantially. Therefore, it is important to emphasize the phrasing ‘fuel use cost’, instead of fuel price (without emission allowance costs).

The use of SAF has no emission allowance costs. Vice versa, during the years 2025 – 2029, the aircraft operators will receive so-called SAF allowances based on the price differential between SAF and fossil jet fuel, and depending on the SAF type. Renewable fuels of non-biological origin (RFNBO) would provide highest number of the SAF allowances, due to high production and investment cost related to this fuel type.

The fossil jet fuel has been widely interpreted as tax exempted energy form, due to the interpretation of the Chicago convention Article 24, which was established in 1944 when the International Civil Aviation Organization was founded. For example, Wild, Mathys and Wang estimated in their case study (2021) that in Switzerland the fossil jet fuel tax would have increased the air ticket fares 10% and decreased the passenger demand by 11%. This would have caused a negative employment impact for the aviation sector, and higher fiscal revenue would have been needed to offset that. Thus, the overall fossil jet fuel tax impact would have been negligible.

Rising energy related costs, are not as bad for the airlines as expected, for various reasons:

- Airlines hedge their fuel purchases, which stabilises their fuel price exposure on a long-term
- Since covid-19 the airline customers have started booking their tickets later, and the share of lower-price, early bookings have become considerably smaller
- Like in the past, the airlines will pass some of the price increase to their customers, because all airlines face the same fuel cost hike
- Higher airline operating costs decreases the capacity provided by the airline, when low-margin routes are discontinued, this also means lower CO2 emissions (Bouwer and Dichter, 2022)

In addition to the traffic program and alternative fuels, the airlines have also other measures to reduce their CO_2 emissions:

- Aircraft technology development, for example newer, more fuel-efficient fleet

- Improved operational fuel efficiency, for example, Sobieralski has studied operational use of a social cost index (2023) incorporating the environmental costs to the cost index metric used by the flight crew
- Improved air traffic management
- Market-based measures, such as emissions trading, levies and carbon offsetting

The decision to use SAF is usually made on the executive level, due to the high cost, and is considered emission reduction investment rather than an energy purchase. The airlines may have differing business models and aircraft fleet, thus their need for SAF use may differ from each other. For example, inter-continental flights are currently out of EU ETS scope, and global competition is very fierce. On the other hand, SAF is easier funded for the short regional flights with modest fuel burn, when the additional cost may only be a few euros per flight ticket.

What comes to funding, the airlines have taken different approaches. For instance, Air France - KLM announced already in January 2022 that the standard SAF admixture is added to the ticket price as a surcharge ranging from 1 to 12 euros. This can be considered as transparency, because France introduced 0.5% SAF blending mandate effective from 1 January 2022, and Air France – KLM wanted to pass these additional costs directly to the customers.

SAF purchase differs from traditional fossil energy trading, because the cost of emission reduction must be carefully analysed, in addition SAF certification and used feedstocks play a vital role, for example palm feedstocks are avoided. Therefore, SAF purchase agreements are often prepared in co-operation by the airline's sustainability unit, fuel purchasing and the Executive Board.

3.4 Air traffic charges

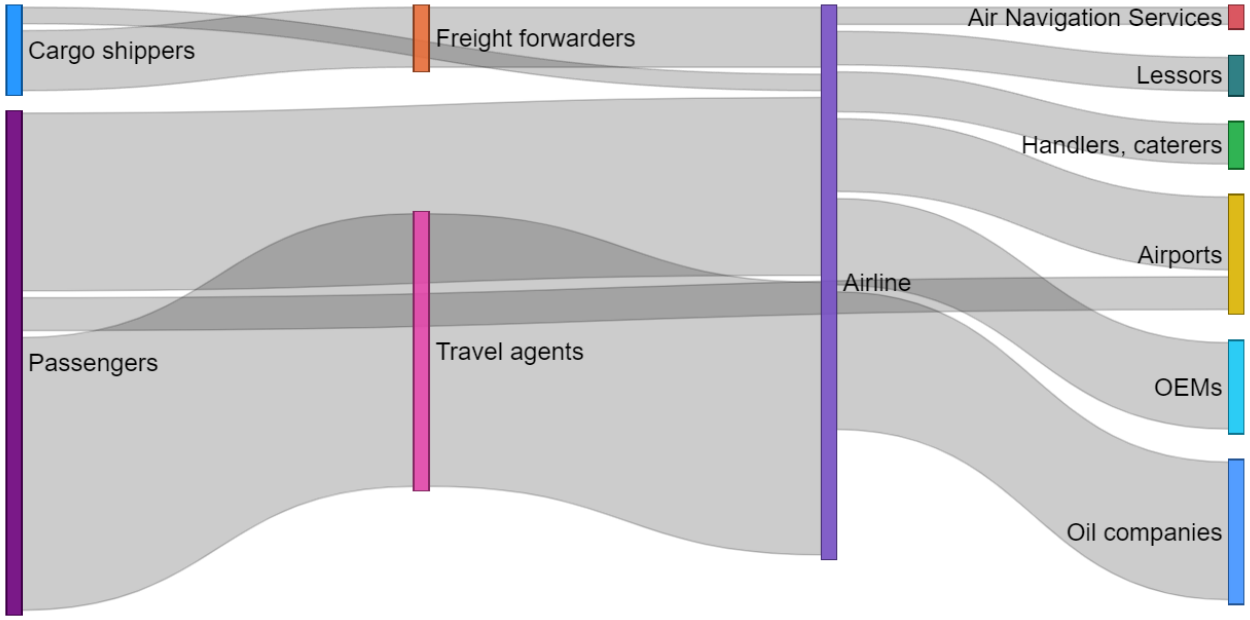
Salman and Bing (2021) analysed that even if there are a lot of enablers for the SAF use, there are various anti-goals such as the risk for airlines' financial status, and policy setting such as fossil jet fuel taxation and SAF mandates plays a vital role.

Further to the first research question of this thesis, I decided to analyse how aviation traffic charge mechanism could be used to promote the use of SAF. The aviation pays by itself for different kinds of infrastructure needed for the flight operations, contrary to the road or rail transportation, where infrastructure is often publicly funded. The infrastructure for commercial aviation is financed via traffic charges, such as landing, passenger, ATC, emissions and noise fees.

Due to recent amendment in the proposed EU legislation, it may become as a surprise to certain airports that the fuel distributors may fulfil their EU SAF blending mandate in any EU Member State, thanks to “SAF flexibility mechanism”. In other words, this means that SAF may not be available from all major airports. Therefore, it may be in the airport operators’ interest to build up incentive mechanisms to promote the SAF use from their airport, especially if the airport operator companies have ambitious Scope 3 emission reduction targets.

The aviation value chain is complicated, but the IATA estimated that prior to covid-19 pandemic, there were 36.1% revenue flow to the oil companies and 22.9% to the airports and air navigation service providers (ANSPs). Thus it could be considered that the airports are actually returning some revenue back to airlines via SAF incentives.

Figure 5. Indicative revenue flows within the aviation sector, based on the value chain analysis by the IATA and McKinsey (2022).



Stargate, a consortium project selected by the European Commission, has published a catalogue (2022) of SAF actions to the airports. The actions have been split in three main categories:

1. Increase SAF uptake
    - Applying authority
    - Financial support
2. Increase SAF awareness
    - Providing information

3. Increase airport leadership on SAF
    - Stakeholder engagement
    - Aligning own organisation

In the catalogue, the fee differentiation in the airport charges, is part of applying authority and it is considered that airports are using the infrastructure position to push other stakeholders towards SAF use and stimulate sustainable behaviour by the airlines. On the other hand, it was emphasised that the fee differentiation must be integrated with the standing agreements regarding charges, plus there is a risk to a conflict with the airlines.

The catalogue also presents SAF Incentive Fund, which can be funded via airport revenue- or non-revenue-based mechanisms, such as direct investments by the airport company shareholders.

Although this thesis is focusing on the incentives linked to the aviation traffic charges, other incentive mechanisms will be briefly represented, to understand the total cost impact of the SAF use. This is important, when the aircraft operators are planning their SAF purchase locations.

The thesis will not cover later development, for example SAF mandates within the European Union as from 2025 as such, but is concentrating on the ramp-up phase 2022 - 2023.

3.5 Managerial implications

The importance of incentives is not only related to the European market. Bhatt, Zhang et al. (2023) evaluated in their sensitivity analysis that feedstock cost and renewable fuel incentive are key cost drivers impacting the SAF costs in relation to the deployment of SAF Chicago's O'Hare International Airport in the US.

The airport companies, which have not yet launched their own SAF incentives, should consider doing so. The airport companies should not remain isolated actors within commercial aviation, which do not participate in the emission reduction activities towards more sustainable commercial aviation. The profit margins in the commercial aviation are so narrow that it is very unlikely that SAF purchases would take place without incentives – or mandates, in other words compulsory legislation. Majority of the airport revenues are from the aircraft operators, thus financing the SAF incentive is actually a 'polluter pays more' mechanism, and allowed by the EU directive 2009/12/EC.

According to P.J. McManners (2016), during his research process it emerged that long-term strategic planning, facilitating a dialogue between stakeholders, innovation in both technology and business models plus educating the general public to generate support for change, are key elements to bring sustainability inside the policy process.

It should be noted that the airline ownership type could have impact on the corporate social responsibility (CSR) performance. The leadership or culture may not be strong enough in mixed-ownership airlines, where managers and shareholders display conflicts of interest. According to a case study (Tsai-Chi, 2021), return on assets of state-owned and private airlines gradually improved after incorporating and implementing environmental and social performance indicators. The reason mixed-ownership airlines perform the worst on CSR is related with leadership and culture. Due to mixed-ownership, the leadership or culture may not be strong enough. In addition, managers and shareholders display severe conflicts of interest.

Furthermore, for the airlines with better environmental-social-governance (ESG) performance, the share value is not so volatile, offering better defensiveness. Thus, incorporating ESG strategies to promote sustainability could help achieving higher shareholder wealth. (Chen et al. 2022)

Considering this, it is vital that the airline has implemented environmental performance indicators. This supports the dialogue between internal stakeholders within the airline. In the case of SAF use, it is required that the airlines' sustainability teams work closely with their colleagues from purchasing responsible for traffic charges and jet fuel. Traditionally the link between traffic charges and sustainability has not truly existed, or in the case of noise charges the airlines have very limited possibility to influence after the decision regarding aircraft fleet utilisation has been made. Furthermore, the airlines should demand at the traffic charge consultations that the suggested 'polluter pays more' mechanism is introduced in the traffic charge schemes, to ensure that all stakeholders attend the emission reduction activities related to commercial aviation.

4 Research

The research work was conducted using publicly available information, mainly annual reports plus charges and conditions documents, which the airport companies publish after the consultation period. The consultation is a requirement laid down in the EU directive 2009/12/EC regarding airport charges and is a dialogue together with the airport users, mainly the aircraft operators, to take their viewpoints into consideration when the charge levels are settled. Furthermore, there needs to be enough time for the airlines to update their booking systems, that the adjusted traffic charge levels can be included in the air fares when the tickets are sold.

Article 3 of the EU directive 2009/12/EC on airport charges clearly states that airport charges cannot discriminate among airport users, but that does not prevent the modulation of airport charges for issues of public and general interest, including environmental issues. The criteria used for such a modulation shall be relevant, objective and transparent.

According to the European Commission (2021) the term ‘carbon leakage’ refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. This could lead to an increase in their total emissions.

Lai and Christley pointed out (2022) that when considering differentiated take-off and landing fees, it should be noted that they may result in ‘aviation leakage’ between airports, as well as countries, with airlines moving operations to airports without charges, thus limiting consumer choices.

Therefore, when planning SAF incentives, the airport companies must carefully balance the risk of carbon / aviation leakage and the public pressure for more sustainable aviation.

Qualitative research method was used for this thesis, because some details such as SAF price levels are not necessarily publicly shared. On the other hand, third research question was to analyse the most attractive incentive mechanism, including attributes which are not directly linked with the economics, such as complexity of the incentive mechanism.

The research questions:

1. What are currently available traffic charge related incentives encouraging the uptake of sustainable aviation fuels?

2. What is the economic impact of these SAF incentives?

3. What could be the most attracting incentive mechanism from the aircraft operators' viewpoint to increase the use of SAF?

are reviewed in subchapters 4.1 - 4.4.

4.1 Incentives at the Amsterdam airport, Royal Schiphol Group N.V.

Amsterdam Airport Schiphol is operated by Royal Schiphol Group N.V. There are more than 260 000 aircraft movements and 25 million passengers per year travelling to, from and via Amsterdam. The airport's SAF incentive became applicable as from April 2022. Typically, the airport traffic charge schemes change from 1st January, or when the IATA timetable periods change in April or November.

It is stated in the Schiphol Airport Charges and Conditions document (2021) that Royal Schiphol Group N.V. allocates 15 million € as a SAF funding during the years 2022 – 2024. The funding is available for all qualified airlines, and it is 500 € per refuelled SAF metric tonne (1 000 kg), and 1000 € for per refuelled e-fuel (synthetic kerosene) metric tonne.

Qualifying SAF must be produced in Europe, preferably from European feedstock, and have a minimum GHG reduction of 70% compared to the full life cycle of fossil kerosene, adhere to the RED (Renewable Energy Directive) certification and is uplifted from Amsterdam during the incentive years.

The qualifying airlines must inform the airport company in advance, by 1st April, regarding the forecasted quantity and submit updated forecast by 1st October each year. In case the forecasted quantity exceeds the available incentive funding, the qualifying airlines will be informed by 1st May, and eligible funding is allocated proportionally to the share of forecasted quantities per qualifying airline. The qualifying airlines will receive a credit note by mid-May following the incentive year.

Considering the low e-fuel availability, the incentive could be used to fund 30 kilotonnes of other types of SAF (mainly HEFA-SAF) during 2022 – 2024, energy quantity corresponding to approximately 250 long-haul roundtrips from Amsterdam.

This incentive is rather simple, and the economic impact is easy to understand. The restriction regarding the production location of SAF may increase the SAF cost, because hydrogen is needed for the HEFA-SAF processing, and hydrogen is produced using natural gas. Natural gas prices in Europe increased considerably since the war in Ukraine started. In addition, the preference for European feedstock also increases the SAF price, because the feedstock prices in Asia tend to be lower than in Europe.

The magnitude of the SAF incentive programme may sound massive. However, Royal Schiphol Group N.V. states in its Annual Report (2023) that it had three main revenue streams, totalling to 1491 million € in 2022:

1. Aviation 870 million €
2. Commercial 460 million €
3. Alliances & participations 161 million €

Therefore, 2.5 million € used for SAF incentives in 2022 was reducing only 0.29% the aviation revenues, and 0.17% the total revenues. The airport company considered in its Annual Report that the launch of the programme was successful, and 5 000 tonnes of SAF was subsidised in 2022, almost 25% of all SAF delivered in the airport. More than 10 airlines showed their interest in the programme.

Additionally, Royal Schiphol Group N.V. listed in the report that further to the United Nations Sustainable Development Goal (SDG) 13 Climate Action, 20 000 SAF tonnes were delivered at the Amsterdam airport in 2022. Other material aspects regarding sustainable aviation were linked to SDG 11 Sustainable cities and communities and SDG 16 Peace, justice and strong institutions.

4.1.1 HBE biotickets in the Netherlands

In addition to the incentive introduced by the airport, there is an aviation opt-in possibility in the Netherlands. Opt-in means that the Dutch government accepts that sustainable aviation (and maritime) fuel is voluntarily used to fulfil the road transportation biofuel blending mandate under the European Renewable Energy Directive (RED). SAF supplied to the Dutch market, mainly delivered to the Amsterdam Schiphol aviation fuel system, generates so-called HBE biotickets. These biotickets can be sold at the market for the obligated parties, road transportation fuel distributors, who must either blend in biofuel molecules or buy the biotickets to fulfil their blending obligation to reduce the GHG emissions in the road transportation.

These HBE biotickets may have a considerable value, 1 000 – 2 000 $ / neat SAF metric tonne (mton) depending on the used feedstock and the fuel market situation. The aviation biofuels benefits from higher multipliers, +20%, compared to the road transportation fuels produced from the same feedstocks. The higher multiplier was introduced to cover higher production costs of SAF, compared with the road transport fuels. (Nederlandse Emissieautoriteit, 2023)

Unfortunately the HBE market has been very volatile, thus causing an economic risk for the party responsible for selling the HBE tickets onwards.

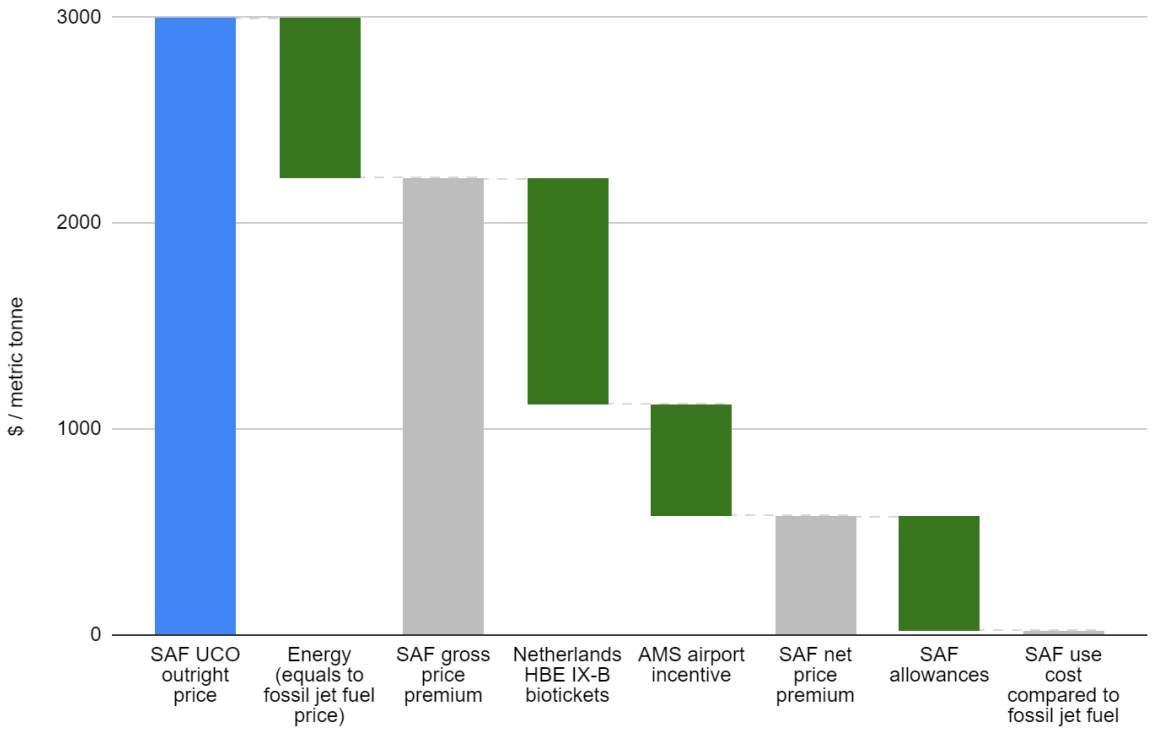
4.1.2 Economic benefit for SAF in the Netherlands

The aircraft operator has a three-fold economic benefit from their SAF use:

1. The Amsterdam airport incentive approx. 520 $ / mton
2. The Netherlands opt-in 1 000 – 2 000 $ / mton
3. The EU ETS allowance cost saving approx. 300 $ / mton

Naturally the first two are limited to limited SAF volumes, but these all are vital drivers to increase the SAF supplies to the European market.

Figure 6. The total impact of different SAF use incentives for Amsterdam Schiphol airport fuel deliveries.



As it can be seen from the Figure 6 above, the SAF net price depends on multiple variables:

- Fossil jet fuel price (fossil energy market)
- Dutch HBE IX-B bioticket value (biofuel market)
- Dutch HBE IX-B bioticket aviation opt-in multiplier (legislation)

- AMS airport incentive availability (public policy)
- EU ETS allowance price relating to SAF allowances (EU carbon market)
- € vs $ exchange rate (global economy)

Considering all these variables, the SAF net price may vary and it is very difficult to forecast in advance the emission reduction cost. Furthermore, the Figure 6 shows that all incentives are vital to reduce the price difference between SAF and fossil jet fuel.

4.2 Incentives at the London airport, Heathrow Airport Holdings Ltd

London Heathrow Airport is operated by Heathrow Airport Holdings Ltd. There are more than 470 000 aircraft movements and 80 million passengers per year travelling to, from and via Heathrow. The airport's SAF incentive became applicable as from January 2022.

The airport company aims reaching a 4% SAF mix by 2025 by covering 50% of the forecasted SAF cost differential. For the first year, 2022, assumed SAF mix is 0.5% and the SAF incentive pot 10 million £. The SAF incentive pot is 122 million £ during the years 2022 – 2025.

According to the decision document (Heathrow Airport Limited, 2021), the incentive is focusing on fuelling at Heathrow, and not considering the arriving flights fuelled with SAF. This decision was made to stimulate new SAF supply in the UK sooner. Based on the customers' (aircraft operators) feedback, the allocation is based on the available seat kilometres (ASK) in 2019, i.e., prior to covid-19 pandemic, which is a decent proxy for the energy needed for the flight operations. Furthermore, it is underlined that the airport company does not require that SAF uplifted at the airport to be treated separately to any reporting that may be required for the UK Emissions Trading Scheme (UK ETS) or any other Governments' requirement.

In other words, this means that the same SAF delivery can be used for the UK ETS obligation, and the UK RTFC (Renewable Transport Fuel Certificates), if so decided by the customer. Even combining all incentives, it is likely that the SAF net price is higher than fossil jet fuel price.

According to Conditions of Use –document (Heathrow Airport Limited, 2021), the incentive is 460 £ per metric tonne of SAF, so the value is slightly higher than the Schiphol incentive.

This incentive is also very simple, and the economic impact is easy to understand. The most complicated detail is the allocation based on the ASK, because the customers need to wait before they receive the information regarding their SAF incentive allocation. Most likely this allocation process

was included because there are several home market carriers operating from Heathrow, and the traffic charge credits obtained via the SAF incentive must be proportional to the magnitude of flight operations by different aircraft operators.

Heathrow Airport Holdings Ltd reported in its results for year ended 31 December 2022, that it created 38 million £ incentive scheme, which was fully 'subscribed' by the aircraft operators in 2022 meaning that at least 0.5% of the jet fuel delivered to Heathrow airport was SAF. The share for 2023 is 1.5% and the scheme is oversubscribed. The total revenue for the airport company in 2022 was 2 913 million £, thus 38 million £ for the SAF incentive scheme can be considered a marginal investment.

4.2.1 RTFC tickets in the United Kingdom

Like in the Netherlands, the UK also has a bioticket system, but the system is based on the volume of biofuel delivered to the UK market. The system is called Renewable Transport Fuel Obligation (RTFO), and the biotickets Renewable Transport Fuel Certificates (RTFC). Recent removal of biodiesel anti-dumping duties opened the door for imported road transportation biofuels, and the bioticket values have decreased since this decision was made. The UK RTFC related biovalue for HEFA-SAF has been around 1 000 – 1 200 $ / mton.

4.2.2 Economic benefit for SAF in the United Kingdom

The aircraft operator has a three-fold economic benefit from their SAF use:

1. The Heathrow airport incentive approx. 550 $ / mton
2. The UK opt-in 1 000 – 1 200 $ / mton
3. The UK ETS allowance cost saving approx. 300 $ / mton

Again, the first two are limited to small SAF volumes, but these all are vital drivers to increase the SAF supplies to the UK market.

4.3 Incentives at the Düsseldorf airport, Flughafen Düsseldorf GmbH

Düsseldorf airport, the fourth largest in Germany, is operated by Flughafen Düsseldorf GmbH. There are close to 100 000 aircraft movements and 8 million passengers per year travelling to, from and via Düsseldorf. The airport's SAF incentive became applicable as from January 2022.

The airport company promotes provision and use of SAF fuels certified in accordance with RED, which are produced with renewable energy and only from residual materials, not competing with food production.

In accordance with Tariff Regulations for Düsseldorf Airport (Flughafen Düsseldorf GmbH, 2021), the airport reimburses 250 € per pure tonne of SAF, up to 1000 € per refuelling / departure. The customer must prove that SAF has been obtained from Düsseldorf airport, and the flight number and date must be provided.

The incentive is only half of the Amsterdam Schiphol incentive, but the economic impact is easy to understand, and the customer does not have to wait for the allocation to be calculated. Because the incentive is limited per refuelling, the magnitude of the operations by certain aircraft operator is automatically taken into consideration and further process step to proportionally allocate the incentive is not required.

4.4 Incentives at Stockholm and Gothenburg airports, Swedavia AB

Swedavia AB is a Swedish airport company operating a network of Swedish airports and has adopted an environmental target that 5 per cent of all jet fuel used at Swedavia airports shall be renewable by 2025.

Swedavia supports up to 50% neat SAF premium cost for approved applications by the customers (Swedavia Airports, 2021). The lower limit is 125 000 and upper limit is 6 million SEK, per the airline group. Total funding available in 2022 is 20 million SEK, and incentives will only be given to volumes exceeding the requirements of national emission reduction mandate.

This incentive is also easy to understand, and it is the only one based on dynamic price differential, i.e., actual SAF and fossil jet fuel prices. Swedavia provides a credit note within 30 days from the application. The SAF must be sustainably sourced, but Swedavia does not specify any criteria for certification. Additionally, the refuelling must take place at one of Swedavia's airports.

According to the Year-End Report (2023), Swedavia AB made 4 846 million SEK net profit, thus the total SAF funding of 20 million SEK would have been only 0.4% profit reduction.

4.4.1 CO_2 emission charge modulation

In addition to the incentive based on the price differential, Swedavia offers the possibility of accounting for Sustainable Aviation Fuel (SAF) that has been used, to deduct the non-fossil proportion of emissions from the CO_2 emission charge modulation. This emission charge adjustment applies only to flights to or from Stockholm Arlanda (85 000 movements, 18 million passengers per year) or Gothenburg Landvetter (23 000 movements, 4.4 million passengers per year), based on the recently adjusted national law (Transportstyrelsen, 2020).

The fee modulation is a complicated mechanism, based on adjusting the emission charge. This charge depends on the emissions during landing-and-take-off cycle (LTO), which is aircraft fuselage and engine type–specific certification value available via the ICAO engine database. The fee modulation is a bonus/malus mechanism, meaning that airlines allocating SAF to their Arlanda or Gothenburg flights are rewarded (with bonus), and the others, polluting more, pay a higher charge (malus).

In the example presented in the Swedavia charges documentation, a flight operated with older generation of Airbus A320, the operator would receive a bonus of 290 SEK, if operating with 20% SAF blend. If operating with 100% fossil fuel then the CO_2 emissions charge would be 236 SEK. Therefore, the benefit would be 526 SEK (approx. 50 $). Considering that a short flight for example to and from Helsinki would require trip fuel approximately 4 400 kg for the roundtrip, 20% SAF blend would have to be 880 kg. Thus the incentive would be 50 $ / 0.88 SAF metric tonne = 56.8 $ / SAF metric tonne. This incentive is clearly a bigger benefit for the local airlines operating short flights, because the longer the flight, the higher trip fuel required. High trip fuel quantity would require high SAF quantity to reach similar 20% share, or the other way round – 880 SAF kg would be very small share on a long-haul flight. Thus the aircraft operator needs to carefully consider how to allocate its SAF use.

The mechanism is cost neutral to the airport company, and SAF volumes required by the Swedish mandate are not taking into consideration, because the modulation would apply equally to all aircraft operators. Furthermore, this mechanism applies regardless of the SAF uplift location, and these volumes can be retroactively allocated only twice a year (Swedavia AB, 2021).

The idea behind this complicated mechanism has been to encourage the aircraft operators to allocate their SAF use wisely. There is a clear incentive for Swedavia's customers to allocate the SAF use to certain routes to/from Arlanda and Gothenburg. Furthermore, the SAF use can be allocated to those aircraft types having highest emissions during the LTO cycle.

This must be emphasized: this is an airport company sustainability reporting initiative and reducing the emissions during the landing and take-off to/from the airport the company operates makes sense, because the airport can report this Scope 3 related emissions reduction in their sustainability report. For example, Swedavia AB reported in their Annual and Sustainability Report 2021 (2022) that the air traffic carbon footprint at Arlanda was 82 kilotonnes of CO_2 in 2021 and 77 kilotonnes of CO_2 in 2020.

Table 1. Carbon footprint at the Stockholm-Arlanda airport.

$ktCO_2$	Air traffic		Ground transport		Swedavia		**Total**	
year	*2021*	*2020*	*2021*	*2020*	*2021*	*2020*	*2021*	*2020*
Arlanda	82	77	30	31	0	0.05	112	109

Air traffic carbon footprint takes the emissions during the LTO cycle into account. Ground transport carbon footprint covers the passengers' emissions to/from the airport and Swedavia carbon footprint is relating to the airport company's own activities (Scope 1). This clearly shows why the airport companies should consider Scope 3 emissions, air traffic related emissions are far higher than airport company's own emissions – even though only a small portion of the flight, operated in the airport vicinity, is considered!

5 Conclusion

The different airport incentive mechanisms were reviewed in Chapter 4. Most of them were similar with each other, but there were also some differences regarding the value or the product origin.

5.1 Cost incentive

The airport companies incentivize the use of SAF mainly in three different ways:

1. Fixed incentive value per SAF metric tonne
2. Fixed percentage value for SAF price premium (price differential between SAF and fossil jet fuel)
3. Modulated emissions charge

Other airports have fixed value for the incentive, but Swedavia mechanism takes the price changes in the fuel market into account, and the incentive covers 50% of the price premium (differential between SAF and fossil jet fuel). It should noted that all incentives are in local currency, although airline jet fuel is usually invoiced in the US dollars, thus there is an currency exchange rate related risk.

Table 2. Economic impact of different SAF incentive mechanisms at the European airports effective for 2023.

	Schiphol	**Heathrow**	**Düsseldorf**	**Swedavia / incentive**	**Swedavia / Modulated emissions charge**
Cost incentive per SAF metric tonne	500 € / 1000 € for e-SAF	460 £	250 €	50% of the price premium	56 $

5.2 Traffic charge modulation

In addition to the SAF incentive scheme, Swedavia has introduced modulated emissions charge, where polluters pay more and aircraft operators with a lower carbon footprint pay less. This in line with Article 3 of the EU directive 2009/12/EC. A lower carbon footprint, often measured as carbon dioxide emissions per revenue tonne kilometre, can be achieved via using a different aircraft type, for example using a propeller aircraft instead of small jet aircraft. Therefore, the traffic charge modulation is not only related to the SAF use. However, higher carbon footprint can be lowered via the SAF use.

Table 3. Airport fee differentiation based on the SAF use at the European airports effective for 2023.

	Schiphol	**Heathrow**	**Düsseldorf**	**Swedavia / incentive**	**Swedavia / Modulated emissions charge**
Airport fee differentiation	no	no	no	no	yes

5.3 National SAF blending mandates

In the Netherlands SAF can be used as an opt-in alternative for fulfilling the road transportation biofuel blending mandate, using the HBE biotickets. The use of SAF generates biotickets, which can be sold at the market for the mandated parties (road transportation fuel distributors).

There is a similar mechanism in the UK, RTFC tickets. The SAF users can benefit from the biotickets and the incentives at the same time. Combining different mechanisms is a very powerful economic driver.

There is a national SAF blending mandate in Sweden, thus Swedavia incentive is only applicable to the volumes exceeding this national emissions reduction requirement, to avoid double counting.

Table 4. Incentives and national SAF blending mandates at the European airports effective for 2023.

	Schiphol	**Heathrow**	**Düsseldorf**	**Swedavia / incentive**	**Swedavia / Modulated emissions charge**
Other SAF incentives	HBE tickets	RTFC tickets	--	--	--
National blending mandate	no	no	no	yes	yes

5.4 SAF production location

Royal Schiphol Group N.V. requires that SAF used under the incentive scheme is produced in Europe, to be eligible for the SAF incentive. This is very strict requirement considering the limited SAF supply currently available, but then again similar limitations have been proposed in the US,

where politicians may decide to change the blender's tax credit to a producer's tax credit as a protectionist measure. It should be noted that Amsterdam is part of the European fuel hub, ARA region (Amsterdam-Rotterdam-Antwerpen), and the oil refinery business has a big impact on the local economy.

Table 5. SAF production location requirement for the SAF incentive mechanisms at the European airports effective for 2023.

	Schiphol	**Heathrow**	**Düsseldorf**	**Swedavia / incentive**	**Swedavia / Modulated emissions charge**
SAF production location	Europe	--	--	--	--

5.5 SAF uplift location

Most airport companies want to promote the SAF supply at their airport, and the SAF incentive is limited to the SAF uplifts from their airports. Swedavia's modulated emissions charge differs from this principle, but then again its main goal is to reduce Scope 3 emissions at the vicinity of Arlanda and Gothenburg airports by allocating SAF for the landing-takeoff cycles regarding the flights to/from these airports.

Table 6. SAF uplift location limitation linked with the SAF incentive mechanisms at the European airports effective for 2023.

	Schiphol	**Heathrow**	**Düsseldorf**	**Swedavia / incentive**	**Swedavia / Modulated emissions charge**
SAF uplift location restricted to the airport	yes	yes	yes	yes	no

5.6 Complexity of the SAF incentive mechanisms

The SAF incentive mechanisms with clear economic value, e.g. € / metric SAF tonne, were considered simple. The aircraft operators can easily analyse in advance what would be their net cost after the different incentives.

Swedavia's modulated emissions charge is the most complex mechanism, but like explained earlier, the target is to get SAF volumes (purchased regardless this incentive) allocated to flights to/from Arlanda or Gothenburg. For example, the aircraft operator could allocate the incentivised

SAF, uplifted from Schiphol to a flight to Gothenburg. The additional economic value via lower emissions charge is very small, but still better than nothing. At the same time, Swedavia lowers Scope 3 emissions.

Table 7. Complexity of different SAF incentive mechanisms at the European airports effective for 2023.

	Schiphol	**Heathrow**	**Düsseldorf**	**Swedavia / incentive**	**Swedavia / Modulated emissions charge**
Complexity	simple	simple	simple	simple	complex

5.7 Most attractive incentive mechanism

Considering the current, relatively high price premiums, from the airlines' viewpoint the most attractive SAF incentive mechanism is not a stand-alone scheme, but availability of multiple incentive mechanisms at the same time is required. Schiphol airport is a good example of that: airport incentive, HBE -biotickets and EU ETS related cost savings create a powerful incentive combination. Despite overlapping mechanisms, the use of SAF usually remains more expensive than the use of fossil jet fuel, partly due to the tax-free status of fossil jet fuel.

Naturally it depends on the aircraft operator's traffic programme, which SAF incentive mechanism is most attractive. The aircraft operator needs to consider not only the destinations, but also the aircraft type to be used. For example, Düsseldorf and Swedavia modulated emissions charge would have the most economic outcome for the narrowbody aircraft due to lower fuel quantity, and it could be interpreted that these incentives would benefit most the home base carriers.

The oversubscribed airport incentives include a clear message: the aircraft operators are interested in using the subsidized SAF, even if the price difference between subsidized SAF and fossil jet fuel remains considerable. The aircraft operators should actively participate the traffic charge consultation processes, to ensure that the airport operators offer incentive schemes or modulated traffic charges. Like mentioned before, the aviation sector has been considered as the most difficult sector to implement sustainability, and all stakeholders must be involved in this difficult task.

5.8 Learning reflection

When I started writing this thesis, I was concerned if there would be fundamental changes due to the European legislation process or the availability of public information. Unfortunately both of these concerns did materialise to certain extent. This meant revised text to certain chapters when

there was new info available related to the legislation process. Regrettably the public information was not too detailed, thus I decided to keep the focus on comparing different incentive systems rather than analysing their holistic economic impact.

The lessons I learnt during the writing of this thesis relate to research methodologies and ESG reporting. Due to the nature of literature review, this work did not include networking or consultation.

Unfortunately my daily work schedule was more hectic than I thought in advance, leaving very limited time for the thesis work.

6 Declaration of competing interest

As the author, I declare that at the time of writing this thesis I was employed by the Sustainable Aviation Fuel producer. However, I did my outmost to keep this thesis as neutral as possible what comes to financial interests, if any.

References

Abdi Yaghoub, Li Xiaoni et al. Exploring the impact of sustainability (ESG) disclosure on firm value and financial performance (FP) in airline industry: the moderating role of size and age. Environment, Development and Sustainability. 24, 5052–5079 (2021).

Argusmedia.com. Argus Biofuels 15th August 2022 (2022).

Barke A, Bley T et al. Are Sustainable Aviation Fuels a Viable Option for Decarbonizing Air Transport in Europe? An Environmental and Economic Sustainability Assessment. Applied Sciences 12(2), 597 (2022).

Bhatt A, Zhang Y et al. Evaluation of performance variables to accelerate the deployment of sustainable aviation fuels at a regional scale. Energy Conversion and Management, 275 (2023).

Bouwer Jaap, Dichter Alex et al. Why rising fuel prices might not be as bad for the airline sector as it seems, McKinsey & Company (2022).

Chen Chun-Da et al. Understanding how ESG-focused airlines reduce the impact of the COVID-19 pandemic on stock returns. Journal of Air Transport Management, 102 (2022).

European Commission. Directive 2009/12/EC of the European Parliament and of the Council of 11 March 2009 on airport charges.

European Commission. Climate Action, Carbon leakage (2021).

Flughafen Düsseldorf GmbH. Tariff Regulations for Düsseldorf Airport (2021).

Franklin A and Blyton P. Researching Sustainability: A Guide to Social Science Methods, Practice and Engagement. Earthscan. (2013)

Heathrow Airport Limited. Conditions of Use including Airport Charges from 1 January 2022 (2021).

Heathrow Airport Limited. LHR Conditions of Use Airport Charges Decision (2021).

Heathrow Airport Limited. Results for the year ended 31 December 2022 (2023).

International Air Transport Association. Sustainable Aviation Fuels, Fact Sheet 5 (2018).

International Air Transport Association. What is SAF? (2020).

International Air Transport Association, McKinsey & Company. Understanding the pandemic's impact on the aviation value chain (2022).

International Civil Aviation Organization. Sustainable Aviation Fuel Guide, version 2 (2018).

International Civil Aviation Organization. Assembly – 40 th Session, Working Paper A40-WP/189 (2019).

International Energy Agency. Aviation (2022).

Kolosz B.W., Luo Y., et al. Life cycle environmental analysis of 'drop in' alternative aviation fuels: a review, Sustainable Energy Fuels, 4, 3229-3263 (2020).

Lai Y.Y., Christley E., et al. Analysing the opportunities and challenges for mitigating the climate impact of aviation: A narrative review, Renewable and Sustainable Energy Reviews, Volume 156 (2022).

McManners P.J. Developing policy integrating sustainability: A case study into aviation. Environmental Science & Policy, 57, 86-92 (2016).

Nederlandse Emissieautoriteit (NEa). Registering delivery of biofuels 2022 - 2030 (2023).

Oehmichen K, Majer S et al. Comprehensive LCA of Biobased Sustainable Aviation Fuels and JET A-1 Multiblend. Applied Sciences 12(7), 3372 (2022).

Roundtable on Sustainable Biomaterials. RSB Principles and Criteria (2016).

Royal Schiphol Group N.V. Annual Report 2022 (2023).

Royal Schiphol Group N.V. Schiphol Airport Charges 2022 – 2024 (2021).

Salman Ahmad, Bing Xu. A cognitive mapping approach to analyse stakeholders' perspectives on sustainable aviation fuels, Transportation Research Part D: Transport and Environment, Volume 100 (2021).

Santos Kristiana et al. Soaring sustainably: Promoting the uptake of sustainable aviation fuels during and post-pandemic. Energy Research & Social Science, 77 (2021).

Seitz D, Frey U et al. Archetype analysis in sustainability research: methodological portfolio and analytical frontiers. Ecology and Society, 24 (3). (2019).

Stargate within EU Green Deal. Catalogue of Airport SAF Actions (2022).

Sobieralski J. Sustainable air transportation through the operational use of a social cost index. Journal of Cleaner Production 385 (2023).

Swedavia AB. Airport Charges & Conditions of Services valid from 1 January 2022 (2021).

Swedavia Airports. Sustainable Aviation Fuel (SAF) Incentive Programme 2022 (2021).

Swedavia AB. Swedavia Annual and Sustainability Report 2021 (2022).

Swedavia AB. Year-End Report January – December 2022 (2023).

Transportstyrelsen. Transportstyrelsens slutredovisning på regeringsuppdrag om miljöstyrande start- och landningsavgifter I2019/02304/TM (2020).

Tsai-Chi, K. et al. Do corporate social responsibility practices improve financial performance? A case study of airline companies. Journal of Cleaner Production, 310, 127380 (2021).

Voigt, C., Kleine, J., Sauer, D. et al. Cleaner burning aviation fuels can reduce contrail cloudiness. Commun Earth Environ 2, 114 (2021).

Wild P., Mathys F., Wang J. Impact of political and market-based measures on aviation emissions and passenger behaviors (a Swiss case study), Transportation Research Interdisciplinary Perspectives, Volume 10 (2021).

Appendices

Appendix 1 Amsterdam Schiphol SAF incentive

Appendix III Conditions SAF incentive

Funding

- Total available funding under this incentive is € 15 million, with the following allocation per Incentive Year:
  - 2022: € 2.5 million
  - 2023: € 5.0 million
  - 2024: € 7.5 million
- The incentive is available to all Qualifying Airlines using Qualifying SAF. Any remaining available support at the end of an Incentive Year will not be carried over to the next year.

Financial details

- € 500 per refueled metric tonne (1,000kg) of SAF (biofuels)
- € 1,000 per refueled metric tonne of e-fuels (synthetic kerosene)

Conditions (cumulative)

- Qualifying SAF:
  - reduces at least 70% CO2 compared to fossil kerosene in its full lifecycle;
  - must be produced in Europe, preferably from European feedstock;
  - adheres to EU certification standards (RED II Annex IX, Part A or B), and
  - is used for refueling at AMS between April 2022 and March 2023, April 2023 and March 2024 or April 2024 and December 2024 ("Incentive Years").

- Qualifying airlines:
  - notify Schiphol of their interest to uptake Qualifying SAF at Schiphol, including a realistic statement of the forecasted quantity for that Incentive Year, no later than April 1st of each Incentive Year, and
  - provide an updated forecast by October 1st during each ongoing Incentive Year.

Schiphol will communicate the notification procedure well before the start of the Incentive Year.

- To receive the SAF incentive, Qualifying Airlines must:
  - provide Schiphol with a proof of contract for the purchase of Qualifying SAF, including the technical specifications of the SAF and carbon reduction certificate;
  - provide Schiphol with a proof of delivery at Aircraft Fuel Supply (AFS);
  - provide any other information that Schiphol considers relevant to determine whether the conditions of this SAF-incentive are fulfilled;
  - share this information for April-September of each Incentive Year no later than October 15th in the respective Incentive Year, and
  - share this information for October-March of each Incentive Year no later than April 15th of the following year. In the final Incentive Year, starting April 2024, this period is defined as October – December, with the requirement to share this information no later than January 15th, 2025.

Procedure

Schiphol will establish the total forecasted quantity of SAF-uptake, as indicated by Qualifying Airlines in April of each Incentive Year.

- If the total forecasted quantity does not exceed the available amount of SAF-incentive for that year, the amount of funding corresponding with each Qualifying Airline application will be reserved for those airlines until September 30th. Schiphol will inform airlines accordingly by May 1st.
- Should the forecasted quantity exceed the available incentives, Schiphol will inform each Qualifying Airline of the maximum quantity of funding that is available under this incentive for that airline by May 1st. In principle, eligible funding is allocated proportionally to the share of forecasted quantities per Qualifying Airline.

Schiphol

- Schiphol reserves the right to apply a 'fair use policy', e.g. for situations in which statements of a Qualifying Airline on the total forecasted quantity of SAF-uptake appear or have proven to be unrealistic, in which case funding is allocated on the basis of reasonableness.
- Qualifying Airlines with an uptake volume of Qualifying SAF that exceeds their allocated budget share of the SAF incentive are eligible to receive the SAF incentive over this additional quantity if any budget for that Incentive Year remains. The remaining budget will be allocated proportionally to the share of Qualifying SAF uptake that was not earmarked for the SAF incentive for that Incentive Year. The incentive value of € 500 per refueled metric tonne of SAF and € 1,000 per refueled metric tonne of synthetic kerosene still applies.

By November 15th of each Incentive Year, Schiphol will provide an interim update to each Qualifying Airline, containing:

- An overview of the incentives receivable for that airline over the period April-September;
- An updated maximum quantity of SAF per airline that is eligible for the incentive in the period October-March, based on the updated forecast.

By May 15th in the following Incentive Year, Schiphol will provide a final overview to each Qualifying Airline, containing:

- An overview of the incentives receivable for that airline over the period April-March of the previous Incentive Year;
- A credit note which will be settled with future invoices and /or due payments OR a separate payment (option to be determined by Schiphol).

Remarks

- Schiphol will treat information received from airlines as confidential. Any publication with regard to this incentive be in a form that is sufficiently aggregated and not traceable to individual airlines.
- Schiphol reserves the right to change the conditions and incentive amount per metric tonne, to be announced no later than May 1st for the April-September period or November 1st for the October-March period.

Appendix 2 London Heathrow SAF incentive

8 **SAF incentive 2022 – 2025**

8.1 A SAF Incentive Scheme will apply between 1 January 2022 and 31 December 2022, the terms of which are set out below.

8.2 In this paragraph 8 of Schedule 4, the following terms shall have the following meanings:

Airline	means an aircraft operator holding a valid operating certificate and who carries passengers to and from the Airport in accordance with these Conditions.
Airline SAF Allocation	means the Airline's allocated share of the SAF tonnage that qualifies for the SAF Incentive Pot.

Airline SAF Proposal	means the tonnage of SAF an Airline proposes to deliver to the Airport between 1 January 2022 and 31 December 2022.
ASK	means the available seat kilometers for each Airline, based on: (i) actual operations in 2019 where the Airline operated at the Airport during 2019; or (ii) actual operations between December 2020 and November 2021 where the Airline has commenced operations at the Airport since 2019.
SAF	means a qualifying sustainable aviation fuel, as set out in Heathrow's SAF Incentive Guidance.
SAF Credit	means an Airline's share of the SAF Incentive Pot based on the SAF Premium multiplied by the tonnage of SAF delivered by the Airline to the Airport in 2022, up to a maximum amount of their Airline SAF Allocation.
SAF Incentive Guidance	means the guidance document that Heathrow will endeavour to publish by 1 January 2022 which sets out further technical details and requirements of the Incentive Scheme.
SAF Incentive Pot	means the total SAF Credit to be paid to qualifying Airlines calculated at a maximum of £10m GBP for 2022 and based on 50% of the SAF Premium required to achieve 0.5% SAF mix at Heathrow.
SAF Premium	means the additional price paid for SAF compared to fossil kerosene fuel, up to a maximum amount of £460 GBP per tonne of SAF.

8.3 The maximum cumulative SAF Credit applied across all qualifying Airlines together will be:

(a) £10 million GBP in 2022;

(b) £23.1 million GBP in 2023;

(c) £48.1 million GBP in 2024;

(d) £99 million GBP in 2025.

8.4 Heathrow reserves the right to amend the figures for the SAF Credit, SAF Premium, the maximum cumulative SAF Credit, Airline SAF Allocation and the SAF Incentive Pot from 2023 onwards at its sole discretion for reasons including, but not limited to, changes in the SAF Premium, Government policy or any other factors.

8.5 In order to participate in the SAF Incentive Scheme, Airlines must confirm their intention to participate by 5pm (UK time) on 31 January 2022 and submit details of their Airline SAF Proposal to Heathrow, in the manner set out in the SAF Incentive Guidance. Failure to submit an Airline SAF Proposal in time means the Airline shall not be able to participate in the SAF Incentive Scheme.

8.6 Following receipt of the Airline SAF Proposal, Heathrow will, by 5pm (UK time) on 14 February 2022, notify the Airline of their Airline SAF Allocation.

8.7 The Airline SAF Allocation will be calculated by:

(a) reviewing the Airline SAF Proposal;

(b) calculating the proportional ASK for each Airline making an Airline SAF Proposal;

(c) dividing the SAF Incentive Pot proportionally between participating airlines, by reference to the cumulative Airline SAF Proposals and ASKs.

8.8 If, following receipt of all Airline SAF Proposals and calculating Airline SAF Allowances, the scheme is undersubscribed, the SAF Incentive Pot will be reduced accordingly.

8.9 Subject to these Conditions, where an Airline has delivered SAF to the Airport meeting its Airline SAF Allocation, it may qualify for a SAF Credit.

8.10 Evidence of SAF delivery to the Airport (in accordance with the requirements set out in Heathrow's SAF Incentive Guidance) must be provided by 5pm (UK time) on 31 January 2023 and will be required for verification prior to allocation of any applicable SAF Credit.

8.11 If, by 23h59 (UK time) on 31 December 2022, an Airline has not delivered its full Airline SAF Allocation then:

(a) it will not qualify for any SAF Credit; and

(b) if it chooses to participate in the following year of the SAF Incentive Scheme, the Airline's following year Airline SAF Allocation will be reduced by a percentage amount equivalent to the SAF volume which was not delivered in the previous year.

Heathrow may, at its sole discretion, exempt an Airline from the consequences set out in this paragraph 8.11 in circumstances where the Airline has delivered at least 95% or more of its Airline SAF Allocation, and the reasons for not delivering 100% of its Airline SAF Allocation are wholly outside of the Airline's control and the Airline can provide evidence supporting such reasons to Heathrow by 31 January 2023.

8.12 If, prior to the date on which the SAF Credit is applied, an Airline ceases operations at the Airport (including but not limited to, for reasons of insolvency), any SAF Credit relating to that Airline will no longer be applicable.

8.13 Subject to these Conditions, any applicable SAF Credit will be implemented by way of a credit to each qualifying Airline's Heathrow airport charges account by 31 March 2023 (inclusive). A SAF Credit is non-transferable, has no cash value and cannot be withdrawn or cashed-out in any way. A SAF Credit can only be used against airport charges incurred by way of operations at the Airport. If, as at the date of intended application of the SAF Credit, you have outstanding debts owing to us, you have 21 days in which to confirm which account debt the amount should be receipted against. If no such confirmation is forthcoming, the SAF Credit will be applied so as to be receipted against the oldest outstanding undisputed debt on your Heathrow airport charges account.

Appendix 3 Düsseldorf SAF incentive

4. Programme to promote ecological sustainability in air transport

FDG promotes the use of new, ecologically sustainable forms of propulsion in air transport at the Düsseldorf location in the near future. This applies both to purely electrically powered aircraft and to alternative aviation fuel, hereinafter referred to as "Sustainable Aviation Fuel" (SAF).

4.1 Electric aircraft

In order to promote flights with an exclusively electrically powered aircraft (i.e. aircraft without a combustion engine), for commercial aviation as well as for aviation in general, the landing and take-off fee is reduced to a fee of € 1.00 per tonne MTOW or part thereof.

4.2 Use of alternative fuels/sustainable aviation fuel (SAF)

FDG promotes the provision and future use of alternative jet fuel at the Düsseldorf Airport. The FDG only promotes the use of blendable fuel that is certified in accordance with the EU Renewable Energy Directive REDII. Hence, it is the aim of the FDG to exclusively promote the use of fuels whose production only uses electricity from renewable energy sources and only residual materials or residual biomass that do not compete with food production.

To participate in the funding programme described in 4.2, the airline must register once informally with the FDG by sending an e-mail to SAF@dus.com no later than four weeks before the start of a funding period or the start of operations in Düsseldorf. It is not necessary to re-register for subsequent periods, provided that there has been no change in relation to the initial registration.

FDG reimburses € 250.00 per tonne of blendable SAF refuelled up to a maximum amount of funding of € 1,000.00 per refuelling / departure, but not more than € 100,000.00 per year and airline.
The following requirements must be met:

- The airline or the aircraft pilot must prove that they have obtained SAF locally for the departure out of Düsseldorf.
- Funding is per tonne of pure SAF, whereby the mixing ratio is taken into account accordingly.
- The airline or the pilot must provide the FDG with proof of the above, i.e. with flight number and date, or aircraft registration number and date, to be sent monthly to FDG by e-mail to SAF@dus.com by January 10 of the following year at the least.

5. Definitions

5.1 The funding period corresponds to the calendar year.

5.2 Flights: all take-offs and landings in Düsseldorf of scheduled commercial passenger flights in large-scale aviation (FDG flight types 11 to 38 without flight types 12 and 22 = redirected flights), the operational flight number of which bears the code of the respective airline. Code share flight numbers are not taken into account.

Appendix 4a Swedavia SAF incentive

Swedavia Airports

2022-01-01

Swedavia – Sustainable Aviation Fuel (SAF) Incentive Programme 2022[1]

Swedavia has adopted an environmental target that 5 per cent of all jet fuel used at Swedavia airports shall be renewable by 2025. To support airlines operating scheduled and/or charter traffic at any Swedavia airport that are using SAF Swedavia continue its Sustainable Aviation Fuel Incentive Programme during 2022.

Swedavia supports up to 50 % of the premium cost for neat SAF for approved applications. The lower limit for Swedavia is to support with 125 000 SEK, which makes the minimum premium cost 250 000 SEK for an airline group[2]. The maximum support from Swedavia to an airline group is 6 MSEK until September 1st, 2022, after which the limitation is waived. The total fund available for use during 2022 is 20 MSEK.

Since a national reduction mandate for SAF has been introduced, incentives will only be given to volumes exceeding the requirements of that mandate.

Application Procedure

An airline group interested to participate in the incentive programme must contact Swedavia before any purchase with a completed application. Based on the application and the remaining funds in the SAF Incentive Programme, Swedavia will make a decision and reserve the decided funding from the SAF Incentive Programme. When the decision is made the airline will be informed.

The required written verifications (including proof of refuelling) must have been submitted to Swedavia no later than 4 months after a completed application has been filed. If the reserved funds have not been used, the funds are released back into the incentive fund.

The verifications must show the purchase order, including the price of the fuel, the volumes of SAF purchased, the refuelling ticket and the sustainability documentation.

The funding will be provided once Swedavia has received, checked and approved the requested documentation. Swedavia will pay out the funds as a credit within 30 days after having approved the documentation.

Criteria of the Programme

The neat sustainable aviation fuel must be sustainably sourced. The refuelling with sustainable aviation fuel must be made at one of Swedavia's airports.

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[1] Valid between January 1st and December 31st, 2022
[2] Airline group consists of one or more airlines

Rules and regulations

The Programme for 2022 will operate between January 1st, 2022 and December 31st, 2022. The total funding for this Programme is 20 MSEK. The support will be offered for as long as there are funds remaining during the given period.

The application process starts January 1st, 2022 at 00:00 CET, Swedavia will not accept applications prior to the start of the application process.

The cost premium may be provided by the fuel supplier. If no such information is given the cost premium will be calculated by subtracting the actual cost for neat SAF (submitted by the airline) with the spot rate for Jet Fuel[3] at the date the request was first processed.

Each airline group is allowed to apply for the incentive once per month. An ownership threshold of 51 per cent is applied to determine whether a particular airline belongs to a group or not.

The support will be divided equally in cases where several airlines are applying for the last amount of the fund during the same day.

Since a national reduction mandate for SAF has been introduced from 1st of July 2021, incentives will only be given to volumes exceeding the requirements of that mandate.

The currency used to calculate the support is SEK (Swedish krona). Swedavia reserves the right to apply conversion rates for purchases made in any other currency.

Manipulation with the required annexes or other required information, may cause the airline to be disqualified from the Programme. Swedavia reserves the right to disqualify an airline from the Programme if the airline in Swedavia's view fails to comply with the criteria and rules and regulations for the Programme. Nor will any incentives be paid if the airline has not fulfilled its obligations to Swedavia.

Any dispute arising in connection with the incentive programme shall be settled in a Swedish court under Swedish law.

Swedavia's Conditions of Services posted on www.swedavia.com shall apply to the Programme.

For more information about the Swedavia Incentive Programme, please contact your contact person or send an e-mail to aviationbusiness@swedavia.se

[3] Using the Jet Fuel Price Monitor (Europe & CIS)
https://www.iata.org/publications/economics/fuel-monitor/Pages/index.aspx

Appendix 4b Swedavia modulated emissions charge

2.3 CO2 Emission Charge

Swedavia is active in mitigating climate affecting emissions and considers sustainability to be of critical importance for the future of the aviation industry. The CO2 Emission Charge is designed on bonus malus principles to be revenue neutral for Swedavia and to incentivise airlines to continuously improve their CO2 efficiency.

The CO2 Emission Charge follows the standard landing and take-off (LTO) cycle and is based on certified engine data in the LTO cycle in accordance with International Civil Aviation Organization (ICAO)s Engine Emission Databank. The absolute amount of CO2 in the LTO cycle is calculated based on the average measured fuel flow values for all LTO modes of the individual engine[2] multiplied with the thermodynamic constant 3.16 to express the amount of CO2 emitted.

An adjustment to actual conditions is made for taxi times in ICAO's LTO cycle (instead of the standard time of 26 minutes) according to the table below. The following standard ICAO LTO cycle times are applied without adjustments at all airports: Approach 4 min, Take-Off 0.7 min and Climb 2.2 min.

Taxi times applied at each airport

Airport	Minutes
Stockholm Arlanda	17:30
Göteborg Landvetter	13:00

LTO cycle modes: approach, taxi, take-off and climb

CO2 aircraft per mode = Number of Engines x (fuel flow x mode time x 60 x 3.16) (in kg CO2)

CO2 aircraft = Σ CO2 aircraft per mode for all 4 modes

Each individual aircraft's CO2 is divided by either the number of seats or the number of tons in MTOW (depending on their segment) to receive a relative efficiency measurement to compare against the airport's expected average CO2 efficiency.

Traffic segment	Relative efficiency measurement
Passenger Traffic ≤ 175 MTOW	CO2 per seat
Non-passenger Traffic ≤ 175 MTOW	CO2 per ton in MTOW
All Traffic > 175 MTOW	CO2 per ton in MTOW

Passenger traffic is defined as being designated ICAO's subclass "P" and the number of tons in MTOW is rounded to the nearest 1 000 kg.

If the aircraft has lower relative CO2 emissions than the expected average for the airport 2022, it receives a bonus in accordance with the bonus formula. If the aircraft instead has higher relative CO2 emissions than it expected average for the airport, it receives a malus in accordance with the penalty formula. The input data for the airports and traffic segments can be found in the tables below.

[2] See ICAO's Aircraft Engine Emission Databank

Formulas for calculating Reward/Penalty	
Bonus formula (if aircraft CO2 < average CO2)	$\frac{(aircraft\ CO_2 - average\ CO_2)}{(minimum\ CO_2 - average\ CO_2)} \times maximum\ reward$
Malus formula (if aircraft CO2 > average CO2)	$\frac{(aircraft\ CO_2 - average\ CO_2)}{(maximum\ CO_2 - average\ CO_2)} \times maximum\ penalty$

If the aircraft CO2 would be identical to the average CO2, the charge is 0 SEK.

The average emission values per segment is estimated the year before and the max/min rates are set to render a net zero result for Swedavia per airport and traffic segment. The overall financial result of the differentiation is evaluated the year after, and in the event of a surplus or deficit, the total deviation from the principle of revenue neutrality is adjusted for in the following year's airport charges by an adjustment to the total cost base.

	Stockholm Arlanda			Göteborg Landvetter		
	Passenger traffic ≤ 175 MTOW	Non-passenger traffic ≤ 175 MTOW	All traffic > 175 MTOW	Passenger traffic ≤ 175 MTOW	Non-passenger traffic ≤ 175 MTOW	All traffic > 175 MTOW
Estimated average emissions	11.91	31.03	23.06	11.54	29.36	21.04
Maximum CO2	20	50	27	20	50	27
Minimum CO2	10	20	17	10	20	17
Max Reward [SEK/MTOW]	-6.94	-14.82	-9.13	-6.37	-11.29	-3.46
Max Penalty [SEK/MTOW]	14.75	15.32	5.22	22.35	26.03	4.44

If there is no information available about engine type and/or emissions, charges are calculated based on the least favourable values for the specific type of aircraft.

The charge is exempted for aircraft with and MTOW less than 5 700 kg, helicopters, and for traffic exempted in accordance with the exemptions stated in 1.3 and 2.1.4.

Deduction of SAF-proportion from modulation

Swedavia offers the possibility of accounting for Sustainable Aviation Fuel (SAF) that has been used and thereby deduct the non-fossil proportion of emissions from the modulation. This decision applies regardless of where the SAF has been refuelled so long as airlines can verify their purchase and subsequent injection of the SAF into the fuelling system and attest to only attributing the volumes to routes to or from Stockholm Arlanda or Göteborg Landvetter. Such SAF-volumes can only be allocated on a retroactive basis at a maximum two times per year and airline on a consolidated basis, which will result in the issuing of a credit equal to the impact the fuel volumes would have had if directly included in the CO2 Emission Charge calculations.

The following formula is applied in order to adjust the CO2 calculation in accordance with the reported share of SAF compared to total fuel consumption of the route (round trip).

Formula used for reported SAF	
Adjusted aircraft CO2	$adjusted\ CO_2 = Total\ CO_2 - CO_2\ from\ SAF\ proportion$

An application must be made using Swedavia's application form and be supplemented by the following verifications and information (in Swedish or English):

- Proof of purchase and refuelling
- Sustainability documentation
- Total fuel consumption for the route to which the SAF is allocated

Airlines will also be able to account for SAF from national blend in requirements, but these volumes are capped to the specific requirement (e.g. not possible to aggregate total SAF volumes to ARN/GOT as destination if the requirement is 2% of overall fuel). SAF pertaining to a blend in-requirement and refuelled at ARN or GOT is excluded from the modulation as an inclusion would affect all airlines equally and ultimately serve no differentiation purpose for the modulation. SAF volumes relating to blend in requirements/reduction schemes may only be reported after the calendar year is concluded and an application must be made before 1 April the following year. Such applications must also contain a verification from the airlines' fuel supplier of the rate of compliance as Swedavia will only credit actual SAF and not accept volumes substituted by penalties.

For a complete list of requirements connected to the documentation – please see Swedavia's application form for SAF-reporting on https://www.swedavia.com/about-swedavia/airport-charges/ along with information relating to the submitting of applications.

Examples of the CO2 Emission Charge

Arline A operates a A320 at Stockholm Arlanda with the following engine data and capacity, which receives a penalty of 236 SEK due to higher relative emissions than the estimated airport average.

Airline A: A320, without SAF

Airport	ARN
Engine	CFM56-5B4/3
MTOW (tons)	77
No of engines	2
%-SAF	0%
Passenger flight?	Yes
Number of Seats	165
Fuel to CO2 factor	3,16

	Approach	Taxi	Take-Off	Climb	Sum
Fuelflow per engine (kg/s)	0,32	0,10	1,14	0,94	N/A
Mode time (s)	240	1 050	42	132	1 464
Fuel per engine and mode (kg)	75,84	107,10	47,96	123,95	355
Total fossil CO2 per mode (kg)	479,31	676,87	303,13	783,35	2 243

Fossil CO2/Seat (kg)	13,59
Penalty/Reward per MTOW	3,06
Total Penalty/Reward	236 SEK

Negative values are rewards and positive values penalties

Airline B operates with an identical aircraft but uses SAF at a 20 % blend in. Airlines B is initially invoiced the same penalty, 236 SEK, however the effects of the SAF is adjusted for retroactively upon completion of the SAF-reporting. The total effect of the adjustment is then 236 - (-290) = 526 SEK in order to include re-payment of the amount initially invoiced and apply the adjusted performance.

Airline B: A320, with SAF

Airport	ARN
Engine	CFM56-5B4/3
MTOW (tons)	77
No of engines	2
%-SAF	20%
Passenger flight?	Yes
Number of Seats	165
Fuel to CO2 factor	3,16

	Approach	Taxi	Take-Off	Climb	Sum
Fuelflow per engine (kg/s)	0,32	0,10	1,14	0,94	N/A
Mode time (s)	240	1 050	42	132	1 464
Fuel per engine and mode (kg)	75,84	107,10	47,96	123,95	355
Total fossil CO2 per mode (kg)	383,45	541,50	242,51	626,68	1 794

Fossil CO2/Seat (kg)	10,87
Penalty/Reward per MTOW	-3,77
Total Penalty/Reward	-290 SEK

Negative values are rewards and positive values penalties