# Fuels supply chain – SAF, sustainability criteria, best practice framework and future options

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This report covers ALIGHT WP2:
D2.1 Report on the decision process and other circumstances involved to establish a production facility and identification of possible alternative delivery options (as updated).
D2.2 Guidance on sustainability criteria and best practice framework.

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# Acronyms

| | |
|---|---|
| AAM | Advanced Air Mobility |
| ADR | Aeroporti di Roma |
| AI | Artificial Intelligence |
| Air BP | Air BP Limited |
| ALIGHT | A Light House Airport |
| AMS | Amsterdam Airport |
| AOC | Airline Operations Committee |
| APU | Auxiliary Power Unit |
| ASTM | American Society for Testing and Materials |
| ATC | Air traffic control |
| AtJ | Alcohol-to-Jet |
| AZEA | Alliance for Zero Emission Aviation |
| BECCS | Bioenergi with CCS |
| BKL | Brændstoflageret Københavns Lufthavn I/S |
| BoL | Bill of Lading |
| BtL | Biomass to Liquid |
| CAF | Conventional Aviation Fuels |
| CCS/U | Carbon Capture Storage/Usage |
| CDR | Carbon Dioxide Removal |
| CfD | Contracts for Difference, agreement to exchange the difference in price |
| CIA | Ciampino Airport |
| $CO_2$ | Carbon Dioxide |
| CoA | Certificate of Analysis |
| CoC | Chain-of-Custody |
| CoQ | Certificate of Quality |
| CORSIA | Carbon Offsetting and Reduction Scheme for International Aviation |
| CPH | Copenhagen Airport |
| DAC | Direct Air Capture |
| DCC | DCC & Shell Aviation Denmark A/S |
| DLR | Deutsches Zentrum Für Luft und Raumfahrt EV |
| DTI | Teknologisk Institut |
| DTU | Danmarks Tekniske Universitet |
| EASA | European Union Aviation Safety Agency |
| EEA | European Economic Area |
| eGSE | Electric GSE / Electric Ground Support Equipment |
| EI | The Energy Institute |
| ENI | Eni S.p. Italian refinery |
| eSAF | Electric and hydrogen based SAF |
| EU | European Union |
| EU ETS | EU Emissions Trading System |

| | |
|---|---|
| EU RED | EU Renewable Energy Directive |
| eVTOL | Electric Vertical Take-Off and Landing |
| FAME | Fatty Acid Methyl Ester |
| FCO | Fiumicino Airport |
| FGF | Fly Green Found |
| FID | Final Investment Decision |
| FSII | Antifreeze additive-product |
| FT | Fischer-Tropsch |
| GH2 | Gaseous hydrogen |
| GHG | Green House Gas |
| GPU | Ground Power Unit |
| GREET | Greenhouse Gases, Regulated Emissions, Energy Use in Technologies (US) |
| GSE | Ground Support Equipment |
| HEFA | Hydro-Processed Esters and Fatty Acids |
| HTL | hydrothermal liquefaction |
| HVO | Hydrogenated Vegetable Oil |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| IoT | Internet of Things |
| IRA | Inflation Reduction Act |
| ISCC | International Sustainability and Carbon Certification |
| JIG | Joint Inspection Group |
| LCA | Life-Cycle Analysis |
| LCAF | Low Carbon Aviation Fuel |
| LH2 | Liquid hydrogen |
| MARS | Multiple Aircraft Ramp System |
| MBM | Market-Based Measures |
| MK1 | Miljøklasse 1 Diesel (environment classification) |
| MRV/A | Monitoring, Reporting, Verification/Accounting |
| MW | Megawatt |
| NEA | Nordic Network for Electric Aviation |
| NEIS | National Energy Independence Strategy (Lithuania) |
| NISA | Nordic Initiative for Sustainable Aviation |
| NOx | Nitrous Oxide |
| OEMs | Original Equipment Manufacturers |
| OLGA | Holistic & Green Airport. Parallel EU Project. |
| PCA | Preconditioned Air |
| PoC | Proof of Compliance |
| PoS | Proof of Sustainability |
| PPP | Public Private Partnership |
| PTD | Product Transfer Document |
| PtL | Power-to-Liquid |

| | |
|---|---|
| RCQ | Refinery Certificate of Quality |
| RAT/RAM | Ram Air Turbine |
| RED | Renewable Energy Directive |
| REFUA | ReFuelEU Aviation |
| RFNBO | Renewable Fuels of Non-Biological Origins |
| RLCF | Renewable and Low-Carbon Fuels. Industrial Alliance. |
| RSB | Roundtable on Sustainable Biomaterials |
| RTC | Recertification Test Certificate |
| RWGS | Reverse Water-Gas Shift reaction, - a chemical converting process |
| SAF | Sustainable Aviation Fuels, sustainably certified synthetic blending component |
| SAS | Scandinavian Airlines System |
| SBTi | Science-Based Targets Initiative |
| SCS | Sustainability Certification Schemes |
| SFJ | Kangerlussuaq Airport |
| St1 | Finnish/Swedish oil- and energy company |
| STIP | Sustainable Transport Investment Plan |
| TUHH | Technische Universität Hamburg |
| TULIPS | Parallel EU Project |
| UDB | Union Data Base |
| UK | United Kingdom |
| UK Def. Stan 91-091 | United Kingdom's Defence Standard 91-091 |
| UNFCC | United Nations Framework Convention on Climate Change |
| UNIPR | Universita Degli Studi Di Parma |
| V2X | Vehicle-to-everything |
| VCE | Venice Airport |
| WP | Work Package |

# Acknowledgements

Project ALIGHT was launched in 2020, planned for four, but was extended to 5 years. It is a Horizon 2020 EU funded project whereby key partners meet to collaborate with the mission to:

- Enhance sustainable aviation, and
- Bring forward the necessary solutions, knowledge, guidelines, and best practice handbooks supporting an efficient airport paradigm shift towards zero emission aviation and airport operation.

WP2 and NISA thank all Project ALIGHT consortium partners and external partners who collaborated on the reading, authoring, and editing of this report.

**Project ALIGHT 17 partners:**

*Airline*: SAS

*Airports*: Copenhagen, Rome, Vilnius, and Warsaw.

*Fuel supplier/handler*: Air BP, BKL

*Sustainability Certification Scheme*: Roundtable on Sustainable Biomaterials

*Industry Association*: IATA

*Knowledge Institutions*: DLR, DTI, NISA, Hamburg Univ. of Technology, University of Parma.

*Technology providers*: Airbus, Hybrid Greentech, BMGI Consulting

Copenhagen Airport (CPH) was selected as the airport where to develop and demonstrate two sustainable solutions for implementation, namely:

1. The supply, implementation, integration, and smart use of SAF and SAF blends.
2. The development, integration, and implementation of smart energy system (including renewable energy sources, energy storage and energy management).

## ALIGHT Objectives

- To facilitate Copenhagen Airport as a Lighthouse Airport, showing the sustainable way towards zero emission airport operation.
- To facilitate the deployment of sustainable aviation fuels (SAF), e-mobility, energy storage and waste heat recovery at Copenhagen Airport (Lighthouse airport), Rome Airport, Vilnius Airport (fellow airport) and the new Warsaw Airport.
- To secure knowledge transfer and tools supporting a smooth and efficient replication on a pan-European scale.
- To facilitate the integration of smart & sustainable airport deployment into urban planning and cities strategic development for a bold vision by 2050.

ALIGHT will thereby contribute to achieving the environmental targets set by national governments, of the Paris Agreement, the Renewable Energy Directive (RED II) and others through the reduction of GHG and other air emissions by the aviation industry, ALIGHT will also contribute to developing a bold vision for the sustainable airports of the future.

## ALIGHT approach

Copenhagen Airport is the lighthouse for the H2020 Smart Airports project ALIGHT. CPH will showcase the way to the sustainable airport of the future. The mission is to give best practice recommendations that can be replicated by other airports.

A best practice guide for Sustainable Energy Fuel handling and logistics will be developed. An innovative concept for a cost-effective fuel supply chain will be demonstrated at CPH.

Solutions for renewable energy for ground activities and vehicles within the airport will also be found. This includes own production of sustainable energy, energy storage and electrification.

# Introduction to the report

**ALIGHT Work Packages 2:**
**Fuels supply chain – SAF options, sustainability criteria and best practice framework**
WP2 tasks have been to analyse the conditions and prerequisites for SAF supplies to the airport, and to determine how implementation and use can be handled, administered, and developed. The background for this was the goal of creating conditions for a sustainable future airport. The activities in this work package have thus primarily been aimed at areas and issues that have predominantly been outside the airport, or figuratively speaking, aimed at topics that belong before the airport, but of course, as elements that must be fed into the airport. This covers a wide range of topics, including SAF feedstocks, manufacturing processes, deliveries, logistics, transport, rules, procedures, delivery methods, and infrastructure, many of which are international regulations and other locally adapted versions or elements of the fuel supply chain.

The tasks set have been formulated as the following deliveries:

"Report on the decision process and other circumstances involved to establish a production facility and identification of possible alternative delivery options"

"Guidance on sustainability criteria and best practice framework"

The tasks have been handled through report D2.1, delivered in month 22 of the project period, and the present report D2.2, which concludes with the end of the project.

Developments in both legislation and practice since the first delivery have necessitated a significant update, which is fully incorporated in D2.2.

WP2 has worked on several formulated objectives, which are shown and explained below:

**Identification, preparation, and visualization of relevant documentation processes/ structures in the SAF/fuel supply chain for subsequent reporting/accounting**
This involves all relevant criteria, approvals, regulations, and procedures for the fuel supply chain, certifications and inspections that form the basis for SAF blending, procedures and subsequent transport, storage, supplier distribution, receiving at the airport fuel farm, delivery to aircraft and final reporting to EU and national authorities. The fuel infrastructure and associated logistics at CPH (and airports), as well as quality control of SAF and the blended fuel delivered to the airlines, including accounting and reporting, have been reviewed and are handled through established reporting structures.

**To create the optimal conditions for the supply of SAF to CPH, including future opportunities (e.g., future production facilities in proximity to CPH)**
The report reviews the best possible conditions for supplying used quantities of CAF and SAF via pipelines between the fuel terminal and the airport fuel farm. Segregated storage of SAF mixed fuel reviewed as a potential future option. Production facilities in the vicinity of the CPH location, as well as the geographical, energy, and raw material framework conditions, and the political and economic aspects of the potential facilities, are described and analysed in several ways.

**To act as a link between supplier, possibly suppliers, and end users**
Producer/supplier connection implemented through dialogues with NESTE, with a possible agreement on deliveries to several airlines. Meetings and development dialogues with fuel producer and supplier St1 (Finnish/Swedish), in connection with end users/airlines, were held. Cooperation with and information from three eSAF project owners in Denmark, one in Norway and two in Sweden have been part of the WP2 activities.

In addition, active involvement in the MtJ process with Topsøe, SkyNRG, the University of Aalborg, and DTU, as well as further active engagement in the ASTM approval process for 100% SATF (SAF), was carried out during the project. - Also, in line with developments during the project period and in dialogue with the EU Project officer, it includes dialogues and collaboration with developers and manufacturers of electric aircraft, external airports and more.

**To investigate two options for the necessary supply to the airport, considering product prices, delivery capacity, sustainability, and continuity**
The possibilities for increasing SAF supply have been pursued vigorously from 2021 to 2024. Options for supply have included dialogues with St1 and NESTE, DCC Shell Aviation, and other suppliers and airlines, as well as communicated proposals, and have been tested. Both delivery capacity and end-user capability have been extremely low for several reasons. With the implementation of RefuelEU Aviation, it seems balanced volumes in line with requirements will be achieved by 2025. Prices fluctuate and vary depending on location, time, and delivery time. Sustainability, according to REDII/III, has been followed and analysed. Still, several questions were also raised regarding volumes, prices, and quality, as well as dialogues and research on fraud and life-cycle analysis.

**To prepare methods and check quality, delivery, and quantities in an upcoming SAF flow**
In the review of best practices for feedstocks, production routes, SAF pathways, the regulatory framework, and sustainability criteria, several methods are outlined for insight and handling of upcoming SAF supplies. Formal reporting systems that include the above as well as SAF and CAF quantities, qualities, blends, delivery locations, etc., must take place in the established

system for reporting aviation fuel use to national authorities as well as the Union Data Base and EASA, which are prepared, described, and discussed with several relevant actors.

**Specific objectives regarding supply line, impact, and Key Exploitable Results**
The conditions for storage tanks for SAF, blend-in, ordering, off-airport storage, transport to the airport fuel farm, and aircraft fuelling have been established, reviewed, and applied for the quantities agreed upon between the supplier and airlines. Future options for the possible establishment of alternative methods, storage, and blending have been reviewed and discussed with relevant parties in the supply chain, included in dialogues with fellow airports (primarily D2.2), and described in chapters 1 and 3.

With thorough assessments of the limited possibilities for accessing, using, and implementing SAF quantities for CPH in the first four years of the project, the efforts have been targeted at accelerating the establishment of alternative opportunities to promote SAF. This has included concrete initiatives, such as the SAF Pool initiative, active participation in national committees and fora, with the explicit aim of introducing SAF use among relevant and accessible users. In addition, there has been an appropriate and extensive series of activities around political decisions, both nationally and at the EU level, that address SAF mandates, quantities, prices, improvement proposals, concerns, recommendations, etc. For several well-argued, need-based reasons, there has been a clear focus on alternatives to the biomass products currently used. Extensive engagement in and dialogues with manufacturers of PtX-based eSAF products and developers in Denmark, the Nordics and other countries has been carried out and has thus formed the basis for the proposals and recommendations made in the project. Intensive dialogues with producers of existing HEFA-based fuel products, Neste and St1, form the basis of the work package's activities.

With a parallel, result-oriented approach, the project has been a significant factor in analysing and communicating the future of zero-emission aviation. ALIGHT's work on "The aircraft stand of the future" has, with parallel engagements in national, Nordic, and European development activities, contributed to a broad understanding that airports, airlines and authorities can increase efforts for the prerequisites that need to be in place to be able to handle and operate the aircraft, energies and supplies of the future. Organizing conferences and workshops, as well as participating in several external activities, has also had a noticeable impact and is primarily covered in chapters 2, 3, 4, 5, 6 and the D5.5 report "Future aircraft stands and Conceptual design".

The SAF use challenge: As a historical background, four factors have led to a different understanding of the forecast presented at the start of the project than was expected at the time. 1. Access to SAF in the period 2021-25 was not achievable to the expected extent, which, in any case, made the forecast impossible. 2. COVID-19 set the development at a slower pace due to the financial situation of end users and other priorities, which also left its mark on manufacturers, developers, and legislators. 3. Decision-making, financing and ordering of SAF is primarily a matter for airlines, which, with the situation as shown in points 1 and 2, have not given the project great opportunities to influence SAF volumes. 4. In the period 2022 to 2024, the European aviation sector has been in a tense waiting or preparation position for RefuelEU Aviation. First, regarding the content before and after its adoption and subsequent implementation, which includes a 2% mandatory SAF blend-in from 2025, increasing to 6% in 2030. One consequence has been that the project's forecast has been revised to 2% in 2025, and the largest fuel supplier has most recently confirmed that this target will be met. Expectations and correction thereof are included in the internal ALIGHT risk analysis from 2022 and a revised forecast in 2023.

SAF supply to CPH is established through the existing pipeline and supply system. It runs from the SAF storage tank at Prøvestenen to the pumps pipe valves where SAF is blended with the conventional fuel. Assessment of the existing supply line shows a high degree of safety and maturity, and that it can supply the airport with SAF if blend-in is used. This central model is assessed as the safest in terms of compliance with standards, criteria, and inspections. These described key exploitable results concern the development or assessment of a concrete supply model for sustainable aviation fuel (SAF) for Copenhagen Airport (CPH) as well as a transferable concept for use at other airports. Where it is not established, it is recommended to install. Of course, considering whether it is possible and appropriate, all local conditions are considered, including whether it is sufficiently flexible regarding product and supplier variation. But otherwise, the pipeline model is often the optimal method for transporting mixed SAF from a fuel storage terminal and is thus a transferable concept for use in many other, primarily larger airports. Although SAF products are still limited, all signs indicate they will expand for many years to come. The practical transport methods are qualified, integrated, applied, and evaluated in real conditions, drawing on extensive experience and cooperation with supply chain actors.

The assessments also consider options for connecting to local SAF production (e.g., from a future Danish PtL plant or biorefineries), including raw material and technology choices (HEFA, eSAF). It is assumed that SAF will continue to be supplied to existing purpose-built SAF tanks at the fuel terminal, provided that current and potential suppliers can agree to use the same SAF storage tank or additional tanks in the future. Assessment of alternatives, such as an additional pipeline or supply by tanker truck, shows that the costs, both in terms of construction and operation, do not make this attractive.

Overall, alternative physical delivery scenarios are included. Analysis of possible supply routes to CPH - including access to pipelines, road transport, storage, and handling at the airport's existing or newly established tank facilities. The setup in which national political considerations prevail, or whether access to 100% SAF is desired, should be considered. It might be worth noting that other airports may have different assumptions.

Scalability and integration: Assessing how the solution can scale with increasing demand, as well as how technological and energy integration can be achieved in collaboration with partners (e.g., via PtX collaborations), are essential elements. - IPR potential: Lies in existing system integration technologies and models for energy-efficient supply chains, which can be updated and patented or standardized in possible partnerships or individually. It can also be actualised elsewhere through the ALIGHT project, possibly the best related project partner, DLR, which has worked with fuel distribution systems.

**To develop input for best practice recommendations, together with fellow airports**
Based on best practices, recommendations have been developed for relevant users, such as future buyers of SAF. Furthermore, a case study was conducted in CPH on current supplier deliveries to airlines. Initiatives and opportunities from fellow airports and many ALIGHT partners are also included as examples of best practices, learnings, development tools, and knowledge and experience exchange.

From the start of the project, the focus has been on preparing recommendations and proposals, and on identifying key considerations related to the topics discussed and addressed along the way.


As a result, multiple perspectives are examined and challenges identified throughout the process, leading to the development of comprehensive checklists and questions for ongoing procedures among airports, airlines, authorities, and other stakeholders. These tools serve as prompts for further analysis and careful consideration in planning and roadmap development.

**Roadmap for the possible future optimal supply of SAF and energy to the airport**

Airports are key centres for traffic, trade, tourism, and transport integration, and must carefully plan for long-term fuel and energy security. Future-focused airports should serve as innovation and energy hubs, efficiently managing resources and infrastructure updates to meet evolving needs.

Access to energy and fuel supplies in necessary quantities, qualities, and prices can change over time. It is therefore essential to consider how a large airport can best secure its activities, customers, and functions. Extensive restructuring can result in significant changes in existing framework conditions and current models, procedures, and ways of doing things. This may entail changes for current players but also create exciting and future-proof conditions for relevant players, both current and new.

Should the airport choose a long-term, integrated business model as a strategic solution for future deliveries, it will require thorough preparation, including investment decisions and legal and competitive analyses, which, in turn, will lead to extensive new agreements and contracts. This would be a long-term, strategic approach that integrates production, supply, logistics, political regulation, and collaboration among key players. An overview outlining the key conditions for supplying fuel, SAF, and energy to the airport towards 2050 could be usefully divided into three main phases: Short-term (2026–2030), medium-term (2030–2040), and long-term (2040–2050).

**Focusing on the following key areas:**

**1. Infrastructure and logistics:** Expansion of storage and distribution capacity for, in and around the airport, possible SAF integration into existing fuel systems and possible pipeline solutions.

**2. Local and regional production:** Establishment of SAF production in geographical proximity to the airport, e.g., via Power-to-X facilities nearby, to minimize transport distances and emission footprints and to create common interests.

**3. Securing energy supply:** Through external/internal, long-term capacities and updated infrastructure.

**4. Political and economic framework:** Strengthening incentives through support schemes, differentiated tax policy, quota incentives and requirements for increasing use of climate-improving fuels and energies.

**5. Cooperation and stakeholder involvement:** Close coordination between airlines, energy and fuel producers and suppliers, airport operators, public authorities, and energy producers, as well as the organizations of the key stakeholders.

**6. Technological development and innovation:** Support for new energy and fuel technologies and certification and approval systems that promote sustainable development and are scalable.

**7. Long-term** political, legal, investment and cooperation agreements

**8. Integrated solutions** on many, probably all, levels. Digitization, AI, and automation will play significant roles.

From a time perspective towards 2050, the inclusion of new energies such as electricity and hydrogen, and openness to other options, would necessarily be incorporated into overall assessments, analyses, and decisions. Electric and hydrogen aircraft may be on the market within a few years, and energy supplies for this should be integrated with fuel and SAF supplies. Partly for reasons of infrastructure adjustments, but also because several of the traditional fuel producers/suppliers are in the process of expanding their business areas into new energy sources. Therefore, assessments and decisions on changes should consider the full range of options.

The conditions for the delivery of SAF and jet fuel to CPH are assessed as optimal, with a dedicated SAF tank and a blend-in option before pipeline supply to the airport. If conditions are also to be optimal in the long term, and possibly in another setup, a comprehensive strategy is required that aligns infrastructure, SAF access, integrated energy policy, logistics, stakeholder collaboration, and market mechanisms. Therefore, consideration is recommended for a structured framework that addresses current needs and future opportunities, as well as strategic goals and potentially high-hanging fruit.

Several forecasts indicate that securing increased SAF supplies will be difficult after 2030. For these reasons, it is appropriate to examine new solutions and developments involving multiple stakeholders, each contributing in various ways to the process of making long-term political and investment decisions.

The report examines political decisions, implementation challenges, and highlights the need for alternative SAF sources from waste, carbon and biomass. It also suggests solutions based on strong collaboration and financing models that integrate energy and aviation fuel into national and cross-national energy policy.

# 1 Fuel supply chain and best practice framework

Supply chain - product delivery and arrival conditions

## 1.1 Introduction

The SAF supply chain involves numerous steps that are challenging for most people to follow. Its processes are complex, especially since SAF products, sometimes blended with conventional fuel, are handled in restricted pipelines and tanks accessible only to a few specialists who manage fuel flows, take samples, or perform inspections during transport or mixing.

Regardless of whether it is SAF or conventional fuel, mixed, before or after, there is almost always a lot of transport and tank storage involved. It is also implausible that the same staff can follow the entire process.

On the contrary, the fuel transport process depends on several well-qualified people handling the many tasks along the way. Therefore, it is also crucial that international rules and standards have been drawn up for how the fuel components are handled, inspected, and analysed, - and not least that they are followed so that the product reaching the aircraft has the precise specifications and qualities for all the described parameters. This is a comprehensive, continuous process taking place worldwide, covering large quantities transported by ships, barges, trucks, or railways, and delivered through many different pipe systems.

Every fuel product is delivered from the refinery or manufacturing site with a certificate confirming that it meets the applicable specifications, both before and after any blending. For a SAF product, also a certificate confirming its sustainability.

WP2 has, as part of the ALIGHT project task, described what this means along the supply chains. Thus, documentation for the SAF supply chain regarding the properties of aviation fuel (batch composition, environmental/sustainability/certification properties, etc.) is reviewed under WP task 2.7, from the refinery to the end user. This includes the processes for product arrival conditions, supply via pipelines, tanks, and hydrant systems, according to task 2.3, where alternative supply routes are also reviewed.

Despite rigorous requirements for all steps in the supply processes, there may be different delivery conditions, which in turn may be related to transport distances, airport size, storage facilities and airside conditions, which means that experiences gained and established solutions could be insightfully brought to understanding and application on both small and large scales as planned in task 2.5.

The following sections review the processes, documentation, and challenges from the refinery through transport, storage, blending, and arrival and storage at airports, ready for use in the aircraft. The section concludes with suggestions and questions regarding the role the airport can play as SAF increasingly enters the market and how airports can actively use it, for example, to support scope 3 reporting.

## 1.2 Production flow at refinery

Fuel producers are not directly part of RefuelEU Aviation because the legal framework primarily aims to regulate and promote the use of sustainable aviation fuel (SAF) through requirements on the demand side. First, suppliers, and then European airlines, must use an increasing amount of SAF blend-in, according to the adopted mandates. The European Commission assesses that increasing demand and a stable future market will motivate producers to invest in new production and technology development.

The European Commission estimates that increasing demand and a stable future market will motivate producers to invest in new production and technological development, even without binding quotas or requirements.

The Commission also estimates that the stricter sustainability requirements for production, as well as the EU's taxonomy for sustainable investments, will motivate producers to restructure their operations.

In particular, the built-in requirements for SAF on sustainability, documentation, and transparency, formulated in EU RED II/III with associated reporting requirements, are expected to motivate the necessary changes. Based on these considerations, the Commission has decided not to include oil companies or fuel producers directly in the RefuelEU Aviation regulation. Indirectly, because the requirements, criteria, and mandates under which the suppliers must operate are largely directed backwards to the production stages. The manufacturers also participated in the consultation processes regarding SAF production volumes before the design of RefuelEU Aviation.

RefuelEU Aviation states that it is the fuel suppliers who have the mandate to ensure that all aviation fuel made available to aircraft operators at major EU airports contains the agreed minimum proportions of SAF.

As an introduction to this chapter on fuel supply and scale-up and scale-down solutions, you will find a brief overview of what happens on the production and distribution side in and from the refinery. The intention is to show what precedes distribution, storage, use and the associated framework conditions for aviation fuels. Regardless of whether we are talking about the production of fossil fuel, SAF, or co-processing of SAF, regardless of which SAF type or SAF pathway is involved.

SAF is a common term for aviation fuels derived from non-fossil sources and based on specific criteria, considered sustainable. The advantage of an approved SAF product is that it can be used across the global aircraft fleet and integrated into the existing fuel infrastructure throughout the supply chain. So far, however, only a blend of a maximum of 50% in order not to fall below a certain aromatic content and other blending constraints. ASTM is working on approval of a 100% SAF blend-in, expected in 2025 or 26, in a pathway with a minimum aromatic content. In a later phase, a 100% aromatic-free SAF will be approved, primarily aimed at (future) jet aircraft that do not require a minimum aromatic content (read more in chapter 3).

Another chapter of the report describes some new SAF production companies, providing some examples of development and establishment projects focusing on PtX-based fuels, also called efuels, eSAF or synthetic fuels, with a review of some of the technical, political, and economic challenges they face around fall 2025 (Read more about eSAF in chapter 4 and 5).

According to US government sources, it is estimated that more than 1 billion litres of kerosene are used by international aviation every day, i.e., more than 11,500 litres every second

As an introduction to the manufacturing process, the two illustrations below provide a general overview of the steps that lead a fuel product from production to airports and end users. Figure 1 shows the main elements of a fuel refinery where the most common fossil oil-based products are produced. Figure 2 shows the combined SAF blends and how their distribution could proceed.

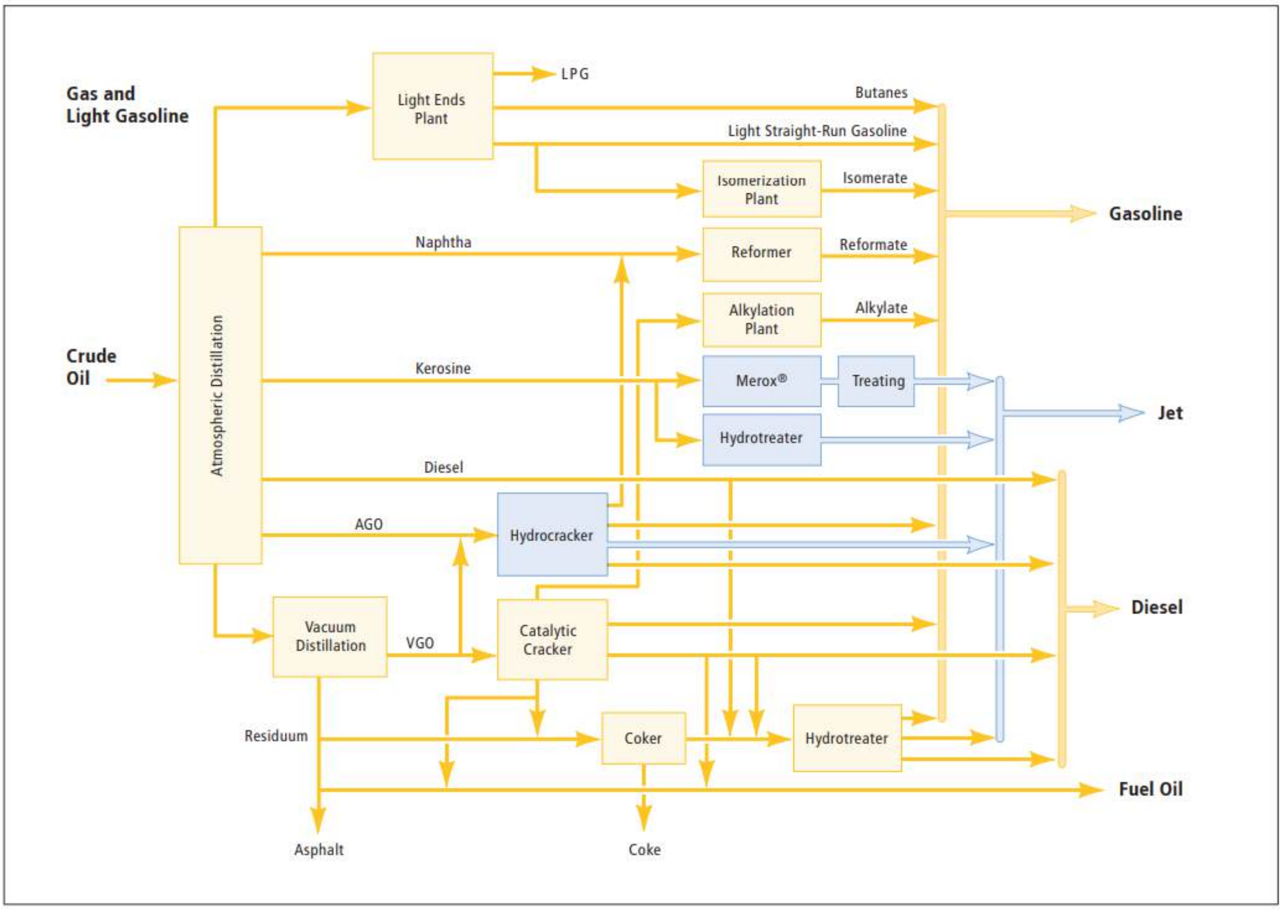


*Figure 1 Schematic of a modern conventional oil refinery* [1]

As shown in Figure 2, SAF is included in the production setup, and the illustration further shows the primary distribution channels before, when and after the blended fuel product reaches the market.

**Distribution:** SAF must be blended with Jet A-1 before use in an aircraft, and before it is integrated into the airport's storage, distribution, and hydrant systems. If SAF is co-processed with conventional Jet A-1 at an existing conventional jet fuel refinery, the fuel would flow through the supply chain in a business-as-usual model. SAF produced at stand-alone facilities would be blended with Jet A-1 at existing fuel terminals and then delivered to airports by barge, pipeline, train, or truck. The fuels could also be blended at a fuel terminal directly upstream of an airport, or thousands of miles away, and transported by pipeline or vessel to a terminal near the airport. There would be no change to the fuel operations at the airport, as airports are expected to continue receiving blended fuel through the same pipelines or trucks as with

[1] Chevron: Aviation Fuels Technical review, 2007

conventional fuel. Due to stringent fuel quality standards, it is currently the practice to certify SAF to ASTM D1655 or Def Stan 91-091 at the upstream airport.[2]

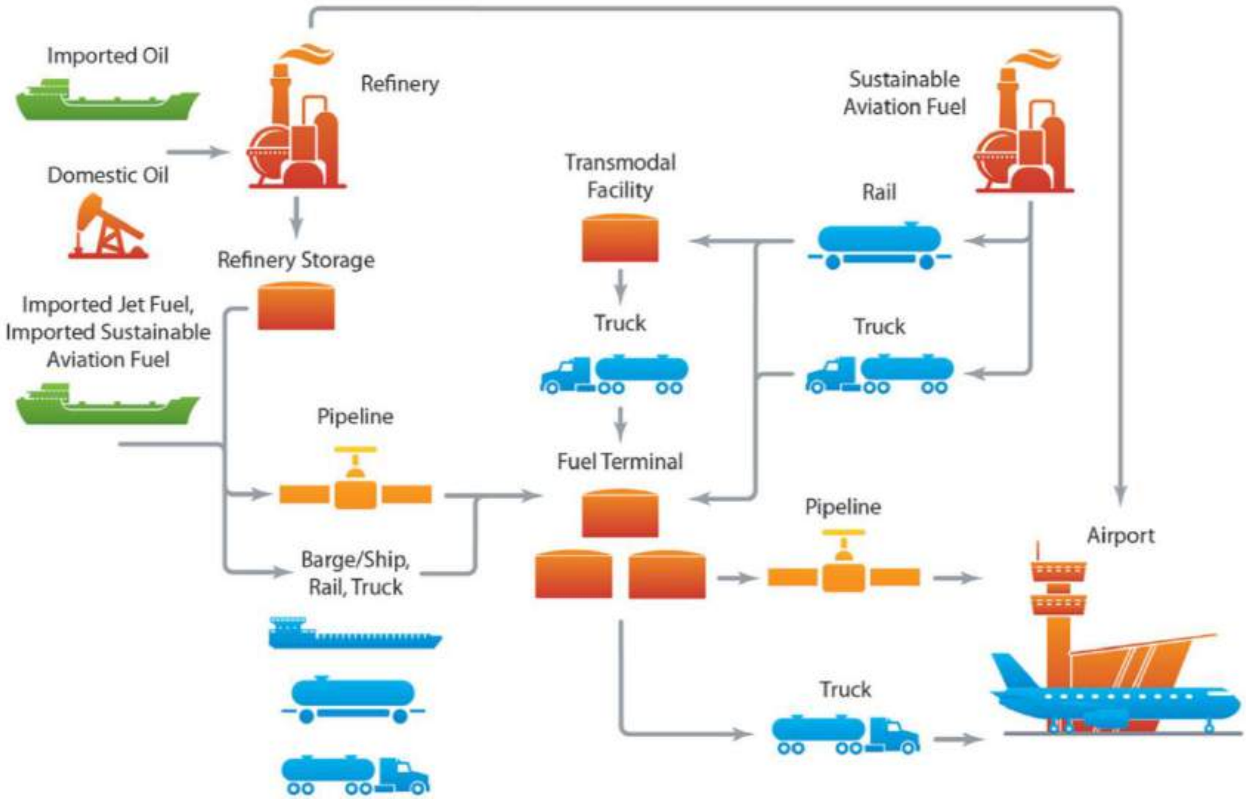


*Figure 2 Illustration of SAF distribution* [3]

## 1.3 After the refinery

A conventional fuel product (CAF) from a refinery comes with the Refinery Certificate of Quality (RCQ), issued in accordance with the relevant specification. When the fuel leaves the refinery, it is transported by pipeline, truck, rail, or barge directly to the airport tank farm or an intermediate terminal before reaching the airport. Here, the fuel will be reinspected at each transition point, and a Certificate of Analysis (COA) will be issued in accordance with the relevant specification.

[2] ASTM. ASTM D1655: Standard Specification for Aviation Turbine Fuels - used w/ JIG-standard to define jet fuel quality.
[3] US Department of Energy, Alternative Fuel Data Center: Fuel supply chain.

The process is similar for neat SAF, but it includes additional steps. As with CAF, an RCQ will be issued at the refinery, but in this case, it will be issued in accordance with the appropriate annexe of ASTM D7566, not ASTM D1655 or Def Stan 91-091. As such, the neat SAF cannot yet enter the CAF supply chain. First, the neat SAF must be blended with CAF up to the limits specified in ASTM D7566. When the fuel is mixed, it will be tested in accordance with ASTM D7566. Once it is confirmed that the blended fuel meets this specification, it will be released in accordance with ASTM D1655. From there, the fuel is considered to have the same properties as CAF and can thus be considered and handled as regular Jet A-1.

In a later stage, the RCQs, COAs, and recertification test certificates are used for quality control in contracts between buyers and sellers.

### 1.3.1 PoS - Proof of Sustainability for biofuels, bioliquids and biomass fuels

The blend-in SAF product is, in principle, accompanied by a document: Proof of Sustainability (PoS), which addresses the sustainability of the SAF product: "A certified economic operator must provide proof of sustainability documentation for any batch of outgoing sustainable material, no matter if that is the raw material, intermediate product or SAF. The PoS contributes to establishing a robust chain of custody in the SAF supply chain, based on a hypothetical SAF supply chain". (See PoS template next page. Examples of data in a completed PoS template from both ISCC and RSB can be seen in the IATA publication "Understanding SAF sustainability certification") [4]

Subsequently, when the product changes ownership, which can happen several times, a Recertification Test Certificate (RTC) is prepared. However, the end user does not always receive the full documentation, which is why it is recommended to make requirements for this in the purchase contract.

When fuels are transported from the production site, there will typically be several transport shifts between different modes of transport or between tanks. This can be done through pumps, pipelines, tankers, tanker trucks or rail transport. The most common, as in Copenhagen, is that the fuel is transported to a terminal for storage and possibly blending before being transported to an airport by pipeline, or, in some airports, by truck, train, or ship.

Next page:
*Figure 3 Certificate: PoS [5]*

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[4] IATA: Understanding SAF sustainability certification, June 2024, Appendix III + Data Elements in a PoS in Appendix I.

[5] RED Cert, redcert.org. : Proof of Sustainability (PoS-REDcert), 2025

## Proof of Sustainability for Biofuels, Bioliquids and Biomass fuels V3.0

For Biofuels, Bioliquids and Biomass fuels according to the Revised Renewable Energy Directive (EU) 2018/2001 (RED III)

REDcert EU

| | |
|---|---|
| Unique Number of Proof of Sustainability: | EU-REDcert-PoS - YYYYMMDD - XXXXXX |
| Date of Physical Supply: | DD.MM.YYYY |
| Date of Issuance: | DD.MM.YYYY |
| Contract Number: | Unique contract number |

### Supplier

Name
company

Address
street, no.
postal code, city
country

Certification Scheme: **REDcert-EU**

### Recipient

Name
company

Address
street, no.
postal code, city
country

Certificate Number EU-REDcert-XXX-XXXXXXXX

### Transaction data

**Place of dispatch**
physical loading, logistical facility, distribution exit point OR gas grid entry point
☐ same address as the supplier
Address
street, no.
postal code, city
country

Date of physical loading

**Place of reciept**
physical delivery, logistical facility, distribution entry point OR gas grid exit point
☐ same address as the recipient
Address
street, no.
postal code, city
country

### General Information

| | |
|---|---|
| Type of Fuel | |
| Type of Raw Material | |
| Additional Information (optional) | |
| Country of Origin (of the raw material) | PLEASE SELECT |
| Country of Fuel Production | PLEASE SELECT |
| Mass Balance Option | PLEASE SELECT |
| Quantity | $m^3$ mt (metric tons) |
| Energy content | MJ |

### Sustainability criteria of the biomass according to Article 29 RED III

| | | |
|---|---|---|
| The material complies with the sustainability criteria according to Art. 29 (3), (4) and (5) RED III 1) (agriculture crop) | yes | no |
| The sustainability criteria according to Art. 29 (2) RED III were taken into account 2) (agriculture residues) | yes | no |
| The sustainability criteria according to Art. 29 (3), (4) and (5) RED III were not taken into account 3) | yes | no |

### Information about any incentive/subsidy (e.g. for biogas/biomethane)

Is there any incentive/subsidy in the renewable energy sector the material may have received so far? yes no
If yes, please specify

### Greenhouse Gas (GHG) information

Total default value according to RED applied yes no

$$e_{ec} + e_{ec}{*} + e_l + e_p + e_p{**} + e_{td} + e_{td}{***} + e_u - e_{sca} - e_{ccs} - e_{ccr} = E$$

**Calculation of GHG emission4) savings for biofuels/biomass fuels** yes no

for biofuels/biomass fuels (94 $gCO_2eq/MJ$)

**Calculation of GHG emission4) savings for electricity and/or heat production** yes no

Electrical efficiency (ηel) % Heat efficiency (ηh) %
Fraction of exergy in the electricity (Cel) % Carnot efficiency (Ch) %

for bioliquids (for energy installations delivering electricity (183 $gCO_2eq/MJ$))

for bioliquids (for energy installations delivering only heat (80 $gCO_2eq/MJ$))

for bioliquids (for the electricity or mechanical energy coming from energy installations delivering useful heat together with electricity and/or mechanical energy (183 $gCO_2eq/MJ$))

for bioliquids (for the useful heat coming from energy installations delivering heat together with electricity and/or mechanical energy (80 $gCO_2eq/MJ$))

**Date when the installation started operation5)**

**Note:** GHG emission savings shall be at least 50% for biofuels/bioliquids/biomass fuels produced in installations starting operation before 6 October 2015, at least 60% for biofuels/bioliquids/biomass fuels produced in installations starting operation from 6 October 2015 and at least 65% for biofuels/bioliquids/biomass fuels starting operation from 1 January 2021.

1) Applicable for biomass from agricultural, aquaculture, fisheries and forestry including residues from agricultural, aquaculture, fisheries and forestry residues
2) Applicable for waste and residues other than agricultural, aquaculture, fisheries and forestry residues
3) Applicable for waste and residues other than agricultural, aquaculture, fisheries and forestry residues
4) Saving is calculated automatically based on the fossil fuel comparator according to the RED:
(EF – EB)/EF where EB = total emissions from the biofuels/bioliquids/biomass fuels and EF = total emissions from the fossil fuel comparator
5) An installation is deemed to be in operation if it produces biofuels, bioliquids, or biomass fuels for the first time in accordance with its intended purpose after establishing that it is technically ready for operation. The date the installation became operational does not change if individual technical or structural parts are replaced after initial start-up.

* Disaggregated default values for cultivation: 'eec' – for soil $N_2O$ emissions only (these are already included in the disaggregated values for cultivation emissions in the 'eec' table of the RED III)
** Disaggregated default values for oil extraction only (these are already included in the disaggregated values for processing emissions in the 'ep' table of the RED III)
*** Disaggregated default values for transport and distribution of final fuel only (these are already included in the table of 'transport and distribution emissions etd' of the RED III)

## Quality Control Documents in the fuel supply chain

Documentation must accompany the product to its destination. The most common are:

### Refinery Certificate of Quality (RCQ)

The RCQ is the original document describing the quality of an aviation fuel product. It contains measurement results made by the product originator's laboratory of all the properties listed in the latest issue of the relevant specification. It provides information on the use of additives, including their types and amounts. Includes details relating to the identity of the originating refinery and the traceability of the product described. RCQs shall always be dated and signed by an authorized signatory.

### Recertification Test Certificate (RTC)

RTC demonstrates that recertification testing has been carried out to verify that the aviation fuel quality has not changed and remains within the specification limits, for example, after transportation or tank shift. The RTC shall be dated and signed by an authorised laboratory representative who is performing the testing. The results of all recertification tests shall be checked to confirm that the specification limits are met and that no significant changes have occurred in any of the properties. A diagram of the main steps in the supply chain, including references to the main specification and other quality documents.

### Certificate of Analysis (CoA)

The CoA may be issued by independent, certified, and accredited inspectors or laboratories, and it contains the results of measurements of all the properties listed in the latest issue of the relevant specification. It provides information on the identity of the originating refiner and the traceability of the described product. Shall be dated and signed by an authorized signatory. *Notice: CoA shall not be treated as an RCQ.*

### Practical delivery conditions

It must be ensured that certification documentation, standards, criteria, and agreements are complied with under production, transport, and storage conditions across all parts of the supply chain, in both the physical, practical, and administrative areas. This includes that all SAF products /advanced sustainable fuels comply with the EU's sustainability criteria, such as REDII/III, and that it is assessed whether all challenges along the way are met according to standards and inspection criteria. Transport and delivery conditions, including quantities, methods, and administration, must be adaptable to airports of varying sizes, layouts, and locations. Experiences across these and already established solutions can, depending on the circumstances, yield insights and possibly be applied on both a small and large scale.

Commercial and public airports maintain on-site fuel storage facilities, commonly referred to as tank- or fuel farms. These facilities include a network of interconnected equipment designed to safely receive, store, and distribute fuel either through a hydrant system or directly via fuel trucks to aircraft. At CPH, where BKL is responsible for fuel farms and fuelling activities, truck delivery is rare but can occur under special circumstances.

A typical fuel farm comprises various components, such as storage tanks, pipelines, flow control systems, meters to measure fuel volumes entering and exiting, filters to eliminate contaminants and water, pumps for pressurizing the fuel, safety mechanisms to prevent and manage leaks, off-loading stations for refuelling trucks, and underground hydrant systems leading to aircraft stands, where the fuel is connected to and pressurized into the aircraft's fuel tanks, most often using mobile vehicles.

In general, it is the state that requires airports to have the necessary infrastructure in place and to develop it in accordance with aviation needs. Fuel infrastructure, such as tanks/farms and facilities, is typically owned by fuel companies or consortia in various constellations. However, hydrant systems can be owned by the airport or by the fuel companies, who, as storage and hydrant operators, are also responsible for daily operations (see next page, figure 4).

Smaller airports may adopt alternative models, either managing their own fuel systems or outsourcing operations to third-party providers.

Generally, and most widely used in Europe and America, ASTM D1655 or DEF Stan 91-091-compliant jet fuel containing Sustainable Aviation Fuel (SAF) is recognized, regardless of the specific SAF blends requested for individual flights or airlines. When SAF is blended into the general fuel supply in a mass-balance system, airlines or their customers can calculate the relative environmental or economic benefits of the fuel mix.

The widely used fuel consortia, which we see at most European airports, use the common infrastructure to ensure the efficient delivery of fuel to airlines, leveraging coordinated resources. The model is that airlines can enter fuel contracts with different suppliers or producers independently of the airport's fuel consortium. The purchase of fuel, including the quantities, prices, and contract lengths, remains with the individual airlines. The airport's fuel consortium is not involved in this but controls the operations and infrastructure on which airlines, airport facilities, and total traffic at the airport depend.

In Copenhagen, the fuel arrives by ship at the storage facility Prøvestenen, where Enport A/S owns the tank facility and is responsible for subsequent pipeline transport to CPH. - MB Energy owns Enport and has BP Aviation and DCC & Shell Aviation as customers, i.e. active users/tenants of the tank facilities. In addition to Enport A/S, Samtank A/S is also the warehouse keeper at Prøvestenen (owned by the oil company OK).

Figure 4 shows the composition of the setup at the airport in Copenhagen Airport receiving the fuel from Prøvestenen storage tank.

### 1.3.2 Fuel supply into Copenhagen Airport

This section covers the logistics of supplying fuel to Copenhagen Airport. The three subsequent delivery methods will be presented and shortly discussed. The picture below is a visualization of the fuel delivery process from the arrival of fuel at the main fuel terminal, Prøvestenen, through pipelines to the airport and to the aircraft via the hydrant system at Copenhagen Airport.

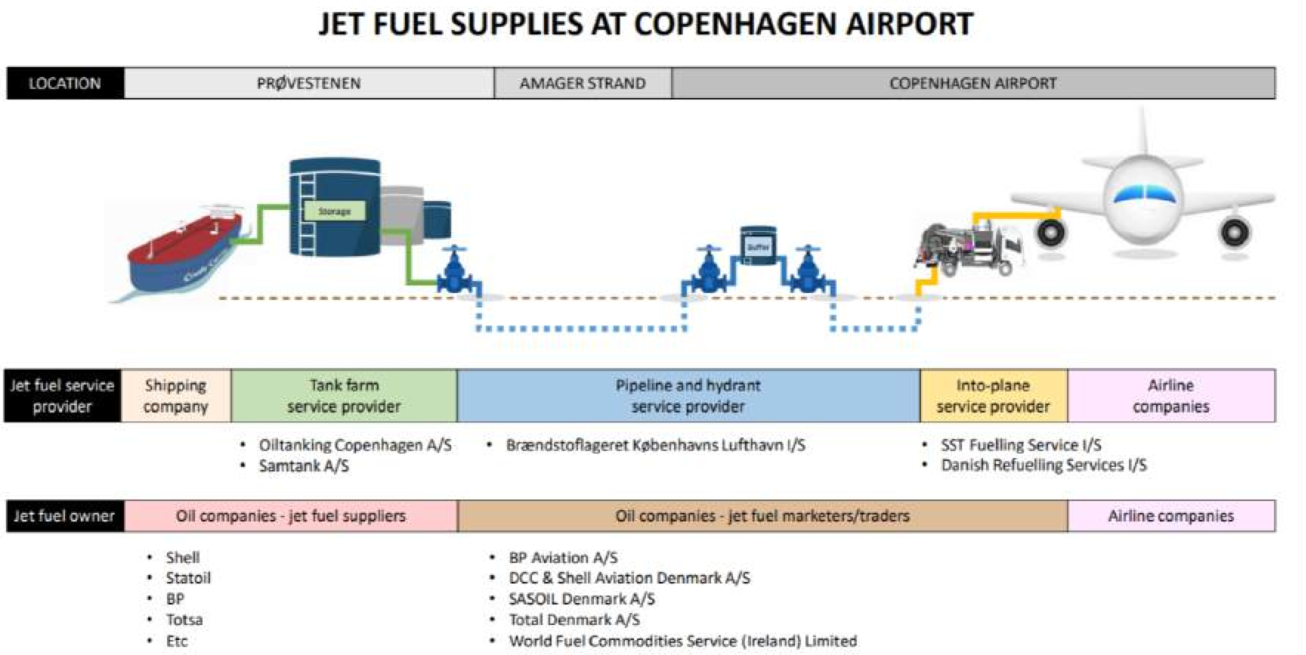



*Figure 4 Copenhagen Airport; Jet fuel supply* [6]

Copenhagen Airport is supplied with fuel jet A-1 through BKL I/S as the fuel operator and storage handler.

When the jet fuel arrives in the country, it is delivered to the fuel terminal, Prøvestenen, 6.8 km from Copenhagen Airport. It is transported to the fuel terminal by sea in large tankers, from where it is pumped to the terminal's storage tanks, which may contain significant amounts.

[6] BKL, (CPH fuel farm operator), internal presentation.

Upon arrival at Prøvestenen, a rigorous testing protocol is conducted by an external, authorised company (an independent inspection). The test is to ensure that the hydrocarbons meet the ASTM specifications. If a ship has several separate storage tanks installed, the approved inspectors must analyse the fuel from each compartment before it is transferred to the storage tanks.

From the pier, the jet fuel passes through a segregated, product-dedicated pipeline that enters the fuel terminal and is then distributed to various storage tanks.

From the terminal, the jet fuel is pumped through a large pipeline to the airport. At the airport, at airside, it undergoes a filtering and quality check to ensure there is no water or impurities in the fuel and that its quality meets the Recertification Test Certificate. Then it is stored in tanks inside the airport, from where it is distributed through the hydrant piping system to the individual aircraft stands and airplanes.

The entire process of storage, handling, and delivery upstream of the Airport is compliant with EI/JIG 1530, which sets the standard for managing fuel[7]. At the airport, fuel is handled in accordance with JIG 2. There is no difference in handling SAF vs. conventional fuels, as the fuel received is approved Jet A-1.

### 1.3.3 Standards and procedures for jet fuel arrival at airports

To get an overview and to be generally applicable, the following is a review and partial summary of key aspects of arriving jet fuel with or without SAF at airports, illustrated with selected airports at the end.

The receipt of jet fuel at airport tanks follows strict international standards. The fuel must comply with the previously mentioned approved specifications, typically ASTM D1655 for Jet A/-A1 or DEF STAN91-091, which specify the physical/chemical properties such as density, freezing point, flash point, aromatic content, Sulphur specifications, etc. In practice, this is ensured by each delivery being accompanied by a Certificate of Analysis (COA) confirming compliance with ASTM D1655. DEF STAN91-091 contains similar requirements and requires traceability, so each fuel batch must be documented with a batch ID and consistent test results throughout the supply chain. Furthermore, any approved additives (e.g., FSII antifreeze or electrical conductivity additive) must be specified and within the specified concentration limits. Overall, the standards require that the jet fuel upon arrival is flawless, free of water and certified.

[7] JIG, (Joint Inspection Group) 2019: *JIG Standards: JIG 1 and JIG 2 Manuals*, 2nd Edition. jig.org

**Sampling upon receipt:** Extensive sampling checks are always carried out upon receipt.

**Tanker deliveries (by truck or train):** Before unloading or emptying, a "white bucket" visual check is carried out of all tank truck compartments. Each compartment is drained of a few litres, and the fuel is inspected for turbidity, particles, or water (so-called clear & bright test). If visible contamination is detected, further draining is performed; if the sample does not settle after a few stirs, the entire delivery is rejected. At the same time, the fuel density (API gravity) is measured and compared with the value on the waybill to detect any cross-contamination. During actual unloading, the differential pressure across the receiving filters is monitored, and the filters are tested for water using a membrane test or an electronic sensor, if necessary. After emptying, the tanks and tank sump are allowed to settle (typically 1 hour/foot of product for jet fuel), and the bottom is then drained to remove any remaining water or particles.

**Ship deliveries:** When receiving from the ship, JIG's procedures are closely followed. The ship's tank covers and valves are ensured to be closed upon arrival, and the tanks' filling height (ullage) is measured and compared with the cargo documents. All compartments are examined for water (physical or electronic test) before pumping. If larger quantities of water are found, the unloading is slowed down, and the water is handled according to the procedures described. Samples are then taken: One litre "midsamples" is taken from each tank compartment for control and condensation tests (static and additive concentration). In addition, a single five-litre retention sample (mix of all compartments) is taken, sealed, and stored for possible later checks. During unloading, "control samples" are also taken from the receiving line near the ship approximately 5 minutes after pump starts.

**Pipeline deliveries:** When received by pipelines, the JIG 2 control scheme is followed. The unloading point must be correctly colour-coded (see EI1542)[8], and the fuel must pass through an approved filter/water separator (EI1581)[9]. During the pressure test, the differential pressure is continuously observed to capture any impurities. For a single product, control samples are typically taken from the pipe for filters at the start, midpoint, and end of each batch, and the density is then compared with the Release Certificate value. For multigrade supplies, corresponding sampling is carried out (every 2 hours and batch change), and clear procedures are in place to avoid mixing interfaces. Any alarms for excess water or density deviations are handled immediately in accordance with established pipeline sampling procedures.

**Documentation:** Each delivery must be accompanied by adequate documentation, which is checked before the fuel is added to the warehouse.

[8] Energy Institute, EI1542
[9] Energy Instutute, EI1581

**Bill of Lading (BoL):** Contains the fuel type (e.g., Jet A-1), quantity, API gravity and any additives. The operator verifies here that the type, volume, and density match the order.

**CoA:** Certificate from the refinery or terminal confirming that the quality meets ASTM D1655/DEF STAN[10] specifications. The CoA must be signed by authorized personnel and cover all tests (including additives) as required by the JIG standards. The COA results must be checked against the samples received. Cleaning and Sanitation Certificates: If the means of transport is not dedicated to jet fuel, documentation of proper cleaning or approval of previous loads is required (see JIG 4.5.1). Only pre-approved products may be included in the load. All additives (e.g., FSII) must be listed on the BOL with quantities. If FSII is added, check that the amount corresponds to 0.10–0.15% by volume. Static additive (Di-EGME) is also recorded; if absent, additional safety measures are implemented.

**Traceability documentation:** According to DEF STAN 91-091, the fuel batch must be traced back to the manufacturing site via unique batch IDs and associated certificates (CoQ/CoA/Release Certificate). This ensures quality assurance from the refinery to the tank. The plants themselves are routinely inspected according to JIG and EI guidelines to ensure that the receiving equipment is always functioning properly:

**Colour coding and labelling: Discharge points (hoses, tap arms, etc.) must be colour** coded according to the Energy Institute standard (EI1542) so that Jet A-1 is not confused with other products. Labels also indicate flow direction.

**Dedicated equipment:** Each grade has its own hoses and couplings. Hoses, valves, and gauges are inspected for leaks and wear before use. For example, non-fuel approved hoses (EI1529/ISO1825) may not be used for dry systems. If multiple products supply the same depot, positive physical separations (e.g., double shut-off valves or blanking) are installed between the Jet A-1 pipe and other pipes, and these valves are regularly tested for tightness.

**Ship unloading:** Before unloading, ensure the ship's tanks are properly inspected and sealed. Inspectors check that all inspection hatches are sealed and locked upon arrival. Internal conditions of compartments are noted as necessary.

**Filter and pressure monitoring:** The receiving facility is equipped with water separators and filter units (EI1581 qualified). During unloading, the differential pressure (DP) is closely monitored. A sudden increase in DP may indicate blockage or contamination, triggering a stop. Similar monitoring is performed for leaks during delivery.

[10] ASTM, ASTM D1655/DEF STAN

**Tank design and safety:** Airport tanks must meet JIG/EI design requirements, be marked with product and inspection dates, and have satisfactory bottom volume (min. 110% of the largest tank) and overfill protection. Vent valves with coarse mesh sizes (approximately 5mm) prevent clogging. Overfill protection systems are regularly tested in accordance with JIG 2 (e.g., annual pressure and functionality tests). These points are reviewed annually during a detailed JIG inspection (Joint Inspection Group engineers follow a checklist covering many conditions).

**Handling after delivery:** Once the fuel has been pumped into the tank or hydrants, fixed routines are followed: Draining: As soon as a fuel storage facility is filled, all inlet valves are closed, and the tank is allowed to rest (typically one hour per foot of fuel height) to allow particles and water to settle. Several bottom samples (tank sumps) are then taken, and the filters are emptied of the collected water or particles. In daily operation, tank sumps are emptied at least once a day to ensure “clear and bright” fuel, free of water or biomass.

**Material selection and maintenance:** Fuel lines, hoses, and tanks are made of corrosion-resistant material (e.g., stainless steel or coated tanks). Copper and copper alloys must not be used as they react with additives. All internal surface protection must be intact (e.g., epoxy coating). The filters are cleaned and serviced regularly (per JIG’s maintenance schedule).

**Documentation:** All results from acceptance tests are recorded in a logbook or an electronic system, with the signature of the responsible person. Any rejections or problems are formally recorded. The operator also maintains detailed procedures (operations manuals) for each step so that the plant personnel at each receiver point can follow a fixed checklist.

**Examples from major European airports:** The procedures described above are generally used at all major airports.

**Amsterdam Schiphol (AMS):** Here, approximately half of the jet fuel is received via a 16km underground pipeline from the fuel terminals at the port. The rest is delivered by ship to the port and on to the fuel plant. All deliveries are checked according to JIG/EI standards. For example, the joint fuel consortium Amsterdam Airport Fuel Network takes daily spot samples from hydrants and depot tank sumps, which are tested for water, in accordance with JIG2/3.

**London Heathrow (LHR):** The airport is continuously supplied via a 47km pipeline from ExxonMobil’s Fawley refinery (Southampton). There are two separate tank farms serving the airport hydrant network. Supplementary deliveries are made by tanker trucks. Heathrow Hydrant Operating Co. (a consortium) continuously follows the above procedures: incoming deliveries are inspected, CoA/BOL’s are checked, sampling is carried out, and all data records (flow, time, filter statuses) are recorded electronically.

**Other major depots:** Most major European airports, e.g., Frankfurt, Paris-Charles de Gaulle, Zurich, are operated as joint users of depots/hydrant installations, with several oil companies using the same facility. All these depots are JIG certified and undergo annual unannounced inspections. The arrival of a floating barge or tanker triggers the same procedures with white buckets, CWD checks (Chemical Water Detector), and sampling. For example, Total Energies announced in 2023 that its certified inspectors conduct JIG inspections at up to 2,000 airports worldwide each year.

**Precision and level of detail:** Both the standards and practical procedures are described in detail. JIG's publication series contains well over 100 pages of specific requirements. For example, the JIG2 standard Airport Fuel Depot/Hydrant covers more than 30 individual control points for tank colour, valve design, bottom drain, overfill protection, filter classes, document archiving, and so on. Each depot prepares its own detailed operating instructions and checklists in accordance with JIG/EI. Operators train staff and keep logs at every step, from acceptance testing to release procedure. The processes are tied to specific instructions and are enforced by both internal audits and independent inspections. (Detailed description).[11]

Later in this section, the key rules, approvals, procedures, and administrative provisions that apply to aviation fuel/SAF transport, storage, and handling at large and small airports are reviewed.

Each element of the supply chain outline is shown in the following table

[11] Detailed description:

- Defence Standard 91-091 Issue 18 Date: 28 December 2024: Link.
- Total Energies short version and JIG: Link.
- Aviation fuel handling guide: Link
- JIG STANDARDS Issue 13, page 1 of Inspection of Airport Depot/Hydrant/Into-plane, Jan 2022: Link
- Port of Amsterdam, Airport example: Link

| Infrastructure element | Description |
|---|---|
| Pipeline | Pipelines can transport aviation fuel from one point to another and are often located underground. They can be multi-product pipelines or aviation fuel-only pipelines.<br>Pipeline networks can span international geographies, covering hundreds of kilometres, for example connecting ports with inland hubs. At the same time, pipelines can also be built for shorter distances, for example to connect a terminal with an airport storage. |
| Tanker | Tankers are large ships capable of transporting large volumes of aviation fuel between ports. They can transport aviation fuel over long distances, for example importing from other countries or reaching islands. |
| Barge | Barges are flat-bottomed ships used to navigate (inland) waterways such as canals and rivers. |
| Rail | Where rail infrastructure exists, rail offers a flexible and cost-effective method of transporting aviation fuel. Generally, it is more expensive than barges, but can reach places not connected to a waterway.[23] |
| Truck | Trucks represent the most flexible method for transporting aviation fuel. Due to the limited volume that a truck can carry, it is relatively costly and rarely used for long distances. Its main use is for the "last mile" delivery. |
| ***On-airport infrastructure*** | |
| Airport storage (or fuel farm) | An on-site storage facility dedicated to storing aviation fuel at a specific airport. |
| Hydrant system | A hydrant system is a system of underground pipelines at an airport carrying fuel from the airport fuel storage facility to the hydrants at the aircraft parking stands. |
| Hydrant dispenser vehicle | A truck equipped with specialised equipment to connect the hydrant system to the aircraft wing. Aviation fuel passes through the vehicle to refuel the aircraft. |
| Refueller | Refueller trucks are specialised trucks equipped with fuel tanks and aircraft refuelling equipment. They generally fill their tanks at the airport fuel storage and then drive to each individual aircraft that needs refuelling. |

*Figure 5 Elements of the supply chain* [12]

[12] European Union, Assessment of the production and supply of SAF in Union airports (...), 2025 page 31

**Recertification Test Certificate (RTC):** EI/JIG 1530 provides a Standard to assist relevant parties in maintaining aviation fuel quality from the point of manufacture through to delivery to airports. The Standard includes mandatory industry-accepted provisions and good-practice recommendations for the design, functional requirements, and operational procedures that apply upstream of airports. Provides quality control and testing of jet fuel to ensure compliance with international specifications (ASTM D1655 or Def Stan 91-091). [13]

**JIG 2 Standard Aviation Fuel Quality Controls and Operating Standards for Airport Depots and Hydrants:** Provides the standard for the design of joint airport storage and handling systems, where relevant to quality control considerations, and for the operating and quality control procedures to be used in such systems, where fuel is stored before being transferred to aircraft, - includes pipeline systems, tanks, and hydrant systems. JIG 2's main objective: To ensure the integrity and safety of jet fuel while it is stored and transported within the airport's supply chain.[14]

**Quality Assurance Requirements for Semi-Synthetic Jet Fuel and Synthetic Blending Components (SBC):** EI 1533 is a supplement to EI/JIG Standard 1530 and focuses on quality management requirements for semi-synthetic jet fuel and synthetic blend components (SBC), also **referred to as SAF**. The standard ensures that these alternative fuels meet the necessary quality requirements and safety standards before use in aviation. EI 1533 builds on the requirements of EI/JIG 1530 and ensures that semi-synthetic and synthetic fuels can be integrated into traditional fuel chains without compromising safety or quality. [15]

### 1.3.4 Alternative logistics - Mass balance

As described in the previous section, the preferred means of delivery is through conventional logistical routes. The advantages of SAF are generally that the product, when blended with traditional fuels, is approved as Jet A-1 and is identical to conventional fuel. Therefore, there are no specific challenges regarding physical delivery. However, the challenges are enormous when it comes to calculating blend-in quantities, administering tasks, and determining which customers should be attributed and in what quantities.

A system in which SAF is blended with conventional fuel and uses existing pipelines is called a mass balance system. This mass balance focuses on tracking physical fuel volumes and percentages, which is why it should not be understood as a general mass balance concept for reporting and accounting for SAF or for tracking and reporting sustainable SAF attributes

[13] JIG/Energy Institute: JIG Standards: JIG 1 and JIG 2 Manuals, 2019, 2nd Edition: Link.
[14] JIG/Energy Institute: JIG Standards: JIG 1 and JIG 2 Manuals, 2019, 2nd Edition: Link.
[15] JIG/Energy Institute: JIG Standards: JIG 1 and JIG 2 Manuals, 2019, 2nd Edition: Link.

(environmental documentation). It still involves several challenges to replace ordinary fuel with SAF. First, we must be aware of volumes and percentages in the mass balance and be adequately monitored by fuel operators. Currently, it is not approved for SAF to exceed 50 vol% in the blend, depending on the pathway. In most cases, a lower blend is used due to potential variations in some subcomponents in the fuel. SAF blends are usually transported and delivered to fuel terminals in a 30-45% blend-in.

Mass balance is a chain of custody model that allows the physical blend-in of SAF across the supply chain, but requires a proportional allocation of the SAF attributes to the end-user and is generally managed in a local supply system

A mass balance system must be able to track the product's attributes in documents and transfer attributes to the purchaser of the fuel. In the future, this will affect financial benefits and environmental documentation, driven by emission savings.

Under RefuelEU Aviation, the responsibility for registering, documenting, and reporting SAF blend-in percentages and quantities delivered to airports and their respective airlines primarily rests with the fuel supplier. This encompasses all aspects of fuel-related data management, including accurate documentation of deliveries, SAF blending ratios, and compliance with sustainability criteria. All relevant information must also be systematically reported in the Union database to ensure transparency, traceability, and alignment with EU regulatory requirements

The common practice up to and including 2024 has been for producers, possibly via a carrier, to deliver a finished product, applied to the fuel operators' facilities at the terminals in purpose-built storage tanks located before the airport, where a standard quality check is carried out to ensure compliance with ASTM and EI/JIG 1530 standards. The received blended fuel has then, in agreement with end users, been further blended with the fossil fuel, and from there the fuel is handled in the same way as any other jet fuel.

Separate transport and subsequent mixing activities, along with the inspections they entail, complicate SAF's route to the aircraft and lead to increased costs. Especially in a market that is not yet developed, it must be assumed that greater maturity, increased competition, larger volumes, and the adoption of better routines will lead to lower prices for end users.

Having access to the sea for a producer enables easier, more efficient transport, which presumably also makes it possible to better utilise existing logistical practices, while the associated challenge of ensuring correct documentation along the way remains.

### 1.3.5 Segregated delivery

As previously mentioned, the SAF blend-in via a mass balance system is, by far, the easiest and cheapest delivery method. Direct physical delivery of SAF blends to individual aircraft is an alternative option, which could also be established at many airports. At present, this can only be done with dedicated trucks. This may be an option at airports where the fuel farm, pipe, or hydrant systems do not exist, are out of service or are undersized. If it is to be implemented regularly, possibly on dedicated flights, thorough prior analyses should be carried out to determine the benefits that can be achieved, either through regular truck use or by installing tanks for the specific purpose. Depending on the background and purpose of segregated SAF delivery, it also requires an analysis of which airports and flights can achieve the most positive results, compared to doing nothing or pursuing completely different solutions.

There may be several examples that can justify in-depth assessments of possible segregated deliveries. By separating the supply of, for instance, high-blend SAF to specific aircraft and/or designated long-haul routes, it may be possible to design a supply targeted at high-emission flights and thereby achieve greater emission reductions than an evenly distributed SAF percentage across all aircraft. A segregated supply of high-blend SAF, possibly in the longer term as 100%, could significantly contribute to contrail avoidance, reduce non-$CO_2$ effects from aircraft, and improve air quality at airports.

Another example could be that a company, an airport, a selected route or a political decision or ambition should lead to achieving a specific reduction target regarding aircraft emissions. If the goal is to increase the reduction effort beyond what is legally required and if the actors can handle and administer a workable model, one element could be establishing separate or segregated supply facilities. This could be via trucks or by establishing separate tanks for the purpose. Whether the analyses point to trucks or tanks will depend mainly on the planned quantities and on how the fuel can be transported and stored both before and after arrival at the airport.

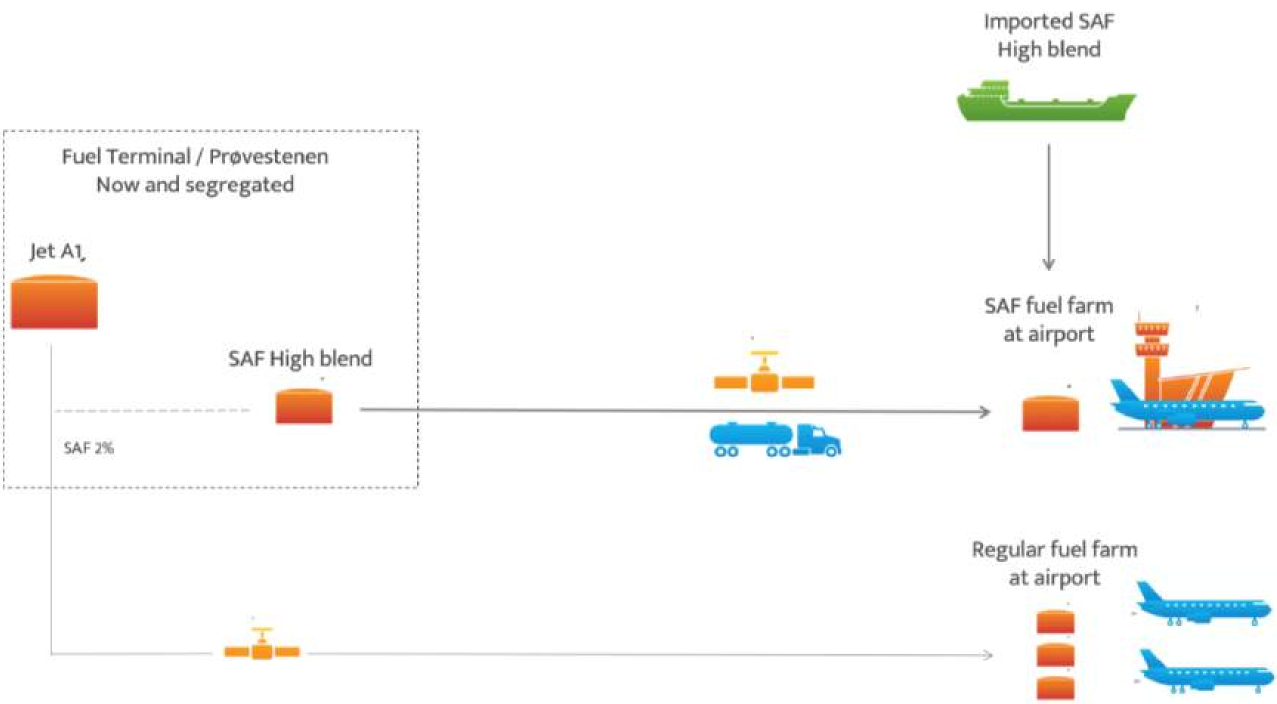



*Figure 6 Example of segregated fuel supply* [16]

Practically, however, segregated delivery poses significant challenges. With CPH airport as an example: The current logistics design of the airport does not allow SAF to be isolated in the hydrant system. An alternative could be to deliver by truck. Currently, CPH only has four trucks, operated by two into-plane operators, each with a capacity of approximately 12-14.000 litres. The largest road trucks in Denmark can hold 35-40,000 litres, and the largest airport trucks (not road) can be supplied with refuelling vehicles up to 65,000 litres. However, it is unrealistic to use the latter in CPH due to space constraints, where the maximum capacity is around 20,000 litres. Trucks with that capacity could be an option, but in perspective, a single long-haul aircraft typically carries 60,000-90,000 litres of fuel per departure. Within the existing framework, with several daily long-haul departures, a fuel supply system based on truck deliveries with a continuous, larger-volume supply will be a significant challenge. Creating a segregated hydrant system will also be a major challenge, particularly regarding infrastructure complexity and budget.

Other airports may find a feasible solution with a separate system, something that must be assumed to be dependent on many infrastructural factors. The most significant opportunity for establishing segregated refuelling systems will be in connection with the establishment of new airports or major expansions, all of which are related to local conditions and the planned air traffic.

[16] NISA, own illustration, 2025

Compared to a permanently installed tank for SAF blend-in, a mobile solution offers greater flexibility, but both are best suited to smaller airports without hydrant systems and where the need for large daily quantities is limited. The activities at Sønderborg Airport are an example of this, and CPH's airport in Roskilde is another example of a smaller location where the customer Vestas/HeliService has a contract with DCC Shell Aviation for a segregated supply of a SAF blend-in with approximately 40%.

### 1.3.6 Alsie Express, Sønderborg Airport

So far, experience has been gained with segregated deliveries at two locations in Denmark. The first delivery of SAF in Denmark took place in 2021 to Alsie Express, a smaller airline that primarily operates on the route between Sønderborg and Copenhagen with approximately 4% SAF blend on the airline's 3-4 daily flights to the destination. Refuelling in Sønderborg covers the return trip. DCC & Shell Aviation has delivered SAF to a separate tank in Sønderborg. Since this SAF destination was both a segregated delivery and the first SAF delivery in Denmark, it is explained in more detail below.

Before delivery, the necessary quantities of blended SAF, schedules, and quality requirements were agreed upon between the supplier and recipient. Planning and coordination were given high priority to ensure a satisfactory process, with both parties ensuring that all regulatory requirements and internal standards were met throughout delivery. Subsequently, the agreed quantity and blending percentage were transported by truck from the Prøvestenen storage facility in Copenhagen to Sønderborg Airport. The fuel is pumped into the agreed storage facilities at Sønderborg Airport, after which the required quality controls are carried out.

From this storage facility, the aircraft are supplied with blended SAF for daily departures. As mentioned, delivery began in 2021, and it has been agreed that it will be a continuous SAF delivery, with the possibility of increasing the SAF quantity. In the process, the parties have continuously exchanged experiences and ensured that all regulations, standards, and procedures are carried out as they should.

### 1.3.7 Roskilde Airport, Vestas

CPH's Roskilde Airport is another example of a smaller location where the customer, in this case Vestas/HeliService, had a contract with DCC & Shell Aviation for a segregated SAF supply for daily helicopter flights between Roskilde Airport and a destination north of the German border in 2024. The agreement included a SAF mix of approximately 40% delivered to the customer's take-off destination at Roskilde Airport. The contract has been entered into and implemented as a temporary arrangement to cover several specific transports for a period of 6 months during the completion of the offshore wind farm Baltic Eagle in the Baltic Sea through the year 2024.

Unlike the supply to the storage facilities at Alsie Express, these supplies were made via a dedicated tanker truck to Roskilde Airport, from which the fuel, with the agreed 40% SAF, was pumped directly into the vessel/helicopter's tank. Quality controls were carried out in accordance with applicable rules and standards, like those in Sønderborg. A more detailed review of all formal guidelines, criteria, and procedures is shown later in the section. How to receive, store, and dispense jet fuel will be reviewed in later sections.

It is possible to establish similar physical delivery at most airports. The conditions and circumstances must define the need for this. The two examples show alternative supply options that serve specific purposes. Similar or completely different specific needs may arise for specific SAF blend-in, for aircraft with specific flights, or for aircraft designated to fly, for example, 100% drop-in SAF. Could be, for ex., a dual-fuel system with a "Smart Use of SAF," as described by Airbus and DLR, ALIGHT WP3 Task 3.6.

The quantities involved, how often it should take place, the costs, and, not least, the physical conditions at a given airport will set the framework for its realisation. An example of this is provided in the case from the measurement campaign at CPH:

**SAF air quality measurement at the CPH case**

*"As part of the ALIGHT project, several measurements of the air quality at the airport have been carried out in connection with ordinary air traffic. As part of this measurement campaign, tests have been conducted with an admixture containing approximately 35% SAF. It was therefore necessary to do the direct segregated filling of the aircraft from which the emissions were to be measured at Copenhagen Airport. However, it was only possible to achieve this high SAF blend-in and fill on the selected aircraft at Arlanda Airport in Sweden. The aircraft then flew the ARN-CPH route and was refilled each time it turned into ARN. Separate tanker capacity was used. This involved the use of approved handling procedures, safety, and quality controls, and a carefully described procedure for the individual steps in the SAF deliveries. Experts from DLR subsequently performed the measurements over three weeks, following carefully calculated patterns adapted to wind strength and direction, temperatures, and other traffic activities at Copenhagen Airport. SAS provided aircraft, and the testing process was carried out as planned with results documenting reduced amounts of soot and ultrafine particles in the measurement areas"* - Journal of the Air Transport Research Society [17]

[17] Science Direct. Segregated supply of Sustainable Aviation Fuel to reduce contrail energy forcing – demonstration and potentials, June 2025

### 1.3.8 100% SAF

Looking a few years ahead: The commissioning of a future 100% SAF, Synthetic Aviation Turbine Fuel (SATF), could be a completely new and epoch-making measure. This will, of course, require ASTM approval of the SAF products. According to ASTM[18], the approval process is well advanced, with the expectation that it will be completed before the end of 2025. The approval process is taking place in two tracks:

**1.** Approval of a 100% SAF/SATF drop-in product with a minimum content of aromatics. Such a SAF drop-in will be a Jet A-1 product, and when it is on the market, it will be possible to use it in existing aircraft fleets and existing ground and transport installations.

**2.** Approval of 100% SAF/SATF without aromatics, fully-SATF (also named Jet-X), which will be able to be used in aircraft where seals, pumps and sensitive materials do not require aromatics, which means it will be a long time before it is on the market for use. Thus, the ongoing ASTM approval process of fully SATF is in the first round for use in tests. The overview below is a status of the ASTM process:

## Drop-in vs paraffinic fully-SATF

Drop-in: not just compatible with particular engine and/or aircraft, but fleet-wide and infrastructure-wide compatible

| | 100% or A + B + ... | |
|---|---|---|
| **Composition:** | Fully formulated Jet A/A-1 | **Subset** of Jet A/A-1 |
| **Applicability:** | Fleet Wide drop-in | **Designated** aircraft/engines only |
| **Example pathways:** | CHJ (D7566 Annex A6),<br>FT-SKA (D7566 Annex A4),<br>ATJ-SKA (D7566 A8),<br>future: HEFA-SKA, multi-blend, others | FT-SPK (D7566 Annex A1)<br>HEFA-SPK (D7566 Annex A2)<br>ATJ-SPK (D7566 Annex A5) *certain types* |
| **Specification:** | ASTM D7566 | **New standard** needed |
| **Regulatory Cert/Substantiation:** | No change | **Required** for each intended aircraft/engine model |
| **Infrastructure:** | No impact | **Separate** supply chain/handling/storage required |

ASTM Task Force est. Apr '21
Chair: G. Andac (GE), Vice-Chair: M. Rumizen (Air Company)
**Approval of use of conforming fully-SATF as Jet A/A-1**

ASTM Task Force est. Apr '22
Chair D. Parmenter (Airbus), Vice-Chair: A. Hobday (Rolls-Royce)
**NOT approval of use as Jet A/A-1 or as a new fuel; to be used for testing**

*Figure 7 Illustration of Status of the ASTM process [19]*

[18] General Electric / NISA. Emails between Martin Porsgaard and Gurhan M. Andac. MP question: "A presumption that a ballot on drop-in SATF will be possible this year...? Yes, it is very possible at this point but not certain". February 7, 2025
[19] ASTM, The ASTM process, received from the ASTM task force-chair, February 2025.

Most major aircraft manufacturers have announced when they will bring new aircraft and engines to market, with a certain aromatic content not required. Airbus and Boeing have announced they will launch such aircraft from 2030 onwards, while ATR has committed to achieving 100% SAF readiness for its aircraft family by 2025.

Regarding the question of which aromatic composition should be used for a 100% SAF blend-in, research and development of sustainable aromatic products are also underway and must be considered, depending on price and quality, as a central part of the decision.

In addition, it is a prerequisite for the use of 100% SAF that it be decided, prioritised, and, presumably, dedicated to use where it makes the most sense. The production of 100% drop-in SAF will not only be a comprehensive challenge in the manufacturing stage but will also require adjustments to transport and storage conditions, along with associated approvals and inspections, to ensure it is permitted, prioritised for use for the stated purpose, and delivered in the correct mixtures.

As part of such a development process, it can be investigated whether some airports may be more suitable for establishing separate fuel systems. Questions about solutions with separate tanks on the ground will be a natural part of such assessments, for example, the possibility of filling SAF blends in separate tanks in the aircraft, which could be used under specific critical conditions where a high blend of SAF provides the most noticeable non-$CO_2$ reduction.

### 1.3.9 Future 100% SAF options

The specific physical measures and associated procedures for high-blend SAF are described in more detail in WP3.8, covering several SAF usage scenarios. This is analyzed in various system design requirements in relation to a future possibility to reduce non-$CO_2$ effects and improve local air quality by using high blend SAF on selected flight routes and/or selected aircraft. One of the options analysed is a dual-fuel system with "Smart Use of SAF". This could, for example, enable the aircraft's fuel tanks to be supplied with Jet A-1 and high blend SAF in separate tanks for possible use of high blend SAF under flight conditions where non-$CO_2$ emissions can be reduced as much as possible.

In addition to the many existing procedures, inspections and approvals associated with fuel handling throughout the supply chain, the implementation of separate SAF supplies to selected aircraft will impose additional requirements to avoid mixing with CAF in the storage facilities before the airport and in the tanks, pumps, and pipe systems at the airports and to prevent unintentional uplift to an aircraft. All of this requires the implementation of additional safety procedures and, not least, the training of personnel on the ground and in the aircraft to prevent all forms of incorrect storage, mixing and deliveries at all stages of the supply chains. Scenarios on these topics are reviewed in ALIGHT WP3.6.

### 1.3.10 Segregated SAF storage tank at airports

To realise the non-$CO_2$ benefits of prioritising large SAF blends for international flights, available options must be explored, as trucking sufficient volumes for long-haul flights is limited.

Another option that does not involve such quantity limitations would be if the geographical and physical circumstances of an airport allow the installation of a large tank with separate pipe supplies to dedicated stands via the existing or via a modified hydrant system. This would, of course, be an investment-heavy solution determined by local conditions, the size of the additional tank, length and dimensions of the pipelines, the complexity of (new) pipelines, connection to parts of the existing hydrant system so that the separate SAF product can flow to dedicated stands and the selected aircraft. A Canadian study shows that custom-made pipelines for SAF would have capital costs of around USD 1 million per kilometre. [20]

In the future, circumstances may require segregated supplies of 100% SAF or high-blend upstream aircraft. Such significant changes demand early preparation, as planning, investment, and installations take time. Key topics to consider include:

## Considerations regarding airport SAF storage tank

- SAF on selected long-haul routes contributes significantly more to GHG emission reductions due to less non-$CO_2$ emissions
- Supplies with trucks are a capacity challenge and costly in terms of manpower, equipment, time, and congestion
- $CO_2$ and non-$CO_2$ Climate Credits may in the future become attractive to the extent that they can justify the investments in updated infrastructure with separate SAF refuelling options
- What could be the best SAF tank location upstream of the airport?
- Airside, landside. What's possible/not possible to achieve? If there are restrictions, could they be reassessed?
- If a concept is developed to place SAF in separate tanks in the aircraft, for use during non-$CO_2$-critical routes, it could increase interest in the option of segregated refuelling.

[20] CBSCI: Demonstrating the supply of biojet fuel using existing airport infrastructure, January 2019

It is common practice and recommended that SAF blending facilities not be located at airports to prevent any misunderstandings in which ordinary Jet A-1 (with or without SAF) could be mixed up with the segregated product.

However, in the case of CPH, where the fuel is transported to the airport via pipelines, it would be significantly cheaper to use a separate tank than to install a parallel pipeline from the fuel terminal to the tank. There are two ways to supply SAF with a high blend for such an additional tank facility. Either direct delivery to a tank by truck if the driving and traffic conditions allow it, or by ship if port and facility conditions allow it. For airports with pipeline transportation of jet fuel, it must also be investigated and calculated whether periodic SAF high-blend deliveries can be made through the existing single pipeline system to the dedicated SAF high-blend storage tank facility at the airport. This requires that the dedicated SAF tank at the fuel terminal be sequentially connected to the existing pipeline. Another prerequisite is that calculations must be made of how much fuel, with or without a lower SAF blend, needs to be "pushed" out of the pipeline before it is filled with the high SAF blends and when switching back from the temporary solution. This is a crucial calculation challenge that requires insight into pipe dimensions and lengths, pressure conditions, pump capacities and buffer options, and, not least, whether the method can be approved and carried out in accordance with the necessary quality and safety procedures. Such a calculation task is not an unfamiliar topic in the gas and fuel industry, but, to our knowledge, it could be a completely new activity in connection with the segregated supply of jet fuel to airports. Fuelling aircraft with a high SAF blend can bring environmental benefits by reducing the formation of contrails and improving air quality on ground:

*"Uptake of sustainable aviation fuels, that typically have lower aromatic concentrations and lower sulphur content, will contribute to reducing the non-$CO_2$ climate impacts. A further reduction of the aromatic and sulphur content in aviation fuels could reduce contrail cirrus formation, improve air quality in and around airports and increase the quality of the fuel for the benefit of airlines, both through high energy density and lower maintenance costs due to lower soot levels"*
- European Parliament 2022, amendment 25 [21]

[21] European Parliament 2022, amendment 25

### 1.3.11 "Green route" and segregated SAF supply

As a result of a political decision to establish a "green route" in Denmark, the possibility of establishing a segregated supply to potential airports is also being investigated. In the following section, we will examine the circumstances this could create for the actors involved, especially suppliers and fuel service providers at airports. The political agreement and the associated negotiations on implementing a "green route" are reviewed later in this report.

The political decision aims to achieve the highest possible SAF blend-in on a selected route. The ambition is a 100% drop-in SAF, which requires ASTM approval. If this is not achieved, a 50% blend-in or as high a blend-in as possible is desired. To realise this, segregated deliveries are required, implying segregation throughout the supply chain. Here, we will assess the aspects of the product being received in tank capacity at the fuel terminal or airport and delivered to the end user.

At the time of writing, the route and thus the destinations, quantities and other conditions are not known. However, all Danish routes are within 240 km, which means the delivery to aircraft will be approximately 1500 litres per departure. It is planned to first conduct an official tender process, which will take place at the end of 2025. Until then, potential players are encouraged to prepare and investigate the possibilities.

There will be several prerequisites for the realization in both CPH and at the possible destination(s), for example:

**1.** That satisfactory high blend SAF products can be delivered,

**2.** That the products can be stored in their own tanks. Storage at the fuel terminal will require separate tank capacity, unless the existing SAF blend tank can be used to both supply the airlines with the legally required 2% and serve as SAF high-blend storage for the "green route".

**3.** Transport between the storage tank and the aircraft must be organized. Includes availability of trucks with the necessary capacity. With many departures per day, trucks and personnel will need to be available accordingly.

**3b.** With storage in a tanker truck, this can be done at the airport with the necessary personnel.

**4.** With a high blend SAF tank located at the airport, transport from the tank to the aircraft must be done by truck or a separate pipe and hydrant system.

**4b.** Requires that a larger tank capacity is available for filling the truck regularly.

**5.** If delivered to an aircraft from a truck, separate pumps must be used that can lift the fuel to the aircraft tank.

**6.** It should be considered and thus further assessed whether segregated deliveries of high blend SAF for the above-mentioned domestic purposes can be seen as a precursor to a future shift to use 100% drop-in SAF for selected long-haul aircraft, which can thus achieve significant reductions in non-$CO_2$ emissions.

From an overall perspective, with a broad, long-term view, many conditions must be changed.

To understand the most important challenges and implications of the political ambitions for 100% SAF or the highest possible blend-in percentage, relevant parties have begun analysing segregated solutions. As a starting point, the use of high-blend SAF in a segregated system will entail significant changes with high initial and operational costs. There may therefore be good arguments for looking at solutions that go far beyond the ambition of a green route to Danish domestic. With a different starting point, in the ALIGHT project WP 3.6, DLR and Airbus investigated some operational aspects of segregated SAF deliveries. The ambition with this has been to put into perspective the contributions to reducing non-$CO_2$ effects and to improve air quality at airports and in the immediate neighbourhood. It should only be mentioned briefly here that the considerations regarding SAF supplies and airports include pricing and infrastructure changes, and, of course, the question of who will bear the additional costs on top of the premium price for SAF. All of this requires further analysis and must be included in any decision-making processes.

## 1.4 Rules and procedures for jet fuel tanks (terminals and fuel farms)

In this section, we will go through the most important rules and conditions that apply to the journey of jet fuel (with or without SAF) from the refinery to the distribution point (often called a fuel terminal) and then to the point of use at the airport (often called a fuel farm). The review highlights aspects related to transportation, storage, and safety.

**Key Stakeholders in the SAF Supply Chain**

- **SAF/Jet A-1 Producers:** Manufacture fuel via conventional processes or advanced pathways such as HEFA, Fischer–Tropsch, or Power-to-Liquid (PtL). They sell to the spot market or directly to fuel suppliers, with traceability and sustainability documentation attached.
- **Fuel Suppliers**: Purchase fuel either on the spot market or directly from producers. They organize bulk transportation (ship, rail, truck, pipeline) and contract with airlines for supply, ensuring documentation and compliance.

- **Distributors:** Manage physical transportation of fuel to airports but typically do not own the product commercially. They may own infrastructure and operate under service contracts with fuel suppliers.
- **Storage Operators:** Manage storage facilities at ports and airports, responsible for quality control, inventory, and infrastructure. They receive payment through contracts with fuel suppliers.
- **Fuel Farm Operators:** Handle storage and transfers within the airport perimeter (hydrant systems, refuelling trucks). They do not own the fuel but provide management and handling services under contract.
- **Into-Plane Operators:** Perform the actual refuelling of aircraft, ensuring safety, compliance, and accurate traceability. They contract with fuel suppliers and use the airport's hydrant or truck refuelling systems.
- **Airlines:** Purchase SAF and Jet A-1 through contracts with fuel suppliers, integrate SAF into corporate sustainability strategies, and account for SAF volumes (even if not physically segregated in uplift).
- **Airport Operators:** Facilitate on-site infrastructure, storage, and logistics, while supporting broader decarbonization strategies. They do not directly procure or handle fuel.
- **Regulatory Authorities:** Organizations such as ICAO, EASA, FAA, or national aviation authorities set compliance frameworks, certification requirements, and blending mandates for SAF deployment.

In practice, and with more minor local variants, the SAF supply chain is defined by multiple handovers of custody and responsibility, each governed by strict certification and sustainability requirements. These interdependencies ensure that SAF can be fully integrated into existing aviation fuel systems without compromising safety, performance, or accountability.

### 1.4.1 Regulations

The regulation of jet fuel (Jet A-1) is based on JIG 2; tanks at fuel terminals and the transportation of jet fuel are subject to both national and international standards to ensure safety and quality in the handling of aviation fuels. Below are some of the general rules that apply. At national level, there may be different regulations and legislation:

## International standards

**ASTM D1655 or Def Stan 91-091:** This standard specifies the requirements for liquid turbine fuels, including Jet A and Jet A-1, and ensures that the fuel meets the necessary quality and performance requirements.

**API Standard 1542:** This standard addresses the marking of airport fuel identification equipment, which is essential for the proper identification and handling of different fuel types.

## National rules

**Building Regulations and the Environmental Protection Act:** General requirements for the storage of hazardous substances, including jet fuel. (Approved containers, tanks, ventilation, ignition-protected).

**Labelling and warnings:** Containers and tanks containing jet fuel must be clearly labelled with contents and relevant hazard pictograms. Proper handling reduces the risk of accidents.

**ADR-convention**: The transport of dangerous goods is regulated by the ADR Convention (European Convention concerning the International Carriage of Dangerous Goods by Road).

**Spill prevention**: Procedures to prevent spills during both the storage and transportation of jet fuel. Includes regular inspection of equipment and training personnel in proper handling of the fuel. In the event of a spill, there must be readiness plans.

**Waste treatment**: Fuel residues or waste products must be disposed of in accordance with applicable environmental regulations to protect both people and the environment. Proper storage of the waste until disposal and use of approved waste treatment facilities.

### 1.4.2 How to receive, store and dispense jet fuel

Safe and regulatory-compliant fuel procedures are essential for the operation of jet fuel storage and handling. Two crucial standards for fuel handling are NFPA 407 (Aircraft Fuel Servicing) and ATA 103 (Fuel Procedures), which contain specific safety requirements.

## Checklist and summary of jet fuel handling and fire safety

## Receiving jet fuel

**Tank inspection before delivery:** Ensure the tank has space for the fuel (and bundled if not by pipeline)

**Test for contamination:** Clear and Bright Test: Visually check for particles and water in the fuel using a glass jar

**API Gravity Test:** Verify the fuel density (775-840 g/L or 37-51 API degrees), which should match the delivery document

**Filtration and settling time:** Filter the fuel and allow it to settle for (e.g.,) at least 30 minutes per level-meter of fuel in the tank. As described in the applicable standard

**Sump Drain and Test:** Drain the bottom of the tank and perform a White Bucket Test to find water, sludge, or particulates

**No Simultaneous Receiving and Dispensing:** Simultaneous receiving and dispensing of fuel is not permitted

## Jet fuel storage (Tank requirements)

**Epoxy-lined steel tanks for jet fuel. Tanks must have:**

- Access manhole with a ladder
- Floating suction line and
- Water drains to the sump with proper slope
- Overfill protection and alarms

**Maintenance:**

- Take samples to ensure product quality.
- Marking + Labelling: Identify with black-and-white markings and appropriate warning signs
- More requirements as stated in the appropriate standards (JIG 2 in Europe)

## Jet fuel dispensing

**Material Requirements**: No cast iron, copper, galvanized steel, or other yellow/red metals in fuel systems. Only steel, stainless or aluminium is allowed.

**Filtration:** Change of filters/separators must meet EI 1581 and EI 1596 standards and include water drains, pressure gauges, and filters with "Go-No-Go" technology that stops fuel supply upon detection of water. Filter date must be marked.

**Safety requirements:**

- **Emergency stop stations:** Must be easily accessible and capable of stopping all fuel supply.
- **Deadman control:** Fuel supply requires constant manual activation (upper and lower wings).
- **Static protection:** Aircraft and fuel systems must be grounded with cables to avoid electrostatic charging.

- **Additional measures:** Allow fuel to rest for a minimum of 30 seconds after filtering to reduce static charging. Fuel hoses must meet API Bulletin 1529 standards and be tested with documentation. Fuel tanks must be equipped with proper filtration technology.
- **Fire safety:** Each tanker must have at least two 6 kg ABC-fire extinguishers. Large systems require an additional wheeled truck extinguisher.

*Notice: It is important to note that the above checklist is not necessarily complete, but rather a useful tool to assess, maintain and improve fuel safety. Regardless of any economic challenges, focusing on established and preventive procedures related to fuel handling is of great importance for aviation safety.*

## 1.5 Key measures and guidelines for SAF supply to airports

Both national and international regulations govern the supply of Sustainable Aviation Fuel (SAF) to all airports to ensure it is handled, transported, and stored correctly. While small airports typically lack the advanced infrastructure of larger airports, all must still comply with applicable safety, quality, and environmental standards.

Supplying SAF to all airports requires balancing existing infrastructure with the regulatory requirements for safety, quality, and sustainability. Solutions such as certified transport, proper storage, and incentives for infrastructure development play an important role in promoting the use of SAF. At smaller airports, this may be challenged by storage capacity, equipment, staff/training, and/or higher prices due to smaller quantities supplied, again depending on tank capacity, transport distance, etc.

In principle, several methods can be used for SAF combustion in aircraft. Four main routes for integrating SAF into the supply line are shown in the figure below. While Mass balance is the most widespread so far, Book & claim is expected to gain momentum, however, primarily as a voluntary supplementary scheme and outside the EU. At larger EU airports, direct delivery is practised to a limited extent. 100% SAF delivery may in the future become an additional method of SAF delivery, depending on future regulations, targets, and the possibility of access to it. As a rule, however, the same key measures and guidelines for SAF supply to airports will apply. The key differences are how the SAF quantities are recorded, calculated, and attributed to the right actors.

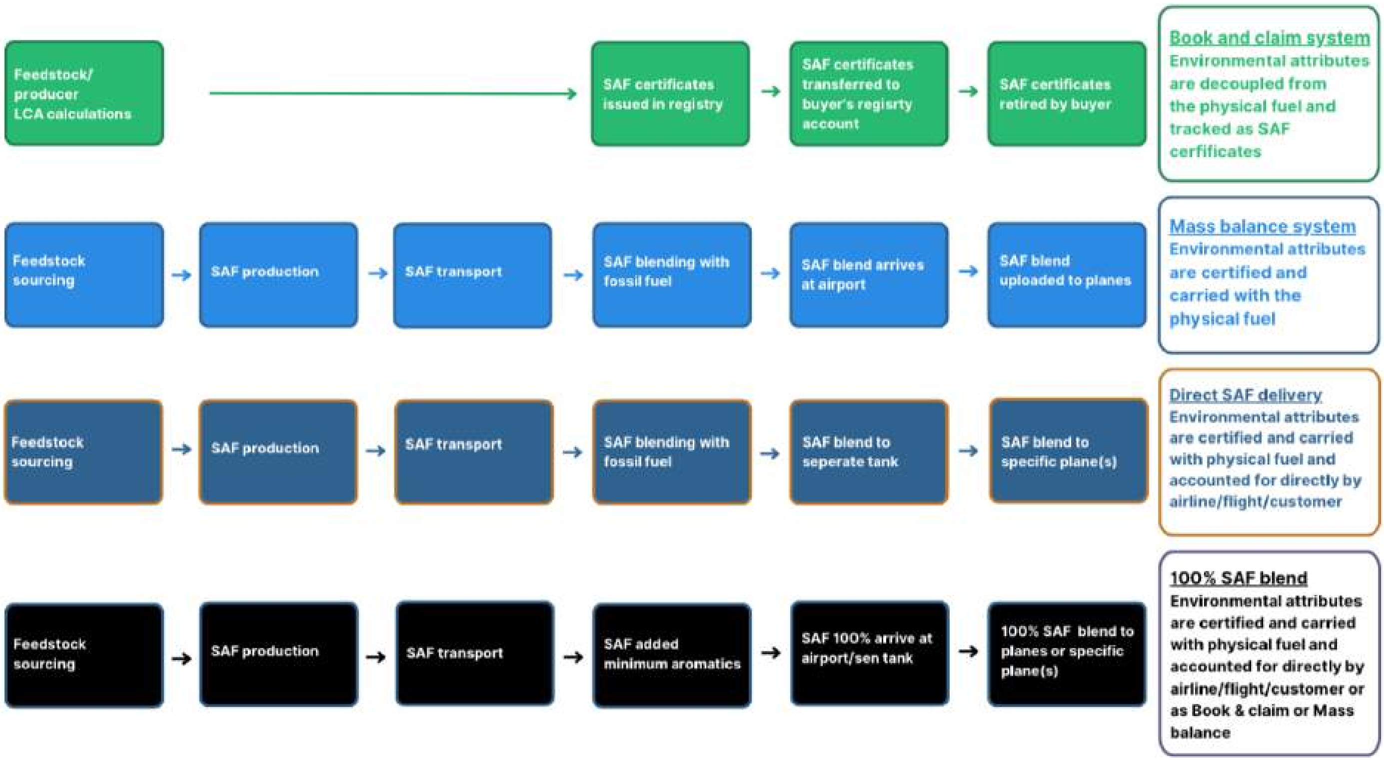



*Figure 8 Four different SAF administration ways*

*SAF delivery options / Book and claim options* [22]

As stated in RefuelEU Aviation, European Union airports must ensure that all aircraft operators can obtain aviation fuel containing the minimum SAF proportions set out in the RefuelEU Aviation Regulation. This means that the airport must facilitate access to the necessary infrastructure to deliver, store and refuel aircraft with SAF. A task that is unlikely to cause any airport problems, as both the blend-in obligations and the blend-in process itself lie with fuel suppliers.

In addition, Union airport operating bodies must undertake to facilitate aircraft operators' access to hydrogen and electricity for the propulsion of future aircraft, and to provide the infrastructure and services necessary for the delivery, storage and lifting of such hydrogen and electricity for refuelling or recharging the aircraft (more about new propulsion in chapter 6).

Also, because of RefuelEU Aviation, the registration, documentation, and reporting of SAF blend-in percentages and quantities delivered to airports and to respective airlines are solely the responsibility of the fuel supplier. This includes all forms of fuel-related data registration and reporting associated with deliveries.

[22] NISA, 2024: Based on WSS ENERGY's Book and Claim overview.

### 1.5.1 Reporting obligation

Aviation fuel suppliers are thus obliged to report in the Union Database the following information relating to the defined reporting period:

**A.** The amount of aviation fuel supplied at each Union airport, expressed in tonnes

**B.** The amount of SAF supplied at each Union airport, and for each type of SAF, stated in tons

**C.** The conversion process, the characteristics and origin of the feedstock used for production, and the lifecycle emissions of each type of SAF supplied at Union airports

**D.** The content of aromatics and naphthalenes by percentage volume and of sulphur by percentage mass in aviation fuel supplied per batch, per Union airport and at Union level, indicating the total volume and mass of each batch and test method applied to measure the content of each substance at batch level

**E.** The energy content for aviation fuel and SAF supplied at each Union airport, for each type of fuel. Fuel suppliers' reporting to the EU Database must be done no later than February 14th of each reporting year, starting in 2025.[23]

## Review of SAF transport, safety, quality, and traceability from refinery to end user

### Safety and quality

**Compliance with ASTM standards:** SAF must meet ASTM D7566 requirements before blending with conventional jet fuel. Once blended, it must meet ASTM D1655 or Def 91-091 for Jet A/Jet A-1 fuel.

**Quality control during transportation:** SAF must be transported in tanks and/or pipelines certified for aviation fuel to avoid contamination. Suppliers must conduct approved tests of the fuel to ensure it maintains the correct specifications during transportation and all transport shifts.

**Transport, logistics and storage:** The fuel must be transported with approved tanks on trucks, trains, ships or through approved pipelines, if the infrastructure allows such solutions. Transport by road, sea or rail requires approved tanks and equipment that meet national and international safety standards for transport of dangerous goods/chemicals.

[23] Europarl Europa; Fuel suppliers reporting, Article 10, 2022

**Storage:** Major airports might be connected to fuel terminals with several tank options, from which SAF blends are transported to the airport and potentially to smaller airports as well. Depending on the capabilities of the individual terminal, a separate tank for SAF blends is the preferred option. Tank storage facilities in terminals and fuel farm tanks at airports must comply with several provisions regarding spill prevention and chemicals legislation.
(*Airport storage checklist; See section further below)*

## Traceability and documentation

**Tracking of SAF deliveries:** Suppliers must ensure that the origin and sustainability certification of SAF products (e.g., ISCC or RSB) are documented and traceable throughout the supply chain (*see section 1.3.1 about PoS).*

**Compliance with sustainability criteria**: Delivered SAF must meet national and international requirements for reducing greenhouse gas emissions (internationally, ICAO CORSIA standards; in the EU, RED II/III criteria; and RSB or ISCC certification).

## Infrastructure and blending

**Local infrastructure**: Smaller airports without advanced hydrant systems must ensure proper storage and handling of SAF through tank facilities or directly via tanker trucks.

**Blending rules**: SAF is typically delivered already mixed with fossil jet fuel. Blending max is 50%, but usually it's 35-40% (to prevent blending constraints).
*Notice: As stated earlier, the final blended product must meet ASTM D1655 or Def Stan 91-091 – a SAF product may have values for individual content items that are outside the specification limits.*

## Environmental and safety regulations

**Environmental protection**: Delivery and storage of SAF must comply with environmental regulations that prevent spills or leaks and ensure proper disposal of residual products.

**Safety when handling**: Airport personnel must be trained in handling SAF safely and following procedures for fuel receipt and storage

## Support and incentives

**Public support schemes**: Smaller airports may receive support or incentives to integrate SAF through national or regional programs, which might be the EU's Fit for 55" initiative, to gradually increase the use of SAF and/or by national schemes. In the US, the Low Carbon Fuel Standard (LCFS) or Renewable Fuel Standard (RFS), provides economic benefits for SAF deliveries.

**Collaboration models:** Delivery can be carried out through cooperation with fuel consortia, fuel suppliers, and/or regional airlines. SAF Pool schemes can be established, for example, by several airlines joining forces to achieve better prices for SAF supplies (which must be on top of EU mandates)

### Segregated delivery agreements

Claim arrangement: the delivered SAF quantities are fed into the ordinary fuel supply for all users, but the ordering airlines or other customers pay for and are credited for them. If airlines or airports want SAF blends handled and used on specific flights or aircraft (i.e., segregated supply), this must take place alongside the ordinary fuel supply, which must therefore be agreed and arranged between the parties involved in the supply chain. - If separate transport of SAF blends to such airports is particularly challenging, it could be investigated whether regional fuel hubs or mobile facilities can be established to facilitate SAF delivery, if storage and transport can be carried out in accordance with regulations.

A solution for segregated supply could be to use a separate tank for SAF blends at the airport. It could also be a truck with a dedicated SAF tank for storage. The prerequisite is that fuel can be transported from there to the aircraft in a manageable manner. The mobile solution offers the most excellent flexibility, but both solutions are best suited to smaller airports without hydrant systems and where the need for large daily quantities is limited. CPH's Roskilde airport is an example of a smaller location where the customer Vestas/HeliService has a contract with DCC Shell for a segregated supply of a SAF blend-in with approximately 40%.

**Shared supply arrangements**: Smaller airports can collaborate with nearby airports to ensure more efficient delivery and storage of SAF blends, as is the case with ordinary fuel delivery, with or without SAF included in the supply. Provided that storage and transport can be carried out in accordance with regulations.

Providing SAF to airports requires balancing existing infrastructure with regulatory requirements for safety, quality, and sustainability. Solutions such as certified transport, proper storage, and incentives for infrastructure development play an important role in promoting the use of SAF in both large and small airports. Preventing quality defects, damage, and waste, and ensuring continuous control throughout the supply chain are core issues for reliable supply.

## 1.6 Purposes and parameters of airport storage

Airports' fuel storage capacities vary. In all cases, some form of storage takes place, and it is therefore relevant to clarify the purpose of storage at the airport and which parameters are important to understand in depth and to control.

At major airports, fuel storage is less about capacity and more about ensuring flow. The tanks in a fuel farm act as buffers in a flow-through system, allowing fuel to be received, settled, and delivered, while also serving as backup during short supply interruptions or reduced terminal flow. Furthermore, this is also where quality checks are carried out, the fuel is filtered and drained of any water and impurities. At CPH airport, there are several tanks with a total capacity of approximately 7,5 million litres, which also serve, to a limited extent, as storage and must therefore meet the established inspection, quality, and safety regulations. Other airports may have larger or smaller buffer and tank capacities. For all forms of jet fuel storage, with or without SAF blends, several additional purposes and parameters must be considered. (See: *IATA Guidance on Airport Fuel Storage Capacity*). [24]

The following list covers relevant purposes or key areas for airports in general. Therefore, some topics are not appropriate for all airports, but the checklist shows which areas to focus on regarding storage. The checklist also outlines the scope and complexity of managing storage at a major airport, as well as the measurable parameters relevant to each of the defined purposes.

**Demand:** To accommodate current demand and future growth, and space for unexpected demand reductions.

**Supply:** Accommodation of regular current supply, buffer for supply schedule, cover significant supply interruptions and accommodate future supply developments.

**Stock management**: To allow for day-to-day stock fluctuations and allow for seasonal variations in stock. To provide an appropriate level of redundancy in case part of the infrastructure fails.

**Quality Control**: Allow for settling time & quality control checks for tank release. Maintenance requirements (preventive and breakdown).

**Regulatory Requirements**: Compulsory stocks, if imposed by the authorities or the state. Time allowed for customs/airlines requirements.

[24] IATA, Guidance on Airport Fuel Storage Capacity

## 1.7 Checklist of measurable parameters

| Issue | Potential Purpose | Is potential purpose relevant at this airport? | Measurable Parameter (Do not quantify if purpose not relevant at this airport) | Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport) |
|---|---|---|---|---|
| | 3.4 To allow for seasonal variations in stock | Yes / No | 3.4.1 Quantify normal seasonal variations in supply, demand and stock levels | |
| | 3.5 To provide a facility to re-blend unbatched fuel at the location (if relevant) | Yes / No | 3.5.1 Does this location receive unbatched fuel? | |
| | | | 3.5.2 What quantities of unbatched fuel are received and in what frequencies? | |
| | | | 3.5.3 What is the expected frequency of needing to re-blend and in what quantities? | |
| | | | 3.5.4 Need to determine how many additional tanks will be required. | |
| | | | 3.5.5 Expected frequency and impact of receiving off spec cargos? | |
| | 3.6 To provide a level of duplication in case part of the facility fails | Yes / No | 3.6.1 Understand current facility | |
| | | | 3.6.2 Understand risk of failure of part of the existing facility. | |
| | | | 3.6.3 Understand security risks. | |
| 4. Quality Control | 4.1 To allow for settling time & quality control checks | Yes / No | 4.1.1 How many tanks are there currently? | |
| | | | 4.1.2 Required settling time. | |
| | | | 4.1.3 Time taken to perform quality control checks. | |
| | | | 4.1.4 Any limitation on when own staff / lab can perform quality control checks (i.e. is this 24 hours, 7 days a week?) | |
| | | | 4.1.5 Is fuel receipt continuous? | |
| | 4.2 Maintenance requirements | Yes / No | 4.2.1 Types of maintenance performed at airport (e.g. tank cleaning) | |
| | | | 4.2.2 Frequency & duration of each type of maintenance. | |
| | | | 4.2.3 Understand legal obligations in this area | |
| | | | 4.2.4 Impact on storage of each type of maintenance (e.g. 1 tank out of service at a time) | |
| 5. Regulatory Requirements | 5.1 Compulsory stocks, if imposed by the State | Yes / No | 5.1.1 Understand legal obligations in this area | |
| | | | 5.1.2 Quantity of stock that the State requires to be held at the airport | |
| | 5.2 To provide sufficient time to meet Customs requirements | Yes / No | 5.2.1Understand legal obligations in this area | |

| Issue | Potential Purpose | Is potential purpose relevant at this airport? | Measurable Parameter (Do not quantify if purpose not relevant at this airport) | Quantification of Measurable Parameter (Do not quantify if purpose not relevant at this airport) |
|---|---|---|---|---|
| 1. Demand | 1.1 To accommodate current demand | Yes / No | 1.1.1 Average day / month demand, peak day/month demand | |
| | 1.2 To accommodate future demand growth | Yes / No | 1.2.1 Planning horizon and the airports growth potential | |
| | | | 1.2.2 Average day/month demand, peak day/month demand | |
| | | | 1.2.3 Opportunities for incremental expansion of storage capacity | |
| | | | 1.2.4 Confidence in obtaining suitable locations and land for future expansion | |
| | 1.3 Ullage for unexpected demand reductions | Yes / No | 1.3.1. Frequency and impact of weather considerations (e.g. hurricanes / typhoons) | |
| | | | 1.3.2 Frequency & scale of major changes in demand | |
| 2. Supply | 2.1 To accommodate normal supply schedule | Yes / No | 2.1.1 Standard quantity of a batch by delivery method used (i.e. pipeline batch, ship cargo size, block train, truck size) | |
| | 2.2 Buffer for supply schedule | Yes / No | 2.2.1 Understand Supply Infrastructure (including off-airport storage) | |
| | | | 2.2.2 Understand pipeline schedules | |
| | | | 2.2.3 Understand size of tankers, railcars, etc | |
| | | | 2.2.4 Understand off airport storage | |
| | 2.3 Cover against significant supply interruptions | Yes / No | 2.3.1 Supply Infrastructure (including off-airport storage) | |
| | | | 2.3.2 Security of supply (i.e. how many supply routes, highest % of total airport supply from any one route, what % of lost supply can be made up by spare capacity on alternate routes, how long to restore 'lost' supply?) | |
| | | | 2.3.3 Frequency & scale of major supply interruptions | |
| | | | 2.3.4 Availability of fuel contingency plan for airport community | |
| | | | 2.3.5 Scope & impact of contingency plan (known at Heathrow as the "allocation system") | |
| 3. Stock management | 3.1 To allow for day-to-day stock fluctuations | Yes / No | 3.1.1 Quantify normal variability in supply and demand. | |
| | 3.2 To allow for normal stock fluctuations within a day | Yes / No | 3.2.1 Quantify normal variability in stock levels within each day | |
| | 3.3 To allow for normal airport operations | Yes / No | 3.3.1 Quantify any individual stock holdings by Suppliers | |
| | | | 3.3.2 Quantify the need for a strategic reserve, if any | |
| | | | 3.3.3 Hydrant/non hydrant operation | |

*Figure 9 Checklist: Guidance on Airport Fuel Storage Capacity* [25]

[25] IATA: Guidance on Airport Fuel Storage Capacity. May, 2008

## 1.8 Documentation and information in the SAF value chain

After the above review of SAF and conventional fuels' paths from producers to airports, the following section provides an overview of the most relevant documentation areas and information that must be maintained throughout the SAF value chain.

Purchasing and delivering SAF blends involves extensive documentation requirements covering product content, pricing, and sustainability. Throughout the SAF value chain, documentation is essential to ensure compliance with legislation and sustainability standards, and to manage economic and environmental aspects properly. Although much has been tested, there remains a need to clarify what documentation is required, by whom, when, and how end users should be involved. Numerous actors play specific roles in documentation, which serves not only as control material but also supports accurate pricing, GHG reduction calculations, climate credit allocation, and legal compliance.

Value chain documentation also goes to authorities and customers, who need different documents and calculations. With RefuelEU Aviation's requirements for supplier and airline reporting from 1 January 2025, data value and quality are expected to improve significantly. Planned measurement, verification, and reporting (MRV) are outlined in the ALIGHT D3.2 Handbook.

## Value chain review

Review of the area in the SAF value chain where documentation and reports are relevant and can add necessary and useful knowledge to the actual actors.

### Feedstock for production

**Sustainability certificate:** Documentation from certification bodies such as RSB (Roundtable on Sustainable Biomaterials) or ISCC (International Sustainability and Carbon Certification) must demonstrate that a SAF product meets the established sustainability criteria (See section 1.3.1 on PoS).

**Feedstock documentation:** Information about the raw material used to produce SAF (e.g., used cooking oil, waste biomass, captured carbon, etc.) does not conflict with biodiversity, food production, environmental protection, or water resources.

A fuel product from a refinery comes with an RCQ (Refinery Certificate of Quality). The RCQ is performed at the refinery for the fuel on a batch level. Contains the batch number, batch quantity, refinery name, date, and documentation that the tested fuel complies with ASTM D1655 or Def 91-091.

## Refining and production of SAF

**Production documentation:** Information about the production process, e.g., which technology is used (HEFA, FT processes, AtJ, PtX, etc.), but also an approval that the process is assessed as sustainable. A Certificate of Analysis (COA) must be completed. It contains the same information as an RCQ but is tested against ASTM D7566 or DEF stand. 91-091. A COA includes that the tested fuel meets ASTM D1655 or D7566. COA is generated when SAF and Jet A-1 are blended, confirming that it remains ASTM D1655 or Def 91-091 approved.
**Quality certificate:** Documentation that the SAF meets applicable technical standards for aviation, such as ASTM D7566, the specification for SAF, and after the blend, it meets Jet A-1 standard, ASTM D1655 or Def Stan 91-091
**Greenhouse gas calculations (GHG emission data):** Life Cycle Assessment (LCA) with details on reduction in $CO_2$ emissions compared to fossil jet fuel. (Read about LCA in 3.7.1)

## Transport and logistics

**Delivery documents, batch tracking:** Documentation that ensures traceability of the transport route and storage from production to end user, including volume and sustainability certification for the specific delivery.
**Transport certificates:** Documentation from transport companies that confirms safety and correct transport due to regulations for dangerous goods and environmental protection. [26]

## Sale and purchase of SAF

**Purchase documentation:** Purchase agreements and contracts at all stages of trade, specifying delivery terms, volumes, sustainability criteria, and PoS (Proof of Sustainability). Fuel suppliers must be able to provide the necessary sustainability certification documents to the airline/buyer that enable them to claim associated environmental properties under greenhouse gas emission schemes. [27]
**Carbon credit certificates:** In some cases, carbon credits or reductions are transferred via mechanisms such as the EU ETS, where documentation must be provided to obtain credits. PoC (Proof of Compliance) is valuable documentation.

The implementation of RefuelEU Aviation SAF mandates presents many challenges regarding pricing and calculation assumptions, not least that suppliers will pass on a greater share of

[26] ADR and IATA: Aviation Fuel Jet-A1. 2007
[27] European Union, RefuelEU Aviation/RED, Brief. Regulation EU, 2023: Link.

the additional costs to customers. For example, airlines receive the necessary sustainability documentation, and especially the penalties that can be applied if the required amounts of SAF cannot be delivered. This is further complicated by the fact that many airports have very few suppliers, each with different conditions for access to the mandated SAF volumes. In a supply-constrained, immature market, the limited competition between fuel suppliers is a major challenge. Many airports have three or fewer fuel suppliers, which can exploit their dominant position to dictate contracts and pricing terms to airlines. [28]

As mentioned earlier, customers other than airlines can also purchase SAF. From 2025, provided that the SAF quantities that are to be blended exceed the minimum amounts specified in the EU mandates. This is aimed, for example, at companies, institutions, travel companies, large customers or individuals who want to use SAF for their own transport tasks or travels. Several airlines and private agencies have launched programs that can handle such SAF purchases. A well-developed program for this has been prepared by Air France, with a set of General Terms and Conditions of Sale for the SAF Option, which offers customers the opportunity to voluntarily contribute to the development of the use of more sustainable aviation fuels. [29]

## Fuel distribution and end use

**Fuel quality documents:** Certificates confirming that SAF meets the requirements of ASTM D1655 or Def 91-091 for jet fuel when blended with fossil jet fuel.

**Blend percentage documentation:** Evidence of the specific proportion of SAF in the delivered blend, most often a low percentage, but varying from 0.5 to as high as 40% in some cases.

**End user sustainability reporting:** Documentation of the use of SAF in aircraft, which can be included in the airline's sustainability reporting and $CO_2$ accounts. May also be passenger or cargo customers who have purchased SAF shares. It might consist of a Product Transfer Document (PtD) confirming the transfer of ownership from the seller to the end user.

## Monitoring and reporting

**Regulatory requirements:** Compliance with national and international requirements, in particular RefuelEU Aviation, EU ETS (Emission Trading System), CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) and national climate targets or initiatives.

[28] IATA, Access to SAF in Europe, 2025. Align all issues with IATA Refuel EU Aviation Handbook, 2024.
[29] Air France, General terms and conditions of sale of the SAF option

**Verification reports:** Independent third-party verification of sustainability data and $CO_2$ reductions to validate SAF's actual environmental impact.

The above-mentioned measures and documents not only ensure transparency in the value chain but also support a more correct and sustainable use of SAF in the aviation industry. These measures are not static but will develop over time. Documentation requirements may change, and sustainability criteria will be developed as experience is gained, along with greater transparency and, not least, new and more sustainable products that will replace or distance from limited and/or questionable products, especially in raw materials such as used cooking oils and certain other biomasses.

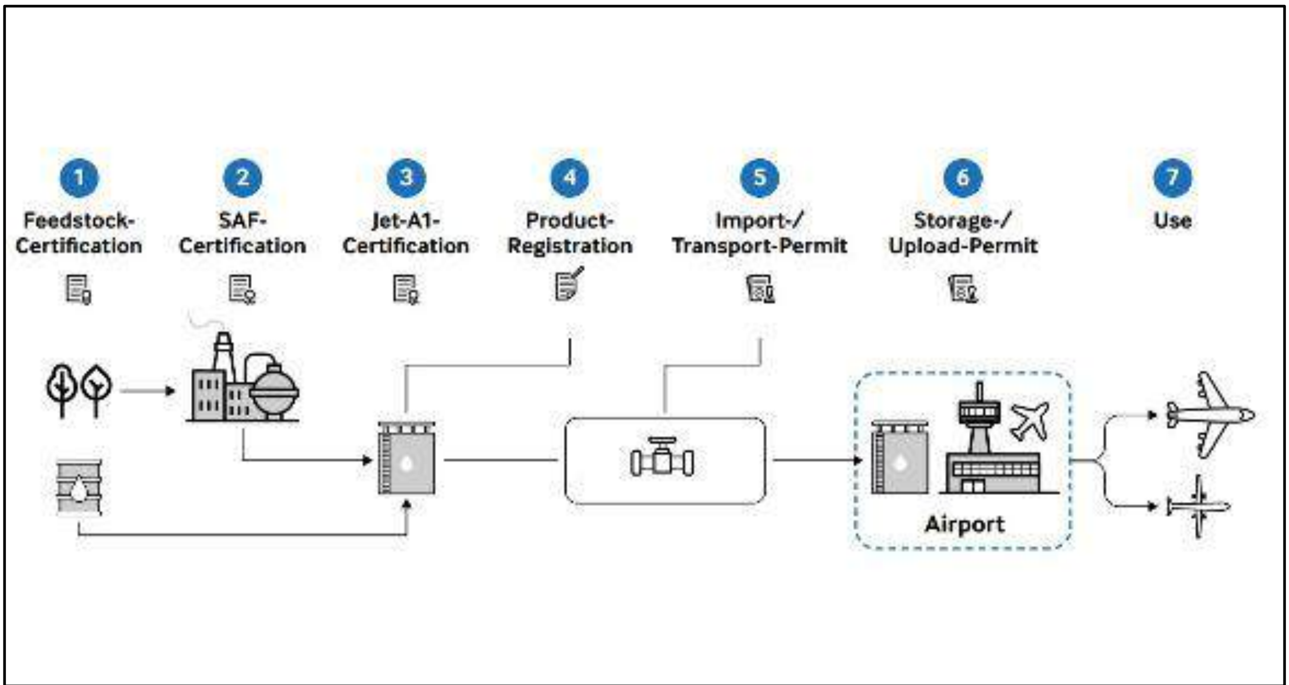



*Figure 10 Overview of the central steps in SAF's path from feedstock to end use*
*- each of which must be documented in the form of certificates, registrations or permits* [30]

## 1.9 Best practices

The following section reviews the key elements of a "best practice" for fuel and SAF at airports. The content elements and topics reviewed so far are intended to be replicable and can serve as a generic overview for a standard, generally applicable toolkit. The previous five sections reviewed the following areas:

[30] ACI, Study to support the decarbonization goals of the industry, Supply chain of sustainable aviation fuel, 2022

- Refinery and production facility
- After the refinery
- Key measures and guidelines for SAF supply to airports
- Purpose and parameters for airport storage
- Documentation and information in the SAF value chain

Based on these reviews, and in continuation thereof, the following section addresses the topic of “best practice” for guides, standards, and tools for fuel logistics, fuel quality monitoring, and accounting at airports. As "best practice handbooks", JIG 1, JIG 2, and EI 1533 serve as essential guides for airport authorities, fuel suppliers, and airlines to ensure safe, efficient, and environmentally sound fuel management. These documents describe what the handbook should contain by outlining the procedures, operational standards, and tools for managing the fuel step-by-step —from supply chain logistics to quality control and emissions accounting. The starting point is an airport receiving inspected and approved Jet A-1 fuel from a supplier. This can be conventional jet fuel or conventional jet fuel blended with SAF to specified quantities.

It may be recommended to align several of the topics with the content of the Airport Development Reference Manual (ADRM) published by IATA and ACI, especially the sections on digitalisation, jet fuel infrastructure, local environmental issues and sections dealing with airport environmental and sustainability management. [31]

## Key elements of a ‘best practice’ for fuel and SAF at airports

### Fuel logistics at airports: Overview of the fuel supply chain

**Outlines the fuel logistics process, including:**

- **Fuel transportation:** From production facilities, fuel terminals or depots to storage tanks or fuel farms at the airport via pipelines, tankers, or rail.
- **Storage:** Guidelines for maintaining optimal storage conditions in airport tanks to prevent contamination or degradation.
- **Hydrant system operation:** Best practices for operating and maintaining underground hydrant systems that distribute fuel to aircraft efficiently and safely.

[31] IATA: IATA AGM & World Air Transport Summit 1-3 June 2025

- **Access** to detailed descriptions and drawings of surface and underground tank systems, piping, pumps, valves, inspection wells and everything relevant in relation to use, maintenance, protection, and monitoring.

**Key considerations for efficient logistics:**

- **Scheduling and forecasting:** Use of predictive analytics to optimize fuel delivery schedules based on flight operations and seasonal demands.
- **Minimizing fuel losses:** Implementation of advanced metering systems to monitor and reduce losses due to evaporation, spillage, or leakage.
- **Sustainability measures:** Emphasis on reducing the carbon footprint of the logistics process, such as using renewable energy, electric or hybrid fuel trucks.

**Recommended Tools:**

- **Logistics Management Software:** Digital platforms for real-time tracking of fuel deliveries and inventory.
- **GPS-enabled tankers and pipelines:** To monitor the movement of fuel and ensure timely delivery.

## Fuel quality monitoring

**Fuel quality is critical to aircraft performance and safety:** The handbooks provide or refer to detailed protocols for maintaining fuel specifications in compliance with conventional fuel standards and alternative pathways, such as ASTM D1655 or Def Stan 91-091 for Jet A-1, and ASTM D7566 and the certification schemes for SAF.

**Testing and Inspection Procedures. Pre-receipt inspections:** Ensure that fuel arriving at the airport meets required specifications through sampling and laboratory testing.

**Periodic testing:** Guidelines for regularly testing stored fuel to monitor contamination (e.g., water, microbial growth) and degradation.

**On-wing testing:** Use of portable testing devices to verify fuel quality before fuelling aircraft.

**Contamination Prevention and Remediation**: Best practices for handling and storage. Procedures to prevent contamination by water, particulates, or microbial growth.

**Filtration systems:** Guidelines for installing and maintaining filtration systems in storage tanks and refuelling trucks.

**Corrective actions:** Steps to be taken in case of contamination, including fuel polishing or disposal.

**Recommended Tools**: Fuel Analysers: Advanced devices for measuring parameters like density, water content, and flash point. Microbial test kits: Portable kits for rapid detection of microbial contamination in fuel tanks.

## Accurate fuel usage and reporting

Fuel suppliers are responsible for ensuring that all data regarding quantities and qualities of delivered fuel and SAF blend-ins are documented and reported in accordance with the regulation RefuelEU Aviation. Agreements for sharing relevant data between suppliers and airports/tank farms/hydrant service providers should be finalised/recommended.

**Accurate accounting** ensures regulatory compliance, cost control, and reliable reporting of emissions data.

**Detail methods** to measure, record, and reconcile fuel usage across the (local) supply chain.

**Procedures for Fuel Accounting**, tracking fuel transactions: Guidelines for recording every transfer of fuel, from storage tanks to aircraft.

**Inventory reconciliation:** Steps to compare fuel deliveries, withdrawals, and remaining inventory to identify discrepancies.

**Emission reporting:** Methods for calculating $CO_2$ and GHG emissions based on fuel consumption, in compliance with schemes like EU REDII/III, RSB and ISCC.

**The composition of the fuel**, including the SAF content, affects air quality at airports and in surrounding areas. Continuous measurements of air quality and ultrafine particle content are recorded and reported to support improvement.

**Fraud Prevention and Audit Compliance; tamper-proof systems:** Implementation of secure fuel meters and sealed storage systems.

**Audit trails:** Maintenance of detailed logs for all fuel transactions to ensure transparency and facilitate regulatory audits.

**Recommended Tools:**

- Fuel Management Systems (FMS)
- Software for automated tracking of fuel inventory, transactions, and usage.
- Updated data solutions: For creating tamper-proof records of fuel supply and usage.
- Emission calculators
- Tools to estimate GHG emissions based on fuel burn rates and flight profiles.
- Observe and consider SAF Sustainability Guidance for Airports, *see ALIGHT D6.1*
- Airports' GHG inventories have three scopes, which are based on the amount of control an airport has in reducing the emissions:

**Scope 1:** emissions from airport-controlled sources
**Scope 2:** indirect energy emissions; emissions from purchase electricity, heating, or cooling.
**Scope 3:** is related to emissions from third parties, aircraft, or passenger access to the airport.

## Key performance Indicators (KPI's) for monitoring and improvement, to assess and improve fuel logistics, quality, and accounting

**Fuel delivery accuracy:** Percentage of deliveries meeting schedule and quantity targets.

**Emission reduction:** GHG reductions achieved through SAF usage and optimized logistics.

**Air quality improvements:** Use of fuels with reduced aromatics and other soot content and limiting engine operation at stands and aprons.

### Training and capacity building – emphasize the importance of training airport staff and operators in:

Safe handling of aviation fuel

Using advanced testing and monitoring tools

Complying with local and international standards and regulations

Procedures, routines, and ongoing follow-up on all forms of fuel use, incl. reduced use

## Cockpit tasks and responsibilities

In addition to the rules and guidelines for handling fuel at the airport, including SAF, there are strict precautions regarding aircraft refuelling. Regulations and procedures, such as those for emergencies or sudden incidents, can and should be used alongside the handbooks that cover airport and fuelling personnel and conditions on the ground.

Before, during and after refuelling, the captain has ultimate responsibility for ensuring that the aircraft has the correct amount of fuel, that safety precautions are followed, and that any problems during refuelling are correctly handled.

**Before refuelling:** Planning and confirming fuel quantities and communicating with the ground handling team.

**During refuelling:** Monitoring the process, ensuring safety procedures and emergency preparedness.

**Electronic systems:** Under certain conditions, the aircraft's electrical systems must be limited or shut down to prevent sparks.

**Communication with cabin crew:** If passengers are on board during refuelling, the cabin crew must be informed and prepared for an evacuation if necessary.
Prohibition of the use of mobile phones and spark-generating equipment near refuelling.

**Emergency procedures:**

- Fuel leakage: If a leak is detected, refuelling must be stopped immediately, and the ground crew and the captain must be informed.
- Fire hazard: If a fire or spark occurs, the aircraft's Fire Procedure must be initiated, which may include evacuating the aircraft and activating fire extinguishing equipment.
- After refuelling: Confirmation of fuel quantity, signing of fuel documents and approval for departure.

*Detailed description in the airline's Operation Manual (OM), Standard Operating Procedures (SOPs), ICAO Annex 6 and national aviation authority regulations (EASA/FAA etc.).* [32]

### 1.9.1 SAF Supply Chain

**1. Feedstock** Raw materials like UCO, agricultural waste, forestry residues, or synthetic fuels.

**2. Producer** SAF is processed using methods like HEFA, Fischer-Tropsch, or Alcohol-to-Jet.

**3. Blending** SAF is blended with conventional jet fuel (up to 50%) and certified for aviation use.

**4. Transport** Blended SAF is transported via truck, rail, or ship to distribution hubs.

**5. Storage** SAF is stored in fuel depots before being distributed to suppliers.

**6. Supplier** Distributes fuel to airports via pipelines or other transport methods.

**7. Pipeline** SAF is moved through pipelines or tankers to the airport's fuelling system.

**8. Fuel Farm at airport** Fuel is stored and prepared for aircraft fuelling.

**9. Aircraft Refuelling** SAF is delivered to aircraft for use in commercial and cargo flights.

[32] Operation Manual, (OM) + Standard Operating Procedures (SOPs) ICAO Annex 6 EASA FAA

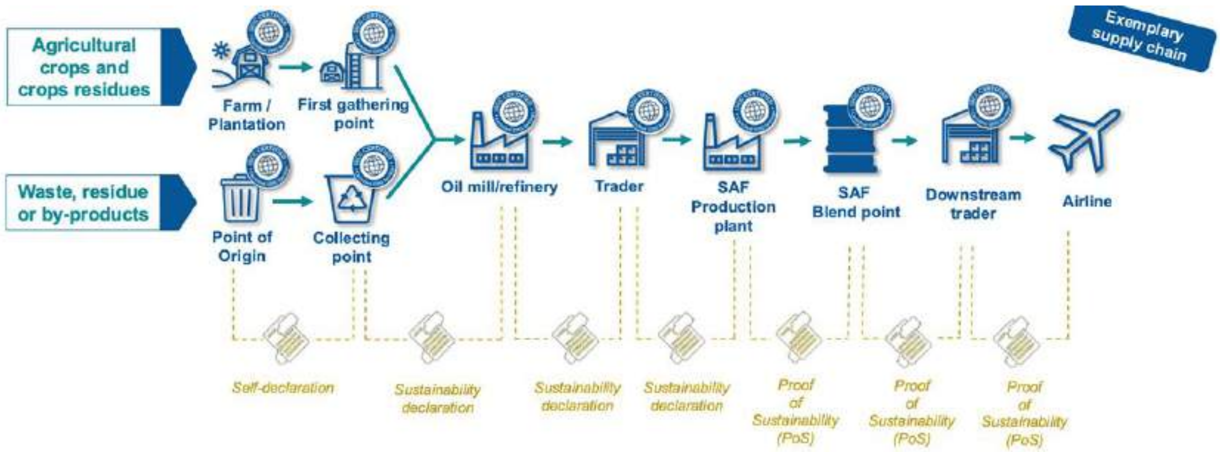



*Figure 11 SAF supply chain illustration* [33]

At all airports, best practices are essential to ensure efficient and sustainable fuel management. The manuals JIG 1, JIG 2, and EI 1533 serve as the central handbooks for airport fuel managers, authorities, fuel suppliers, and airlines, describing the procedures, standards, inspections, methods, and tools required to handle fuel responsibly. This includes managing the supply chain logistics, where clear agreements with suppliers ensure a stable supply, while systems used can monitor the safe transport of fuel to aircraft and prevent spills and safety risks. The transport, measurement, maintenance, and storage of fuel must be carried out under strictly controlled conditions, which requires regular inspection of tanks, pipes, equipment and means of transport.

Manuals outline fuel testing and control in line with international standards. Staff are thoroughly trained to ensure proper handling, and procedures cover every step from fuel arrival to aircraft refuelling, where the airline's Operation Manual procedures also apply.

Environmental considerations are highlighted as an important part of fuel management. This includes the use of emission-saving technologies and the collection of data to measure and report fuel consumption and $CO_2$ emissions. Through detailed emission accounting systems, the airport can identify opportunities to reduce climate and environmental impact and promote the use of more sustainable alternatives.

To act on factual information and measurements, airports must have access to fuel supply information on quantities/qualities, and so on, as discussed in the later sections.

Digital platforms can monitor fuel levels and the status of the supply chain in real time. These systems improve cooperation among airport authorities, suppliers, and airlines by enabling effective communication and data exchange, thereby supporting better decision-making. Operational tools, such as integrated IT solutions, also support smooth operations and

[33] ISCC, IATA, June 2024: Link.

resource optimisation. For example, installing digital twins. A concept that can concretely model decisions about blending SAF with conventional jet fuel in a real-time emission monitoring. DLR participates in the Fuel Track campaign at CPH, where fuel composition and emissions during taxi operations were mapped. Provides the opportunity to link flow and composition data directly to emissions—an important input for a real-time digital twin to optimise fuel use at the airport.

Crisis management is another important element, in which emergency procedures are outlined for handling unforeseen events such as fuel shortages or spills. Transparency and documentation are also key principles, with all processes carefully detailed and reporting standards implemented to ensure compliance with both internal and external requirements. Regular audits support this by evaluating and improving the procedures on an ongoing basis.

The handbooks serve as the basis for structuring all guidelines into a coherent, step-by-step guide that ensures actors across airports and countries – from fuel suppliers to airlines – work in the same direction toward the goal of safe, efficient, and environmentally friendly fuel handling at airports.

### 1.9.2 SAF Supply Infrastructure at Copenhagen Airport
***- Assessment, Transferability and Strategic Potential***

The sustainable aviation fuel (SAF) supply infrastructure to Copenhagen Airport (CPH) is currently operational and integrated into the airport's existing fuel supply system. SAF is delivered via the established pipeline network, originating from the dedicated SAF storage tank located at Prøvestenen. From this point, the blended product is further mixed with conventional jet fuel at designated mixing points before entering the pipeline system and being transported to the airport. This setup ensures compliance with required fuel standards and quality control procedures throughout the blending and distribution process.

A comprehensive assessment of the existing infrastructure confirms that the system demonstrates a high degree of operational maturity, technical reliability, and regulatory compliance. It demonstrates robustness in terms of safety, traceability, and inspection readiness, crucial parameters for aviation-grade fuel operations. The current model is the most appropriate and reliable delivery method, particularly in the context of blended SAF, and it fulfils all criteria for sustainability verification, emissions accounting, and alignment with relevant EU and international standards (ASTM D7566, CORSIA, RefuelEU Aviation and RED II/III requirements).

The pipeline-based supply model is not only deemed feasible at CPH but also a robust, scalable method for SAF integration elsewhere. Its transferability is underscored by the fact that many international airports already rely on similar infrastructural backbones. Where such systems are not in place - e.g., at newly established or exciting bigger airports - it is considered strategically advisable to design and prepare for SAF integration from the outset, as seen in emerging airport projects across Europe.

Despite the current limited availability of blended SAF, both market developments and political direction at the EU level demand that the volume and variety of SAF types (e.g., HEFA, eSAF, and PtL-based fuels) will expand significantly in the coming years. This reinforces the pipeline model's future relevance, as it is well-positioned to handle mixed fuels within the framework of operational and regulatory standards.

The assessment further encompasses the potential for linking SAF delivery and infrastructure with emerging local production facilities in Denmark, including power-to-liquid (PtL) plants and biorefineries. Here, feedstock availability, production pathways (e.g., HEFA, Fischer-Tropsch, alcohol-to-jet), and technological maturity are considered. Results indicate that future SAF volumes - regardless of origin - can be routed to and stored in the existing Prøvestenen facility, if suppliers conform to the same blending and certification procedures.

Alternatives to the pipeline model, such as delivery by road tanker or the construction of a parallel SAF-specific pipeline, have also been analysed. However, these alternatives are currently not deemed economically attractive due to high capital and operational expenditures, increased complexity, and a lower degree of integration with the airport's fuel management system.

The infrastructure assessment considers scalability and long-term integration with evolving energy systems, including rising SAF demand and integration into PtX frameworks with energy stakeholders, thereby aligning aviation decarbonisation with national energy strategies, renewable hydrogen, and carbon capture and utilisation.

From an innovation and intellectual property rights (IPR) perspective, the SAF supply model holds strategic value. Opportunities lie in system integration technologies, modular design principles for SAF handling, and digital monitoring systems for blending and emissions tracking. These could form the basis for patents, licensing models, or standardisation across EU airports under green aviation initiatives such as the ALIGHT project, with potential relations to DLR and other technology-focused consortia with advanced measurement and control programs.

In conclusion, the SAF supply line to Copenhagen Airport exemplifies a mature, efficient, and transferable model that is aligned with current and future requirements for sustainable aviation fuel distribution. Its assessment and strategic framing provide a foundation for broader deployment, within the Danish context and across European and international airport systems.

Exceptions to this may be in situations where geographical or physical conditions are too complex, where economic investment conditions exist, or where national policy decisions prescribe separate solutions, or where it is preferable to work with multiple or higher blend-ins.

Fuel supply methods have been a significant issue in the development of Warsaw's new airport. For several reasons, the solution for now will not be to establish a fuel pipeline system, see more in section 1.9.7

### 1.9.3 Case: DCC Shell Aviation SAF supply

Based on many years of experience and somewhat shorter but already gained experience with the first few years of SAF supplies to Copenhagen Airport, the routines are exemplified and summarized in the following. Obviously, the relationship between the fuel supplier, the pipeline and hydrant service provider at the airport, and the airline as end user is central to SAF implementation and understanding. This applies regardless of whether it concerns voluntary purchases of SAF quantities, or the mandated requirements introduced as of 1 January 2025.

DCC Shell Aviation has set up a separate tank for storing fuel blended with SAF. The mixed product is sourced from a manufacturer or an established distribution hub and received by DCC Shell Aviation at a mixing ratio of 35-40% SAF. The fuel products from the tank are distributed to the airport in quantities in accordance with agreements with airlines or other customers.

Before the delivery to the airport, a contract has been entered into between a specific buyer regarding mixed SAF quantities, prices, and delivery times. From 2025, the agreement will mainly cover the required 2% mixing. To a limited extent, quantities voluntarily in addition. The central issues in the process between the supplier and the airline are shown in the table below.

The entrance to this is that DCC Shell Aviation, as the only supplier, has supplied a SAF blend-in to CPH, thereby limiting the scope for options and the implementation framework for the activity. The table provides a review of the SAF supply line, including the relationships among suppliers, airports, and airlines, and the documents and conditions intended to ensure compliance with all rules and recommendations.

### 1.9.4 SAF supply to CPH

| SAF supply. Delivery and doc. DCC Shell to CPH year 2023-25 | For each supply chain point: which document, where, and how EU sustainability requirements are met. How is the compliance of delivered SAF ensured? |
|---|---|
| **Feedstock, type(s) certification** | Feedstock used is in compliance with RED II/III: POS, ISCC approved |
| **Feedstock transport(s)** | Included in POS, ISCC-approved |
| **Production method, SAF type** | Produced using the HEFA Conversion Process |
| **Production location** | The POS delivered to the end user describes the product's origin and composition. |
| **SAF, Jet A1 cert./inspection** | ISCC (SAF Certification) is used to ensure that the fuel complies with the relevant sustainability criteria detailed in RED II/III. |
| **Blended with CAF at prod. site or?** | SAF arrives as a blended product at Prøvestenen. Transported to the airport through existing pipelines in accordance with airline contracts |
| **Transport to 1, 2, 3... permits** | The blended product arrives from the ship. Pumped into dedicated SAF blend tank, inspected. Transported via pipeline to the airport fuel farm, inspected. |
| **Import permit** | Fully in line with national regulations |
| **Blend facility, storage, inspections.** | Product approval at Prøvestenen - ISCC Certified. |
| **Vol. to airport/BKL (order by airlines)** | Actual deliveries 2023 aprox. 0,08%. 2024 0,08% based on supply to Air Greenland. 2025 expected 2,08% (WP2estim.) |
| **Airport/BKL received, doc** | The airport does not receive certificates from DCC & Shell Aviation. No regulation or agreement regarding this |
| **Airport storage (fuel farm)** | Inspected according to JIG specifications when received |
| **Mandated reporting issues** | POS to airline/end user, Union Data Base and to national authorities. Then PoS is then declared "retired" |

After the previous sections with a significant focus on CPH, and many large and general topics about SAF and fuel handling, we will briefly review the conditions of these topics in fellow airports.

### 1.9.5 Case: First SAF delivery to FCO

The first delivery of SAF to Fiumicino Airport (FCO) on 15 October 2021 marked a significant step in Italy's green aviation transition. However, the project's first test proved complex, as the implementation required specially designed logistical, operational, and regulatory procedures distinct from standard fuel flows. Consequently, the project can best be considered a challenging and exciting pioneering effort rather than a fully replicable model, despite meeting essential safety and quality aspects.

The choice of FCO as the test airport was due, among other things, to the airport's status as ITA Airways' primary hub, its strategic infrastructure for both hydrant and tanker delivery, and its connection to the pipeline from the port of Civitavecchia. These factors created better conditions for testing SAF modalities but also highlighted the complexity of conducting the first operation via tanker under special access and security rules.

At the heart of the logistics were ADR's Post Holder Movement Office and Safety Management department, which together established several procedures – including airside permits, customs checks with the Guardia di Finanza, security escorts, and integration into the fuel-handling system.

The SAF blend was accompanied by documentation and quality assurance in accordance with ASTM D1655/Def Stan 91-091, confirming its compatibility with existing Jet A-1 systems.

On the day of the first SAF test on 15 October 2021, ADR closely monitored the entire operation to ensure that all activities were in line with the agreements made between all stakeholders – including customs and the Guardia di Finanza (GdF). Any changes to the arrival time were communicated proactively, and coordination with the relevant security and customs authorities was carried out in accordance with the agreements specifically arranged.

Before the tanker entered the FCO area and the fuel handling depot, four carefully designed security checkpoints were conducted: a security briefing with the driver, checking the tank seals, reviewing customs documents, and finally verifying the fuel quality. After approval of these four steps, the tanker was weighed at the weighbridge, escorted through the customs gate, and onto the airside, accompanied by ADR and fuel handler staff in accordance with security-approved routes.

Before the actual handover, i.e., the transfer of the SAF mixture to the "into-plane" tank, Full compliance with quality parameters, including no water content and correct density, was ensured through sampling. The transfer was carried out by removing the seals in the presence of the ground handling agent and was conducted by Levorato in collaboration with Eni. Only after double-checking and completely emptying was the operation completed, after which the tanker was escorted out through the customs gate and driven back from the airport.

This process illustrates a typical pioneering project: although the first SAF delivery was completed without technical problems, it required extensive, temporary procedures that deviated from routine procedures. The project was both insightful and necessary in terms of testing operational, regulatory and safety aspects, but it clearly showed that without a systematic integration of such routines into Business-As-Usual, direct replication is difficult. Although the delivery on October 15, 2021, was completed safely and quality-assured, it was carried out in accordance with specific, tailor-made procedures. For SAF deliveries to become operationally replicable, permanent integration of these control steps and safety routines into existing airport protocols is required.

Shortly after, in March 2022, the FCO tests were expanded with a pipeline delivery via existing infrastructure from Civitavecchia. This phase validated the mass-balance approach, in which the SAF was distributed via hydraulic systems alongside Jet A-1, with minimal additional equipment or costs.

Both tests demonstrated that although security, access and documentation requirements can be implemented in practice, the first delivery requires special procedures that are not always integrated into the ordinary processes. The project created unique experiences and routines – but at the same time showed that, with the many adjustments to infrastructure and management systems, it is difficult to consider the initiative generally replicable. Despite the costs and complexity of the procedure, the FCO case shows the value of combining analysis of logistics infrastructure, certification, and collaborative regulatory processes. The experience forms the basis for recommendations to integrate standardized security requirements, mass balance reporting and logistics integration into future SAF implementations, so that other airports can also accelerate their transition to climate data-supported procedures.

The first SAF delivery to FCO demonstrates that SAF integration with segregated tanker supply is technically feasible with current infrastructure, but only through special, temporary, and extraordinary measures to ensure segregated supply conditions. To establish a truly scalable and stable supply model, it is recommended to incorporate SAF access into existing supply systems. If segregated systems are to be used, they should be done on a large scale with separate tank pipelines and hydrant systems.

In accordance with EU mandates, ADR is currently supplied with SAF blend-ins without specific problems or separate procedures in the existing fuel system.

### 1.9.6 Case Vilnius Airport

Recent developments, including both participation in ALIGHT and, not least, the adoption of RefuelEU Aviation, have affected both CPH and participating fellow airports in many areas. Regulations on the incorporation of SAFs have risen to the top of the agenda, and climate considerations are now a reality that affects decision-making, investments, and management.

The focus of the ALIGHT project is Copenhagen Airport, and the idea is that experiences, recommendations, and considerations from there, as well as influences in all other directions, should benefit the overall development of efforts to enable airports and other partners to tackle climate challenges.

At Vilnius Airport (VNO), all existing infrastructure for fuel storage, quality assurance and aircraft refuelling is operated under a long-term agreement with UAB Baltjet. At the same time, companies such as BGS, Naftelf, and RSS Motors are responsible for delivering fuel to the terminals. AB Orlen Lietuva plans to introduce a SAF blend with conventional JETA-1 in the second half of 2025 and transport this blend by rail to the airport refuelling facilities — a concrete step towards the practical integration of SAF in line with the ReFuelEU Regulation.

However, a regulatory framework from the Lithuanian Transport Safety Administration to enforce the use of SAF is still lacking, as sanctions in case of violations have not yet been established.

Lithuania is therefore undergoing a significant adjustment of its national legislation to meet the requirements of the ReFuelEU Aviation Regulation for increased use of sustainable aviation fuel (SAF). A draft law incorporating these requirements is currently being reviewed as part of the national implementation and is expected to be adopted soon.

A national target of at least 5% SAF use in aviation by 2030 has been set, but it falls short of the ReFuelEU target of 6%. The effort is being made within the broader energy policy framework defined by the updated National Energy Independence Strategy (NEIS) from 2024 and the national energy and climate plan 2021–2030. According to NEIS, Lithuania's share of renewable energy should account for 55% of total energy consumption by 2030, 85% by 2040, and reach 100% by 2050.

To meet both national and European targets, several necessary adjustments have been identified: In 2025–2026, AB Orlen's SAF blend is expected to be operationalized, requiring investment in rail supply and tanker logistics. In addition, it is crucial to establish regulatory sanctions and compliance standards through the Transport Safety Administration, and to clarify specific implementation requirements as defined by VNO's owner, LTOU.

Infrastructure improvements are expected to continue towards 2030, including the establishment of at least six stands with capacity for electric and hydrogen aircraft, as well as the modernization of refuelling facilities to receive SAF. To align with the minimum requirements of the ReFuelEU Regulation, it is recommended that the national SAF target be set at least 6% and that the NEIS ambitions be aligned with the national energy and climate plan.

Considering these elements, the period leading up to 2030 points to a critical phase in which Lithuania establishes the necessary legislative framework, infrastructure, and compliance mechanisms for an effective and lawful SAF implementation. Targeted coordination among the ReFuelEU requirements, national strategies, and practical operational measures will be crucial for the country's ability to meet both national and European climate ambitions. Considerations on, e.g., segregated SAF tanks and supplies with, for example, high blends have not been part of the considerations. However, these considerations, along with other recommended tools and replication issues, will influence future activities and priorities.

### 1.9.7 Case SAF and CPK – future supply and facilities

Given the complexity of physical installation and functionality, as well as the need for prior planning and design, it is crucial to make far-reaching decisions that will last for decades. Refuelling facilities with pipelines, pumps, and hydrant systems are relatively inflexible once integrated into an already complex infrastructure. The considerations have been a high priority in planning the new airport in Poland, which, in many ways, has been necessary to ensure the airport can achieve the set goals. In addition, which SAFs and fuels will constitute the future supplies? How can and should a new airport optimally organize for this?

In connection with the upcoming commissioning of the new airport, CPK is not expected to establish its own SAF production facilities internally or in the immediate vicinity, but will instead partner with national and regional producers. Poland does not yet have large commercial SAF producers in operation, but Lotos/Orlen is planning SAF expansion towards 2030. Public and private players, including those mentioned, will be invited and integrated through partnerships and limited production agreements. The goal is that future players will be able to produce and deliver both HEFA-based SAF and eSAF in accordance with the policies and regulations laid out in the EU's ReFuelEU Aviation targets.

CPK is planning modern, efficient fuel and SAF storage infrastructure, including fuel installations with separate tanks for Jet A-1 and SAF blends.

Storage in isolated tanks and integration via existing standardized hydrant network – incl. testing, blending and traceable mass balance systems. The plan includes the establishment of dedicated fuel stations for SAF and the possibility of adapted delivery via tanker trucks until a possible pipeline infrastructure is fully developed.

The national fuel and SAF production facilities are located more than 100 km from CPK, which implies robust planning for fuel transport and storage. While the CPK project focuses on air and rail, it's possible that fuel transportation to the airport could be addressed through pipelines or new infrastructure in the future, but this is not part of the current CPK project scope to facilitate that part.

Partners such as Orlen and LOTOS have been consulted in establishing CPK's infrastructure plan and have expressed their willingness to deliver modern Jet A-1 and SAF via internal tank facilities and distribution channels.

The plan for CPK includes establishing dedicated SAF fuel stations and the possibility of adapted delivery via tanker trucks until the pipeline infrastructure is fully developed. Preliminary delivery terms will be multimodal logistics via road and rail, with possible storage facilities connected to CPK's tank farm; from here, the possibility of pipeline access upon establishment. With a future SAF supply situation with possibly several different suppliers of SAF, including also various types of SAF, it may be challenging to determine a delivery method that best considers flexibility and sustainable choices, which, for example, implies:

The following options are in play:

- Purchasing SAF from the ORLEN refinery in Plock, which is a key source in the initial phase of the airport's operation
- Importing SAF from international producers, such as electrofuels projects from Germany, Sweden, or Italy. Depending on where it can be obtained.
- In addition, production of SAF from biogas, biomass and captured $CO_2$ using renewable energy (according to possible e-$CO_2$ approaches) is being considered

CPK plans to ensure SAF availability through diversified supply sources (local and foreign), multi-stage logistics and storage, and cooperation with suppliers that provide certified sustainable fuel. CPK anticipates activity on decisions and controls for supplies, including quantities, mixing ratios, and environmental parameters. CPK is also preparing to handle varied amounts and types. Airlines and customers will be the decisive decision-makers and demand-setters in this regard.

In the final part of the planning phase, it can be said that, in the initial period after the airport opens, deliveries will be made by rail to CPK, presumably from Plock/Gdansk. At a later stage, it could be transported via fuel pipeline directly from the refinery and/or tank terminals. At CPK airport, blend-in SAF products will be delivered to storage tanks and from there delivered to aircraft via fuel hydrant systems or airport tankers.

## 1.10 The role of airports in the development and use of SAF

Fuel management at the airport, including associated infrastructure, rules, and handling activities, is handled by a fuel consortium, also known as a pipeline- and hydrant service provider. This fuel consortium is the central player between the fuel supplier and the airline, the fuel buyer. Airport operations are not usually a part of it. Formally and structurally, regardless of which jet fuel product it is. Quantities, prices, delivery times, and terms are, first and foremost, a matter between the supplier and the airline, including when it comes to SAF blend-in. Upon arrival at the airport, it is blended and thus approved as a Jet A-1 product. Associated invoicing, calculations, and reporting to the Union Data Base, EASA, and national authorities are obligations that fall on fuel suppliers and airlines, respectively.

However, airports have different opportunities to play a role in developing and applying SAF as part of the global effort to reduce aviation $CO_2$ emissions. This role could, for example, involve acting as both a facilitator and an active participant in the process alongside airlines, fuel suppliers, and authorities to promote wider adoption of SAF.

The opportunity to directly fund SAF may vary depending on the airport's ownership structure, corporate rules, and policies. Some airports may be able to directly support specific SAF development activities or help establish production facilities. Several airports have been involved in many different initiatives. However, no set recommendation can be given on how or what airports should engage in. However, among the options to consider are examples from airports that have made certain choices.

In Sweden, the dominant airport owner, Swedavia, has purchased SAF for all internal business travel for several years. The concept was subsequently expanded with a budget framework that allows airlines to have half of the premium price of SAF compensated by Swedavia. An airport-financed model that has been decided also applies in 2025. Incentives will only be given for volumes exceeding the requirements of the national SAF mandates and the ReFuelEU Aviation mandates, both of which come into effect in 2025.[34]

Other airports, such as Clermont-Ferrand Airport and Munich Airport, have, through agreements with fuel suppliers, enabled airlines to request and purchase an agreed quantity of blend-in SAF through airport initiatives.

Similarly, the Spanish airports of Madrid, Barcelona, Palma de Mallorca, and Seville, which are responsible for over half of Spain's air passenger traffic, have also enabled airlines to refuel agreed quantities of SAF on customer demand. CEPSA, which supplies the products, began deliveries to Seville airport in mid-2023, which were subsequently extended to include the other airports mentioned.

In January 2016, Oslo Airport, owned by Avinor, became the first hub in the world to have SAF blends delivered to its fuel infrastructure (main fuel farm, hydrant, and dispensing system). The

[34] Swedavia, Sustainable Aviation Fuel (SAF) Incentive Programme, 2025

project was initiated by AirBP and the Lufthansa Group and carried out in collaboration with Avinor, SkyNRG, Neste, SAS, and KLM. In 2018, the Norwegian government announced the introduction of a national mandate in January 2020. Fuel suppliers were required to ensure that at least 0.5 per cent of the total fuel sold each year consisted of advanced biofuel. In 2022, the mandate was met with 3.2 million litres of HEFA SAF made from animal fat that is not suitable for food and feed, originating in Europe. Avinor has, over the years, initiated or participated in SAF analyses and political discussions on making SAF available. In 2023, an Avinor-supported study was published that investigated the potential for SAF production from non-biological raw materials (hydrogen, $CO_2$, waste, plastic, etc.).[35]

Amsterdam Airport Schiphol: Through a dedicated SAF coalition, the airport collaborates with key industry partners to advance a unified, strategic sustainability approach. As part of its **Powering the Future** initiative, Schiphol supports airlines by partially covering the cost gap between SAF and conventional jet fuel while also providing additional support services. This financial assistance enables airlines to integrate a higher percentage of SAF into their operations, accelerating the industry's shift toward more sustainable fuel alternatives.[36]

Los Angeles Airport, LAX, plays a key role in promoting a sustainable aviation ecosystem through its Airline Incentive Program, which actively supports and incentivises the use of SAF. The program provides airlines with various benefits, including fee waivers and financial incentives based on their SAF consumption. By reducing financial barriers to SAF adoption, LAX makes it easier for airlines to choose a more environmentally friendly fuel option without significantly increasing operational costs.

CPH, in collaboration with stakeholders in Danish aviation, has engaged in professional and political initiatives to have SAF developed for the Danish market. The Danish government has introduced a passenger tax, half of which is to be returned to financing SAF and sustainability in aviation. Danish Aviation and the Climate Partnership for Aviation have worked on proposals for how passenger tax funds can best promote the sustainability transition.

CPH is also a member of Project SkyPower, est. 2024. SkyPower is an alliance of CEOs from different global companies with a stated goal of supporting e-SAF projects towards an investment decision (FID) by the end of 2025. Several promising e-SAF projects have been announced, but none have yet been launched. This is what Project SkyPower is trying to change. The project’s projections show that the global e-SAF market could reach 250 billion euros by 2050 and create almost 90,000 direct jobs. CPH is the only airport in the project and thus contributes to adaptation across the aviation ecosystem from an airport perspective. Other participants include Arcadia, Air France/KLM, SAS, easyJet, Velocys, Topsoe, SkyNRG, Technip

[35] Anivor, Sustainable Aviation Fuel from Non-biological feedstocks, 2023
[36] Royal Schiphol’s Group: Quality of life. Annual Report Schiphol Final Version, 2023/2024

Energies and others. (See Project SkyPower section 5.2.3). Furthermore, in November 2024, SAS, Copenhagen Infrastructure Partners, Copenhagen Airport, and Aalborg Airport entered a partnership to promote Danish production of PtX-based sustainable aviation fuels.

The selected examples above are various ways, directly and indirectly, that airports can engage in the development, dissemination, and use of SAF. In continuation, it is recommended to review the suggestions or questions in the table below, which provide airports with the opportunity to consider SAF commitments further.

| What role can airports play in the development and use of SAF | | | |
|---|---|---|---|
| **Indicate yes/no if it is up to the airport to decide** | **Direct** | **Indirect** | **Airport decision yes/no** |
| Purchase SAF for the airport's own flights or shipments | X | | |
| Purchase SAF for the airport's users against full or partial payment | X | X | |
| Price agreement with producers/suppliers or bulk purchase agreements on behalf of airlines/customers (SAF Pool) | | X | |
| Investment in own tanks to purchase and store SAF | X | | |
| Financial support for airlines and customers' purchases of SAF | | | |
| Increase in Pax or take-off fees to pay the SAF premium price | X | | |
| Establish airport incentive schemes to co-finance SAF premium prices | X | | |
| Establish airport incentive schemes to co-finance SAF premium prices | | X | |
| Establish partnerships to scale up the SAF-marked | | X | |
| Can the airport, possibly through partnership, establish a SAF and energy supply chain? | X | X | |

Perhaps the above scheme can be included in airports' considerations of potential investments, engagements, or participation in activities that help scale up SAF to the market. Many airports are, of course, already involved in several of the points, and more topics can undoubtedly be added as mentioned at the outset. There may be legal, structural, or other factors that limit where and how a specific airport can get involved.

For further consideration of such engagements, ACI has outlined some examples of airport SAF activities, including specific examples from selected global airports. More can be read in the report" Guidance on Airports Contribution to Net Zero Aviation".[37] In the report "SAF Sustainability Guidance for Airports", RSB has also reviewed many options airports can pursue, depending on national and formal conditions.[38]

Airports can also take innovative steps by supporting research and development projects that promote the production and use of SAF, such as entering partnerships with fuel producers, research institutions, and technology companies that develop new methods for producing SAF.

Airports can play an essential role in creating economic incentives and promoting political support for SAF. As mentioned in the chart, this can be done by offering discounts to airlines or customers that use SAF, or by supporting the implementation of regional or national support schemes that subsidize the production and distribution of SAF.

Airports can also act as platforms for dialogue, information, and knowledge sharing on SAF and more sustainable solutions. For example, conferences, workshops, and collaborative initiatives can be organized to bring stakeholders together to discuss challenges and potential solutions. Initiatives like these open the opportunity for an airport to become a driver of innovation and collaboration, thereby contributing to a more sustainable future for aviation.

A topic currently in its infancy and closely aligned with the long-awaited breakthrough for eSAF is the possibility of large airports becoming involved in capturing carbon for storage or use. It should be assessed whether the amount of carbon in and around the runways has a concentration that makes it worthwhile to design DAC facilities in relation to this. If it is considered attractive to develop CO2 capture at airports, it also has the added advantage of demonstrating concrete initiatives to reduce aircraft emissions in the local environment. With direct air capture of carbon, it must be assumed that other harmful and nuisance substances can also be reduced. Düsseldorf Airport has unveiled plans to establish the world's first fully integrated Direct Air Capture to Sustainable Aviation Fuel (DAC-to-SAF) facility. Airports are encouraged to follow this and assess their own local, political and investment opportunities in parallel (see also section 5.4 and Greenlyte x DUS Airport).

[37] ACI, Guidance on airport's contribution to net zero aviation, June 2022
[38] RBS, SAF Sustainability Guidance for Airports 2022

### 1.10.1 How airports can ensure solid SAF data for scope 3 reporting

To further enhance the airport's sustainability potential, data on SAF deliveries must be available. Calculations of the airport's scope 3 are entirely dependent on this, and it also applies to airport users, especially airlines, which each receive SAF data from suppliers.

Airports can report on Scope 3 emissions by collecting and analysing data from third-party activities within their supply chain and operational areas. As Scope 3 covers indirect emissions from suppliers, airlines, passengers, and other stakeholders, accurate reporting requires a systematic approach.

This means that for airports to report on Scope 3 emissions effectively, they need to have strong communication with airlines, suppliers, and transport providers, use standardised calculation methods, and implement digital solutions for data collection and analysis. Transparent and accurate reporting is essential for both managing sustainability initiatives and reducing aviation's overall climate footprint.

As airline emissions are the dominant source of airport emissions, access to data on SAF deliveries is essential for developing airports in a sustainable direction. The calculation of the airport's Scope 3 emissions depends largely on this data, which also applies to airport users, especially airlines, which receive SAF data from their suppliers and must report their fuel figures, emissions, and SAF quantities to the authorities and EASA.

| Airports' access to SAF data for scope 3 reporting | | | | |
|---|---|---|---|---|
| **Indicate yes/no if SAF data is accessible and if standardized** | **Airport** | **Data supplier** | **Authority** | **Data agreed yes/no** |
| Agreement with fuel supplier on whether $CO_2$ e/GHG data is available? | | | | |
| Agree on how the relevant data will be retrieved/delivered | | | | |
| Agreement with operating airlines on whether $CO_2$ e/GHG data is available? | | | | |
| Agree on how the relevant data will be retrieved/delivered | | | | |
| Agreement with respective national authorities on whether and how $CO_2$ e/GHG data is available? | | | | |
| Agreement with Union Database on whether and how $CO_2$ e/GHG data is available? | | | | |
| Agreement with EASA on whether, and how, $CO_2$ e/GHG data is available? | | | | |
| Access to relevant data for use in scope 3 reporting has been agreed - and data access described. | | | | |

*Notice: While this is being reported, it is not known whether and how airports gain access to data in a qualified manner that could contribute to effective scope 3 reporting. It is recommended that this be clarified among relevant actors in the indicated SAF value chain.*

Other emission data from several actors, suppliers and activities that must be attributed to scope 3 is relevant as well. Therefore, it is also essential to build solid data sources and sustainability information with these actors, which must be kept under control —for example, catering, waste, and supply companies, as well as passenger and freight traffic that occurs both landside and airside.

Given that several reporting criteria are a consequence of RefuelEU Aviation, which came into force at the beginning of 2025, it is an obvious opportunity for airports to ensure that data exchange is established with relevant fuel/SAF suppliers and airlines that use the fuel/SAF products. This will ensure a more precise database for completing scope 3 reports in the future. It can also open opportunities for airports to increase their interest in influencing development and thus be able to assess and decide on activities that reduce climate impact and improve air quality.

## 1.11 Roadmap for possible future optimal supply of SAF and energy to CPH

Airports, which play a central role as hubs for traffic, trade, tourism, and transport integration, should soberly consider how best to secure long-term fuel and energy supplies. A future, visionary, and enterprising airport can see its tasks as an innovation and energy hub, where many activities merge or originate, preferably as smoothly as possible, and therefore a place with a strong need to be a prioritized centre for supplies, energy, and solution-oriented infrastructure.

The security of energy and fuel supply in terms of quantities, qualities, and prices can change over time. It is therefore necessary to consider how such a large airport can best secure its activities, customers, and functions. Extensive restructuring can result in significant changes in existing framework conditions and current models, procedures, and ways of doing things. This may entail changes for current players but also create exciting and future-proof conditions for relevant players, both current and new.

Should the airport choose a long-term, integrated business model as a strategic solution for future deliveries, it will require thorough preparation, including investment decisions and legal and competitive analyses, which, in turn, will lead to extensive new agreements and contracts. This would be a long-term, strategic approach that integrates production, supply, logistics, political regulation, and collaboration among key players. An overview outlining the key conditions for supplying fuel, SAF, and energy to the airport towards 2050 could be usefully divided into three main phases: short-term (2026–2030), medium-term (2030–2040), and long-term (2040–2050).

With focus on the following key areas:

**1. Infrastructure and logistics:** Expansion of storage and distribution capacity for, in and around the airport, possible SAF integration into existing fuel systems and possible pipeline solutions.

**2. Local and regional production:** Establishing SAF production in geographical proximity to the airport, e.g., via Power-to-X facilities in Jutland, Zealand or southern Sweden, to minimize transport distances and emission footprints and to create common interests.

**3. Securing energy supply:** Through external/internal, long-term capacities and updated infrastructure.

**4. Political and economic framework:** Strengthening incentives through support schemes, differentiated tax policy, quota incentives and requirements for increasing use of climate-improving fuels and energies.

**5. Cooperation and stakeholder involvement:** Close coordination between airlines, energy and fuel producers and suppliers, airport operators, public authorities, and energy producers, as well as the organizations of the key stakeholders.

**6. Technological development and innovation:** Support for new energy, fuel technologies, certification and approval systems that promote sustainable development and are scalable.

**7. Long-term** political, legal, investment and cooperation agreements.

**8. Integrated solutions** on many, probably all, levels.

When looking ahead to 2050, assessments should consider new energy sources like electricity and hydrogen, as well as other alternatives. Electric and hydrogen aircraft may be on the market within a few years, and energy supplies for this should be integrated with fuel and SAF supplies. Partly for reasons of infrastructure adjustments, but also because several of the traditional fuel producers/suppliers are in the process of expanding their business areas into new energy areas. Therefore, assessments and decisions on changes should consider the full range of options.

In this section, SAF is the central component. Other energies, such as electricity and hydrogen, are reviewed elsewhere in the report. As shown earlier, the conditions for the delivery of SAF and jet fuel to CPH are assessed as optimal with dedicated SAF tank and blend option before supply through the pipeline to the airport. If conditions are to be optimal in the long term and possibly in other setups, a comprehensive strategy is required that aligns infrastructure, SAF access, integrated energy policy, logistics, stakeholder collaboration, and market mechanisms. Next, as an ALIGHT and WP2 recommendation or topics for consideration, is a structured framework that addresses both current needs and future opportunities:

### Strategic objectives

- Ensure cost-effective, secure, and scalable SAF supply to CPH
- Enable compliance with EU and national mandates (e.g., ReFuelEU Aviation)
- Ambitions to go beyond the minimum requirements
- Position CPH as a Nordic SAF hub, regional logistics and innovation hub
- Foster regional (Greater Copenhagen) innovation and job creation

### Supply Chain Infrastructure, blending and storage

- Establish or secure on-site or nearby storage/blending facilities for SAF blends (e.g., high blends)
- Expand fuel farm capacity at or near the airport with SAF-compatible tanks and maximum flexibility
- Pipeline Access. Ensure the needed integration of SAF into existing pipeline networks, and/or create dedicated procedures and infrastructure
- Collaboration with relevant fuel suppliers, handlers etc.
- Logistics. Multimodal access: rail, road, potentially maritime (via nearby ports, harbours)
- Intermodal hubs to reduce SAF transport costs from production sites (ship/barge)

### Proximity-based SAF production facilities

Dialogue and collaboration capitalize on regional projects in Denmark and southern Sweden

**Confirmed or emerging projects:**

| Project Name | Location | Type | Relevance to CPH |
|---|---|---|---|
| Arcadia eFuels | Vordingborg | eSAF | Potential 2029, (100 km) |
| PTX Fjord | Aalborg | eSAF | Potential 2030, (250 km) |
| European Energy/Metafuels | (South Jutland) | eSAF (Aerobrew) | Mid-term supply |
| St1 | Sweden (Gothenburg) | HEFA SAF | Mid-distance, current prod. |
| Preem | Lysekil, Sweden | HEFA SAF | Regional option, 2027 |

It must be assumed that products from one of these refineries, current or future, could be delivered to SAF hubs near Copenhagen, provided the proper logistics agreements are in place. These are the closest possibilities identified today. An analysis of whether facilities can be established closer to CPH is an open question. Still, it should be included in future considerations, including discussions with manufacturers, developers, politicians, authorities and investors. This should, of course, include specific calculations of emissions caused by distances, including those from refineries or fuel terminals located at greater distances than those mentioned. In all cases, the mode of transport, quantities, technology and other factors come into play.

Ensuring enough high-quality, sustainable aviation fuel (SAF) for specific airports and airlines at prices and terms that match the market goes far beyond the aviation industry and its fuel suppliers. It involves a broader range of actors – for example, energy companies, fuel producers, certifiers, authorities, financial institutions and EU and national regulations/approvals. In addition, there are considerations of security of supply, access to raw materials, transport and storage facilities, sustainability criteria, and investment willingness, all of which rely on legal and regulatory frameworks.

It is therefore a complex interaction between energy policy, climate ambitions, technological development and market structure. A long-term, effective system for supplying SAF to airports requires that the right actors work in a coordinated manner within a stable, long-term framework. This underlines the need for SAF to be seen not only as an aviation issue, but as a strategic element in national and European energy and industrial policy. - Here are some inputs for consideration:

### Policy & regulatory enablers

**a.** National SAF mandates

- Ensure straightforward implementation of Denmark's contribution to ReFuelEU Aviation (2% SAF by 2025 → 70% by 2050 and national initiatives)
- Enable early-phase incentives for SAF uptake (e.g., national tax initiatives, SAF price premium support etc.)

**b.** Cross-border harmonization

- Align with Sweden/Norway policies to avoid leakage of SAF supply or demand
- Establish bilateral SAF corridors in the Nordic/Baltic region

### Market stimulation & offtake mechanisms

**a.** Airline offtake agreements

- Encourage long-term offtake deals between SAF producers and CPH-based carriers (e.g., SAS, Norwegian)
- Explore Green Premium programs for passengers and corporate travel

**b.** Auction-based models

- Consider reverse auctions where airlines bid for SAF allocations with government support

**Stakeholder Collaboration**

- Establish a SAF Working Group at CPH: includes airport operators, airlines, producers, regulators, and academia
- Coordinate within Climate Partnerships for Aviation and Energinet, Ørsted, CIP, Danish Energy Agency, Transport agency and ministries.
- Coordinate with other relevant airports
- Use the Greater Copenhagen Green Hub framework to align regional actors

**Innovation & future opportunities**

- Support R&D hubs near CPH for advanced SAF pathways (e.g., bio, $CO_2$-to-liquid, hydrogen)
- Analyse feedstock options (waste and biogenic $CO_2$, carbon from local industries, power supply), Amager Bakke, Kalundborg Symbiosis, biogas plants and others

**Visualization & Planning Tools**

- Geospatial mapping of current & future SAF supply points (production, blending, storage)
- Simulation tools for scenario planning (volume/cost/$CO_2$ reduction)

## 1.12 Summing up the SAF supply line from producer to end user

This chapter shows that many administrative and practical actions are needed to secure the entire fuel supply path, with or without SAF, from producer to end user, or to involve the airport in SAF.

In general, the review of the many sub-elements of the supply chain formal procedures, approvals, and inspections shows that SAF, as a manufactured blend-in product, can be integrated into existing frameworks. Several handbooks and SAF-related guidelines, inspections, and procedures take this into account, regardless of the SAF product, quantity, or location in the supply chain.

Quality control and approvals of sustainability criteria, feedstocks, and processes must, in principle, be included throughout the supply chain. Proof of sustainability and associated criteria are described and can be handled in the respective processes as the routines are incorporated and followed up. This is of crucial importance for the end user. Administration, reporting, and follow-up are in the EU system placed in the hands of suppliers and aircraft operators who must report to the Union Database and EASA/national authorities, respectively. At least as far as the mandated quantities are concerned. Additional SAF quantities that individual airlines choose to use, or countries that implement requirements beyond the mandates, are, for the time being, up to the respective country/affiliated country to secure data on. It is recommended that this should also be fully handled in the EU reporting systems.

The established procedures enable a qualitative and manageable inclusion of SAF and should not be an obstacle to development at the administrative and practical level. When steps are taken towards segregated supplies, whether within the current 50% blend or the 100% SAF version, once ASTM has approved them, rules must be prepared to guard against any misunderstandings in the supply chain, in storage facilities, or during aircraft refuelling. Such procedures will prescribe complete segregation and separation. Furthermore, if segregated SAF products are to be refuelled at airports, this will involve additional procedures and training of relevant and responsible personnel. In the future, SAF will enter airports and aircraft in increasing quantities. More producers and supply lines are on the way, which increases the reporting, control and follow-up tasks. At the same time, there is great doubt whether the quantities will be available in sufficient quantities and sustainable in acceptable qualities. Topics that are addressed in other chapters in this report.

European airports must facilitate and future-proof the integration of SAF and other fuels into airport infrastructure and operations. These are essential management tasks that require commitment and development. Infrastructure adjustments related to other propellants are addressed in another chapter in the present report and in WP 5. In the SAF topic, the role and opportunities of airports are illustrated as part of this chapter, which also raises some essential prerequisites for the work with scope 3 reporting.

### 1.12.1 Transition to SAF Pool

Agreements on the supply of SAF will, in accordance with current rules and contractual conditions, be matters between one or more fuel suppliers and one or more airlines or customers. A key question is how many such agreements are entered into and to what extent. Another question is how it can be handled in practice. Assuming supply through existing pipelines and hydrant systems, the blend-in SAF will be refuelled on all aircraft. However, the presumed additional price for SAF will only apply to those who choose to enter into agreements in this regard. To promote as broad participation as possible, a model should be established that encourages participation in the scheme. The more companies that participate, the larger quantities of SAF must be delivered. It may therefore be an idea to look at one or more model(s) that make it interesting for as many airlines or companies as possible to participate. A crucial element can be to establish a model that generates a more attractive price than the one the airlines can achieve individually. It could be created through the establishment of a major customer agreement that gives all airlines at the airport the opportunity to participate in. WP2 has taken the initiative to develop a model that should both ensure a more attractive price and disseminate and expand the use of SAF.

# 2 SAF Pool initiative - Case study

## 2.1 Preparations and background

Given a market where SAF is challenging to access, with only a few current producers, and where limited quantities are often partially allocated in advance and are very expensive, there is a need to examine which methods or instruments can be used to accelerate development. Depending on where you are in the value chain for a task like this, several difficulties need to be considered.

Agreements on the supply of SAF will, with ongoing practice, rules, and contractual conditions, first and foremost be a matter between one or more fuel suppliers and one or more airlines. An interesting question is whether there could be a basis for looking at it in a setup that goes beyond the currently established practice. One of the many questions was and continues to be whether several players were willing to enter into joint agreements on SAF deliveries. It was also a prerequisite to find solutions that enabled such agreements to be concluded. And not least, the question of how this would work in practice was of interest and importance.

It should be noted at the outset that the initiative worked on and presented to stakeholders in the first phase was created before the launch of RefuelEU Aviation, with prior knowledge that it was on the way.

The focal point of the SAF Pool initiative was the participating airlines and users of Copenhagen Airport. Furthermore, it was assumed that an agreed supply through existing pipelines and valve systems would be treated as a SAF blend-in in a mass balance system, meaning that the product is filled on all aircraft refuelling at the airport, even if participating SAF Pool participants finance the SAF premium price.

This means that the presumed additional price for SAF had to be paid by those who chose to enter into common purchasing agreements. To promote and reach such a broad participation, it would be preferable to establish a model that encourages participation in the scheme. The more companies that are part of the purchasing agreement, the larger quantities of SAF should be delivered. It has therefore been prioritised to examine models that make it attractive for as many airlines as possible to participate. A crucial element, and thus a key advantage, could be establishing a model that, through larger purchased volumes, yields a more attractive price than the airlines could achieve individually. This should be established by creating a broader customer- and purchasing agreement that invites all airlines to participate.

After several considerations within the ALIGHT project, an initiative was taken to create a model that would secure more attractive prices from SAF suppliers and, through increased purchases, also create opportunities for intensified development, scaled-up production, and greater access to SAF.

## 2.2 SAF Pool model

The model, called SAF Pool, is intended to provide common access to SAF ordering without affecting airlines' right to enter their own contracts with fuel suppliers and manufacturers. Traditional fuel procurement is a central, high-volume economic activity for all airlines. Often, detailed negotiations are conducted, and new agreements are concluded as part of an annual process. Some companies enter long-term contracts, while others enter hedging contracts as a form of insurance against unforeseen price changes. Incorporating SAF procurement contracts into traditional fuel contracts can also be a significant challenge, not least because other pricing structures apply and possible shifts in contract timing may further complicate matters.

It was decided to investigate the feasibility of establishing a SAF Pool for Copenhagen Airport. In the initial phase, NISA/WP2, as a neutral body, facilitated the process with fuel suppliers and airlines. In a subsequent phase, the facilitator role can be carried out by, for example, the airport or an independent body with the necessary skills and knowledge.

### 2.2.1 Normal fuel purchasing protocol

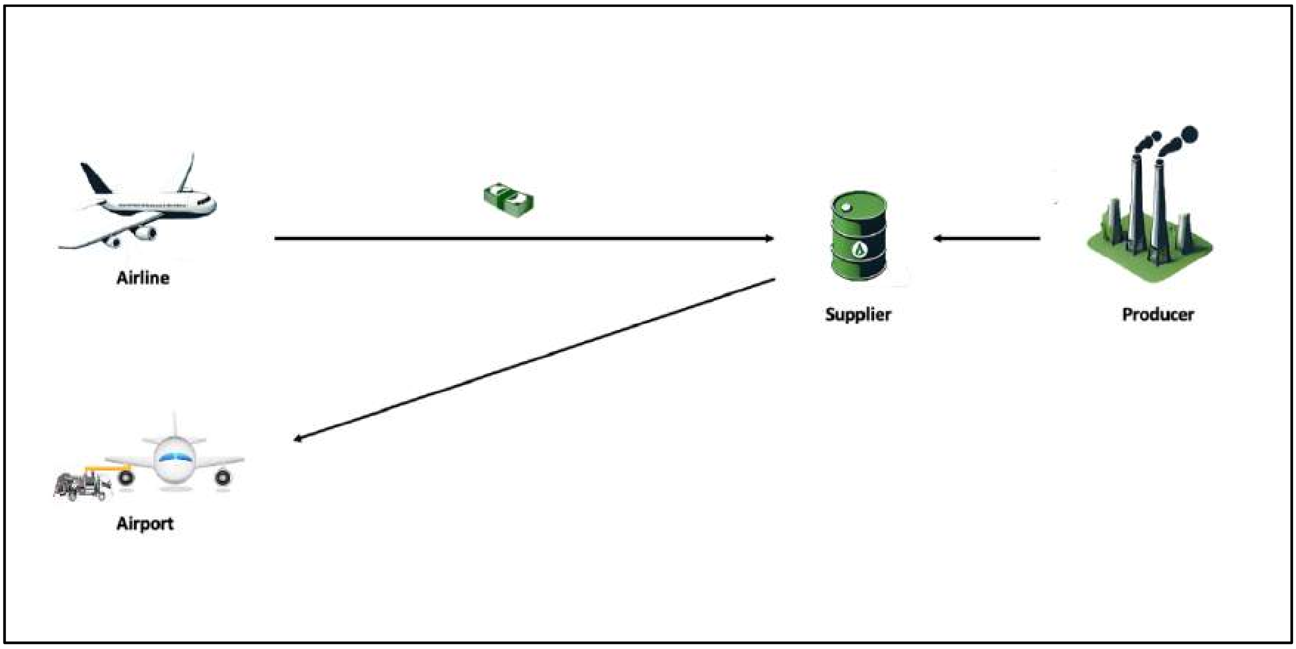



*Figure 12 Simplified, shows the ordinary fuel process flow*

In principle, and as a starting point, participation in the SAF Pool should be offered to all airport users (airlines) where a SAF blend can be delivered. It is also attempted to be established through existing contractual agreements between fuel suppliers and airlines. Prior to the launch, the SAF Pool proposal was discussed internally among WP2 and ALIGHT participants, as well as with external actors, including the Danish Aviation Secretariat and potential SAF suppliers. These discussions were primarily driven by the sluggishness that had become a reality regarding the previously expected growth in SAF deployment. The SAF Pool initiative should aim to bring together stakeholders for SAF purchases, with a view to increasing quantities at CPH and serving as an inspiration for others.

In addition to prices, quantities and delivery conditions, several additional factors must be assessed and approved before an initiative of this kind can be implemented. This involves, in principle, all actors in the value chain, but especially suppliers and airlines. This applies to legal and competition law aspects, so that no one risks doing anything in breach of the rules, including the practical, legal, and contractual conditions for participation, etc. It will be up to the participating parties to ensure that the initiative's contracts and practices comply with all relevant aspects of the legal framework.

### 2.2.2 Potential protocol

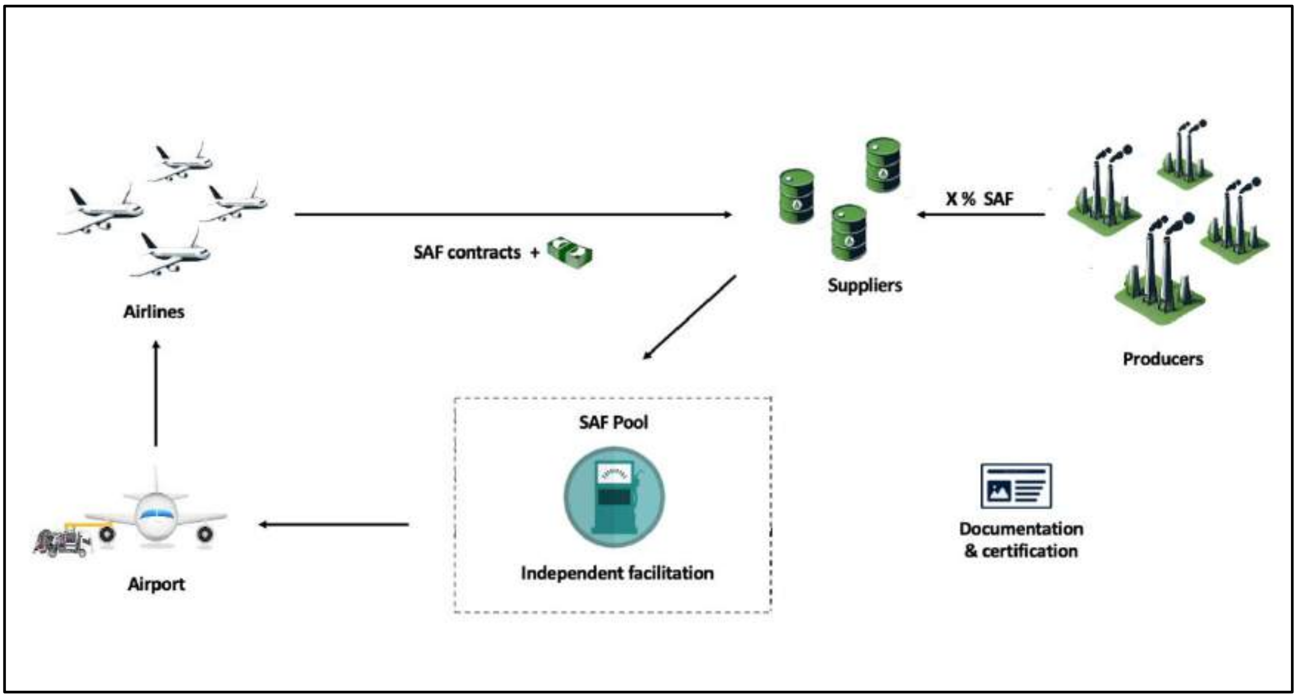



*Figure 13 Potential protocol of the fuel process flow*

The SAF Pool was initially assessed as an interesting concept for many airports and actors within the aviation sector, as a proposal developed in the ALIGHT project, but also in a broader EU perspective and/or other broader applications. As of the end of 2022, there was no knowledge of similar or established models for airlines' joint access to SAF deliveries. With experience from a concrete implementation in CPH, the model could become a significant contribution to the development and continuation of the experiences gained with the SAF work initiated in the ALIGHT project.

As a first step, the SAF Pool was launched for all Danish domestic companies in the fall of 2022, more than a year before the launch of RefuelEU Aviation. The intention was also that the work on the SAF Pool model could provide experience with SAF calculations, insight into pricing and reporting issues, and thus serve as a kind of transitional arrangement for the upcoming EU initiatives. However, with some advanced knowledge of the regulations that would come from the EU, this also created some uncertainty, leading some airlines to doubt how the initiative would fit with the upcoming EU rules.

The following five points were the proposed formulated purpose of the SAF Pool initiative. Along the way, other topics were raised and integrated into the discussions later.

## The purpose of the SAF Pool initiative

1. The aviation industry is collaborating on a common climate challenge
2. The initiative must state that the aviation industry is ready for increased climate action
3. Better conditions must be created for more and better SAF products on the market
4. This first step is followed up with the involvement of more partners who want this development
5. SAF Pool must provide experience with practical and administrative challenges

## 2.3 SAF Pool in a concept of Danish Domestic

The concept was introduced for all four domestic airlines in Denmark just before the turn of the year 2022/2023. Around the same period, the Danish Parliament presented the first plans for a flight passenger tax, as an undefined political support to make Danish aviation more sustainable, as described in chapter 5. The SAF Pool initiative was intended to demonstrate that the Danish aviation industry was taking serious steps to reduce its climate impact. The fact that several companies would join forces to purchase SAF for use primarily on Danish domestic flights could be a first step towards meeting the ambitions of many actors and the political statements aimed at making aviation greener. Initially, using relatively small quantities, the ambition was to expand the concept and use it more as the supply of SAF grows and becomes commercially available, and not least, more sustainable.

There were several important reasons for the SAF Pool initiative. By joining forces in this way, greater interest and dissemination could be created, better prices could be achieved when ordering larger quantities, and the industry could thus show in practice that climate action has high priority.

The parties wanted to emphasize that this was a relevant step away from fossil fuels. It was also pointed out that the SAF products available on the market must be replaced by other, more sustainable types of fuel that are both more widely available and in much larger quantities than has been the case so far. The proposal emphasized that the development should be pushed forward, and decision-makers convinced that investors and producers now really had to get started. For several years, aviation has been heavily criticized for its climate impact, but the conditions for action are challenging when sustainable fuels are not yet sufficiently available. The SAF Pool initiative should therefore be a contributing proposal to bring oil producers into focus! This should also be seen in the light of the fact that several new technologies have been developed and are planned to produce SAF in recent years. In Denmark and several surrounding countries, a strong focus is on eFuels based on Power to X technologies, which the aviation industry has high expectations for and is involved in at various levels.

Also, the SAF fuel producer NESTE, which produces the limited quantities of SAF supplied to Danish domestic customers, stated that they are in the process of planning PtX plants that can produce SAF that meets sustainability requirements and the quantities that are needed to a much greater extent in the future, knowing that other SAF technologies are also in the planning phase. For example, AtJ, based on alcohol and made from waste, wood, and sugary residues, as well as manufacturing processes that use industrial and household waste.

The starting point for the proposed SAF Pool in 2022/2023 was that a minimal amount of SAF was used in Denmark, and that no SAF supply to CPH Airport had yet been established. However, the Danish domestic company Alsie Express had implemented an approx. 4% SAF blend-in, filled on the aircraft from its own tanks in Sønderborg, used primarily for all flights between Sønderborg and Copenhagen. This was the situation when the graph below of total and estimated SAF consumption in Denmark was prepared for the SAF Pool initiative in 2022.

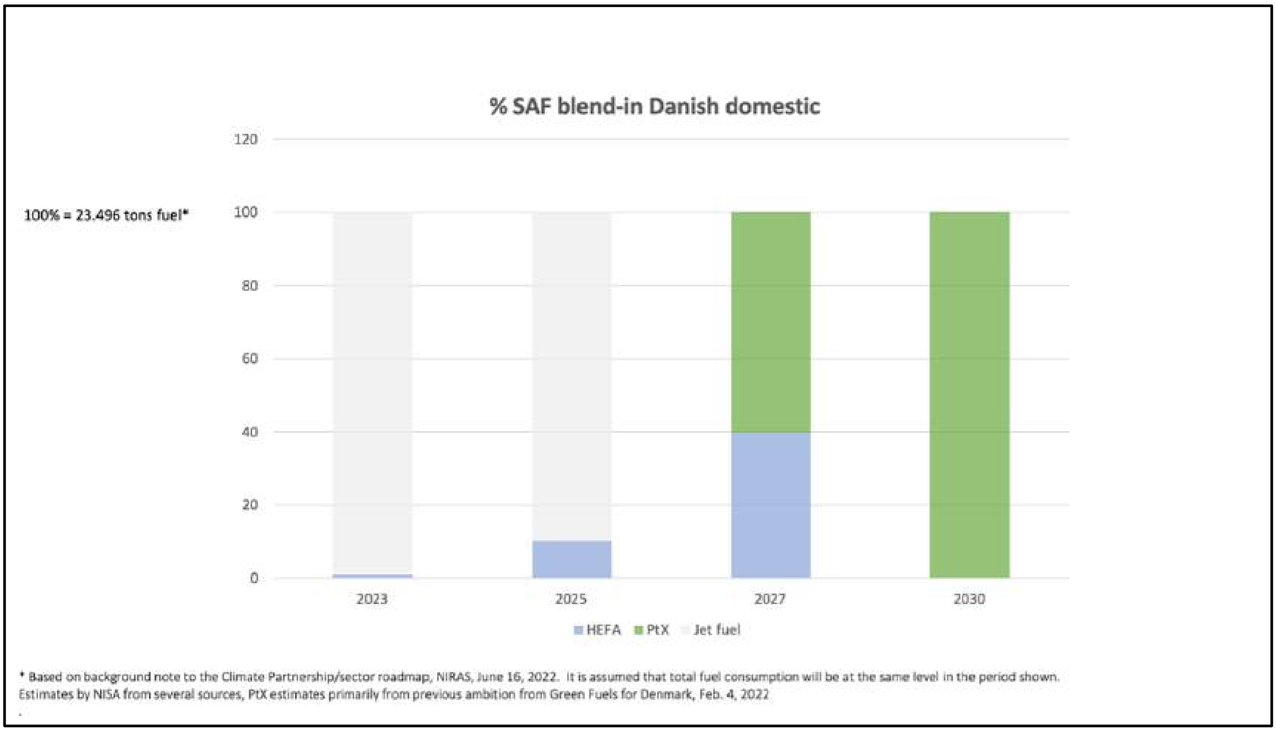



*Figure 14 SAF blend-in in Danish domestic* [39]

*Notice: The graph illustrates the situation we investigated in the SAF Pool initiative in mid-2022. Subsequently, several factors should give a somewhat different picture: Great uncertainty, as we were not out of COVID-19, 2023 Air Greenland started with 5% SAF blend-in on the Copenhagen-Kangerlussuaq route and in 2024, the PtX project Green Fuels for Denmark was dropped, which has the consequence that the green part of the 2027 pillar will not be realized.*

It was also a purpose of the joint initiative that all participating parties gain experience with the many practical and administrative issues related to deliveries, contracts, mixed quantities, and how an airline should handle the challenges of calculating $CO_2$ and climate benefits in the future. There are major administrative tasks involved in determining and subsequently calculating how the new data will be handled and registered, and how and to whom it will be attributed. The initiative was thus to create a basis of experience for the development that, in the years 2022-23, was, and still is, mainly in a start-up phase, and according to national and

[39] NISA's own, June 2022; Danish Climate Partnership, Sector roadmap, NIRAS, June 2022. Green Fuels for Denmark.

international ambitions and goals, will expand significantly in the coming years, not least with reference to the later adopted RefuelEU Aviation.

From the start, the four domestic operators were positive about the SAF Pool initiative, which led to several meetings and discussions. The idea of seeking cooperation on such a vital development was of general interest among participating actors, which were primarily the airlines Alsie Express, DAT, Norwegian and SAS and their joint organisation, Danish Aviation, and in another context, dialogues were held with the SAF producer NESTE and the fuel supplier DCC Shell Aviation. The meetings were initiated and facilitated by NISA and ALIGHT WP2.

Nevertheless, as mentioned in the introduction to the SAF Pool section, during the discussions at several meetings and dialogues, the initiative turned out in a way that most of the participating airlines chose to be reluctant with their participation, which meant that they could not, at the current time, decide to join the SAF Pool initiative in practice. The timing was complicated, and there were several reasons for this the following were put forward:

In 2022, aviation in Denmark faced a political decision to introduce a flight passenger tax, which, as presented, included the possibility that funds from the passenger tax could be refunded to companies to cover additional costs when using SAF. The content of this was not determined, and the airlines had no opportunity to assess how it might interact with the content of voluntary SAF Pool participation. Furthermore, three of the companies had already launched their own SAF initiatives, which could also complicate any decisions on participation in further activities. Thirdly, the entire industry was looking forward to new EU rules on possible mandates and other regulations, and, as a fourth point, there was some doubt and no clear answers about how a SAF Pool activity would interact with existing fuel contracts, both financially and in terms of timing.

Although the SAF Pool initiative with a joint voluntary agreement to purchase larger quantities of SAF would have resulted in lower prices than the individual airlines could have achieved, the uncertainties were too many for the airlines involved to decide to participate. However, it was determined early in the process that a start-up on Danish domestic would be a first step, which subsequently should be followed by a similar invitation to all airlines using CPH, which was therefore initiated.

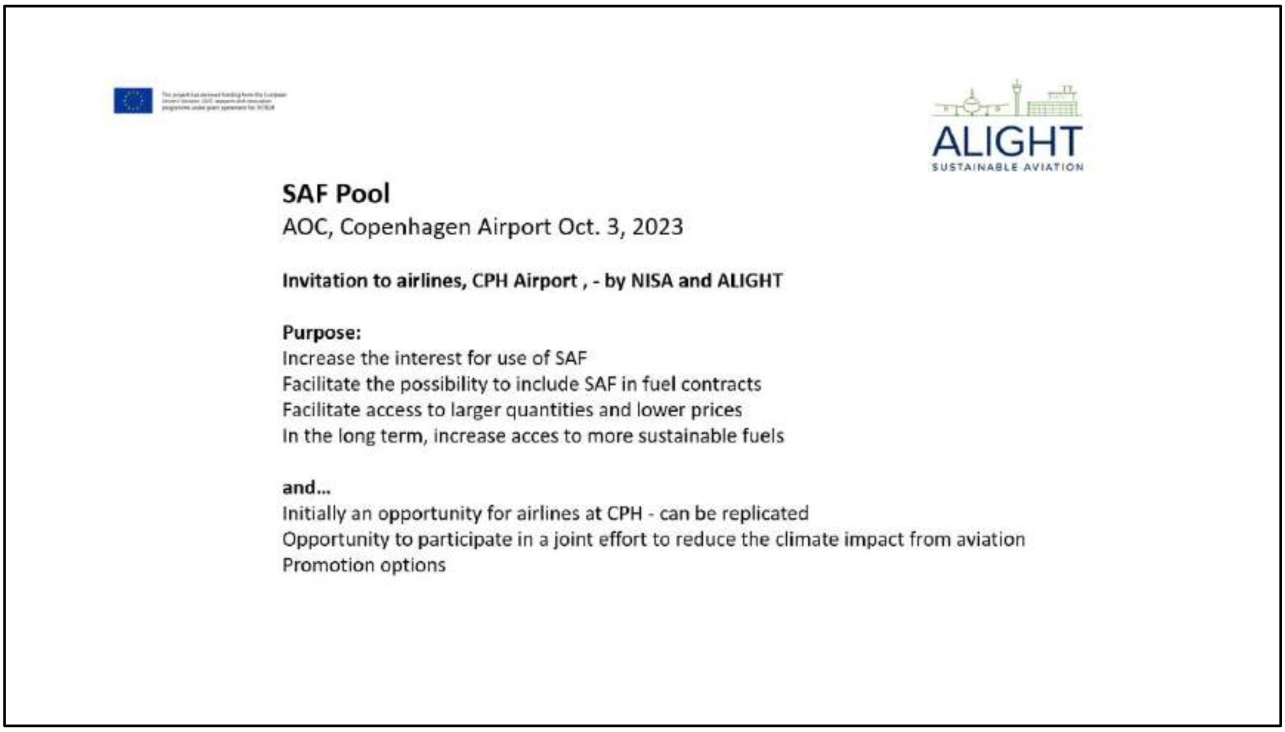
## 2.4 SAF Pool initiative at Copenhagen Airport

With experience from the SAF Pool initiative in a Danish Domestic setup, the proposal was subsequently brought forward to a larger group of potential participants, in a format that enabled all airlines using CPH Airport to participate. Through the previous initiative, it was facilitated on a smaller scale that the SAF Pool had the purpose of promoting SAF use in a Danish domestic context. Domestic airlines were generally positive about the initiative. Still, it was put on hold due to several uncertainties, including the not-yet-determined national political passenger tax, the expected but not yet decided regulations under the upcoming RefuelEU Aviation, and their own internal SAF initiatives and related considerations, as described earlier. Nevertheless, the intention of this next step was to further involve CPH as well as several of the arriving and departing airlines flying international routes, but now with the possibility of including certain aspects of the administrative and reporting challenges that would necessarily be a consequence of the recently adopted SAF mandates in RefuelEU Aviation announced in mid-2023.

Based on WP2's tasks regarding SAF deliveries to Copenhagen Airport, a SAF Pool model was established to promote airlines' interest in purchasing SAF. It is the general practice that SAF supplied to airports is required to be ordered and used in quantities, at prices, and within time frames set by each individual airline. All conditions regarding such deliveries are a purely contractual matter between the supplier and the airline. A further starting point for this activity was that the ALIGHT project came up with the idea to increase the SAF volume on both Danish domestic traffic and internationally during the project period. This intention was possible to push forward with the ALIGHT activities, but as an activity that is completely dependent on decisions from the airlines. In addition, the market opportunities for obtaining SAF were quite limited for several reasons, including price, availability, and national- and EU-level political decisions.

To promote as broad a participation as possible, a model should be established that encourages participation in the initiative. The more companies that participate, the larger quantities of SAF could be delivered. Therefore, the idea was to design models that made participation as interesting as possible for as many companies as possible. A crucial element is to establish a model that yields a price more attractive than the one the airlines can achieve individually. It could be created through the establishment of a major customer agreement that gives all airlines at the airport the opportunity to participate in. SAF Pool could be the way to create a model that aims to ensure a more attractive price and the largest possible use of SAF from an airport-wide perspective.

**Airlines** operating at CPH were invited to the SAF Pool presentation at the AOC meeting on Oct. 3, 2023 - see invitation below. The initiative was presented to inform all airlines in CPH about the option of including SAF delivery agreements in their own fuel contracts, by promoting the possibilities on a larger scale and by providing deliveries and the goal of achieving better prices when purchasing larger quantities. In the proposal to the airlines, it was included that, in virtue of the tasks in ALIGHT, the initiative and the proposed facilitator role should also be a way forward, contributing to handling the documentation and reports linked to SAF deliveries.




Due to the prevailing conditions around SAF quantities, prices, sustainability fulfilment, and, not least, the upcoming implementation of the mandates in RefuelEU Aviation, a great deal of support and commitment to the SAF Pool was not expected.

Nevertheless, it was considered valuable to implement the initiative as far as possible in practice to test, discuss, and refine it. The result of the effort not only reflects the initiated process and what it entailed in terms of dialogues with the actors but also provides insight into the many common and individual challenges faced by all participating parties. The model could, with local modifications, be used in other contexts, as such, which also justifies the need for the initiative to be communicated and commented on by relevant actors.

### 2.4.1 Draft agreements

In the more formal and contractual areas, the content to which participating airlines had to commit themselves was prepared, which in draft versions could include the following three step-by-step agreements:

## 1. LETTER OF INTENT ON PARTICIPATION IN SAF POOL

a. The undersigned airline represented by ____________ wishes to participate in the SAF pool initiative initiated at Copenhagen Airport and initially facilitated by NISA, possibly until a qualified agent/expert, accepted by the participants, can take over.

b. Together with other airlines, trying to provide the opportunity to purchase SAF delivered to CPH.

c. Participation in dialogues and any agreements must be in accordance with applicable competition rules and customs.

d. To the extent that the parties agree, participation is an open and communicative effort that must be shared with other actors and the public to emphasize the participants' shared ambitions to make an effort to reduce the climate impact.

e. With the SAF pool initiative, the parties want to inspire others to take similar initiatives.

f. This letter of intent does not commit to final participation in a SAF pool model.

g. Name of the airline operating at CPH: ____________________

h. Signed by representative of said airline: ____________________ date: ____________________

## THE SAF POOL INITIATIVE AT CPH

...w participates together with other airlines in the SAF pool initiative in CPH.

...n accordance with the points mentioned in the previously concluded letter of ...ptance that the facilitator coordinates the participating airlines' common ...tal volumes of SAF.

c. It will be the total SAF quantity for all participating airlines that through the SAF pool will result in an attractive price, which means that each airline communicates to the facilitator how much SAF it can commit to, preferably on an annual basis.

d. The facilitator works through dialogue with suppliers to provide a price for the SAF share for each airline that is documented to be more attractive than the price individual airlines can achieve.

e. The SAF pool collaboration may not be used to keep potential competitors out and the collaboration may not conflict with competition or tender rules.

f. Airline operating at CPH:____________________

g. Signed by representative of said airline: ____________________ Date: ____________________

## 3. INCLUDE SAF PURCHASES IN FUEL CON...

a. Participating airline will include negotiations with the fuel supplier in the next ... regarding a SAF delivery of a minimum of xx liters of SAF or % share of last yea...

b. Negotiations with the fuel supplier to also include SAF are taking place based ... in the previously signed Letter of intent on participation in SAF pool as well as t... Partner in the SAF pool initiative in CPH.

c. Participating airlines are responsible, as before, for negotiation and contract conclusion, which includes a more specifically agreed SAF quantity.

d. In jet fuel contract negotiations with suppliers, the respective airlines are informed of the benefits of several airlines agreeing to include SAF in the quantities communicated between the parties.

e. Price, quantity, time frame and other conditions regarding conventional jet fuel are a matter exclusively between the individual airline and supplier.

f. Airline operating at CPH:____________________

g. Signed by representative of said airline: ____________________ Date: ____________________

The drafting of the three agreements was part of the preparatory work, and initial discussions were held with a few airlines. Nevertheless, the agreement versions are included here to highlight the essential formal issues involved in the task and to share experiences and inspiration for possible replicable initiatives.

The content of these draft agreements also shows that there are important administrative tasks in connection with coordination and agreement on joint procurement. It must be emphasised again that joint procurement must be conducted through individual contracts between a supplier and an airline, thereby reducing, or perhaps even eliminating, the legal competition element. This is especially ensured by excluding no competitors from the benefits of the joint part of the process. It will therefore be important that the construction of the SAF Pool model and the cooperation cover only the preparatory work on the specific joint orders for SAF procurement, and that, in communication with the supplier, sensitive information is not shared. Therefore, it is natural to consult the legal experts in the companies during the process.

## Main steps of the SAF Pool initiative

### → Find out if there is a basis and sufficient interest in the initiative

### → Call in key players and clarify the further process

### → Clarify the prerequisites

- Participants in the value chain: Producer, supplier, airport, airlines
- Financially and interest–neutral facilitator is chosen
- SAF availability, quantities, delivery time, price
- Legal and competitive conditions

### → Assess the initiative in relation to other initiatives, legislation, mandates, etc.

### → Primary players are airlines/payer: Ensure that SAF purchases can be incorporated into conventional fuel contracts

- Can secondary players participate, for example, airports, customers, etc.?
- Assess the advantages and disadvantages: Value of participating (marketing, $CO_2$ reduction, etc.)
- Investigate the market for SAF qualities, feedstock, transparency, etc.
- Assess whether joint or individual marketing is initiated (possibly combined)
- Clarify who is responsible for which administrative and computational tasks

### 2.4.2 The CPH initiative

Invitations to the AOC meeting were forwarded by CPH's AOC administration to the relevant stakeholders at the airport. At the meeting on Oct. 3, 2023, the proposal was reviewed and discussed. Only 7-8 airlines participated in the AOC meeting, which turned out to be the four from Danish domestic, as well as three or four other large airlines, two of which had also launched their own SAF initiatives. The low number of participating airlines prompted us to send another written information letter to the remaining airlines.

Despite efforts to generate interest in the proposal, the feedback aligned with the discussions and the outcome from the Danish domestic half a year earlier. This meant that airlines that communicated with us on the subject were reluctant, preferring to wait and see, especially regarding internal SAF initiatives and the uncertainty about the consequences of RefuelEU Aviation. A significant part of the reasons for the reluctance was uncertainty about the economic circumstances that would become a reality when payment terms for the EU mandate, and in some countries, also national charges, would come into play. A further consequence in these contexts would be the premium price for SAF in a market with limited supply, fluctuating prices, limited competition, and insufficient transparency in pricing mechanisms.

Also, it was found that most airlines were nonresponsive. Given the reasons mentioned earlier and the unclear situation regarding EU regulations and political initiatives, this was not surprising. As initiators, we absolutely understood the airlines' reluctance, and the fact that many did not respond to the inquiries at all should probably also be understood in the sense that many companies were unable to take a position on the proposal or, at that time, were unable to prioritize an engagement in the proposed SAF Pool activities.

Dialogues with several airlines showed great interest in the SAF Pool concept. If that were all the companies had to decide on, it would have been a much more feasible way to both promote the use of SAF and thereby secure better prices through bulk purchasing.

An important reason for the lack of a position or for no feedback at all was, of course, the great uncertainty about the financial consequences of committing to these SAF deliveries. Many of the participating parties expressed that it was difficult for them to obtain acceptance for their participation in a SAF Pool due to high SAF prices and the limited market quantities, which could make future prices even more disadvantageous.

That this should be the situation was, as mentioned earlier, an understandable consequence of the prevailing circumstances. The purpose of the work on the proposed SAF Pool activities has therefore been to promote a model that can be used and redeployed when conditions permit and are more suitable. This means, first and foremost, that when the necessary quantities of SAF become available, there are not too many uncertainties that would interfere with a qualified decision on the initiative, and that a widespread understanding exists that a joint approach to SAF supply can provide better conditions than an individual approach.

It is worth emphasising that SAF quantities generated through a SAF Pool model will exceed the levels set in the RefuelEU Aviation mandates. The proposal may be relevant if some airlines, airports, or other players prioritise using more than the mandates prescribe, assuming that additional volumes become available. In such situations, the initiative should be adapted to regulatory changes, including the consequences or opportunities they create for such a SAF Pool.

The table/checklist below lists the key inputs, learning points, and suggestions for key prerequisites for possible future SAF Pool initiatives, and thus also serves as a valuable contribution to a replication toolbox.

## 2.5 SAF Pool, Timeline

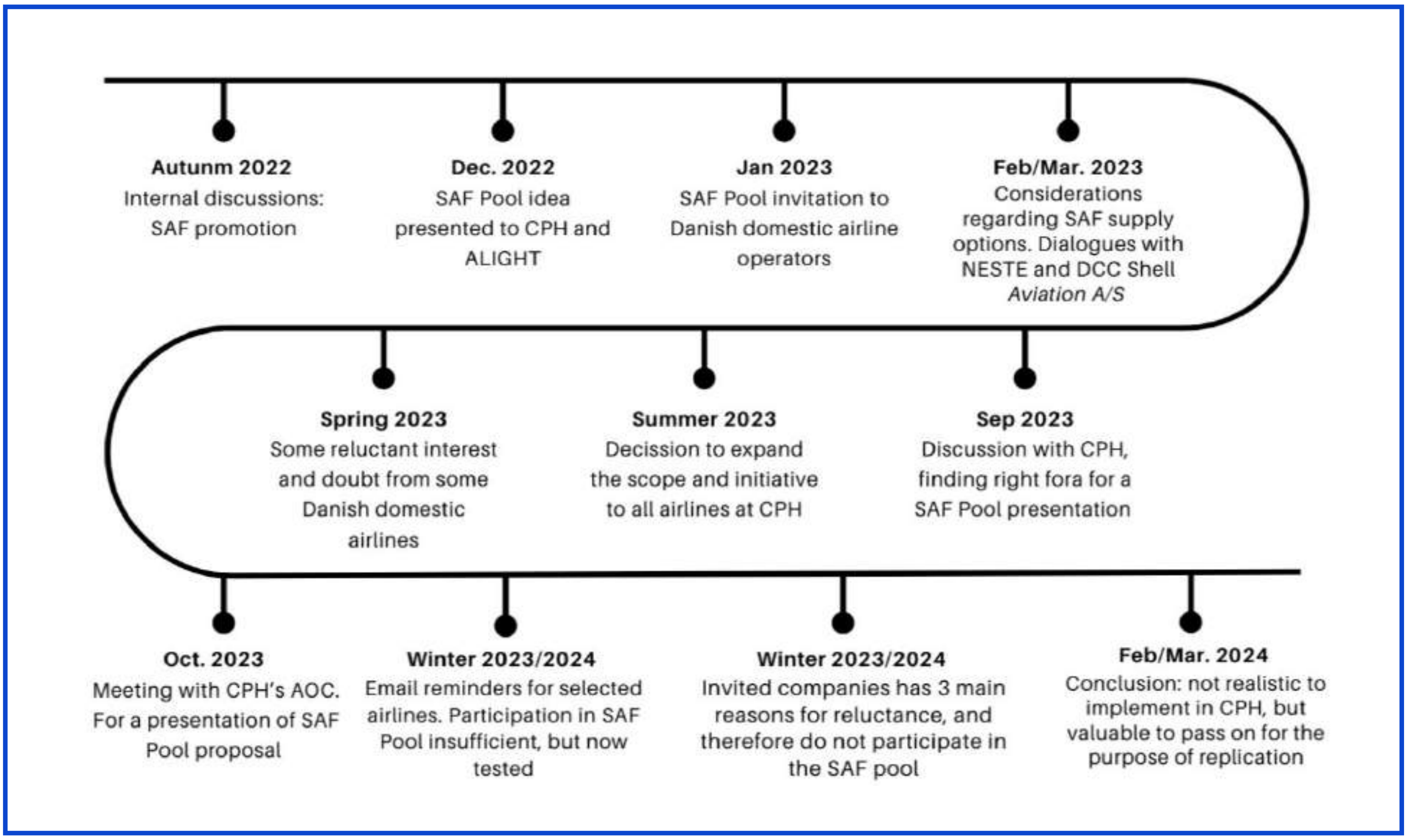



*Figure 15 Timeline of the SAF Pool Initiative*

## 2.6 Conclusion

To sum it all up, the idea of a SAF Pool was to make SAF cheaper and more accessible to Airlines at CPH Airport by optimizing distribution channels and increasing order volume from manufacturers or suppliers.

Unfortunately, there were still many uncertainties associated with this, stemming from various circumstances during the specific period, including RefuelEU Aviation, upcoming passenger taxes, limited market availability of SAF, price uncertainties, regulatory uncertainties, and questions regarding SAF transparency and sustainability.

These uncertainties were significant reasons why the invited airlines, both nationally and internationally, could not at that time decide to participate in the proposed SAF Pool model. The challenges ahead during that specific period for aviation were too uncertain, and in addition, several of the airlines involved had already begun their own processes and entered into agreements to purchase SAF for their own consumption or company programs. The initiative was therefore put on hold for the time being. Along the way, it was assessed as an interesting model for a coordinated industry push to move away from fossil fuels. The possibility remains, however, that as the SAF situation and the associated conditions become more stable, an initiative for a constructive reassessment can be taken. The process has been instructive, and an initiative such as the SAF pool or similar efforts will likely be helpful in the future.

## 2.7 Case Study: First delivery of SAF to Copenhagen Airport

One of the companies that participated in the SAF pool dialogue and at the same time established its own initiative was Air Greenland, also a member of NISA, which in the spring of 2023 entered into the largest agreement for an annual purchase and delivery of SAF in an amount equivalent to 5% of the company's fuel consumption on the round trip between Kangerlussuaq in Greenland and Copenhagen Airport. This made Air Greenland introduce SAF into the fuelling system at CPH. Air Greenland's 5% SAF corresponds to just over 3% of the total fuel consumption on Danish domestic.

**Background and motivation:** Air Greenland was the first company to request sustainable aviation fuel (SAF) for use at Copenhagen Airport (CPH). The initiative was part of Air Greenland's broader green transition, in connection with its fleet renewal and a desire to strengthen its environmental profile. As a state-owned company with roots in Greenland, Air Greenland is closely linked to national political climate goals.

Air Greenland has a fleet of 37 aircraft, including an AIRBUS A330-800neo used for flights across the Atlantic, primarily Copenhagen, and for charter operations; eight fixed-wing aircraft serving the Greenland network and connections to Iceland; and 26 helicopters connecting passengers from sparsely populated areas to the national network airports.

The company has around half a million passengers annually. The route between Kangerlussuaq and Copenhagen was both the most fuel-intensive and logistically the easiest to supply with SAF, making it the obvious choice for the SAF effort.

**Decision-making process and collaboration:** The decision to use SAF was made in 2021 after a lengthy internal process within Air Greenland's management, as well as external dialogues with stakeholders who had experience with SAF. It was subsequently decided that the existing collaboration with the fuel supplier DCC Shell Aviation Denmark was the most obvious. DCC Shell has both expertise in the area and access to SAF produced and sustainability certified. Furthermore, the supplier could integrate it into the existing fuel contract and physically into the desired purpose.

**Purchasing and choice of fuel type:** Air Greenland investigated the possibility of purchasing e-fuels but had to abandon it due to price and lack of availability. Instead, an agreement was reached to buy SAF produced via the HEFA process, with feedstock primarily used cooking oil and animal fat waste from the fuel producer Neste. It was agreed that the delivery would take place according to the mass balance principle, where SAF is mixed with conventional fuel and fed through existing systems without physical separation, with administrative documentation to maintain mass balance.

The annual SAF volume was 700,000 litres, corresponding to 5% of fuel consumption on the route to and from Copenhagen – the most significant amount of SAF used on a single route globally.

**Logistics and handling in CPH:** The first delivery in March 2023 was visibly marked and delivered by tanker truck directly to CPH as a one-off measure to ensure timely, traceable delivery, and to provide an opportunity to market the initiative to the media. Subsequent deliveries will be received by ship at Prøvestenen, where the SAF is stored in a dedicated tank, and from there transported via the common pipeline to CPH's fuel farm and from there distributed in a mass balance system.


DCC Shell took the opportunity of this relatively large and, not least, the continuous deliveries for Air Greenland, to decide to dedicate a separate tank to SAF blends, despite higher initial costs. The investment in a separate SAF tank was made as a first step to meet future increases in SAF deliveries. In the longer term, it was assessed that a dedicated tank capacity would be necessary if SAF were to be scaled up, not only for Air Greenland but also for general deliveries to airports other than CPH.

Air Greenland signs deal with DCC & Shell Aviation Denmark for 5% SAF | SAF Investor

safinvestor.com

*Notice: Go to the article* [40]

**Documentation and traceability:** The delivery was accompanied by fuel documentation that describes, among other things, volume, quality, energy content and price, and additionally, the prescribed documentation unique to SAF, PoS (Proof of Sustainability). The information in the PoS enables the airline to understand what needs to be reported regarding the emission reductions achievable through SAF for the flights it carries out. In this start-up phase, the mandatory information was provided in two documents describing the environmental properties of the purchased SAF: a "SAF sustainability statement" and a "SAF letter" from DCC Shell. This has subsequently been adjusted in accordance with the POS documentation

[40] SAF Investor, Air Greenland signs agreement with DCC & SHELL Aviation Denmark for 5% SAF, March 2023

requirements in RefuelEU Aviation and RED so that Air Greenland can report the reduction of greenhouse gas emissions in accordance with EU requirements.

**CPH's role and future commitment:** CPH played no direct role in the SAF purchase itself or in the physical delivery to the airport but supported the initiative and recognised its importance for the green transition in the aviation sector. The introduction of SAF was seen as an essential step in this direction.

**Conclusion:** Air Greenland's purchase and use of SAF on the route between Greenland and Copenhagen marked a milestone in both the company's and CPH's sustainability work. The first delivery required additional planning and investment in separate logistics, but experience showed that SAF can be integrated into existing systems without compromising safety or operations – especially when using the mass balance principle.

Documentation is central to ensuring transparency and reporting. The initiative contributed valuable insights into how to handle SAF logistically, administratively, and technically in a mass balance model for a large international airport.

The experience from this case of the delivery of a 5% SAF blend-in, carried out in March 2023, i.e., prior to the launch of RefuelEU Aviation, formed the basis for future deliveries and larger SAF initiatives, and shows how cooperation between airlines, fuel suppliers, and airports can drive development in practice, even in a demanding transatlantic aviation environment.

In connection with the first introduction at CPH, DCC Shell and Air Greenland decided to transport the SAF blend separately from the conventional fuel supply to the airport. This deliberate separation increased costs, but it enabled close tracking and timely delivery of the SAF blend to the customer while also visualising Air Greenland's SAF decision.

Subsequent deliveries of SAF blends to CPH are carried out according to the same procedures used for the delivery of conventional jet fuel, as in practice, there is no difference in quality and practical methods for handling a SAF blend and the conventional one, when the products are manufactured, transported and blended according to the described regulations. This also means that the SAF blend's traceability is maintained reliably and transparently through administrative and record-keeping processes.

### 2.7.1 SAF timeline to Air Greenland from CPH

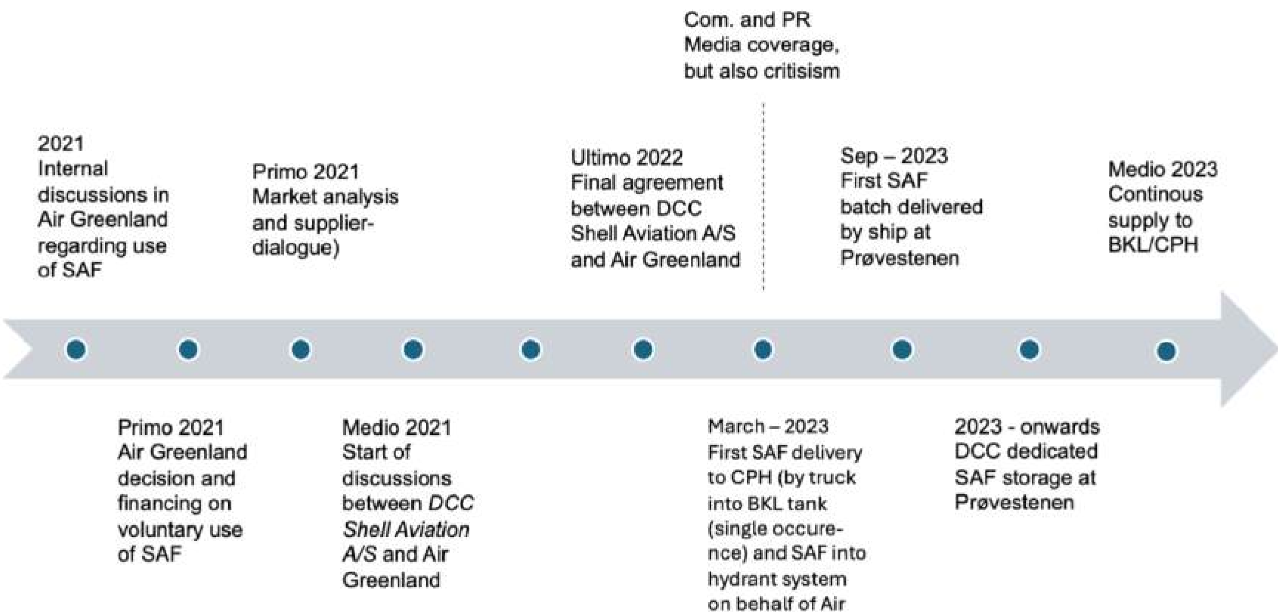



*Figure 16 SAF Timeline / Air Greenland* [41]

Air Greenland's decision to use SAF meant SAF arrived in CPH for the first time, and the company continues to receive deliveries there. The route from/to Kangerlussuaq has now been rerouted to Nuuk, with stopovers in Kangerlussuaq, but the same volumes are still delivered. The initiative from Air Greenland was a strategic long-term decision that must be seen in the context of both the airline's and Greenland's goal to reduce the climate burden.

Due to new routes and a new airport in Greenland, along with the opportunities they provide, the company has chosen to include SAF across its entire route network, so that the agreed 5% has now been converted to approximately 2% SAF usage on all Air Greenland routes. Air Greenland's management has made no secret of its view that UCO-based SAF is a temporary solution until more sustainable SAF products are available. More details on delivery issues, documentation items and terms can be found in the SAF Handbook. [42]

[41] Prepared by NISA, 2024

[42] ALIGHT WP3.2, Best practice handbook and tools for fuel logistics, quality monitoring, and accounting, 2025.

# 3 SAF framework, EU

## 3.1 Introduction

Within the European Union (EU), RefuelEU Aviation is a key policy tool designed to reduce greenhouse gas (GHG) emissions and promote the use of Sustainable Aviation Fuels (SAF). The adopted minimum blend mandates are intended to encourage innovation and thereby ensure the progressive decarbonisation of aviation. This chapter describes the best-practice framework in the RefuelEU context, highlighting the need for sustainable sourcing of raw materials, transparent supply chains, robust stakeholder engagement, effective policy adaptation, and the role of aviation stakeholders.

**Sustainable Aviation Fuel:** SAF is the dominant means of reducing fossil fuel, at least for the next many years. SAF is a drop-in fuel that can be used blended with conventional fuel by up to 50%. Some operators have used SAF for several years. However, only limited quantities have been produced and are available. From a level of around 0.1% to 0.2-0.3% per year at the European level in 2024. In 2025, it is expected to reach 2.0% as prescribed by the EU mandate. All approved SAF products are identical to conventional fuel in terms of quality, specifications, and energy efficiency, and can therefore be used without any reservations up to a maximum of 50% blending. Higher blending percentages are expected to be approved soon.

SAF contains carbon and therefore still emits $CO_2$ when burned. On the other hand, it contains far fewer aromatics and other substances that are particularly responsible for contrails, and it reduces soot and ultrafine particles in and around airports. First and foremost, the $CO_2$ reduction must be achieved using feedstocks that enable it. Various feedstocks and technologies are approved for SAF production. Established sustainability and greenhouse gas reduction requirements must meet EU requirements and be approved through a certification process. The following categories can be used as SAF: Biofuels, advanced biofuels, and synthetic fuels. For example, it could be used oils and waste products from industry, households, forests, agriculture, or excess $CO_2$ from various sources.

**Sustainable feedstock management:** Ensuring feedstock sustainability is central to achieving genuine emission reductions. Under RefuelEU Aviation, feedstocks must be sourced responsibly to avoid competition with food production, protect ecosystems, and maintain biodiversity. In practice, this often means prioritising waste and residue materials, such as by-products from industry, households, and agriculture, that meet the EU's criteria. Compliance with the Renewable Energy Directive (RED) is critical, as it establishes criteria to prevent deforestation and indirect land-use changes. By conducting comprehensive life cycle assessments (LCA's), manufacturers can demonstrate whether the raw materials and energy use meet the required thresholds for greenhouse gas savings.

**Transparent and traceable supply chains:** Credibility in the SAF market depends on robust traceability from feedstock origin to final fuel. RefuelEU Aviation emphasises the importance of transparent supply chains to assure regulators, airlines, and the public that GHG reductions are legitimate. Digital tracking technologies can streamline the verification process by recording every step of production and distribution. At the same time, certifications from recognised EU-level or global standards, such as the International Sustainability and Carbon Certification (ISCC) or the Roundtable on Sustainable Biomaterials (RSB), provide third-party validation of a product's sustainability attributes. Regular audits by EU-accredited bodies aim to ensure that all stakeholders remain accountable. A controversial topic, as there have been examples of fraud in the raw material supply chain, which has increased the EU's control efforts. Likewise, the approval criteria do not account for all the consequences of increased use of biomass UCO, etc.

**Maximizing GHG emission reductions:** RefuelEU Aviation sets clear goals for reducing the carbon intensity of aviation fuels, and SAF producers and suppliers must demonstrate compliance with agreed GHG savings compared to conventional fossil-based jet fuels. In many cases, this involves power generation facilities powered by renewable energy sources to minimise the overall carbon footprint. Continuous monitoring of emissions across the value chain —from feedstock cultivation and collection to fuel refining, transport, and delivery — should ensure compliance with EU climate targets.

**Community and stakeholder engagement:** The successful deployment of SAF projects hinges on effective community and stakeholder engagement, an aspect that RefuelEU Aviation implicitly supports. Early collaboration with local authorities, industry, farmers, and civil society organizations could help align new initiatives with regional development goals. In addition, social impact assessments can identify potential concerns related to pollution, noise, land use, employment, or resource distribution. By addressing these issues proactively, project developers can foster trust, secure local buy-in, and create shared economic opportunities such as job creation and skill development that could benefit communities.

**Economic viability and scalability:** For SAF to gain widespread acceptance, it must be both economically attractive and scalable. SAF is currently significantly more expensive than conventional jet fuel, with production costs ranging from 2 to 6 times higher. Feedstock availability, capital-intensive production processes, and limited economies of scale drive these higher costs. RefuelEU Aviation's blending mandates ensure a minimum level of market demand, helping manufacturers secure investments and achieve economies of scale. Public-private partnerships, financed through mechanisms such as Horizon Europe and InvestEU, further stimulate R&D and infrastructure development. Establishing a coherent, pan-European blending and distribution network can reduce logistical bottlenecks, lower production costs and ensure a stable supply of SAF across multiple airports. While these measures can strengthen the business case for SAF and encourage airlines to adopt higher blends, SAF is expected to remain significantly more expensive than conventional fuel for several years, and specific incentives must therefore be put in place. Thus, in February 2025, the EU launched the rules for the support system established and financed by the EU Emissions Trading System (ETS) to accelerate the use of sustainable aviation fuels.

**RefuelEU Aviation and CORSIA:** RefuelEU Aviation offers a clear legislative roadmap for SAF adoption within the EU. It works in parallel with global initiatives like ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). RefuelEU Aviation is taking further steps and would like to see global initiatives with similar climate regulations. At the same time, standardizing SAF definitions and sustainability criteria across EU Member states is essential to prevent market fragmentation. The uniform rules should encourage SAF supply chain actors to streamline cross-border trade, thereby promoting a more coherent and efficient SAF market in Europe.

**Innovation and technology development:** Ongoing innovation remains critical for expanding feedstock options, improving conversion efficiencies, and lowering production costs. There is a strong need to establish SAF production facilities to meet the EU's adopted mandates and aviation ambitions. Through collaboration with European research institutions, universities, and industry consortia, SAF producers can explore advanced biofuel technologies, e-fuels, and potential alternative feedstocks. Pilot projects, supported by EU grants, serve as a testing ground for these emerging solutions, enabling stakeholders to assess technical feasibility and commercial potential. All this must be supplemented with initiatives that ensure SAF scaling up and accelerate the overall pace of innovation, which requires investment decisions and sales guarantees for the produced SAF, as well as efforts to ensure that oil producers deliver in line with the new market conditions.

**Monitoring, Reporting, and Verification (MRV):** Trust in SAF's environmental benefits also depends on transparent monitoring, reporting, and verification protocols. Under RefuelEU Aviation, fuel suppliers and airlines must regularly disclose key performance metrics, such as lifecycle emissions, feedstock sources, and compliance with sustainability standards. Third-party verification by certified European auditing bodies bolsters credibility, ensuring that data is accurate and consistent with EU guidelines. Annual disclosures further enhance transparency and foster a culture of accountability. This rigorous MRV framework will support RefuelEU Aviation's objectives by confirming that the initiative's goals are being met and that SAF is delivering real-world reductions.

**Public awareness and collaboration:** Public acceptance plays a significant role in the success of RefuelEU Aviation. Awareness campaigns highlighting SAF's potential to reduce aviation's carbon footprint can encourage airlines, airports, and passengers to support the shift toward cleaner fuels, depending on how SAF prices affect ticket and transport costs. And whether increased pressure from media, NGOs, politicians and especially aviation customers will affect the development of aviation in a more sustainable direction?

**Reflections:** A thriving market for Sustainable Aviation Fuels requires a **comprehensive best practice framework** that encompasses everything from feedstock sourcing and supply chain transparency to stakeholder engagement and policy alignment. By integrating these principles into the **RefuelEU Aviation** initiative, The EU has shown both will and tools, although many of the significant and overarching challenges and questions will only be answered in the coming implementation years, for example, will there be sufficient quantities of SAF, will the issue of sustainability be handled satisfactorily, will competition and price developments create imbalances or conflicts, and will oil producers live up to their responsibility to deliver sustainable products under market conditions?

The sections in this chapter review the framework and content of EU decisions, as well as the underlying themes that actors at all levels need to address. For those involved, it is a comprehensive task to ensure that relevant standards, criteria, and agreements are respected throughout the process, which is a prerequisite for the SAF implementation to address and fulfil set goals, regulations, and sustainability in the areas of environment/climate, social, and economic.

The review will focus on the many sub-areas covered by the EU sustainability criteria in line with RED II/III, and on a holistic perspective for meeting the challenges along the way, as described in WP2 task 2.4. The implementation of the far-reaching and necessary SAF intervention mandates may provide a broad framework for the actor but also sets interesting but challenging requirements for the necessary actions.

## Main topics you will meet in the following chapters

- **Potential SAF producers**
- **SAF initiatives**
- **Sustainability criteria and challenges**
- **EU and National aviation policies**
- **The importance of eSAF**
- **Preparation for future propellants and the airport 2050 route**

This section concludes with a reflection on selected challenges, followed by possible action points, recommendations and questions aimed at relevant receivers. The concluding topics can be included as contributions to the project's expanded, broadly arranged TOOLBOX, topics and questions that are replicable and further elaborately within the respective actor's framework.

## 3.2 SAF sustainability criteria and best practice (framework)

It is a huge challenge to replace fossil fuels with a new source that is both sustainable and has at least the same properties and is available in sufficient quantities to be used gradually instead of fossil fuels.

RefuelEU Aviation prescribes that 2% of jet fuel must be SAF by 2025. If we assume that Europe's jet fuel consumption is approximately 70 billion litres per year, then 2% of this represents approximately 1.4 billion litres of SAF in Europe in 2025.

In 2024, during the ramp-up process, the estimated SAF consumption in Europe was typically 130–200 million litres. This corresponds to approximately 0.2–0.3% of total jet fuel consumption.

There is significant uncertainty, as the SAF market remains in its early stages and production and market adoption are evolving, albeit not quickly, but at a faster pace than before, as spurred by the EU SAF blend-in requirements. A figure of 150 million litres for 2024 can be considered an approximate total for SAF use that year.

With the RefuelEU Aviation target of 70% SAF by 2050, 60-70 billion litres of SAF will be needed in Europe, assuming the increase in air traffic can at least be matched by more efficient aircraft, better route-planned flights and the development of new types of fuel, such as electric, hydrogen and hybrid electric aircraft. At a global level, the need will be around 400 billion litres of SAF if international aviation is to achieve Net Zero, and if the projections are credible.

In 2024, approximately 26,000 aircraft worldwide used jet fuel. In 2034, there will be approximately 37,000, according to consulting firm Oliver Wyman.[43] According to preliminary analyses by ATAG and AZEA, respectively, somewhere between 6 and 15% of the aircraft fleet will be powered by electric, hybrid, or hydrogen propulsion by 2050. How this will affect SAF demand, the rest of the aircraft fleet and the emission level at that time is impossible to predict, but according to ECAC: *"The impact of improved aircraft technology indicates an overall 22% reduction of fuel consumption and $CO_2$ emissions in 2050 compared to the baseline scenario. Overall $CO_2$ emissions, including the effects of new aircraft types (conventional, hybrid electric and Hydrogen) and ATM-related measures, are projected to lead to a 29% reduction in 2050 compared to the baseline."* [44]

It is a big question whether the desired SAF quantities can be achieved. Maybe not in the first few years, but in the medium- and slightly longer-term. So far, there are not many SAF production methods available. HEFA (Hydroprocessed esters and fatty acids) is at a high

[43] Oliver Wyman, Global fleet and MRO market forecast 2024-2034, 2024

[44] World Economic Forum, in collaboration with Karney: Scaling Up Sustainable Aviation Fuel Supply, 2024

maturity level and has commercially available conversion technology. The HEFA pathway is the dominant method and is expected to remain so in the short to medium term, until other technologies and feedstocks become available. There are several approved pathways for alternative fuels that, in addition to being approved by ASTM 1655 or Def Stan 91-091 as Jet A-1, SAF must also be approved as sustainable, which in Europe must be done according to the criteria in RefuelEU Aviation and REDII/III.

This chapter focuses on SAF sustainability, primarily examining opportunities, challenges, and policies from a European perspective. Initially, we also look at the SAF topic in a broader global context. Mainly because it is a global challenge and because fuel product flows traditionally occur worldwide. This does not make it easier to ensure and meet targets and criteria, but addressing the challenges must necessarily be international, as both the fuel and the climate impact are global, as is aviation.

### 3.2.1 Global SAF activities

The World Economic Forum (WEF) and Airports Council International (ACI) World co-led the Airports of Tomorrow initiative and, in 2024, published the report *"Scaling Up Sustainable Aviation Fuel Supply."* [45] Here it was found, albeit optimistically, that stakeholders globally agreed that the following key measures will enable the rapid scaling of SAF by saying that SAF and energy producers should focus on deploying effective SAF production capacities and look for long-term demand certainty to de-risk the required funding:

**Airports** can act as impartial matchmakers, encouraging SAF partnerships, driving public awareness and promoting SAF uplift through incentives (e.g., direct subsidies or modulated landing fees).

**Airlines** need robust supplier partnerships to access competitive SAF. In return, they should commit to long-term offtake agreements and potential co-investment in production facilities.

**Original equipment manufacturers** (OEMs) must ensure compatibility of future engines, fuel systems and aircraft with, for example, 100% SAF. Furthermore, they should support technology development through extended partnerships.

**Corporate customers** can take the lead in covering the green premium for SAF while also providing technical expertise.

**The finance sector** must increase green investments, participate in funding for SAF and collaborate with the industry to develop and derisk robust business cases.

[45] World Economic Forum, in collaboration with Karney: Scaling Up Sustainable Aviation Fuel Supply, 2024

**Governments** increasingly recognise the importance of SAF and must enact legislation to drive market development. Scaling SAF depends on strategic partnerships, targeted technology, and supportive regulation and financing. Turning these priorities into action requires collaboration and decisions across the entire SAF ecosystem—from development and production to large-scale deployment for aviation decarbonisation. Globally, many SAF policies have been introduced or discussed, most of which align with aviation's goals, as shown in next illustration.

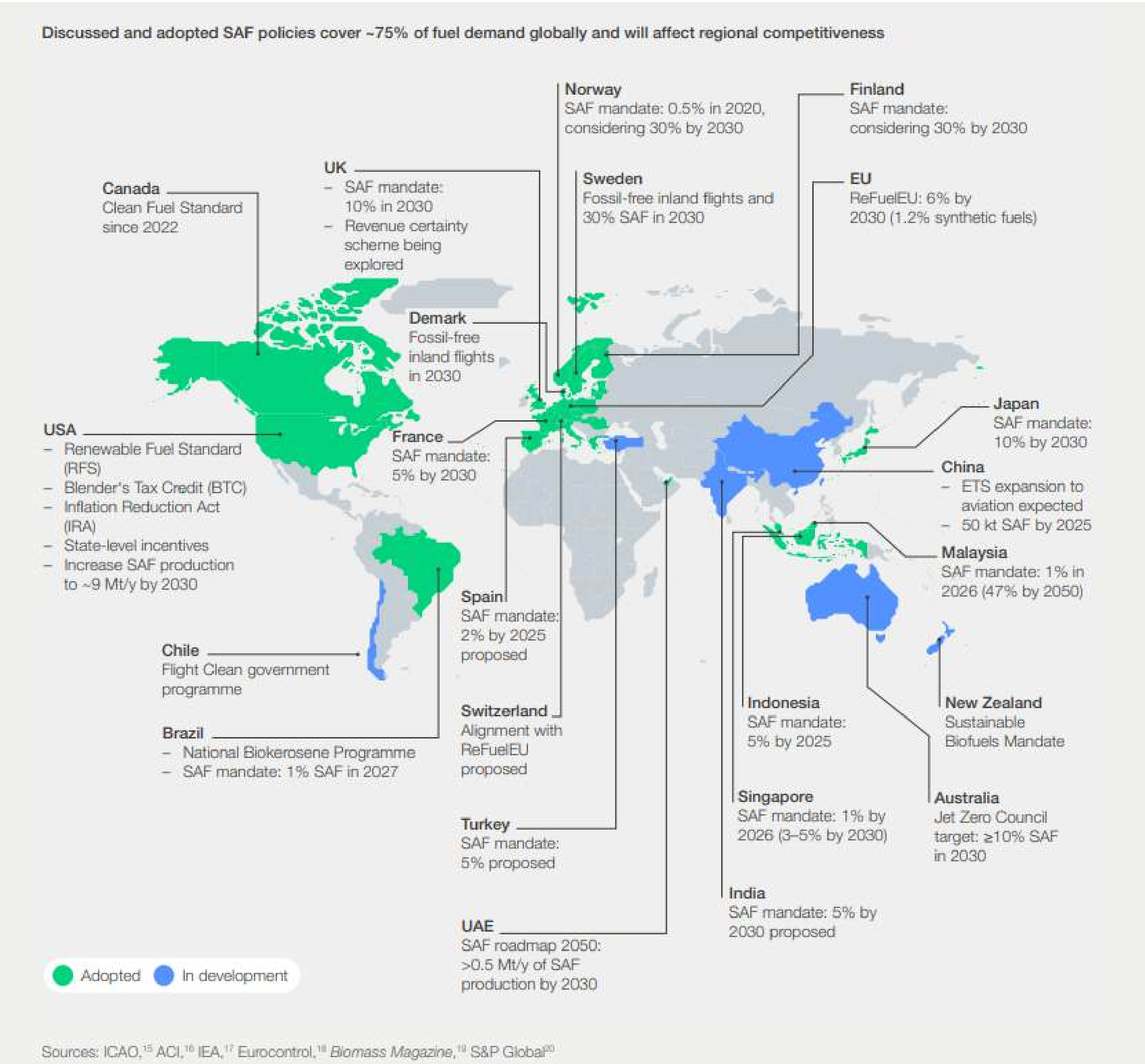



*Figure 17 Political initiatives and statements regarding SAF 2024* [46]

[46] ICAO, ACI, IEA, Eurocontrol, Biomass Magazine, S&P Global

### 3.2.2 A part of the energy policy

In line with recommendations from this project and from many organizations and partners in its analysis of what needs to be done to scale up sustainable jet fuel production, WEF and ACI place great emphasis on collaboration between companies, organizations, researchers, countries and jetfuel producers to find solutions across borders. International fuel developers and suppliers are calling for constructive engagement to explore a possible future public-private partnership that would involve close collaboration among stakeholders to help each other achieve the urgent SAF goals. Initiatives like this are certainly easier said than done, but the illustration here from the WEF/ACI report[47] and a corresponding model and recommendation from IATA give a picture of what such a broad collaboration might involve, based on the highlighted recommendations that include a public-private partnership:

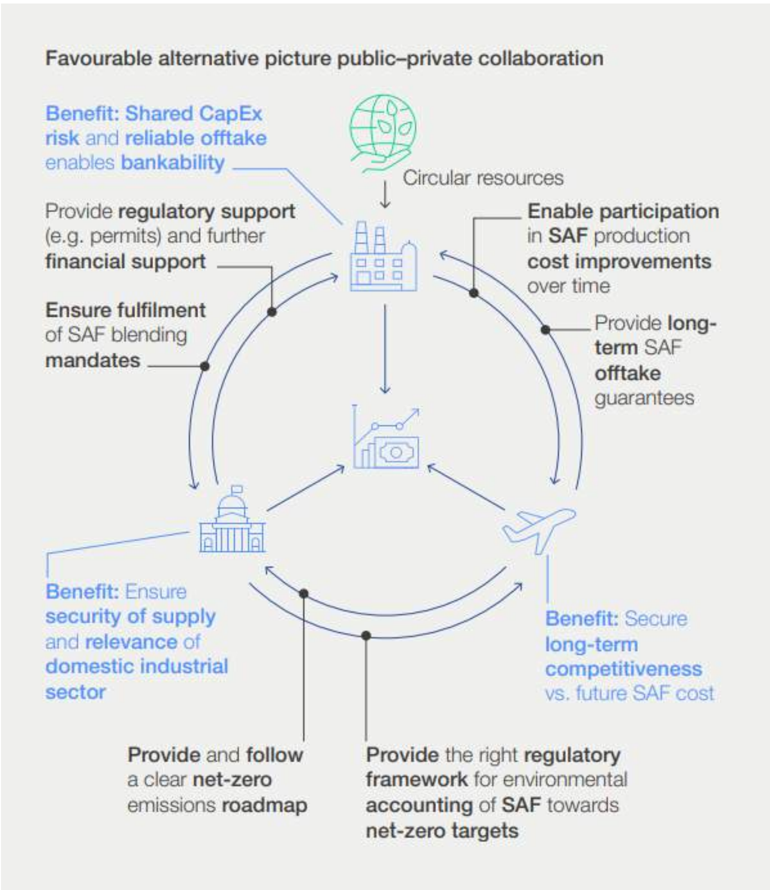



*Figure 18 Public-Private Collaboration* [48]

[47] World Economic Forum, in collaboration with Karney: Scaling Up Sustainable Aviation Fuel Supply, 2024
[48] World Economic Forum, in collaboration with Karney: Scaling Up Sustainable Aviation Fuel Supply, 2024

**A part of the energy policy**

To achieve constructive and long-term solutions in the area of SAF and new propellants, a stakeholder structure involving a wide range of high-level partners is recommended. It's based on experience from many years of fragmented approaches, which have been evident in individual manufacturers trying to enter the market and in individual airlines trying to buy limited quantities of SAF.

**The challenges**

are so huge that they require high-level involvement and political decisions as well as cooperation across countries among companies, researchers, and investors. In all its complexity, simply because a prerequisite for sustainable development of aviation requires that it is part of EU- and national energy policy!

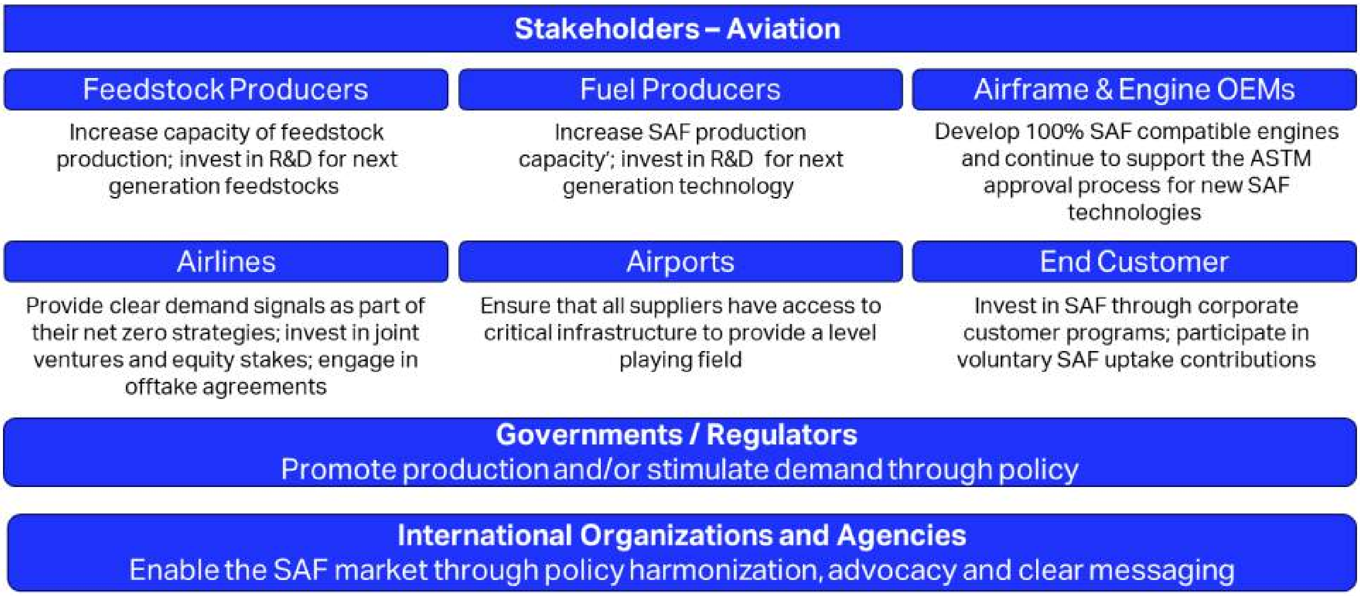



*Figure 19 Stakeholders – Aviation with inspiration from* [49]

[49] IATA: Sustainability & Economics

**SAF and new propellants can only be scaled effectively if it is treated as an integrated part of national and EU energy policy.**
The challenges are too extensive to be solved in isolation. Long-term progress requires political commitment, high-level stakeholder cooperation and alignment with broader energy planning and infrastructure. Sustainable development of aviation requires that it be part of energy policies at the national and EU levels!

Sustainability criteria and best practices for SAF scaling up to the market will be crucial to ensure that SAF use contributes positively to climate solutions, a better environment and, in fact, helps to secure future development. It is therefore relevant to examine the overarching criteria, principles, and practices necessary to achieve the sustainability goals associated with the significant effort, investment, resources, and consideration put into SAF development, production, implementation, and global widespread use.

### 3.2.3 A general approach to SAF sustainability in a European context

An overall sustainability goal for the use of SAF is that it should significantly reduce greenhouse gas (GHG) emissions. To meet this criterion, with reference to REDII/III, SAF must achieve a lifecycle GHG reduction of at least 60-70% compared to conventional jet fuels. This includes emissions from feedstock cultivation, fuel production, transportation, and final combustion. Additionally, the feedstocks used in SAF production must be sourced sustainably. They should not contribute to deforestation, land-use changes, or biodiversity loss. Waste-derived and non-food competing feedstocks are preferable to avoid adverse effects on ecosystems or food security.

Water use and quality are critical environmental considerations. SAF production processes should be designed to minimize water consumption and ensure that water outlets do not contaminate local water reservoirs. Similarly, practices that preserve soil health, such as maintaining organic matter levels and preventing erosion, should be integrated into SAF supply chains.

Social responsibility is another pillar of sustainability. SAF initiatives must uphold fair labour practices, ensuring safe working conditions and the prohibition of forced or child labour. Projects must also benefit local communities without displacing indigenous peoples, reducing rainforest or nature worthy of conservation. Ensuring food security is paramount, as growing SAF raw materials should not compromise the availability or affordability of food.

Economic viability is equally crucial for SAF's long-term success. Market scalability and incentives must be considered to ensure that SAF can meet the growing global demand without sacrificing environmental or social integrity.

To operationalize these sustainability criteria, best practices must be followed. Certification and standards compliance are vital, as a minimum requiring alignment with recognized systems such as the Roundtable on Sustainable Biomaterials (RSB), International Sustainability and Carbon Certification (ISCC), on a global level the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and at the EU level the RefuelEU Aviation and REDII/III. There may also be additional assessments, analyses, expert judgments, or local conditions that need to be included to create a complete basis for decisions.

Life Cycle Assessment (LCA) is a critical tool for assessing the environmental and climate impacts of SAF production. This should involve a critical evaluation of all stages of the SAF life cycle, from raw material cultivation to final incineration, using standardised methodologies to ensure consistency and comparability of impact assessments across industries and applications.

Engaging stakeholders, including local communities, regulators, and industry partners, is important for fostering transparency, understanding, and support. Stakeholder engagement ensures that the concerns of affected parties are addressed, and grievance mechanisms should be established to resolve conflicts and opposing interests that may arise across different parts of the supply chain.

Innovation and continuous improvement are necessary to advance SAF technologies and reduce environmental impacts over time. Investment in research and development can lead to breakthroughs in production efficiency, raw material utilization or technologies, which could further improve the sustainability of SAF.

To implement these practices effectively and to ensure compliance and credibility, mandatory reporting and independent verification are required. SAF producers must regularly submit detailed sustainability reports outlining their performance against established criteria and benchmarks. SAF producers and suppliers must disseminate reports covering greenhouse gas reductions, optimum resource use, social and other impacts. SAF products should be analysed and benchmarked by independent researchers and experts, and developed in ways that increasingly meet sustainability criteria in the future. Such a framework should position SAF as a cornerstone in the aviation industry's long-term transition toward a more sustainable, operational future.

### 3.2.4 Sustainable aviation fuels - definitions

Sustainable Aviation Fuel has no unified definition but is interpreted by many minor variations depending on which organisation, institution, or company one refers to. Despite the lack of a specific definition of SAF, most organisations, institutions, or companies follow the same principles and define SAF as a set of criteria based on sustainability principles. A Sustainable Aviation Fuel (SAF) is a sustainable, non-conventional alternative to fossil-based jet fuel. Several definitions and terminology apply, depending on the regulatory context, raw material base and production technology.

Under the ReFuelEU Aviation Regulation, SAF is defined as different types of drop-in aviation fuels that have distinct characteristics but can be converted through a manufacturing process into a fuel that meets both the specifications for Jet A-1 and the sustainability requirements of EU RED II/III. The following categories apply to be classified as a SAF product.

## Three categories apply to be classified as a SAF product

### 1. Aviation biofuel, which is

A. Liquid biofuel produced from prescribed biomass feedstock, such as used cooking oil, unintentionally damaged crops, and municipal wastewater.
B. Advanced biofuel, which is a liquid fuel produced from prescribed biomass feedstock, such as manure and sludge, oil mill effluent, nut shells, de-kernelled corn cobs and biomass fraction of waste.
C. Biofuels produced from any other biomass source except food and feed crops.

### 2. Synthetic aviation fuel

e-fuel or e-SAF. Fuels produced by synthesizing green hydrogen with captured $CO_2$ that meet the criteria for renewable fuels of non-biological origin (RFNBO) under RED III

### 3. Recycled carbon aviation fuel

Fuel produced from waste streams of non-renewable origin that meet the requirements of RED III (e.g., jet fuel produced from synthetic crude oil extracted from municipal solid waste).

*See the slightly more detailed overview in the table based on RefuelEU Aviation regulatory fuel categories, based on the three mentioned categories that meet the criteria defined in RED.*

| TYPE OF RFEUA AVIATION FUEL | DEFINITION IN RFEUA | COMMENTS |
|---|---|---|
| Synthetic aviation fuels | Art 3(12) | Renewable fuels of non-biological origin in the Renewable Energy Directive (RED)[28] |
| Advanced aviation biofuels | Art 3(8)(a) | Biofuels produced from feedstock listed in Part A Annex IX of RED |
| Aviation biofuels | Art 3(8)(b) | Biofuels produced from feedstock listed in Part B Annex IX of RED |
| Other aviation biofuels[29] | Art 3(8)(c) | Biofuels produced from feedstock not listed in Annex IX of RED and except for those produced from food and feed crops, intermediate crops, palm fatty acid distillate and palm and soy-derived materials, and soap stock and its derivatives |
| Recycled carbon aviation fuels | Art 3(9) | Recycled carbon fuels in RED |
| Renewable hydrogen for aviation | Art 3(16) | Hydrogen for aviation that is renewable fuel of non-biological origin in RED |
| Low-carbon hydrogen for aviation | Art 3(15) | Hydrogen for aviation that is produced from non-fossil non-renewable sources |
| Synthetic low-carbon aviation fuels | Art 3(13) | Drop-in aviation fuel produced from non-fossil non-renewable sources |

*Figure 20 RefuelEU Aviation regulatory fuel categories* [50]

The feedstocks that can be used to produce aviation fuels in each category are further detailed in the EASA link above.

All biofuels that meet the RED III's sustainability criteria may be used to produce SAF, except food- and feed-based fuels as defined in the Directive, intermediate crops, palm fatty acid distillate and all other palm- and soy-derived materials, and soap stock and its derivatives. If any of these materials are included in Annex IX, part B, then they can count towards the SAF targets. Thus, these types of intermediate crops would count towards Refuel EU's SAF targets. Further, any biofuels produced from feedstocks other than those in Annex IX, parts A or B of the directive are capped at a maximum of 3% towards the SAF targets. Unlike the RED III, there is no cap on waste oils and fats in Refuel EU.

Most commonly, the focus is on greenhouse gas (GHG) reductions, calculated using life-cycle assessment (LCA) methodologies. In addition, multiple other sustainability criteria must be fulfilled, often related to agricultural practices, waste management, labour rights, resource preservation (such as water), and renewable energy (RE).

[50] RefuelEU Aviation regulatory fuel categories, 2023

The SAF terminology can be seen as a categorial umbrella for many products that meet ASTM specifications and sustainability requirements. ASTM is a quality and performance approval, but not a sustainability approval. It is also important to note that the ASTM pathways are based on conversion technologies, while the fuel categories in RefuelEU Aviation are based on feedstock and energy inputs with strict eligibility criteria.

In addition, ASTM approves three co-processing technologies that do not require blending but are co-processed directly in the refining process. The three technologies involve co-processing lipids, FT hydrocarbons and hydrotreated biomass with CAF feedstock (typically crude oil) up to 5% for the two methods and up to 24% on the input side for the third. (See section **ASTM approvals** further below)

Regulation has, in recent years, been setting the scene for defining the above categories and can be roughly divided into two regulatory frameworks: RefuelEU Aviation RED II/III and ICAO/CORSIA - see later sections. Also, the SAF sustainability topic will be included in the following sections and be discussed more detailed in the LCA (Life Cycle Assessment) section 3.7.1 *(see also WP3.2 SAF Handbook, section 1)*

### 3.2.5 EU regulations

Europe has taken significant regulatory steps to promote and support the scaling of SAF production and use. Adoption of this has been made with a background in the European Green Deal, which is the EU's growth strategy launched in 2019. It consists of a package of policy initiatives that set the EU on the path to a green transition, with the ultimate goal of achieving climate neutrality by 2050. The Fit for 55 package aims to tackle European challenges and reduce the European Union's environmental impact by 55% in 2030 by setting long-term planning frameworks.

In aviation, this has already had massive impacts, although we are still far from the target. With the RefuelEU Aviation regulation in 2023 came the first fixed SAF mandates, applicable from 1. January 2025 and increasing percentage volumes through 2050.

### 3.2.6 Fit-for-55

As part of the EU Green Deal initiative, the Fit for 55 package was launched in 2021. The legislative package aims to reduce EU emissions by 55% in 2030 compared to 1990 and is the largest climate package published in recent times, with a massive focus on the defossilisation and decarbonisation of the transport sector. This also includes aviation, where the regulation "RefuelEU Aviation" has a main impact on SAF uptake.

The entire Fit for 55 package is a comprehensive set of laws with many challenging goals and requirements, and thus a firm and binding push across all sectors involved, including the transport sector and several others, as shown in the illustration below.

The Fit for 55 package includes a revision to the Renewable Energy Directive to increase the EU-level target for renewable energy sources in the overall energy mix from at least 32% to at least 40% by 2030.

In addition to RefuelEU Aviation, Fit for 55 also includes a decision to phase out free allocation of emission allowances to aviation and to sectors to be covered by the Carbon Border Adjustment Mechanism (CBAM), as well as decisions to implement the global Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) through the EU ETS, i.e. for international flights not covered by RefuelEU Aviation.

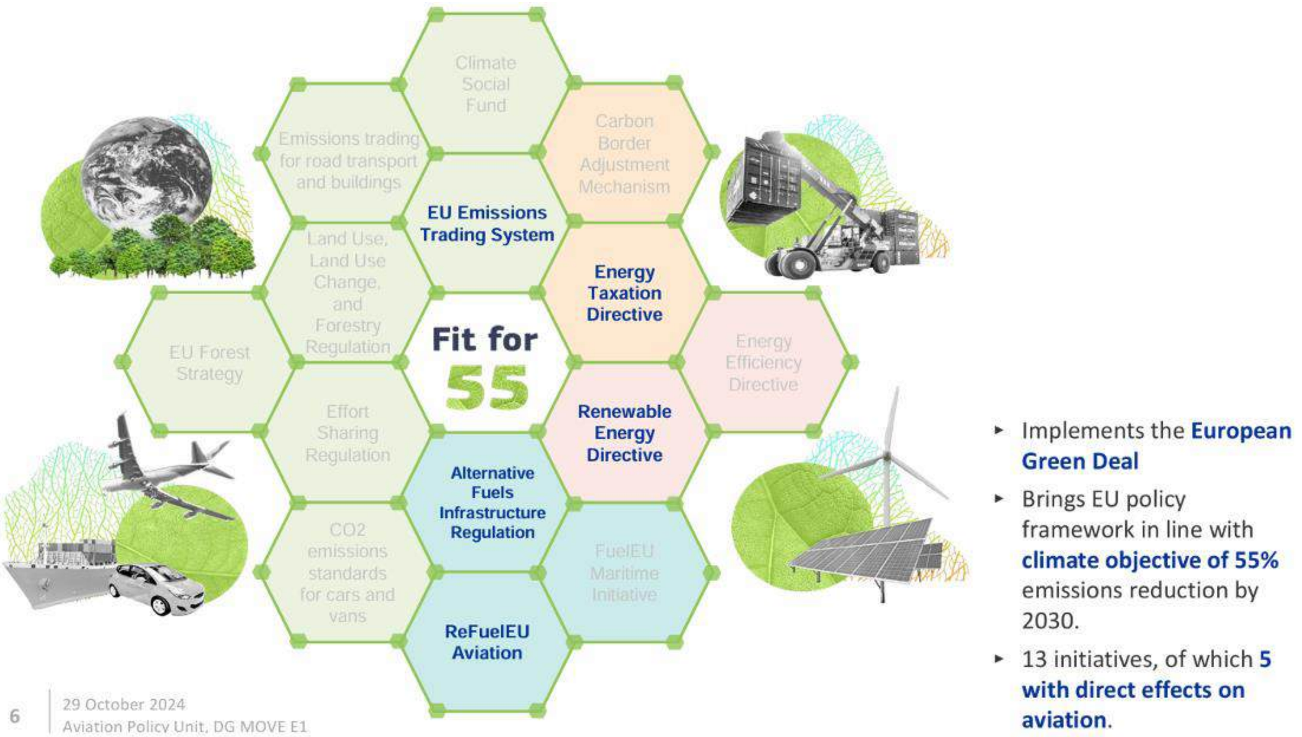



*Figure 21 The Green Deal – based on the Paris Agreement [51]*

The EU has over a number of years, and most recently and perhaps most comprehensively with ReFuelEU Aviation, taken many political/regulatory steps towards technical and operational measures,- such as including aviation in the emission trading system, support the development of the global measure CORSIA by ICAO, the use of sustainable aviation fuels, operational

[51] European Union, The Paris Agreement: The Green Deal. This subsequently resulted in the Fit for 55 packages. This also applies to RefuelEU Aviation, which is seen in the bottom of the puzzle illustration. Fit for the future, April 2024

optimisations, phasing out free allowances in ETS, include SAF criteria in EU RED, 20 million ETS allowances reserved to partially cover the price gap between conventional and SAF price, establish of a monitoring, reporting, and verification system of non-$CO_2$ effects, transparency of emissions data from aviation activities, and 5 million ETS allowances will be added to the EU Innovation Fund. You can read about these initiatives here. [52]

Many initiatives are, or are being, implemented by the European aviation sector and the authorities, which have several tasks related to their implementation. The member states do not have a uniform approach to handling the initiatives, and coordination across countries is likely to be relatively fragmented. Presumably, there are several traditional reasons for this, for example, which ministries are assigned which tasks. In addition, how the tasks are prioritised at the member state level.

However, with regulations and decisions involving fuel, SAF, and, in the long term, also other forms of energy, there are large overlaps with energy policy decisions that concern replacing fossil fuels with renewables, establishing energy plants, PtX and hydrogen development, and more, both nationally and across countries. Aviation is admittedly a minor player in the energy policy landscape, but solutions for aviation must necessarily be included in energy policy, as the same resources, technologies and decisions are increasingly contested. Later in the report, we will return to examples of national policies that include aviation, which is positive, but not necessarily a direct part of energy policy. Therefore, let us pose some questions and topics for consideration, which should be kept in mind in subsequent reviews, especially of the EU political regulations being implemented.

[52] European Commission, Climate Action; Reducing emission from aviation

| SAF and aviation in the national energy policy | | | | | |
|---|---|---|---|---|---|
| **The energy policy** | **Airport** | **Airline** | **Aviation organisation/other** | **Energy/fuel Supplier/producer** | **Authority** |
| Integrated<br>Partial<br>Not | | | | | |
| Need change? | | | | | |
| What topics are proposed to be integrated | | | | | |
| How can I/we take initiative? | | | | | |
| Energy policy coordination? | | | | | |
| Stimulate development /invest through policy | | | | | |
| Stimulate production through policy | | | | | |

*Figure 22 SAF and aviation in national energy policy*

### 3.2.7 Mandates and Fit for 55 overview

As part of the fit-for-55 package, the regulation ReFuelEU Aviation was agreed upon by the EU in Q3 of 2023. The main point of the regulation is to set the stage for the uptake of SAF across Europe. Under the RefuelEU Aviation mandates, fuel suppliers are obliged to deliver a percentage volume of SAF uptake at EU airports that meet specific requirements, starting from the beginning of 2025, with a 2% SAF blend-in increasing every 5 years. The mandates are stated below:

The SAF mandates are divided into two categories. Firstly, there are the overall SAF mandates starting 2025 expressed as a total volume percentage, which include all SAF products that meet the sustainability criteria.

The second category, starting in 2030, is the sub-targets for synthetic sustainable aviation fuels: a specific proportion of the fuel mix must comprise synthetic fuels, such as e-fuels of non-biological origin (RFNBO).

All SAFs must meet the RED sustainability criteria for renewable and sustainable fuels in the EU transport sector. Importantly, REDIII annex IX defines the feedstocks permitted for producing fuels, serving as the central reference point for feedstock selection. REDIII also defines LCA methodologies, thresholds, and ILUC values, all of which are relevant to determining whether a fuel is eligible to be described as a SAF.

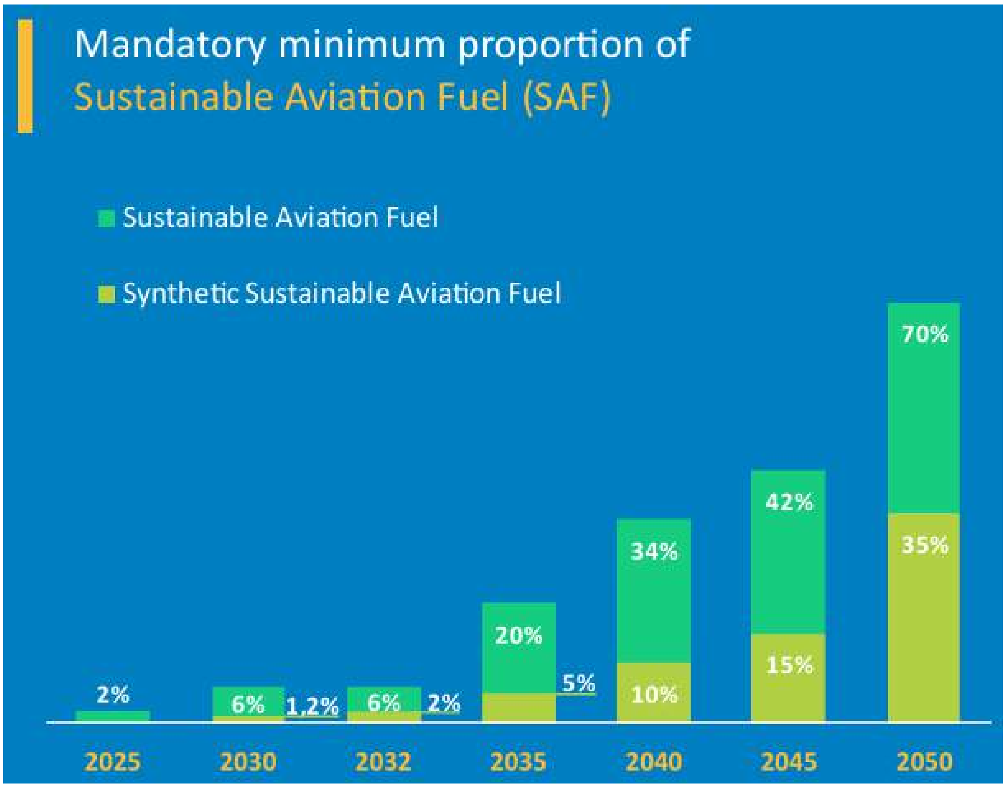



*Figure 23 Mandatory minimum proportion of SAF, acc. RefuelEU Aviation* [53]

*Notice: In 2025, aviation fuel suppliers are required to blend 2% SAF with conventional fossil-based fuels at Union airports, increasing to at least 70% by 2050. Synthetic aviation fuels are subject to an ambitious sub-mandate, starting at 1.2% in 2030, rising to 2% in 2032, and reaching 35% in 2050, as shown in the figure.*

[53] EASA, ReFuelEU, [Mandatory minimum proportion of Sustainable Aviation Fuel (SAF)]

Although the purpose of ReFuelEU Aviation is to promote SAF uptake across Europe, the mandates only apply to EU airports that have over 800.000 passengers a year or freight exceeding 100.000 tons. Airports below these thresholds can voluntarily participate but are not mandated. This means that CPH Airport, Warsaw/Modlin, Roma Fiumicino, Vilnius, and after the latest revision, February. In 2025, 155 airports in the EU will be subject to the regulation. (See complete list of Union airports in-scope of ReFuelEU Aviation).[54]

The responsibility for delivering SAF will rest with the fuel suppliers, who must demonstrate compliance with their yearly deliveries to the union database. In turn, it falls to the member states to check for compliance and issue penalties in the form of a fine if targets are not met. It is up to the member states themselves to define the penalty and local monitoring system if needed. However, article 12 states "*That fine shall be proportionate and dissuasive and not less than twice as high as the amount resulting from the multiplication of the difference between the yearly average price of conventional aviation fuel and SAF per tonne by the quantity of aviation fuels not complying with the minimum shares referred to in Article 4 and Annex I.*" Each member state should report to the commission on specific actions no later than 31st of December 2024.

As SAF volumes are still relatively small, the logistics of transporting 2% specific SAF to all EU airports can be challenging and may not be feasible for all aviation fuel suppliers. To level out these aspects, fuel suppliers are allowed to deliver aggregated volumes to single airports (within member states) from 2025 until 2034.

### 3.2.8 RefuelEU Aviation – A brief overview

To ensure that EU air transport meets the EU's climate targets for 2030 and 2050, delivering on the European climate law [55]

### What is the aim of the regulation

**Key points**

- The RefuelEU Aviation regulation is a key part of the EU's Fit for 55 [56] package of measures designed to deliver the European Green Deal [57]
- The regulation is a legal framework to promote the gradual supply and uptake of SAF in the EU. SAF generates lower life-cycle emissions than conventional fossil kerosene. The life-cycle emission savings range from 65% to 100%, depending on the type of SAF.

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[54] ReFuelEU Aviation, Union airports in-scope
[55] European Union, European climate law
[56] European Commission, Fit for 55
[57] European Union, European Green Deal

**Key obligations**

- **Aviation fuel suppliers** must ensure that the **aviation fuel blend** made available to aircraft operators at EU airports contains a **minimum share of SAF** from 2025 and a minimum share of **synthetic aviation fuels** from 2030. Both shares will increase progressively until 2050. The minimum SAF share will be 2% in 2025, rising to 70% in 2050. The minimum share of synthetic aviation fuels, which also contributes to reaching the SAF minimum share, starts with 0.7% in 2030, rising to 35% in 2050.
- **SAF** must be compliant with the renewable energy directive sustainability and emissions-saving criteria to count towards the targets, and SAF is composed of:
  - **aviation biofuels**, notably advanced biofuels and other biofuels, produced from waste and residues.
  - **synthetic aviation fuels**, produced from renewable hydrogen; and
  - **recycled carbon aviation fuels**.
- Additionally, aviation fuel suppliers may choose to meet both minimum shares with **hydrogen** for direct use in aircraft (renewable and non-fossil low-carbon hydrogen), along with **synthetic low-carbon aviation fuels** (produced from non-fossil low-carbon hydrogen).
- **Aircraft operators** departing from EU airports must refuel with the aviation fuel necessary for their entire flight, avoiding the excessive emissions related to extra weight and minimising the risks of carbon leakage caused by tankering practices.
- **EU airports' managing bodies** must facilitate access to SAF, cooperate and undertake efforts to facilitate the access of aircraft operators to hydrogen or electricity used primarily for the propulsion of an aircraft and to provide the infrastructure and services necessary for the delivery, storage and uplifting of such hydrogen or electricity to refuel or recharge aircraft. [58]

## Enforcement, reporting, and a new flight label

- The regulation also sets out rules on designating competent authorities in EU Member States to implement and enforce the regulation, and on penalty systems in case of non-compliance.
- The environmental labelling scheme established in this regulation, which measures the environmental performance of the flights, will help consumers make informed choices regarding their transport options and further promote more sustainable aviation.
- Aviation fuel suppliers, EU airports and aircraft operators are required to collect data and report to the European Union Aviation Safety Agency and to competent authorities to monitor compliance with their obligations.

[58] European Union, RefuelEU Article 7

### Union database

To improve traceability and prevent fraud or double-counting, REDIII mandates the use of the Union Database (UDB), developed by the European Commission.
All SAF products consumed in the EU that are to be counted towards REDIII targets must be registered in the UDB, regardless of their feedstock or country of origin. The aim is for the UDB to become the overall repository for renewable fuels consumed in the EU, and for it to be used by (aviation) fuel suppliers to report fuel volumes and their corresponding data, as well as sustainability and greenhouse gas compliance for these.

This database tracks renewable fuels from feedstock production to final fuel delivery. Since January 2024, the UDB has been operational for liquid biofuels and will expand to cover gaseous fuels and recycled carbon fuels. All SAF supply chains must be registered in the UDB, including feedstock providers, SAF producers, and aviation fuel suppliers.

The ambition is that this framework under REDIII and RFEUA establishes a consistent, transparent, and sustainable approach to scaling SAF across the EU, aligning with the broader climate and energy targets of the Union.

Currently, the UDB covers the supply chain from feedstock production to the point where renewable fuel is supplied. For SAF specifically, the database should include feedstock producers (or waste collectors), SAF producers, and aviation fuel suppliers covered by RFEUA. There are also plans to include aircraft operators in the database. Such an addition would help resolve the issue of operators lacking clarity on the volume of SAF they receive, thus improving their ability to make accurate SAF usage claims. This should also support their compliance reporting under RFEUA, facilitate emissions accounting under the EU Emissions Trading System, and assist airlines seeking to meet further voluntary climate targets.

## 3.3 Fuel suppliers reporting to Union Database

The following information must be reported in the Union database by the fuel suppliers:

**1.** The amount of aviation fuel supplied at each Union airport, expressed in tonnes.

**2.** The amount of SAF supplied at each Union airport, and for each type of SAF, as detailed in point 3., expressed in tonnes.

**3.** The conversion process, the characteristics and origin of the feedstock used for production, and the lifecycle emissions of each type of SAF supplied at Union airports.

**4.** The content of aromatics and naphthalenes by percentage volume and of sulphur by percentage mass in aviation fuel supplied per batch, per Union airport, and at Union level, indicating the total volume and mass of each batch and test method applied to measure the content of each substance at batch level.

**5.** The energy content for aviation fuel and SAF supplied at each Union airport for each fuel type.

Given its design and capabilities, the EU database is a very necessary and useful tool for implementing and managing SAF accounting mechanisms. It is well-suited to maintaining the principles discussed earlier. Suppliers of aviation fuel can currently register with the UDB and use it to claim delivery of SAF to EU markets. However, it is important to note that 'fuel' cannot be uploaded directly into the database. The prerequisite is that it must first be registered with the type of feedstock and place of origin. Feedstock information is then transferred along the supply chain – via database transactions – by each party that acquires legal ownership.

A biofuel producer subsequently transforms feedstock information into fuel information in the system. Once the fuel has been delivered to the EU market, the aviation fuel supplier can assign it in the database to a specific airport location (referred to as a 'site' under the RED mass balance framework) that reflects the actual time of physical delivery of the SAF.

Further integration of necessary sustainability data is shown below in the PoS topics. -Furthermore, in RefuelEU Aviation article 10, letters c), d) and e), there are additional data that aviation fuel suppliers must report in the UDB on SAF. These data relate to the conversion process for specifying the physical properties of SAF, e.g., energy content, aromatics, naphthalene, and sulphur content; see the transaction data on next page.

**DATA TO BE TRANSMITTED THROUGH THE WHOLE SUPPLY CHAIN AND TRANSACTION DATA**

1. Data to be transmitted through the whole supply chain

(a) name of the voluntary or national scheme;

(b) proof of sustainability number;

(c) sustainability and GHG emission savings characteristics, including:

(i) statement on whether the raw material or fuel complies with the criteria set out in Article 29(2) to (7) of Directive (EU) 2018/2001;

(ii) GHG emission data calculated according to the methodology set out in Annexes V and VI to Directive (EU) 2018/2001 or Delegated Regulation (EU) 2019/807;

(iii) description of when the installation started operation (for fuels only);

(d) name of raw material or name of raw material that the fuel is produced from;

(e) waste or animal by-product permit number (if applicable);

(f) fuel type (for fuels only);

(g) country of origin of raw material;

(h) country of fuel production;

(i) statement on whether the raw material or fuel complies with the criteria set out for low indirect land-use change-risk biofuels;

(j) information on whether support has been provided for the production of that consignment, and if so, the type of support scheme.

2. Transaction data

(a) supplier company name and address;

(b) buyer company name and address;

(c) date of (physical) loading;

(d) place of (physical) loading or logistical facility or distribution infrastructure entry point;

(e) place of (physical) delivery or logistical facility or distribution infrastructure exit point;

(f) volume: For fuels, the energy quantity of the fuel must also be included. For the calculation of the energy quantity, conversion factors in Annex III to Directive (EU) 2018/2001 must be used.

*The EU Commission's report, February 2025 "Assessment of the production and supply of SAF at EU airports..." further states: "The Commission is developing the Union database to enable traceability of renewable fuels from feedstock production to the fuel being placed on a Member State market. The expectation from industry is that the existing PoS system will be integrated into the UDB, so that all the information listed in Annex I of IR 2022/996 is included in the database and can be traced through the supply chain digitally. Once fully operational, it is expected and legally required under RFEUA/RED that the UDB will be used by fuel suppliers – including aviation fuel suppliers under ReFuelEU Aviation – to report renewable fuel volumes and sustainability compliance to Member States"* [59]

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[59] European Union, [Assessment of the production and supply of SAF in Union airports and study on the feasibility of the creation of a system of tradability of SAF in the EU.](), 2025

## 3.4 Aircraft operators reporting to EASA

According to Regulation (EU) No 2023/24051 ("ReFuelEU Regulation"), aircraft operators shall report to the competent authorities and the Agency annually the following information:

**1.** The total amount of aviation fuel uplifted at each Union airport, expressed in tonnes.

**2.** The yearly aviation fuel required, per Union airport, expressed in tonnes.

**3.** The yearly non-tanked quantity, per Union airport, which is to be reported as 0 (zero) if the yearly non-tanked quantity is negative or if it is lower than or equal to 10 % of the yearly aviation fuel required.

**4.** The yearly tanked quantity, per Union airport, for reasons of compliance with applicable fuel safety rules pursuant to Article 5(2) of the ReFuelEU Regulation, expressed in tonnes.

**5.** The total amount of SAF purchased from aviation fuel suppliers, for the purpose of operating their flights covered by the ReFuelEU regulation, departing from Union airports, expressed in tonnes.

**6.** For each purchase of SAF, the name of the supplier, the amount purchased expressed in tonnes, the conversion process, the characteristics and origin of the feedstock used for production

**7.** Total, and the lifecycle emissions of the SAF, and, where one purchase includes different types of SAF with differing characteristics, providing that information for each type of SAF.

Flights operated under the ReFuelEU Regulation departing from Union airports, expressed as the number of flights and in-flight hours.

**Date for the regulation:** Applied 1 January 2024, except for SAF mandates and a few other articles, which applied 1 January 2025[60]

**Sustainability Portal**
EASA (European Aviation Safety Agency) has developed a digital Sustainability Portal for aviation operators covered by the ReFuelEU Aviation Regulation. The portal allows for the reporting of data required under Article 8 of the Regulation. - To comply with the requirements, aircraft operators must complete and submit the official reporting template (Annex II of the Regulation).

[60] European Union, EUR-Lex, 2023

To support this task, EASA has developed a fuel monitoring tool to facilitate the monitoring and reporting of fuel consumption. It supports both operators and verifiers and can be customised primarily to each operator's needs. The portal allows EU Member State authorities to process exemption requests submitted by aircraft operators.

The EASA homepage links to a manual that provides detailed guidance on reporting and verifying data. In January 2025, the portal opened for data submission for the reporting period 1 January to 31 December 2024 [61]

### 3.4.1 Considerations on expanding access to the UDB

As the EU commission also mentions in the evaluation report "Assessment of the production and supply of SAF in Union airports and study on the feasibility of the creation of a system of tradability of SAF in the EU" [62] The current system – and the possibilities and intention of this report – could be used more robustly by expanding the UDB to include aircraft operators as a new user group. Possibly, airport operating bodies could also be added to the UDB. While airport operating bodies and fuel handlers do not own the fuel (the commercial transaction is between the aviation fuel supplier and the aircraft operator), it could be relevant for ETS reporting that the airport to which the fuel is delivered is registered in the database. For example, airport managing bodies could have viewing rights in the UDB, in the same way as other users, such as verifiers who are not themselves involved in the commercial transactions. It could also be useful for reporting on scope 3 emissions. This latter point about airports' access to UDB is also discussed in section 1.10.1 of this report.

### 3.4.2 CORSIA (Carbon Offsetting Reduction Scheme for International Aviation)

CORSIA, established by the International Civil Aviation Organisation (ICAO), is a global market-based mechanism aimed at stabilising $CO_2$ emissions from international aviation. Under CORSIA, airlines are required to offset any growth in emissions from international flights above 2020 levels by purchasing $CO_2$ credits.

CORSIA also provides incentives for the use of SAF. The use of CORSIA-approved fuels can reduce an airline's offset obligation proportionately, provided that the fuel meets the sustainability and life cycle emissions criteria set by ICAO.

Aviation is thus subject to both the EU ETS and the ReFuelEU Aviation Regulation, as well as the global CORSIA Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA),

[61] EASA, ReFuelEU, Updated in 2025

[62] European Union, Assessment of the production and supply of SAF (...) the creation of a system of tradability of SAF in the EU, 2025

established by ICAO. This dual regulatory landscape can seem complex and may lead to overlap for airlines operating both inside and outside the EU.

IATA has called for a harmonisation between the EU and international frameworks. Harmonisation could involve aligning key elements such as monitoring, reporting, and verification (MRV) procedures, fuel sustainability criteria and accounting methods. For example, the EU could recognise CORSIA-compliant SAF pathways and crediting mechanisms, while ICAO could, in turn, consider integrating certain EU safeguards and data standards. This, according to IATA, would reduce the administrative burden, create greater coherence in emissions accounting and help avoid double counting or conflicting obligations.

However, there are relatively large differences between the two systems, which is why the proposal will be a major challenge.

ReFuelEU Aviation focuses on the positive promotion of SAF through binding quotas and requirements for suppliers to ensure an increasing share of SAF delivered in the EU. - CORSIA is a global offsetting scheme where airlines must compensate for the growth in $CO_2$ emissions (relative to 2019 levels) through the purchase of emission units, not necessarily using SAF.

ReFuelEU applies to all flights departing from an EU airport, regardless of the operator's base, whereas CORSIA applies only to international flights between participating countries. ReFuelEU is a mandatory regulation with enforcement mechanisms and sanctions for non-compliance. CORSIA is voluntary in its current phase (2021–2026) and will only become mandatory for most ICAO member states from 2027.

The EU's ReFuelEU applies a number of sustainability and traceability requirements under RED II/RED III and requires documentation, including through the EU's Union Database (UDB). CORSIA has other, less stringent criteria defined in ICAO's Sustainability Criteria and uses a certification system that the EU does not necessarily recognise.

### 3.4.3 EU airports and the Flexibility Mechanism

One aspect of RefuelEU Aviation that may affect airports is that SAF deliveries need not be distributed equally among all airports covered by the provision. To ease the transport and administrative challenges of the relatively limited quantities of SAF, the EU has launched a flexibility mechanism applicable from 2025 to 2034. This mechanism allows aviation fuel suppliers to meet their SAF blending obligations as a weighted average across all EU airports where they deliver fuel, rather than meeting the minimum SAF share at each airport.

In practice, this means suppliers may provide higher SAF blends at certain EU airports, within approved SAF blend-in criteria, to compensate for lower or zero SAF content at other airports, as long as the overall SAF supply meets the required EU-level minimum. Use of the flexibility mechanism is optional, and suppliers must ensure control over its use, including through contractual agreements with aircraft operators.

The rationale, as stated by the EU Commission, is to give suppliers sufficient time to scale up SAF production and distribution while meeting regulatory requirements cost-effectively, without compromising the environmental objectives of RefuelEU Aviation. It allows the sector to gradually expand logistical and technological infrastructure, ensuring full compliance with SAF obligations at every EU airport by 2035, when SAF blending will become mandatory for all aviation fuel supplied in the EU. **However, this flexibility will imply that airports that do not receive SAF or receive reduced amounts will miss out on local air quality benefits.**

The extent of flexibility available to suppliers also depends on how the term “fuel supplier” is defined in each Member State’s incorporation of the Renewable Energy Directive (RED), upon which RefuelEU Aviation builds. Each Member State is responsible for identifying the aviation fuel suppliers subject to RED and RefuelEU compliance obligations. Consultations with Member States have revealed that fuel suppliers are primarily registered and regulated at national level and often operate only within a single jurisdiction. In some cases, national tax rules require suppliers to maintain a legal presence in the Member State, necessitating the establishment of local subsidiaries. This has implications for cross-border operations, which the Commission is reviewing to ensure consistency with the EU’s freedom-of-establishment principle. Notably, RefuelEU Aviation allows a fuel supplier to operate across Member States under a single legal entity. - Despite the flexibility available, most fuel suppliers have not indicated plans to limit SAF supply to a few selected airports. On the contrary, there is a significant demand-side incentive, particularly under EU ETS rules, for aircraft operators to access SAF at as many airports as possible.

The EU considers that this part of the flexibility mechanism does not prevent coordination between suppliers that have difficulties in meeting SAF obligations and others that have surplus SAF at specific airports. Such coordination, where one supplier supplies SAF on behalf of another, could require structural changes to the EU aviation fuel market and may, in some countries, currently be hindered by national legislation or long-term contracts with airport authorities.

It is expected that blend-in SAF will be supplied to at least one airport in each Member State from 2025, thereby supporting a broad and inclusive implementation of RefuelEU Aviation from the outset. This is further supported by the fact that SAF and conventional jet fuel most often share infrastructure in the final stages of distribution to airports. Thus, the mass balance system makes it more cost-effective to distribute SAF on a large scale across interconnected infrastructure without requiring parallel logistics or new physical systems.

The EU Commission's preliminary analysis shows that, despite the flexibility available, most fuel suppliers have not indicated plans to limit SAF supply to a few selected airports. On the contrary, there is a significant demand-side incentive – particularly under the EU ETS rules – for aircraft operators, and presumably also airports, to access SAF at as many airports as possible.[63]

There is no doubt that the Commission has analysed and considered many major and complex issues in relation to the flexible mechanism. While the practical, administrative, and logistical arguments are the strongest, there are also good reasons why some airports may be sceptical or dissatisfied that not all will be part of the development in the first many years, and that a model with uneven implementation is being implemented, and the risk of regulatory complexity and potential market imbalances that may be difficult to understand.

Furthermore, there is also a discrepancy with the EU ETS system. Allowing fuel suppliers to average SAF across airports is interpreted by many as a lack of alignment with the ETS rules. Under the EU ETS, only SAF that is physically delivered to flights can reduce an airline's need for $CO_2$ allowances. With ReFuelEU 's flexibility, airlines can pay for SAF "on paper" without actual capture. This means that airlines must negotiate special contracts to ensure that SAF physically enters airports if they want to claim EU ETS benefits, which is not in harmony with a flexibility mechanism that, in many situations, points in the opposite direction.[64]

### 3.4.4 Reflections on ReFuelEU aviation

The ReFuelEU Aviation Regulation (EU) 2023/2405 was decided in 2023 and marks an important step in the EU's efforts to promote the use of sustainable aviation fuels and reduce the $CO_2$ footprint of aviation. The Regulation introduces binding minimum requirements for blending SAF into jet fuel supplied to EU airports – starting at 2% in 2025 and gradually increasing to 70% by 2050, with a specific quota of at least 35% for synthetic fuels (e-fuels).

The Regulation is now law in all Member States. This means that fuel suppliers are obligated to supply the agreed minimum proportions of SAF.

The launch of ReFuelEU Aviation had a noticeable impact on the aviation industry, even before 2025. As the mandates and initial framework had been publicly known for some time before they were finalised in the fall of 2023, discussions about SAF mandates and their implications have become increasingly widespread among aviation organisations and the public.

[63] Europa Kommissionen, Fleksibilitetsmekanismen for bæredygtige flybrændstoffer i henhold til ReFuelEU Aviation, 2025
[64] SkyNRG, Disentangling ReFuelEU: How will it shape the SAF market? 2023

Both before and after the adoption of RefuelEU Aviation, WP2 has, through several networks, workshops, conferences, and dialogues with developers, SAF producers, suppliers, authorities, and politicians, helped interpret RefuelEU Aviation to assess its potential and challenges.

Fuel producers, suppliers and airlines have initiated more activities and collaborations on future projects over the past year than before, as evidenced by an increasing number of memoranda of understanding or letters of intent. This has recognised that many actors need to participate in this development. Fuel suppliers in Denmark have communicated that they are expected to be ready to take on their part in achieving the 2025 SAF supply target.

There are still uncertainties regarding ReFuelEU Aviation. REDIII increases the complexity of interpreting how each country should receive or implement the regulation. As the SAF industry is still in its infancy in many ways, there is unpredictability and uncertainty. Achieving the 2% SAF blending mandates in 2025 may be somewhat more predictable than the synthetic fuels/E-fuels sub-mandate in 2030, and despite the regulatory certainty to ensure the uptake of e-fuels, there is still no e-fuel readiness across the EU medio 2025, not in the form of plants under construction or agreed FIDs (Final Investment Decisions). A number are in the pipeline, and more e-fuel pathways may be on the way, but with five years to reach the 2030 target, few EU subsidies, few state guarantees, and no current progress in building e-fuel plants yet. When this is the case, there is, of course, justified uncertainty about achieving the agreed sub-mandates.

In the period 2025–2034, fuel suppliers are allowed to meet their obligation as a weighted average across EU airports, which has made it possible to prioritize deliveries to individual hub airports with better infrastructure, but also has the disadvantage that airlines can only obtain $CO_2$ credits in the EU ETS if SAF is physically used for their aircraft – which may be unclear under the flexibility mechanism. Another significant disadvantage is that airports that receive less or no SAF do not achieve improved air quality.

The expansion of UDB to include aviation fuel is positive and is being applied but is not yet fully developed. This instrument is expected to become a central focal point in both accounting and climate contexts. This means that the UDB with announced expansions, for examble to include aircraft operators in the database, can become the factor that meets the need for an MRV and A (monitoring, reporting, verification and accounting) system that we and many others have been asking for, both in relation to prices, transparency and not least in relation to increased sustainability in SAF feedstocks, methods, technologies, qualities and quantities

ReFuelEU Aviation has given a clear signal to the market that SAF will be a central part of the future of aviation in the EU. Airlines and fuel suppliers are working to adapt to the requirements, but there is uncertainty about cost increases, access to SAF, coordination of supply and the interaction with the ETS regulation and CORSIA, which may create unfair burden sharing among airlines.

Investments in production capacity have increased, and new production facilities in and outside the EU are being prepared and, to a limited extent, under construction.

In summary, ReFuelEU Aviation is an ambitious and necessary instrument in the EU's climate policy for aviation. Implementation is underway but faces significant challenges, in particular regarding traceability, fair burden sharing, and compliance with other climate regimes such as the EU ETS and CORSIA. There is a need for ongoing sustainability focus, follow-up, adjustment and dialogue with stakeholders so that the goals are achieved effectively and fairly - without creating inappropriate market distortions.

### 3.4.5 REDII/III

REDII (Renewable Energy Directive II) and its revised version, REDIII, set specific sustainability and greenhouse gas emission reduction criteria that Sustainable Aviation Fuel (SAF) must meet to be recognized as sustainable within the EU. REDIII was launched in 2023 with new targets of 42.5% renewable energy consumption across all sectors by 2030. Of these targets, at least 29% must be consumed in the transport sector, or a minimum 14,5% reduction in GHG emissions compared to those from fossil fuels. These targets are set across the entire transport sector, giving Member States some flexibility to adjust their priorities and to recognise the different pace of sustainable transition in individual Member States. Individual targets are set to create a level playing field.

The REDIII maintains the 2x multiplier for all Annex IX feedstocks, the 4x multiplier for renewable electricity supplied to road vehicles, and the 1.5x multiplier for renewable electricity supplied to rail. It also maintains the 1.2x multiplier for aviation and maritime fuels but applies it only to advanced biofuels. The Directive adds a 1.5x multiplier for RFNBOs supplied to the marine and aviation sectors.

The RED update can generally be summarised as RED II, which sets out the minimum requirements for renewable energy use and sustainability, with targets for GHG emission reductions and renewable energy shares across various sectors, including transport. REDIII raises ambition further by increasing renewable energy targets and introducing more stringent GHG reduction criteria, particularly in challenging sectors such as aviation.

The key differences are that REDIII requires higher renewable energy shares and stricter emissions reductions compared to REDII. As a scope, REDIII includes enhanced criteria for advanced biofuels and RFNBOs in hard-to-decarbonize sectors. In the reporting area, REDIII requires improved transparency and expanded use of the Union Database for real-time monitoring.

EASA on definition and regulation: *"While not being limited by sustainable biomass availability, they are reliant on access to sufficient additional renewable energy electricity, and an energy-efficient*

*conversion process, to achieve significant $CO_2$ emission reductions. Water and electricity are used in an electrolyser to generate hydrogen, which is then combined with $CO_2$ to create syngas. This syngas can then be further converted to SAF via the Fischer-Tropsch (FT) pathway or the Methanol-to-Jet pathway (currently undergoing ASTM D4054 qualification). The $CO_2$ required for the PtL process can be obtained from industrial waste gases, biomass, or direct air capture (DAC). With DAC, the $CO_2$ is directly captured from the air through filters. As the concentration of $CO_2$ in the air is low, this process is very energy intensive but offers high $CO_2$ emission reduction potential once the technology has further matured."*
- EASA: What are sustainable aviation fuels [65]

Summary of major changes to transport fuels policy in the Renewable Energy Directive:

| | 2018 RED II | 2023 RED III |
|---|---|---|
| **Renewable energy in transport** | 14% energy target (out of road and rail fuels) | 14.5% GHG intensity reduction target or 29% renewable energy target (out of all energy supplied to transport) |
| **Advanced biofuels (Annex IX, part A)** | 3.5% (out of road and rail fuels, with multiplier) | 5.5% of a combination of both fuel types, with a 1% RFNBO minimum (out of all energy supplied to transport) |
| **Renewable fuels of nonbiological origin (RFNBOs)** | No target | |
| **Waste oils (Annex IX, part B)** | 1.7% cap (out of all energy supplied to road and rail) | 1.7% cap (out of all energy supplied to transport) |
| **Food- and feed-based biofuels** | Cap at whichever is lower: 7% or 2020 consumption in each member state + 1% (out of road and rail fuels) | Cap at whichever is lower: 7% or 2020 consumption in each member state + 1% (out of all transport energy consumption) |
| **Multipliers** | • 2x for advanced biofuels and waste oils<br>• 4x for renewable electricity used in vehicles<br>• 1.5x for renewable electricity in rail<br>• 1.2x for aviation and maritime fuels, except food- and feed-based biofuels | Towards the overall 29% renewable energy target and all applicable subtargets for either an energy target or GHG target:<br>• 2x for advanced biofuels, RFNBOS, and waste oils<br>• 4x for renewable electricity in vehicles<br>• 1.5x for renewable electricity in rail<br>• 1.2x for advanced biofuels and 1.5x for RFNBOs in aviation and maritime sectors |
| **Fossil comparator** | • 94 $gCO_2e/MJ$ for all transport energy | • 183 g $CO_2e/MJ$ for electricity used in vehicles<br>• 94 g $CO_2e/MJ$ for all other energy used in transport |

*Figure 24 Summary of the Renewable Energy Directive [66]*

To promote and demote certain fuels, REDIII implements several targets and constraints, including those most relevant to aviation fuels:

- **X2 multiplier for advanced biofuels and RFNBO for all transport**
- **Additional X1,2 for advanced biofuels and X1,5 for RFNBO in aviation and maritime**
- **Biofuels from UCO and animal fats are limited to 1,7% in final consumption across all transport**

[65] EASA What are sustainable aviation fuels
[66] ICCT, Policy Update, Provision for transport fuels in the European union's finalized "fit for 55" package, July2023

#### 3.4.5.1 Multiplier X 2

Multiplier X 2 for RFNBOs (Renewable Fuels of Non-Biological Origin) in the transport sector means that the amount of energy from RFNBOs used in transport is counted twice towards the fulfilment of specific EU targets or requirements. RFNBOs become more competitive because they contribute double to the goals that companies and countries must meet, making them attractive despite their higher production costs compared to fossil alternatives. The multiplier is an **incentive mechanism** designed to promote the production and use of these fuels, as they are considered particularly important for reducing greenhouse gas emissions in the transport sector. A possible disadvantage of the X2 multiplier is that it makes it more difficult to compare the actual progress of different Member States in reducing greenhouse gas emissions. A computational and explanatory challenge that can be held up against the X2 multiplier's objectives of promoting green innovation through

**1.** Helping new and promising technologies, such as RFNBOs, to penetrate the market
**2.** Reducing dependence on biofuels by diversifying renewable energy sources in transport
**3.** Increasing the use of Power-to-X: Creating incentives to produce green hydrogen and synthetic fuels, including for the aviation sector

#### 3.4.5.2 X 1,2 and X 1,5 multipliers

The multipliers X1.2 for advanced biofuels and X1.5 for RFNBOs (Renewable Fuels of Non-Biological Origin) in aviation and maritime transport are policy tools used to promote the use of these sustainable fuels in sectors where reducing greenhouse gas emissions is particularly challenging. These multipliers give greater "weight" to the use of fuels when calculating the share of renewable energy relative to the EU's climate targets.

#### 3.4.5.3 1.7% cap on UCO and animal fats

The fact that biofuels made from UCO (Used Cooking Oil) are limited to 1.7% in transport means that there is an upper limit to how large a share of the transport sector's total energy consumption can be met by using biofuels made from UCO and animal fats. This limit is set by the EU's RED II (Renewable Energy Directive II). It aims to ensure that feedstocks such as UCO are used in a sustainable way, while promoting incentives for alternative and advanced biofuels. Why is there a limit of 1.7%? The main objective is clearly to prevent excessive reliance on a single raw material. Used cooking oil (UCO) is an attractive raw material for producing biofuels. It is a waste product and therefore has a lower climate impact than conventional raw materials. However, the supply of UCO is inherently limited, and excessive demand can lead to Illegal trade, for example, the risk of false reporting of UCO origin. Increased use in one sector can also lead to restrictions in other sectors: UCO is used in industries such as chemicals and animal feed. Excessive use of transport can create imbalances.

The cap aims to promote feedstock diversity by encouraging producers to explore and invest in other sustainable feedstocks, such as advanced biofuels from residues and waste, which are not similarly constrained. It prevents indirect land-use change (ILUC). If demand for UCO increases sharply, this could drive increased production of new vegetable oils, such as palm oil, leading to deforestation and biodiversity loss.

EU member states may not count more than 1.7% of transport energy as a contribution from UCO-based biofuels towards their RED targets, but may set a lower cap if they wish, not a higher one.

The 1.7% limit for biofuels made from UCO and animal fat is a policy tool that ensures that resources are used sustainably and does not lead to increased demand for new vegetable oils or fraud. At the same time, it encourages the development and use of advanced biofuels and renewable solutions, which are necessary to ensure a sustainable transition in the transport sector.

Regarding reporting and verification, UCO fuels must be carefully documented, including their origin and production, to ensure traceability and prevent fraud.

The set targets, both overall and specific, count towards member state targets and do not carry over to other regulations. E.g., the multipliers in aviation that count towards a member state's REDIII targets do not carry over into any regulatory framework in the fit-for-55 package, as they often define their own metrics/KPIs.

The regulation sets out a list of criteria that renewable fuels must meet to be eligible to count toward member states' targets. How to calculate these emissions in an LCA is thoroughly described in REDII Annex V for biofuels and advanced biofuels. With the new delegated act 2, there is also a description of the GHG calculations for RFNBOs.

REDII states the approved feedstocks for biofuel, which can be found in REDII ANNEX IX. This list is updated regularly as sustainable practices evolve.

REDII/III serves as a pivotal reference point for many other transport-related regulations, including ReFuelEU Aviation. This makes REDII/III a foundation for defining specific criteria for sustainable fuels, upon which other regulations are built.

#### 3.4.5.4 Delegated act 1 and 2

In June 2023, two delegated acts to RED were adopted, describing the criteria for producing renewable hydrogen and calculating GHG emissions from RFNBO's. Both delegated acts play a vital part in defining sustainable production for RFNBO's (E-fuels).

The first delegated act described the circumstances under which green hydrogen can be produced. In the act, two essential factors play a role in producing green hydrogen. The first is the additionality requirement, which ensures that production of green hydrogen adds to the renewable energy capacity and does not subtract from the national grid's renewable capacity. This is done through a Power Purchase Agreement (PPA) that adds new and unsupported renewable electricity capacity.

An additional important factor is the temporal and geographical correlation, describing how to manage purchasing power in bidding zones where renewable energy is available. Production located in zones with above 90% renewable energy is exempt from this rule.

The second delegated act establishes a minimum threshold for GHG emissions by providing the methodology for LCA. An essential factor in the document is the "*Captured emissions from the combustion of non-sustainable fuels for the production of electricity should be considered avoided emissions up to 2035, as most should be abated by that date, while emissions from other uses of non-sustainable fuels should be considered avoided emissions up to 2040, as these emissions will remain longer*" (paragraph 5, 2023/1185). [67] In practice, this means that $CO_2$ captured from fossil point sources cannot be counted as avoided, but will be included in full after 2040, increasing the price through the ETS system.

#### 3.4.5.5 Reflections on REDIII and the delegated acts

The Directive emphasises the importance of integrating renewable energy sources across all sectors, paving the way for a more resilient, future-proof energy system. Measures are designed to create a harmonised framework that supports renewable energy projects, including those related to sustainable aviation fuel (SAF). - However, there are areas where challenges can be foreseen as administrative complexity and burden. This could make it disproportionately difficult and more expensive for smaller businesses to implement and comply with the rules. Difficulties and ambiguities may arise around specific criteria and the implementation of multipliers. There may be concerns about some ambiguities in the delegated acts. The precise technical criteria and the application of the multiplier could make it challenging to compare target achievements across Member States. It is not inconceivable that certain parts of the RED or the two delegated acts may need to be adjusted along the way.

#### 3.4.5.6 EU Emissions Trading System (ETS)

The EU Emissions Trading System (ETS) is a key part of the EU's climate policy. The system covers all flights within the European Economic Area (EEA). Aircraft operators are required to monitor

[67] Law Teck: European Commission, Commission Delegated Regulation (EU), 2023

and report their $CO_2$ emissions and surrender several allowances annually related to their emissions. Aircraft operators currently receive several free allowances based on industry-agreed benchmarks. The number of free allowances allocated to aircraft operators will be gradually reduced, reaching full auctioning of allowances (i.e., no free allowances for the sector) from 2026. To help cover the price difference between conventional jet fuel and SAF, up to 20 million free allowances will be allocated to aircraft operators purchasing SAF in the 2024 to 2030 period.

Sustainable aviation fuels that meet the sustainability and greenhouse gas savings criteria under REDII are exempt from ETS obligations. ETS incentivises the uptake of SAF through the dedicated reserve of 20 million free allowances, made available between 2024 and 2030. These allowances can be claimed by operators using approved SAF on flights within the EEA, thereby reducing their overall compliance costs.

The ETS allows operators to claim SAF use in two ways. The first is direct physical delivery of SAF to aircraft. The second is to allow aircraft operators to claim SAF use based on "purchase records", a model whereby operators can purchase SAF that is physically delivered to airport infrastructure and attribute the usage proportionately to operations within the EEA, supported by appropriate documentation. The key requirement under both models is that SAF is demonstrably delivered to airport infrastructure to prevent double counting and ensure environmental integrity. Verification and reporting under the ETS rely on harmonised rules and guidelines recorded through the EU database, which is increasingly used as a central compliance and verification tool. As mentioned earlier in the section on Flexibility Mechanism, it is an unresolved challenge for ETS.

#### 3.4.5.7 ASTM approvals

So far, ASTM has approved the following 11 pathways to produce alternative jet fuel products that are not based on fossil oils, unlike conventional Jet A-1 production. Of these, three are in the co-processing category (explained later). As can be seen, approvals have taken place over several years. It can also be added that several additional approvals are currently in the pipeline. Like EASA's assessment, there are four categories, methods, technologies, and feedstocks, that can, so far, be characterised as possible options for producing SAF. After the overview of ASTM approvals shown below, a brief review of Biofuels, Advanced biofuels, Alcohol-to-Jet, and Synthetic liquid fuels (RFNBO) will follow.

## Drop-in SAF-qualified production pathways

| Production pathway | Feedstocks[2] | Certification name | Maximum SAF share |
|---|---|---|---|
| **Biomass Gasification + Fischer-Tropsch (Gas+FT)** | Energy crops, lignocellulosic biomass, solid waste | FT-SPK[3] | 50% |
| **Hydroprocessed Esters and Fatty Acids (HEFA)** | Vegetable and animal fat | HEFA-SPK | 50% |
| **Direct Sugars to Hydrocarbons (DSHC)** | Conventional sugars, lignocellulosic sugars | HFS-SIP[4] | 10% |
| **Biomass Gasification + FT with Aromatics** | Energy crops, lignocellulosic biomass, solid waste | FT-SPK/A[5] | 50% |
| **Alcohol to Jet (AtJ)** | Sugar, starch crops, lignocellulosic biomass | ATJ-SPK | 50% |
| **Catalytic Hydrothermolysis Jet (CHJ)** | Vegetable and animal fat | CHJ or CH-SK[6] | 50% |
| **HEFA from algae** | Microalgae oils | HC-HEFA-SPK[7] | 10% |
| **AtJ with Aromatics** | Sugar, starch crops, lignocellulosic biomass | ATJ-SKA | 50% |
| **FOG Co-processing** | Fats, oils, and greases | FOG | 5% |
| **FT Co-processing** | Fischer-Tropsch (FT) biocrude | FT | 5% |
| **Hydroprocessed Lipids Co-processing** | Hydroprocessed vegetable oils, animal fats, used cooking oils | Hydroprocessed Lipids Co-processing | 10% |

*Figure 25 Overview of SAF pathways* [68]

[68] EASA, Environmental report, 2025

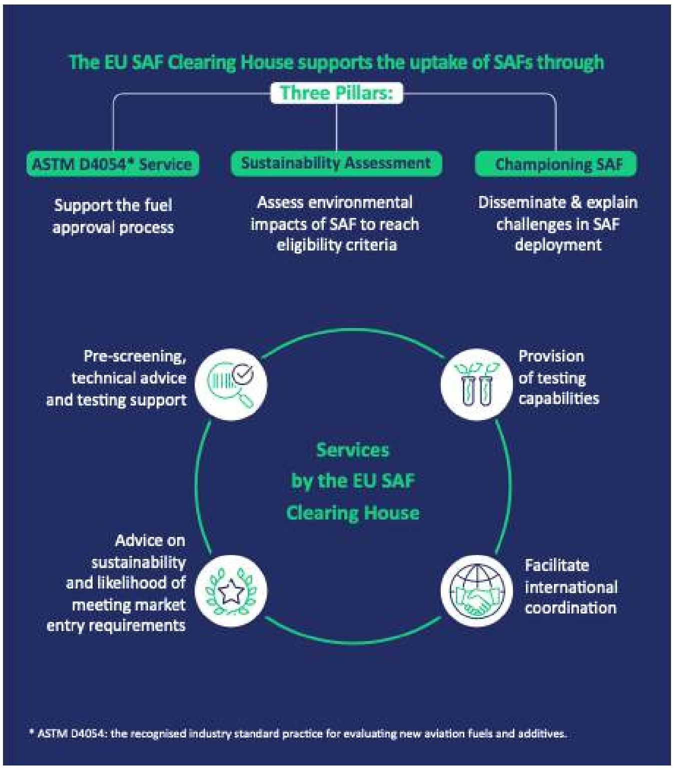


Figure 26 EU SAF Clearing House [69]

**The EU SAF Clearing House:** To help new potential SAF approvals proceed with the least possible delays or misunderstandings before they are processed by ASTM, the EU established the SAF Clearing House in July 2024, funded by the EU and managed by EASA. The SAF Clearing House is a Sustainable Aviation Fuel **'Facilitation Initiative'**, a knowledge centre providing information, data, and stakeholder connections needed for potential fuel producers to advance through the ASTM qualification process, and to help ensure the process goes as quickly as possible.
The Clearing House will be able to assist with pre-screening and advice, testing facilities, and possibly international coordination where this is an advantage.

As mentioned earlier, the RefuelEU/RED fuel categories are mainly based on the feedstocks and their sustainability characteristics that may be used to produce aviation fuel.

The wide range of feedstocks is thus divided into the categories Biofuels, Advanced biofuels, Alcohol to Jet, and Synthetic aviation fuels. For other categories of aviation fuel, namely low-carbon hydrogen and low-carbon synthetic aviation fuels, the RFEUA Regulation refers to "relevant EU law", i.e. the EU Gas Directive from 2024. Here is a brief overview of the three categories. Approved feedstocks see EASA. [70]

**Biofuels** are produced from biogenic/bio-based feedstocks such as used cooking oil (UCO), tall oil, waste biomass, and dedicated energy crops.
Biofuels can play a role in the defossilisation of aviation but are limited in availability due to access to raw materials. The most mature pathway is the HEFA pathway, with SAF from vegetable oils and waste lipids, including used cooking oil and animal fat. When produced from waste lipids, this pathway is referred to as "Part B biofuels". Today, these constitute by far the

[69] EAZA, EU SAF Clearing House
[70] EASA, State of the EU SAF market, Appendix 6.2, 2024

most significant biofuel production in the EU and globally, primarily for the road transport sector.

HEFA is also currently the most competitive SAF production pathway. Still, the availability of raw materials listed in Annex IX Part B is already a decisive limiting factor and will be even more so in the future. They are, in fact, in high demand to produce other biofuels for transport. Furthermore, their decarbonization potential is limited compared to that of advanced biofuels, and, finally, the contribution of Part B biofuels to the EU's renewable energy transport targets is limited under REDIII, prompting member states to promote solutions based on other feedstocks. See the earlier section on the 1,7% cap on UCO and animal fats for transport. This will be further elaborated on in the LCA section.

How much of the UCO and animal fats can be directed towards aviation depends on demand, availability and permits. Many analyses and estimates have been made of how much of the SAF supply can be derived from UCO and animal fats. The lowest estimates are around 3 per cent, while the highest are around 10 per cent. There is no cap on the percentage that can be used for SAF. If you go with the high estimate, other sectors must contribute either because it is politically supported or because there are alternatives.

According to recent literature and peer-reviewed analyses, realistic estimates of the proportion of total jet fuel consumption that can be produced from used cooking oil (UCO) typically range from 1-3%. Under ideal conditions with maximum collection and optimal conversion, the figure could possibly reach around 3-5%. Still, the practical challenges of collection and competition from other uses mean that lower figures are often more representative. A report from Bolton Consultancy [71] highlights a significant increase in global SAF demand, emphasizing that while SAF will generally play a greater role, the supply of UCO as a feedstock remains a limiting factor. This means that SAF growth is likely to be driven by a broader portfolio of feedstocks, while UCO's direct contribution remains relatively modest, at around 3%. Biofuels are required to meet a lifecycle emissions savings threshold of 65% compared to the fossil fuel baseline as defined under the EU RED for facilities that started operations after 2021.

**Advanced biofuels** have great potential but are not yet available on a large scale. SAF can be produced from raw materials such as lignocellulose (e.g., agricultural or forestry residues, grass materials), algae, biowaste raw materials (biogenic content of municipal solid waste) and others listed in annex IX of REDIII.

Advanced biofuels are among the most promising to produce sustainable transport fuels. They have great potential to decarbonise aviation, as they can achieve higher $CO_2$ emission reductions than conventional jet fuel. Advanced biofuels can, for example, be produced

[71] Boston Consulting Group, Consultancy: Global demand for sustainable aviation fuel SAF to explode by 2030, Feb 2025

through the approved and certified Fischer-Tropsch pathway in combination with a biomass gasification process and Alcohol-to-Jet pathways based on ethanol or iso-butanol.

Advanced biofuel is also required to meet a lifecycle emissions savings threshold of 65% compared to the fossil fuel baseline, as defined under the EU RED, for facilities that started operations after 2021. In REDIII, the specific minimum GHG reductions in relation to fossil fuels increase from 50% (2015) to 65% (2026). The GHG score is calculated through a life-cycle assessment using the value and calculation methods described in RED II Annexe V (European Commission N/D, B). The value of the fossil fuel comparator is 94 $gCO_{2\ eq}$/MJ.

**Alcohol to Jet.** This technology produces alcohol from plant-based, sugar-containing waste materials. Alcohol to Jet (AtJ) fuels can be produced from agricultural residues and crops, woody plants, algae and the renewable nobility of municipal waste via an alcohol synthesis. It can be obtained by fermenting various sources, both biogenic and non-biogenic, with ethanol as an intermediate. Another source of non-biogenic origin is the fermentation process of industrial flue gas from heavy industry. - The Alcohol to Jet product can be produced with or without aromatics. GHG Reduction Potential: 40-70%. The GHG reduction potential is moderate to high when using residues or second-generation feedstocks such as lignocellulosic biomass, and SAF derived from first-generation crops like corn or sugarcane is less favourable due to emissions from intensive agriculture, including fertilizer use and land conversion.

**Renewable Fuels of non-biological origin (RFNBO)**, also referred to as Synthetic liquid fuels, e-SAF, Power to Liquids, or eSAF, have considerable potential. Still, both feedstock availability (I.e., primarily electricity supplied by renewable energy production) and technology readiness are major challenges. To be considered renewable, these fuels must be produced from renewable electricity used to produce green hydrogen, which is done by splitting water into oxygen and hydrogen. In a subsequent synthesis process, green hydrogen and carbon monoxide derived from a corresponding carbon source, are converted into a mixture of liquid hydrocarbons.

To produce RFNBOs for aviation, two production routes are considered: Fischer-Tropsch or Methanol-to-Jet. So far, only Fischer-Tropsch is approved for blend-in up to 50%. Methanol synthesis is already used in refineries to produce methanol from syngas. However, for aviation purposes, upgrading methanol to kerosene (and beyond to other liquid hydrocarbons) is not yet approved by ASTM, but an intensive approval process is ongoing (see section 4.2). RFNBOs offer good opportunities for aviation decarbonisation, but the availability of renewable electricity is a major challenge. Capture of $CO_2$ from ambient air also involves significant development steps. In the short term, limited quantities and high prices of RFNBOs are expected, and will be reviewed in chapter 5.

Renewable fuels of non-biological origin (RFNBO) are the other category of SAF considered here, often referred to as synthetic fuels, even though biomass-based Fischer-Tropsch products are equally synthetic products derived from the chemically identical syngas. Fuel products within the RFNBO category are relatively new in development, and experience with the products is scarce; therefore, regulation is limited. Although several of the RFNBO technologies have been known for years, the connection to RFNBO and specifically PtX has recently become an attractive solution, a mainstream discussion and an area of potential huge investments.

The illustration below shows the most likely technologies for manufacturing SAF. It should be noted that the two methanol production routes are not (yet) ASTM approved. A comprehensive approval process is underway and is expected to lead to approval around the turn of 2025/26.

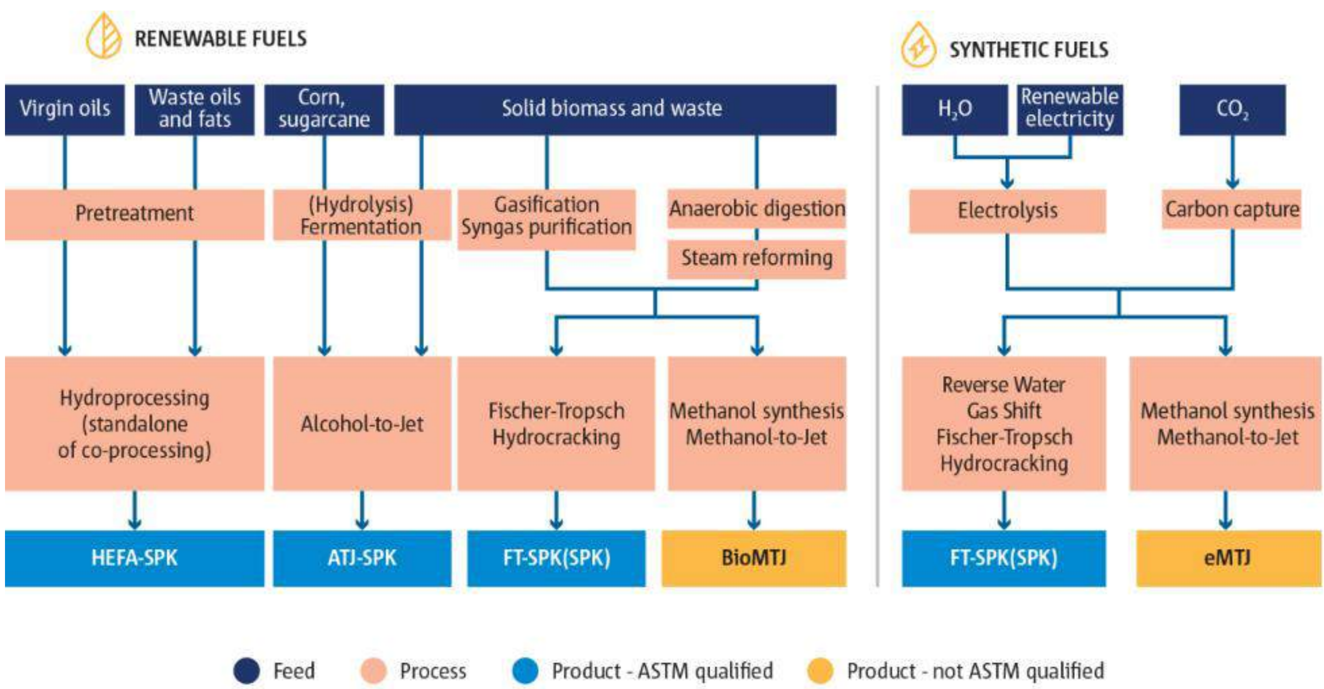


*Figure 27 Most likely technologies for manufacturing SAF* [72]

Sustainability criteria are, for the most part, not categorically set but distributed to individual technologies. RFNBO must achieve a minimum 70% reduction in GHG emissions relative to the fossil fuel comparator to be eligible for EU targets. However, there is currently no regulated methodology to provide guidance on the calculation of the matter, both in terms of power

[72] EASA, Figures and Tables: Figure 6.1, Main SAF production pathways with similar building blocks [8]

purchase criteria and aspects related to the use of carbon, and GHG-scores are therefore presented with uncertainties.

**Temporal and geographical correlations create specific zones of production:** Although many factors determine the location of an E-fuels production facility, these correlations add another layer of complexity that is hard to navigate. E.g., facilities in the western part of Denmark are exempt from negotiating through PPA since the average RE is above 90%, whereas in the eastern part of Denmark, the average is below the required 90%. Making it far more attractive to locate a facility in the west than in the east, creating a discrepancy in the favoured location for future production. This tendency is more extreme in other countries located in southern, central and eastern Europe.

**Co-processing.** Furthermore, ASTM has approved co-processing as a possible SAF production method, but with limitations on the amount that can be used. Some refineries have the capacity to co-produce SAF. Co-production differs from blending because the raw sustainable oils are refined alongside fossil oils, so the end product already contains hydrocarbons from sustainable sources. Not all refineries are equipped for this, and according to the approvals, no more than 5% biogenic feedstock can be blended with crude oil for refining. Co-processed SAF can leverage the conventional fuel supply chain, as the product delivered by the refinery will be a certified CAF containing renewable molecules. For example, Air BP has produced co-processed SAF from its refinery in Lingen, Germany, and Eni in Italy has launched the production of co-processed SAF using cooking oil as 0.5% of the feedstock in the refining process.[73] In general, both EU RED and CORSIA accept the co-processing method. According to Argus Media, there should be 11 co-processing refineries in Europe that produce or are on their way to producing SAF. [74]

Another method that is under preparation is co-processing of hydro-processed mono-, di-, and triglycerides, free fatty acids, and fatty acid esters. This method allows 24% in the feed but only 10% in the output product. Not yet experience with the technique on a full scale.

As for co-processing, there are ambitions to increase the maximum use of sustainable share to 30%. This is particularly justified by the fact that the existing infrastructure at the refineries can be quickly put into use to increase the sustainable share of aviation fuels and support the fulfilment of mandates without requiring major investments. However, ensuring that approved sustainable feedstocks become available remains a considerable challenge in this field as well.

[73] Biobased Diesel Dailey, Eni begins coprocessing SAF at conventional oil refinery in Taranto, Italy, 2021
[74] Argus Media, Spotlight on the European SAF market: countdown to 2025, April 2024

## 3.5 SAF sustainability criteria

Since SAF is the central opportunity for aviation to become more sustainable, the products delivered to aviation must contain the GHG reductions that have been prescribed and agreed. The term " aviation must become 'more sustainable" is a clear indication that SAF, as we know it today, does not bring the industry all the way to its goal. Firstly, there is a very long way to go from the first per mile of SAF in circulation up till 2024 and 2% during 2025, to the 70% in 2050. Furthermore, as we saw in the previous section, SAF, biomass, and, not least, UCO are limited resources. SAF based on biomass does not provide a full reduction in greenhouse gas emissions, and on top of that, there is the challenge of meeting the continued growth in air traffic. As shown in chapter 1 regarding the fuel supply chain and best practice framework, the supply chain is a long series of interconnected processes that involve many people, companies, and transport changes. The first crucial steps in the supply chain involve the raw materials used, production and processing methods, associated treatments, and transport.

Sustainability in SAF production has consequently become a central and widely debated issue across the aviation value chain, engaging fuel suppliers, project developers, policymakers, and researchers alike. Market participants are striving to attract investment and secure policy frameworks that support the scaling up of SAF production and deployment. At the same time, they are navigating the complexity of regulatory requirements, certification processes, and sustainability criteria under frameworks such as REDII/III and ReFuelEU Aviation. The transition is further challenged by the high capital intensity and technological uncertainty of first-mover projects, which must demonstrate both technical feasibility and long-term economic viability in a market still in its early stages of development.

Although airlines can use any Jet A-1 fuel certified under ASTM D7566 or DefStan 91-091, these standards cover only technical properties—not sustainability. SAF must also undergo sustainability approval, demonstrating net carbon reduction through life cycle assessment (LCA) to verify GHG reductions and meet aviation's climate goals. The EU RED, ReFuelEU Aviation, and CORSIA criteria form the basis for SAF approval, typically certified by international bodies such as RSB and ISCC. Many organisations, including CPH, also assess SAF sustainability through the Science-Based Targets initiative (SBTi) criteria.[75]

The following section reviews main SAF sustainability criteria from the EU and CORSIA, outlines main sustainability elements and best-practice frameworks, and concludes with reflections on the topic.

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[75] SBTi, THE CORPORATE NET-ZERO STANDARD, September 2025

| Sustainability criteria<br>RED Renewable Energy Directive (2023, Article 29) | Sustainability criteria<br>CORSIA Sustainability Criteria for CORSIA eligible fuels (Nov. 2022) |
|---|---|
| GHG reductions – GHG emissions on a life cycle basis from biofuels must be lower than from the fossil fuel they replace (fossil fuel baseline = 94 g $CO_2$ e/MJ):<br><br>At least 50% lower for installations older than 5 October 2015, 60% lower for installations after that date and 65% lower for biofuels produced in installations starting operation after 2021. For renewable fuels from non-biological origin, and recycled carbon fuels, the savings shall be at least 70%.<br><br>• Land use change – Carbon stock and biodiversity: raw materials for biofuels production cannot be sourced from land with high biodiversity or high carbon stock (i.e., primary and protected forests, highly biodiverse grassland, wetlands and peatlands). Other sustainability issues covered by the reporting obligation are set out in the Governance regulation [10] and can be addressed through voluntary certification schemes. There are also constraints on forest management.<br><br>• There are additional criteria that are applicable and ensure that electricity used to produce renewable hydrogen and RFNBOs is of renewable and additional origin.<br><br>• There are also limitations on biomass production from feed stocks with high indirect land use change (ILUC) risk and using feedstock that could otherwise be used for food, in order to prevent inappropriate land usage and risk to food security. | For batches produced on or after 1 January 2024, the following Sustainability Criteria are applicable:<br><br>• GHG reductions – CORSIA eligible fuel / SAF must achieve net GHG emissions reductions of at least 10% compared to the baseline life-cycle emissions values for aviation fuel on a life cycle basis (fossil fuel baseline = 89 g $CO_2$ e/MJ), including ECAC/EU an estimation of ILUC and/or DLUC emissions.<br><br>• Carbon Stock - CORSIA eligible fuel / SAF will not be made from biomass obtained from land converted after 1 January 2008 that was primary forest, wetlands, or peat lands and/or contributes to degradation of the carbon stock in primary forests, wetlands, or peat lands as these lands all have high carbon stocks.<br><br>• Permanence – The emissions reductions attributed to CORSIA SAF should be permanent. Practices will be implemented that monitor, mitigate and compensate any material incidence of non-permanence resulting from carbon capture and sequestration (CCS) activities.<br><br>• There are additional criteria that are applicable and address the following themes: Water, soil, air, conservation (biodiversity), waste and chemicals, human and labour rights, seismic and vibrational impacts, human and labour rights, land use rights and land use, water use rights, local and social development and food security. Primarily based on EASA [76] |

[76] EASA, European EU, Environment

To follow the set criteria for SAF sustainability, both EU RED and CORSIA use Sustainability Certification Schemes. CORSIA's teaser below. EU RED also uses Sustainability Certification Schemes prepared by RSB and ISCC, respectively. Negotiations on the final versions are ongoing and are expected to be completed in the spring of 2025. [77]

In order to become eligible, such fuels shall come from fuel producers that are certified by a Sustainability Certification Scheme (SCS) approved by the ICAO Council to perform this certification. Such SCSs shall meet the requirements included in the ICAO document entitled "CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes", which includes requirements related to other CORSIA documents relating to CORSIA Eligible Fuels.


CORSIA Eligibility Framework and Requirements

*Figure 28 ICAO/CORSIA 2024* [78]

## 3.6 How SAF meets EU sustainability criteria in REDII/III

**Objective:** To demonstrate that SAF meets EU sustainability criteria under RED II (Directive (EU) 2018/2001) and RED III (the revised Directive 2023), a systematic approach involving certification, documentation and traceability is required. Briefly, the most essential elements are listed below.

**Scope:** The guidance reviews the environmental, social, and economic sustainability dimensions, including quality assurance, traceability, and reporting throughout the entire supply chain.

**1. Certification Schemes:** SAF producers and suppliers must use an EU-approved certification scheme to demonstrate sustainability. The two most used schemes are ISCC (International Sustainability and Carbon Certification) and RSB (Roundtable on Sustainable Biomaterials). The certification schemes verify that SAF meets the requirements through independent third-party verification.

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[77] ICAO, CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes, 2024
[78] ICAO, CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes, 2024

**2. Compliance with RED II/III sustainability criteria:** For SAF to be recognized as sustainable under RED II/III, it must be documented that it meets the following:

The environmental criteria: SAF must achieve significant lifecycle greenhouse gas (GHG) reductions relative to fossil-based jet fuel. SAF biofuels and advanced biofuels must reduce GHG emissions by at least 60% for installations before 2021, 65% for installations after 2021 and 70% reductions for RFNBO. This is calculated via a life-cycle assessment (LCA) that includes feedstocks, production, energy consumption, transport, and use.

Conservation of biodiversity: The biomass must not come from areas with high biodiversity, such as primary forest, protected natural areas or ecosystems.

Conservation of carbon stocks: The biomass must not come from areas with high carbon content, such as wetlands or forests.

Soil and water protection: Compliance with requirements for the sustainable use of land and water resources is required.

Social and economic criteria: Documentation of compliance with human and labour rights in the supply chain.

**3. Mass balance system:** To ensure traceability, SAF producers must use a mass balance system in the supply chain. Mass balance principle: Sustainable raw materials and their end products (e.g., SAF) are blended with conventional fuels, but the quantity and sustainability characteristics must be documented at each stage of the supply chain. This is verified through traceability documents and audits.

**4. Traceability and documentation:** The producer must keep accurate records of the origin, processing, and distribution of the biomass raw materials. Use digital tools (e.g., blockchain or advanced supply chain management systems) for end-to-end traceability of SAF. Ensure all fuel deliveries are documented, and data is accurately reported to the Union Database.

**5. Documentation and reporting:** SAF suppliers must provide comprehensive documentation to relevant authorities and stakeholders:

Compliance and certification: Valid certificates from an EU-recognised scheme confirming compliance with the RED II/III criteria and the Proof of Sustainability (PoS). Regularly verify that SAF deliveries meet both the technical and sustainability requirements specified in REDII/III. Maintain up-to-date certifications (e.g., RSB, ISCC) that confirm adherence to sustainability benchmarks**.**

GHG emission reports: Documentation of life cycle emissions calculations according to EU standard methodologies.

Supplier declarations: Declarations confirming the sustainability requirements for the SAF quantities supplied.

National reporting requirements: Compliance with the reporting requirements of individual Member States during their implementation of RED II/III.

**6. Audits and control**: **Third-party audits.** Certification bodies conduct regular audits to ensure that all criteria are met.

Regulatory controls: National authorities may require or request additional documentation and data checks to ensure compliance.

**7. Digitization and databases** The EU has established a common platform, the Union Database, to improve reporting, calculations, traceability, and transparency: SAF producers and suppliers must register supply chain information in the database. This is to ensure that the sustainability of the fuel can be traced and verified throughout the value chain.

**Future outlook with the integration of sustainability**

Behind this brief review of how SAF meets the sustainability criteria lies a comprehensive description of the methods, content elements, and procedures for complying with them. The actors in this field have developed and refined the assessment tools over several years of experience. RSB and ISCC are leading actors in this area. LCA is a central part of the process and will be discussed in more detail. The following sections review several key topics crucial to addressing SAF sustainability challenges.

A holistic approach is essential to ensure that SAF deliveries not only meet the stringent EU sustainability criteria but also contribute to broader decarbonization and social equity goals. Ongoing Innovation is crucial. Continuous investment in innovation, technology, and training is critical to meeting evolving regulatory requirements and achieving long-term sustainability. To secure feedback and iteration, it’s essential to use audit findings and stakeholder feedback to drive continuous improvements and update processes as new data and technologies emerge.

Guidance on sustainability criteria must look ahead to ensure development and the best possible basis for tackling new products, increased mandates, and the struggle for resources. Continuous investment in innovation, technology, and training is essential to meet changing regulatory requirements and achieve long-term sustainability. SAF future trends, rules, and criteria require monitoring, analysis, and adaptation. Changes in EU policies (e.g., future updates to REDII/III) and industry best practices will be needed to maintain competitive advantage and compliance with the legislation. The GHG challenge is initially reviewed. In a subsequent section, the LCA methods and potential inherent limitations are discussed in more detail, followed by a review of the topics non-$CO_2$, Direct Land Use Change, and Indirect Land Use Change, as well as the key raw materials crucial to the future availability and expansion of SAF supplies for aviation.

## 3.7 Greenhouse gas emissions

The greenhouse effect is the term for the ability of the atmosphere to retain heat radiation from the Earth's surface, and the insulating effect means that the Earth's temperature is higher than it would be without this ability. The greenhouse effect works by greenhouse gases in the atmosphere absorbing infrared radiation from the Earth and sending it back towards the Earth.

Greenhouse gases (GHGs) are the standard terminology for understanding atmospheric emissions. As the GHG accumulates, the average temperature of our planet rises, and the consequences of undesirable options unfold.

The term GHG encompasses several gases, with $CO_2$ accounting for the largest share in the atmosphere, emitted by anthropogenic activities. Because of the proportion, $CO_2$ is often the primary reference when it comes to GHG, but other gases, both natural and synthetic, are equally concerning to the climate. In aviation, we refer to this as non-$CO_2$, which is proved to have a significant impact on aviation's environmental impact.

To understand and structure the quantification of climate impacts by GHGs, many systems, standards, and frameworks have been developed. The GHG Protocol is one of the most common systems for measuring and managing activities and emissions. To simplify accounting for GHG, the effects of different gases are calculated into a uniform unit known as $CO_2$ equivalent ($CO_2$ e); i.e., the climate impact of the other gases is expressed relative to that of $CO_2$ for a specific time horizon. $CO_2$e is a unit of measurement used to compare the total climate impact of different greenhouse gases by converting the amount of other greenhouse gases, such as methane ($CH_4$) and nitrous oxide ($N_2O$), to the amount of $CO_2$ that would have the same warming potential, thus providing an overall picture of total greenhouse gas emissions. This is done in general terms, as it is associated with several difficulties that are calculated using a linear method. There are differences in the effects of the different gases, especially when the decomposition time of the gases is considered (see the Non-$CO_2$ section later).

### 3.7.1 LCA

A life cycle assessment (LCA) is a methodology for calculating a product or service's environmental impact and resource use. Through collection of data and analysis of the entire supply chain, it's possible to quantify the input/output relationship of energy and material use to give a GHG-score. The methodology enables comparison of the environmental impacts of different products or services, observing results, risks, and improvements, and also identifies activities, technologies, or materials to reduce or avoid emissions.

LCA is a methodology with many variants depending on sector, product, or object. When analysing SAF products, we often refer to a well-to-wake (WTW) model due to its specialization in fuels. Through a structured analysis, the LCA covers the entire supply chain, and within the analysis, it is possible to accommodate various agricultural practices, industrial processes, energy use, transportation modes and consumption. The study can show how individual segments of the value chain perform, but also create uniform metrics of the entire value chain's performance.

LCA can serve as an assessment tool, and despite efficient data collection, there are still challenges to relying on such a tool. The first point is the frame of what is included into the calculations. If an LCA is to be drawn up in connection with the assessment of PtX-based SAF, widely different results may occur depending on the decisive choice of method and circumstances. For example, in the Nordics, there has for many years been a strong focus on sector coupling and utilizing energy/heat across sectors. In many international versions of LCA these are not included and therefore risk calculating a lower GHG-score for products than the actual performance, where possible interactions and sector couplings are included.

RSB and ISCC are the leading players in SAF sustainability certification, and both institutions are approved by both ICAO/CORSIA and EU RED. The description of the RSB process shows that conducting an LCA is a comprehensive task. A standard with subject areas and established criteria underpins the processes designed to evaluate the environmental performance of selected products over their lifecycle. It is based on recognised LCA methodologies (adapted to ISO 14040/14044) and integrates sustainability criteria to ensure that SAF not only delivers greenhouse gas (GHG) reductions but also aligns with broader sustainability standards. Key steps and components of the SAF LCA process:

### 1. Definition of objectives and scope

**Objective:** Definition of the purpose of the LCA study. For SAF, this typically involves an assessment of greenhouse gas emission savings and other environmental impacts (e.g., land use, water consumption, biodiversity) compared to fossil-based jet fuel.

**System boundaries:** The entire value chain is considered, from raw material production (e.g., agricultural residues, waste oil, or dedicated energy crops) through fuel conversion, logistics, blending (if applicable), and final combustion in aircraft. This comprehensive scope ensures that upstream and downstream impacts are captured.

**Functional unit:** A functional unit (e.g., per MJ of energy delivered or per litre of fuel consumed) is established to facilitate meaningful comparisons between SAF and conventional fuels.

## 2. Inventory analysis and transparency

**Data collection:** Detailed data is collected for all inputs and outputs at each stage of the SAF life cycle. This includes raw material extraction, cultivation practices, processing, energy consumption, transport logistics and emissions during fuel combustion.

**Regarding transparency (RSB):** *"First collectors shall have supported evidence back to the point of origin of the material, which shall be available for the auditors to verify. Supporting evidence may include, for example, proof of collection from specific restaurants or renders. The name of the specific feedstock shall be on all documentation. Organizations in the supply chain aggregating and/or forwarding end-of-life products and production residues shall maintain both procurement management and mass balance systems, including:*

*a. A list of all end-of-life products and production residues suppliers with whom the organization is currently engaged. The list of suppliers shall be updated regularly and shall contain the following information:*
*the supplier's legal name, physical address, and phone number, and the contact name.*
*b. Acquisition data, c. contractual requirement and d. sales data"*
- RSB guidelines and criteria for sustainability assessments [79]

The LCA process requires transparent, high-quality data. Any assumptions, data gaps or uncertainties should be documented, and sensitivity analyses are often performed to understand the impact on overall results.

## 3. Impact Analysis

**Environmental Impact Categories:** The process involves quantifying environmental impacts across multiple categories, with a primary focus on climate change (GHG emissions) including impact categories such as acidification, eutrophication, and land-use change.

**Comparison with baselines:** The impacts of using SAF are compared with those of fossil-based jet fuel to calculate relative greenhouse gas savings and additional environmental benefits.

## 4. Interpretation and Reporting

Analysis of results is conducted to identify key impact factors across the supply chain. The purpose of this step is to identify stages where improvements can yield significant reductions in environmental impacts.

Conclusions and recommendations: Based on the analysis, conclusions are drawn regarding the overall sustainability performance of the SAF process. Recommendations for process improvements, technology improvements or changes in raw material procurement may be made.

[79] RSB, guidelines and criteria for sustainability assessments, RSB Traceability Procedure (RSB-PRO-20-001)

Transparency and documentation: The LCA process should ensure that methods, assumptions, and data sources are transparent. Documentation is essential for RSB certification and for stakeholders to verify compliance with EU sustainability criteria.

Alignment with RSB sustainability criteria: The LCA process is integrated with RSB's broader sustainability requirements, ensuring that the assessed SAF pathway not only reduces greenhouse gas emissions but also complies with social, economic, and ecological sustainability standards.

Continuous improvement: The process should encourage ongoing monitoring and periodic reassessment. As new data becomes available or production technologies develop, the LCA can be updated to reflect improvements or new challenges in the SAF supply chain. [80]

### 3.7.2 Two LCA methods

An additional challenge is the choice of LCA methodologies. In general terms, two content-based ways of shaping the analysis exist: attributional and consequential, namely, where the limits are set on what is included in the analysis and on the consequences of those choices and decisions. It is, of course, possible to work with both in the same analyses as an integrated setup. There may be overlaps that are difficult to classify and may shade one method with the other, or parts of it. The possibility of using both methods as two scenarios against each other can be assessed, which, in most cases, must probably be regarded as the best way forward towards the most accurate overall picture possible.

**Attributional** is the most used method related to fuels for aviation and is a calculation of input versus output by various energies and materials. It models a fixed set of input categories, predetermined for each product category (e.g., HEFA), but which can vary across different production processes and feedstocks (e.g., biofuels versus RFNBO). The strength of an attributional LCA lies in the comparability between products and the current evaluation of GHG emissions. The cutback is the lack of system integration and reference to displacement. With market development and product substitution, sustainability is constantly evolving, and even if a product has a satisfactory GHG score, unintended side effects can have a negative environmental impact, which the LCA on its own has difficulty compensating for due to its fixed model.

The alternative is the **consequential** LCA, a model that can be tailored to the specific situation. It considers how products affect other markets, and if the product is cause to displacement. By integrating a system approach, the LCA can better show how the product will affect the

[80] RSB, guidelines and criteria for sustainability assessments

surroundings, and what changes are expected to happen due to demand and response in relation to a given product. *"An attributional life cycle assessment (ALCA) estimates what share of the global environmental burdens belong to a product. A consequential LCA (CLCA) gives an estimate of how the global environmental burdens are affected by the production and use of the product" (Thomas Ekvall, 2025)*[81]. It may be relevant in relation to the preparation of an LCA on the use of used cooking oils. If aviation takes up a larger share of available quantities, the consequence is that other sectors must do without. Then the advantage or disadvantage is moved between the sectors, and the overall GHG emission reduction is not achieved. An ALCA will not immediately take this into account, whereas a CLCA will. To address the criticism of the current practice, it is recommended that a future revision of the LCA model expand to include relevant factors on the consequences side.[82]

It is vital to note that the results of the assessments depend significantly on the input data. It should also be noted that EU regulation specifies how to calculate GHG values using the attributional model presented in REDII. [83]

**Feedstock transparency**

Another controversial issue related to the LCA method, and its challenges, is transparency in the first part of the supply chain. It has been a topic often discussed, and examples of violations or suspicious situations have been reported in the media and discussed among politicians and NGOs. There have been concerns about the transparency of the supply chain for SAF feedstocks, especially regarding used cooking oils.

It can be challenging to document the exact origin of used cooking oils. Thus, it is challenging to verify whether the oils originate from sources that meet the established sustainability criteria, such as whether virgin palm oil could be included. With tens of thousands of collection points for used cooking oil, it isn't easy to fully control. Without adequate traceability, there is a risk that unwanted or non-certified sources are used, undermining the credibility of the sustainable profile.

The quality of used cooking oils can vary considerably. Without strict and transparent quality controls, there is a risk that impurities or incorrect data will affect the final SAF production process. This can raise doubts about whether the feedstock used meets the criteria and standards.

One consequence of this is that information on origin and quality may be manipulated or not recorded correctly. This can lead to SAF being produced from these raw materials not meeting

[81] Tomas Ekvall, Attributional and Consequential Life Cycle Assessment, 2025
[82] Tomas Ekvall, Attributional and Consequential Life Cycle Assessment, 2025
[83] REDII, European Union, Directives on the promotion of the use from renewable sources, 2018

the sustainability criteria set out in, for example, REDII/REDIII and certification schemes such as RSB and ISCC.

**The challenges of scarce waste oils**

The report "Sustainability of fatty waste oils for biofuel production"[84] assesses the sustainability of various fatty waste oils as raw materials for biofuel production. The study covers ten different feedstocks, including used cooking oil (UCO), palm oil waste, spent bleaching earth (SBE), soap residues, animal fat, residues from FAME production, brown fat waste, wastewater, and food waste, compared with conventional transport fuels from fossil oil, gas, and electricity. The analysis focuses on overall sustainability issues, global availability, competing uses, the risk of indirect land-use change (iLUC), geographical dependencies, and possible mitigation measures.

A central focus of the analysis is whether the individual feedstocks are limited resources – i.e., whether increased demand leads to a corresponding increase in market availability. This dimension is particularly important for waste-based feedstocks, as these are often considered “free of charge” in greenhouse gas accounts. Increased demand for scarce feedstocks can lead to market adjustments, forcing other sectors to use new crops or virgin oils, thereby increasing the risk of predation and greenhouse gas emissions.

The results of the analysis show that most of the feedstock examined is either already scarce or is expected to become so in the near future. For example, demand for UCO is high, while availability is limited, which in practice shifts the market and increases demand for cultivated crops and virgin oils and fats, with high ILUC risks. On the other hand, there are feedstocks such as wastewater and food waste, which are currently largely disposed of and therefore have potential for increased utilization without these risks.

Overall, the results indicate that the use of fatty waste oils for biofuel production often involves indirect effects that can lead to increased climate footprint and market distortions. Sustainability assessments of pressed raw materials should consider indirect consequences more thoroughly and ensure that any increase in demand for waste oils matches the increased demand for collection and recycling.

Figure 29 shoes the quantities of transport fuel consumed in 2021, and the amounts expected in 2027 (biofuels) and 2030 (oil, gas, and electricity) (IEA 2023).

[84] LCA, Sustainability of fatty waste oils for biofuel production , april 2025

To understand the given numbers and quantities: 1 EJ = 23,885 kt.

| Transport fuels | 2021 [EJ] | 2027/30 [EJ] | Share in 2021 | Share in 2027/30 | Change 2021-2027/30 |
|---|---|---|---|---|---|
| Oil | 103 | 81 | 90% | 82% | -21% |
| Natural gas | 5.3 | 4.0 | 4.7% | 4.1% | -25% |
| Electricity | 1.6 | 8.0 | 1.4% | 8.1% | 399% |
| **Biofuels, 1st generation** | **3.9** | **4.6** | **3.4%** | **4.7%** | **20%** |
| Maize | 1.5 | 1.6 | 1.3% | 1.6% | 6% |
| Sugars | 0.86 | 1.0 | 0.8% | 1.0% | 11% |
| Soy oil | 0.45 | 0.71 | 0.4% | 0.7% | 60% |
| Rapeseed oil | 0.24 | 0.32 | 0.2% | 0.3% | 34% |
| Palm oil | 0.60 | 0.69 | 0.5% | 0.7% | 15% |
| Other crops | 0.27 | 0.40 | 0.2% | 0.4% | 48% |
| **Biofuels, 2nd generation** | **0.5** | **0.8** | **0.4%** | **0.9%** | **74%** |
| Used cooking oil (UCO) | 0.27 | 0.45 | 0.2% | 0.5% | 64% |
| Animal fats | 0.18 | 0.34 | 0.2% | 0.3% | 94% |
| Other wastes and residues | 0.04 | 0.05 | 0.0% | 0.1% | 45% |
| **Total** | **114** | **99** | **100%** | **100%** | |

*Figure 29 Sustainability of fatty waste oils for production, 2025* [85]

The EU's EASA and ECAC have also acknowledged the problem. Further investigations have therefore been launched, and some initiatives try to limit or solve this complex problem.

[85] Schmidt J, Kreutzfeldt K-E T, Muñoz I (2025). Sustainability of fatty waste oils for biofuel production, 2-0 LCA, 2025

## Sustainability Certification Schemes – Combatting fraudulent practices

*"With so much emphasis being placed on SAF to help reduce aviation emissions, the 'S' in SAF needs to live up to its promise and ensure the effective delivery of emission reductions while avoiding unintended negative environmental and social impacts of its production, thus contributing to the credibility of the sector.*

*Major regulatory frameworks, such as the EU RED and CORSIA, therefore make use of Sustainability Certification Schemes (SCS). The objective of SCS is to ensure that SAF meets the required sustainability criteria by controlling compliance with the sustainability requirements along the SAF value chain on a lifecycle basis. Audits are performed by ISO-accredited third-party certification bodies along the complete value chain, from raw material extraction to delivery of SAF to its point of use. In these audits, the auditor focuses on checking each economic operator's compliance with a defined set of sustainability criteria as well as traceability (Chain of Custody) and life cycle emissions criteria, thus ensuring that SAF is produced in accordance with the relevant regulatory requirements.*

*In recent years, SAF and biofuels upscaling have generated growing concerns about the fraudulent trading of non-sustainable feedstock or biofuels in the EU.*

*Fraudulent behaviour may ensue whereby products are labelled as meeting sustainability requirements even when they are non-compliant. This is highly problematic insofar as these practices threaten both the effectiveness and credibility of climate and renewable energy policies.*

*NGOs and European biofuel producers have repeatedly warned against dubious imports and raised concerns about the effectiveness of the certification schemes, which in part led to the development of the EU Union Database that will increase the transparency and reliability of the tracking system of renewable fuels along their supply chains. The Union Database is appropriately integrated in the reporting process of SAF supplied to EU airports under the ReFuelEU Aviation regulation and the EU ETS.*

*In response to these concerns, certification schemes have generally increased their efforts to enhance the credibility of the system, including unannounced integrity audits at randomly selected plants and economic operators. As a result, some sustainability certificates were withdrawn or temporarily suspended. They have also put in place a transaction database that is linked with the EU Union Database to prevent the relabelling of sustainability declarations, a mapping tool to support risk identification for auditors, specific guidance materials for waste and residue materials and evaluations of the technical feasibility of processing plants to deal with low-grade advanced waste/residue material"*

- EASA, Sustainability Certification Schemes, 2023 [86]

[86] EASA, Sustainability Certification Schemes, 2023

### 3.7.3 Non-$CO_2$

Emissions from aviation have traditionally been addressed as $CO_2$, though the latest research shows that non-$CO_2$ emissions account for between 50-75% of the warming effect from aviation.[87] Based on several studies, it is widely accepted that the RFI (Radiative Forcing Index) and the GWP average around 3.0. GWP (Global warming potential) is defined as the cumulative radiative forcing, both direct and indirect effects, over a specified time horizon resulting from the emission of a unit mass of gas related to some reference gas. The results were supported in December 2020 by the European Union Aviation Safety Agency (EASA), which acknowledged that the climate impact of aviation is around three times higher than $CO_2$ alone.[88] The non-$CO_2$-related impacts, mainly the impact of cirrus clouds and NOx, are generally twice as bad for the climate as $CO_2$ itself. Previous research has shown RFI/GWP levels between 2.0 and 3.0.

Non-$CO_2$ emissions from aviation refer to pollutants other than $CO_2$ that have a climate impact, including NOX, aerosol particles (soot and sulphur-based) and water vapor.

Some types of SAF have been tested and show the potential to create significant reductions in non-$CO_2$ emissions. The use of various types of SAF has also been shown to improve ground air quality, leading to lower levels of sulphur and aromatics that contribute to volatile and non-volatile particulate matter (PM) emissions.

Large parts of the non-$CO_2$ effects are related to the combustion of aromatics in the fuel that lead to the formation of particles in the exhaust jet and consequently to the formation of contrails. When aromatics are combusted, they produce soot, which is the main contributor to contrail formation. At high altitudes and under specific weather conditions, soot attaches to water, forming supersaturated ice crystals that form contrails. Most contrails dissipate within 3 minutes and are estimated to have negligible or no impact. However, if the contrails persist longer, they form cirrus clouds, which can exert radiative forcing, constraining heat from escaping or entering our atmosphere. Although the effect is short, the impact is severe.

The non-$CO_2$ discussion has intensified in recent years, and more studies are revolving around a better understanding of how it affects aviation's environmental impact. Following several flight tests by NASA and DLR, the first live flights to collect data on contrail formation were conducted, and more are expected to be launched to further increase data.

Studies have shown that burning fuels with low or no aromatic content leads to cleaner combustion (reduced soot particle emissions) and can significantly reduce the formation of contrail-cirrus clouds, which are considered the main contributors to the non-$CO_2$ effects. These studies are challenging to perform and only a handful have been carried out, but they all

[87] EASA: Report from the Commission to the European Parliament and the Council, Updated analysis (…) Article 30(4) 2020

[88] EASA, Final report: Updated analysis (…) Article 30(4), page 35-36, 2020

conclusively demonstrate the benefits of using SAF (at least the SAF options which are practically aromatics-free).

One could say that switching from fossil fuel to SAF would also solve the problems with non-$CO_2$. However, there is a challenge associated with a switch to low-aromatic fuels and especially to (non-drop-in) 100% SAF. The challenge is that the aromatics cause gaskets and rubber seals to expand, thereby preventing fuel from leaking from the aircraft's storage, tank and pipelines, which can pose a safety concern.

Conventional fuel is regulated by ASTM D1655 and has an aromatic maximum limit of 25% but no lower limit. ASTM 7566 has regulated thresholds of 8%-25%, which is commonly referred to as the standard for aromatics.

Non-$CO_2$ effects present a much larger climate impact (sustainability) issue than was previously anticipated. Airbus, ATR, Boeing, and institutions like DLR, NASA, and EASA are working towards 100% SAF uptake, which could result in the use of SAF practically free of aromatics. To undertake this task, demonstrations of safety and the development of technologies for the ability to fly on reduced or no aromatic fuel must be undertaken and have already begun by the mentioned organisations and aircraft producers.

Google Research, in collaboration with American Airlines and Breakthrough Energy, has developed AI models using satellite data to predict where contrails form. In a series of test flights over several months in 2025, adjusting flight altitudes reduced contrails by 54%, with only about 2% additional fuel consumption per flight. In fleet terms, this corresponds to about 0.3% increase in consumption, see Investopedia; *Google AI And American Airlines Tested Ways To Reduce Climate Impact Of Flights*[89], and as the Financial Times argues in the article "*Cutting aeroplane contrails is an easy climate win*"[90], that by rerouting just 2% of long-haul flights, the impact of contrails can be halved – at a low cost of USD 5-25 per tonne of $CO_2$ equivalent.

If non-$CO_2$ effects are considered more intensively in the future in the context of SAF sustainability, this could strengthen the focus on the full induced climate impact.

In the EU, non-$CO_2$ has been recognised as a significant challenge for aviation, but it has yet to be regulated. In ReFuelEU Aviation, it is stated that in 2027, the potential solutions for addressing non-$CO_2$ must be reported to the commission, with the purpose of adapting level playing field measures. Through the monitoring system, all flights from 2025 shall be reported and analysed, enabling a better understanding of the scale and impact of non-$CO_2$ emissions to be communicated in the political landscape. The revised EU ETS Directive requires aircraft

[89] Investopedia, Google AI And American Airlines Tested Ways To Reduce Climate Impact Of Flights, August 2029
[90] Financial Times, Cutting aeroplane contrails is an easy climate win

operators to monitor and report non-$CO_2$ aviation impacts once a year. The ambition here is to shape the EU ETS so it can be used as a tool to mitigate non-$CO_2$ impacts.

**European body for jet fuel standards and safety certification**

This European Parliament has requested a pilot project (2023-2027), implemented by DG MOVE and EASA, to explore the feasibility of optimising fuel composition in order to reduce the environmental and climate impacts from non-$CO_2$ emissions without negatively impacting safety (e.g. lower aromatics, sulphur). The project includes preparatory work to develop a fuel standard for kerosene whilst maximizing SAF benefits, as kerosene and SAF will be increasingly blended in the future. The project will also assess the potential establishment of an EU Aviation Fuels Standardisation Body.

EUROPEAN AVIATION FUEL STAKEHOLDER FORUM

*Figure 30 European body for jet fuel standards and safety certification* [91]

**Reporting highlights**

- **Implementation**: Operators must monitor non-$CO_2$ emissions from January 1, 2025, with reporting due by March 31, 2026.
- **Monitoring Methods**:
    - **Method C** (default) uses weather-based modelling and requires primary data collection.
    - **Method D** (simplified) applies to small emitters, relying on predefined climatological data.
- **Integration with EU ETS**: Non-$CO_2$ reporting is now part of the existing EU ETS framework, minimising administrative workload.
- **Verification & Compliance**: Updates to the Accreditation and Verification Regulation (AVR) will support non-$CO_2$ verification, with finalisation expected in 2025.[92]

### 3.7.4 Key non-$CO_2$ Updates

**Reporting:** The European Commission has released an updated Guidance Document for Non-$CO_2$ Monitoring, Reporting, and Verification (MRV) to help aircraft operators comply with new regulatory requirements, and the first version of the NEATS platform was launched on 29 September 2025. - NEATS has been decided by the European Commission and is operated

[91] EASA, European Aviation Environmental Report, 2025, page 60
[92] European Commission, MRV non-CO2 Guidance document for Aircraft Operators, 2025

within the framework of the cooperation agreement between EUROCONTROL and the European Commission's Directorate-General for Climate Action (DG CLIMA). The system will monitor, report and verify (MRV) climate impacts, including contrails and nitrogen oxides (NOx) emissions. The aim is to provide a technical solution that supports the aviation sector's adaptation to the EU Emissions Trading System (EU ETS) and contributes to climate innovation. The NEATS platform allows airlines to upload primary flight data (including flight paths, engine identifications and fuel flow), which can then be used to calculate non-$CO_2$ climate impacts. With the first version, airlines can already now:

- establish user profiles and accounts,
- upload and analyse data,
- prepare for future full compliance with the EU MRV framework for non-$CO_2$ impacts.

The **next version** of the NEATS platform will include functions for validating primary data and calculating non-$CO_2$ impacts. In **version three**, additional reporting options and dedicated interfaces for both verification entities and competent authorities are planned.[93]

### 3.7.5 Direct land use change and indirect land use change

The feedstock to produce biofuels is originally organic matter, most of which is cultivated by agriculture. As demand for biofuels increases, so do the pressures on land use and the prioritisation of feedstocks. This could directly affect the sustainability of SAF biofuel products, as the acquisition of feedstocks can result in significant GHG emissions and potentially put further pressure on food production, food security, biodiversity, and nature.

Of this problem, two terminologies have been developed, DLUC and ILUC, to describe the effects. DLUC refers to a direct change in agricultural practices from food production to energy crops, or from deforestation to energy crops. DLUC is directly observable and can easily be monitored, making it relatively easy to track.

ILUC occurs when biofuel feedstock displaces other products, requiring land-use change to meet demand (termed leakage and spillovers). When biofuels are produced on existing agricultural land, the demand for food and feed crops remains, which may result in the production of the products being moved to another location, which could imply indirect land use change. This process can be challenging to monitor and requires complex economic models, such as adapted LCA models (e.g., consequential), to detect ILUC.

Both DLUC and ILUC is in almost all regulations and certifications regarding biofuel as a common sustainability criterion. For example, ILUC values for biofuels are regulated in REDII.

[93] European Commission, The Commission and EUROCONTROL launch new IT tool to track non-$CO_2$ aviation effects on climate, Sep. 2025

### 3.7.6 Feedstocks

Biogenic feedstocks have been the primary driver of the SAF market and will continue to be a major part of the supply chain for many years**.** Especially UCO and animal fats have a large share of those available and used. However, it is undeniable that there is an upper limit to how much UCO can be obtained and similarly for other biofuels there will be limitations in the available quantities.

Until now, other alternative SAF products are very limited, and are expected to be so for some time to come. Biogenic feedstocks thus constitute the cornerstone of the production of sustainable aviation fuel and play a crucial role in reducing the climate footprint of aviation at least in the short and medium term, and despite the uncertainties associated with many of the biogenic raw materials. With raw materials originating from biological sources, SAF can be produced with significantly lower $CO_2$ emissions than traditional fossil fuels.

Unlike $CO_2$ from fossil sources, the prerequisite for biogenic is that the biological materials absorb $CO_2$ as they grow. Biomass is often considered $CO_2$ -neutral because the amount of $CO_2$ released when burned is equal to the amount absorbed by the plants during their growth. This makes biomass an attractive solution for reducing greenhouse gas emissions. However, there are challenges associated with biomass use, which is why life cycle assessments are crucial for understanding its real climate impact. Although biomass can be $CO_2$-neutral in the long term, burning biomass can result in short-term $CO_2$ emissions. It is therefore crucial to consider the entire life cycle from production to consumption and the consequences thereof to ensure that biomass use is truly sustainable.

Raw materials from biological sources can be obtained from both waste and residue streams as well as dedicated energy crops, which can be grown sustainably to provide biomass for, for example, fuel production. One of the most widely used products is used cooking oil (UCO), which is collected from restaurants, households, and food processing plants. In addition, agricultural and forestry waste that would otherwise be landfilled or incinerated can be used, creating a double win: waste reduction and the simultaneous production of renewable energy. Dedicated energy crops grown on marginal land where soil is unsuitable for food production can also be used. Furthermore, the potential of microalgae and specific industrial organic waste streams for conversion into fuel using advanced technologies is being investigated.

One and the same type of biomass can have multiple end-uses and functions, also within the nature and biodiversity area. Biomass removes $CO_2$ from the atmosphere and stores carbon both in living biomass and biomass products. Biomass can replace fossil- and mineral-based materials with bio-based materials and products, thereby reducing greenhouse gas emissions. But biomass also needs to be restored to absorb $CO_2$ and to ensure the functioning of nature and biodiversity.

As mentioned in the LCA-section 3.7.1, an essential prerequisite for ensuring the sustainable use of these feedstocks is that the entire supply chain is traceable, can be calculated and documented. Certification schemes such as RSB and ISCC play a central role here by ensuring that the raw materials used meet strict environmental, social, and economic criteria. This is essential to meet the EU's REDII/III requirements, which entail significant reductions in greenhouse gas emissions and sustainable use of resources. From a global perspective, agreed sustainability criteria should be used as a basis for the use of biomass, but many aspects remain uncertain, and several aspects of how biomass quantities and qualities develop need to be investigated. For example, how climate change affects crops and growing conditions.

As demand for biomass is increasing and competing across several sectors, including nature protection, it is necessary to set political priorities for its use. This means that the actors concerned will need to understand and discuss the trade-offs between achieving political goals and using the biomass available now, while ensuring future supply.

### 3.7.7 Biomass concerns and balances

With the EU's climate-reduction targets, biomass plays an important role in the transition, but resources are under pressure. First-generation biofuels derived from agricultural crops such as rapeseed, sugarcane and maize are mainly used in road transport, but their future is constrained by sustainability requirements, land competition, and the EU cap on food-based biofuels (max. 7%).

Focus increasingly on second-generation biomass, such as manure, straw, forest residues, and organic waste, for the production of advanced biodiesel, bio-LNG, and SAF. The potential of agricultural residues such as straw is significant, especially in countries such as France, Germany and Denmark, but exploitation is hampered by investment needs, plant location, logistics and transport.

Forest biomass is primarily used for energy and heat, but is increasingly criticised for its impacts on biodiversity and slow $CO_2$ sequestration (sink). Therefore, its role in transport is limited. Access to forest residues, their utilization rate, and management responsibilities vary by country.

Marine biomass (algae and seaweed) is considered promising in the long term but is still technologically immature and expensive. It is also not without problems to exploit.

Overall, it can be said that biomass should only be used in transport where electrification and e-fuels are not realistic – for example, in aviation and heavy road and sea transport. At the same time, EU institutions emphasise the need for a much more developed system analysis, optimised use of waste, higher sustainability requirements and well-thought-out prioritisation between bioenergy and other sectors.

Many analyses of biomass availability have been carried out. With results that vary from the finding that there is sufficient biomass to cover the transport sector's 2030/50 needs on sustainable terms,[94] to analyses that conclude that there is already a global use of biomass (especially soy and palm) that causes greater CO2 emissions than fossil fuels, and that it therefore does more harm than good to biodiversity and climate.[95]

The latest analysis from the EU's Joint Research Centre (JRC) recommends that inappropriate developments be prevented everywhere:

"While biomass production and extraction in the EU continue to grow, its long-term viability is at risk due to declining ecosystem conditions. The JRC report calls for more coherent governance and urgent actions to ensure that biomass production and use are compatible with ecological limits and EU policy goals. JRC therefore proposes a wide range of regenerative actions: EU Biomass supply, uses, governance and regenerative actions.[96]

### 3.7.8 Hydrogen

Hydrogen production is a well-established technology, and demand has increased significantly, almost threefold since the 1970's. The current production process primarily uses fossil fuels — mainly natural gas (i.e., methane), called grey hydrogen, or coal, called black/brown hydrogen. If grey hydrogen production integrates CCS technology that lowers GHG emissions, the process is called blue hydrogen.

The previous three production paths are all unsustainable and utilise fossil fuels. With the expectation of a significant rise in hydrogen demand due to regulation and new technological developments, the most sustainable production will be green hydrogen. This method uses an electrolyser to split water molecules into hydrogen and oxygen. The vital factor is the energy required to operate the electrolyser, which must be renewable, leading to very small emissions and significantly lower than those of all other methods.

Geography is vital to consider because of societal differences in infrastructure investments (Hocksell 2022). In the Nordics, where RE plays a considerable role, countries can produce low-emission hydrogen, but that would not be the case in many other parts of the EU for some time. Geographically opposite, in the southernmost areas such as Africa, the conditions for producing green hydrogen will be even better, with efficient use of solar energy through photovoltaic and wind power plants.

[94] MDPI, Analysis of the EU Secondary Biomass Availability (...) Metric Evaluation for the 2025 Perspective, 2021
[95] Cerulogy, Diverted harvest: Environmental risk from growth in international biofuel demand, October 2025
[96] European Commission, Healthy production systems are key to sustainable biomass supply, June 2025

As previously described, the delegated Act 1 of REDIII has set regulations for what constitutes the production of green hydrogen. The ruleset for green hydrogen is currently not regulated outside the EU.

### 3.7.9 Carbon

With an RFNBO blending mandate from the EU and PtX entering the market, the acquisition of carbon represents both significant opportunities and environmental challenges.

Carbon is naturally present as the primary ingredient in fossil fuels but must be extracted from other sources if it is to be converted into a new fuel product, such as SAF. For this case, there are three viable options: Biogenic sources (such as biogas), point sources (such as industrial flue gases) or direct air capture of CO from ambient air.

Biogenic sources are a combined energy supply and waste management practice. A variety of biomass feedstocks can be used to produce biogas, including animal manure, organic waste from the food processing industry, bio-waste from households, and residues from wastewater treatment plants (i.e., sewage sludge), as well as corn, grass silage, or sugar beets. The production of biogas is a well-known and broadly used technology. Through anaerobic digestion of organic matter, biogas is produced that mainly consists of methane (CH4) and carbon dioxide ($CO_2$), with nearly equal shares.[97] By "classical" gas cleaning processes, the $CO_2$ molecules can be extracted and utilized as the carbon source for PtX process. Since carbon is initially captured in an organic process that can be repeated, biogas is also a form of waste treatment; its feedstock is considered sustainable. However, as with biofuels, we must be aware of the sustainability of the feedstock. If demand for biogas components increases, it poses a risk of fraud or unsustainable practices. This is not as likely nor imminent as the case of UCO, but must still be addressed to avoid negative impacts on the environment.

The second method of extracting carbon is through so-called point sources. When industries generate emissions from production, a carbon capture technology can be installed to separate carbon dioxide from other gases and store them separately. Subsequently, the carbon can be filtered and used in other productions.

If point sources are used to make products like SAF, it becomes an end-of-pipe solution. This means that the emissions are not removed from the total but deferred to other products. This will naturally reduce the total carbon demand in the grand scheme of things, but the carbon will be added back to the atmosphere.

[97] Kaltschmitt & Neuling, Techno-economic and environmental analysis of aviation biofuels, 2018

The third method of extracting carbon is direct air capture (DAC). DAC is one of the most promising technologies in the carbon capture, utilisation, and storage (CCU) and/or carbon capture and storage (CCS) industry. It can potentially deliver enormous amounts of carbon. By extracting carbon directly from the atmosphere, greenhouse gas emissions are reduced. By utilising the captured carbon in production, further emissions are avoided, and if it is stored underground, emissions are eliminated. Although this seems promising, it is not without challenge or reservations. DAC requires large quantities of renewable electricity (RE) to operate, markets need to be established, logistics and facilities figured out and so on.

This kind of carbon market is relatively new, with rules and regulations still evolving. In 2021, key targets for sustainable carbon cycles were set in the EU (European Commission n/d, A). Since 2009, the EU has had a strong focus on carbon capture and storage through the implementation of a CCS directive.[98]

Today and in the future, the challenges of increasing access to renewable energy and feedstocks, hydrogen, and carbon are becoming more relevant, and these can be discussed, commented on, and addressed in the table below, which compiles current topics in this regard.

[98] European Commission, Guidance Documents to the CCS Directive, 2024

| Feedstock challenges | Comments from | Addressed to |
|---|---|---|
| Initiatives that can help ensure greater sustainability of biogenic feedstocks.<br><br>Opportunities in Europe to increase the amounts of available biogenic feedstocks?<br><br>Qualified analysis of feedstock availability in the short, medium and long term?<br><br>Opportunities in Europe to increase the amount of sustainably produced hydrogen?<br><br>Opportunities in Europe to increase the amount of available carbon resources?<br><br>What opportunities exist to influence the development and availability of feedstocks for PtX/eSAF?<br><br>What mechanisms can ensure that usable and sustainable raw materials for synthetic fuels are appropriately prioritized for aviation?<br><br>What mechanisms can ensure that there is sufficient access to renewable energy to produce aviation fuels? | | |

*Figure 31 Questions regarding increasing access to sustainable feedstocks and renewable energy*

## 3.8 Sustainability and SAF procurement tool

Access to SAF is a difficult challenge. Until 2025, there have been very few opportunities to purchase SAF, even though scattered purchases have been made globally, mainly in the USA. The market has been and still is limited and immature. Only very few suppliers have had storage tanks with SAF, and the supply has been small in quantity. In a European context, the choice of production routes or raw materials has been even narrower, as almost only HEFA-produced SAF has been available so far. However, limited co-processing SAF products have also reached the market, presumably especially in France.

In the first half of 2025, the SAF market intensity in Europe appears to have been largely taken over by the RefuelEU Aviation mandate that came into force in 1. January 2025. There are differing assessments of whether the available SAF quantities will be sufficient to meet the 2% minimum requirement from 2025. Some analyses indicate that there will be enough quantities and that producers will be able to meet blending mandates, while others suggest it may be difficult. Many point out that, given current prospects for initiating additional SAF production, it may be even more challenging to reach the 2030 target of a 6% SAF blend-in, of which 1.2% must be synthetic aviation fuel.

Although efforts to meet minimum requirements may become dominant, there must still be room for consideration in the acquisition, evaluation, and use of SAF products. Having described the SAF and jet fuel routes from supplier to airport and to the end user, the following chapter will outline considerations and preparations the SAF buyer can make before placing an order.

The aim is to provide a substantive overview to support and expand the application of sustainability criteria and best practices when purchasing SAF. Regarding SAF buyers, we primarily have airlines in mind, but other actors could also be relevant. These may be companies or consultants tasked with qualifying assessments on behalf of an airline, or experts tasked with assessing the sustainability aspects of one or more products on behalf of an airline's customers. They may also be direct customers or other relevant stakeholders who wish to delve deeper into the subject.

To be considered at all, and thus at a minimum, any SAF product must be able to meet ASTM D1655 or Def Stan 91-091 approval requirements as Jet A-1 and meet the rules and criteria as described in RefuelEU Aviation. Blend-in SAF are certified by ASTM D7566 and, as such, does not necessarily comply with all safety and technical standards for Jet A-1. Blend-in SAF is Jet A-1 and therefore treated in the same manner as Jet A-1. There are no issues with handling, safety, or technical quality.

The sustainability procurement tool/checklist (see next section) aims to enable a more holistic assessment of potential products. Not all SAF products are equally sustainable. It is essential to be aware that SAF will be a very broad category that, in the future, may encompass many products that differ in greenhouse gas impacts, raw materials, factors affecting sustainability, performance, etc. Therefore, end users, customers, media, and authorities will demand data on the value of SAF products, given the overall goal of achieving satisfactory GHG reductions. Even within a single pathway, there can be significant differences in sustainability, determined by the availability of feedstock, transport circumstances or energy use in the manufacturing process. Furthermore, there are divergent views on whether the currently used LCA methods (attributional) are sufficient to provide an accurate picture of the greenhouse gas reductions, and whether LCA methods (consequential), which include the impact on other sectors or environments, should be used instead, or to some extent, when a specific raw material or method is used. There is undoubtedly plenty to do at present to implement the new EU mandates and ensure that SAF deliveries meet the set targets, both in the short and long term. However, the here-and-now challenges must not prevent us from assessing which steps are needed to move forward from a sustainability perspective. Already now there is widespread scepticism or criticism of the primary feedstocks used so far, depending perhaps on which country, region, or what involvement one may have in the subject. But the critical considerations are also relevant reasons why aviation industry players must be aware of sustainability contexts and, from there, be able to discuss, recommend, and work towards the most responsible and sustainable decisions.

The checklist reviewed later is based on the established SAF criteria, which are presented in RefuelEU Aviation and in the Renewable Energy Directives REDII/III, respectively. (Read more in ALIGHT WP 3.2 Best Practices Handbook and Tools for Fuel Logistics, Quality Monitoring). [99]

### 3.8.1 SAF purchasing

Buying jet fuel is already a challenging issue for airlines. Because prices vary, hedging contracts are often entered into to offset price fluctuations. Most often, this is done in combination with short-term contract focus, which is also the preferred method for many companies. Refuelling at different airports is subject to varying fees or charges, and several other factors also come into play. Purchasing SAF can add another layer of difficulty, both within companies and in the mandatory subsequent accounting, including registration and reporting to the EU and authorities. In this section, we review sustainability issues in SAF products and identify considerations relevant to these contexts. (See also SAF price structures, SAF Off-Take Agreement and types of SAF purchasing agreements in ALIGHT WP 3.2 Handbook section 5). [100]

The purpose of a checklist is to support the sustainability criteria and thereby guide best practice, drawing on expert networks. The checklist should enable the right questions to be

[99] ALIGHT 3.2: Best Practice Handbook (...), 2025
[100] ALIGHT 3.2: Best Practice Handbook (...), 2025

raised regarding products, processing, transport, and compliance with relevant regulations, whether these relate to EU criteria, CORSIA, or the company's sustainability goals.

Not all SAF products are on the same sustainability level. It is important to be aware that SAF is only an overarching category consisting of products differing in GHG impacts, feedstock availability, circumstances affecting the sustainability, performance etc. To support the promotion of the "best" sustainable aviation fuel, based on a holistic sustainability performance, we intend to review the main topics. For the buyer, the price of a SAF product is always of great importance. How price and sustainability considerations are combined and decided must be an overall decision based on various short- and long-term factors that can vary depending on what is possible, one's own priorities, and market opportunities.

**There are several ways to purchase SAF,** depending on the objectives, needs, regulations, and market availability. Here are the primary models:

This can be done by direct purchase of physical SAF, where airlines, airports, companies, or others buy SAF directly from producers or fuel suppliers, and, as is most often the case, it is blended with conventional fuel and delivered in a mass balance system to the agreed airport. A physical delivery can also be made directly to an aircraft or airline, but as a segregated delivery, it will incur certain additional costs.

It can also be done through a certificate-based purchase, also known internationally as the Book & Claim model. This is done by the buyer paying for the SAF product, which is then used by airlines elsewhere, where it is more easily accessible. In this system, an independent certification of the $CO_2$ reduction must be issued to the buyer, typically via a digital platform. This enables investment in SAF, even if it is not physically available at a given airport and must be considered a flexible solution for companies that want to reduce their $CO_2$ footprint. Disadvantages of the Book & Claim model may include the airline or buyer not using SAF physically and being dependent on a credible certification mechanism. Furthermore, there is a fear that the possibility of gaining insight into the true sustainability value of products is reduced, for example, due to different criteria across the global landscape and a lack of certainty to avoid double accounting and additionality. For these and other reasons, the Book & Claim model is not part of the RefuelEU Aviation concept but is expected to play a role in the voluntary market. - The choice of purchasing method depends on the company's needs, access to SAF, financial considerations and possible regulatory requirements. In general terms, physical purchases clearly demonstrate the SAF application, while Book & Claim and potential offset agreements are expected to provide greater flexibility and scalability in the market. Until a universally accepted system with sufficient safeguards (e.g., regarding double counting and additionality) is in place, businesses should approach such purchases with due diligence, transparency, and certified documentation.

An airline or airport can also have the purchased SAF quantities co-financed by customers or stakeholders who are invited to participate in a program the company has launched for SAF use. For example, SAS, KLM, and the Swedish airport operator Swedavia have such corporate programs.

**The practical supply agreements** can also vary. The most common are long-term supply agreements that airlines or companies enter with producers or suppliers for the future delivery of fuel, typically combined with a mix of SAF quantities, as further agreed. Agreements can also be made for batch deliveries to specific aircraft, routes, or other more precisely defined purposes, often time limited. There are also examples of airlines making direct investments in production or price-fixed volume agreements, which can ensure supply during specific periods. Here, the most common are agreements to help producers with financing new facilities. Something that requires significant capital commitments and long-term commitments and/or risk of delays in production and does not entail $CO_2$ reductions before deliveries are initiated. Examples of such agreements are United Airlines' agreement with World Energy and Lufthansa's SAF contracts with Neste, but there are several others.

There are also examples of partnerships between airlines and public or government actors that prioritize reducing their carbon footprint. Or associations or foundations such as Fly Green Fund that, on behalf of interested customers, purchase SAF in quantities that, for example, correspond to the flights made annually by the respective customers.

SAF can also be purchased via energy trading platforms or energy markets, where companies can buy fuel as part of an energy certificate or quota-based model linked to the EU Emissions Trading System (ETS) or similar initiatives. This can help create a market that enables scaling. At first glance, it is not a readily transparent structure for the individual buyer to relate to.

With the introduction of the EU's SAF blend-in mandates from the beginning of 2025, the most common procurement method will likely be integrated into standard procurement agreements, with associated supply contracts between suppliers and airlines covering prices, quantities, locations, and duration. However, for the first many years, SAF supplies were concentrated on a limited number of European airports.

All reporting and calculations regarding SAF supplies, blend-in SAF quantities, and qualities are handled in the reporting systems established by the EU, where suppliers report to EASA and airlines report to the Union Data Base. (See sections 3.3 and 3.4)

Regardless of the purchasing method, delivery location, SAF supply agreement, and reporting requirements, there may be good reasons for those who buy SAF to specify which products are supplied. This applies to the quantities provided within the EU mandate: 2% from 2025. It also applies to quantities voluntarily invested beyond the mandate, regardless of the source from which they are supplied.

From a general point of view, it is recommended that every buyer should try to protect themselves as best as possible against questionable SAF products. It is crucial to demand full documentation for Proof of Sustainability (PoS) or Proof of Compliance (PoC), as well as the Product Transfer Document (PTD). There are examples of suppliers failing to provide such documentation to airlines or other SAF buyers. In the future, buyers should stipulate that it is an incorporated part of SAF purchasing agreements. It will often be the end user who needs to document the sustainability of the purchased product and its associated specifications.

There will be several topics, both practical and strategic, that may need further exploration. The following checklist highlights the key topics, questions and challenges:

## 3.9 SAF best practice framework – What to consider ordering SAF

### 3.9.1 Checklist

**1. Compliance**

- SAF must comply with the sustainability criteria of the EU Renewable Energy Directive (RED II/III) and the RefuelEU Aviation Regulation.
- Lifecycle greenhouse gas reduction: Must deliver $CO_2$ reduction compared to fossil jet fuel, at least 65% if biobased and 70% if synthetic/RFNBO
- Renewable energy use in SAF production processes
- Sustainability certification: The fuel must be ISCC EU or RSB certified and registered in the EU Union Database (UDB). [101]
- What is the aromatic content?

**2. Sustainable feedstocks**

- Do not compete with food production, harm biodiversity, or deplete water and soil resources.
- SAF may only be produced from approved raw materials (e.g., used cooking oils, forestry and agricultural waste, $CO_2$ from industry or biogenic)
- Avoid feedstocks linked to deforestation, land-use change, and fossil-based energy
- Life-cycle assessments (LCAs) to measure full supply chain sustainability
- Has the choice of feedstock led to any risk of displacement?

**3. Transparent and traceable supply chains**

- Ensure SAF can be traced back to its origin to maintain accountability

[101] IATA Who Provides SAF Sustainability Certification? SAF Sustainability Certification Guidance, June 2024

- Digital systems for tracking and reporting throughout the value chain
- Sustainability certification from recognised standards (e.g., ISCC, RSB)
- Regular third-party audits

**4. Technological and certification approval**

- SAF needs ASTM D7566 approval to be blended into conventional jet fuel.
- Approved pathways: HEFA (Hydroprocessed Esters and Fatty Acids), AtJ (Alcohol-to-Jet), PtL (Power to Liquid, eFuels or eSAF), FT-SPK (Fischer-Tropsch Synthetic Paraffinic Kerosene)
- All fuel products must meet JIG (Joint Inspection Group) 1 & 2 standards for airport handling

**5. Procurement model and contractual conditions**

- Physical delivery (at a given airport, airplane)
- Mass balance model (delivery to the agreed airport and multiple users)
- Book & Claim model ($CO_2$ reduction is credited to the buyer without physical use of SAF)
- Long-term supply agreements (often with price hedging)

Contracts should ensure:

- Price fixing and indexation (SAF is more expensive than fossil jet fuel)
- Delivery commitments, time and volume (ensuring access to agreed SAF amounts)
- Sustainability certification documentation

**6. Monitoring, Reporting, and Verification (MRV)**

- Ensure accurate measurement and reporting of SAF's sustainability performance
- Demand data/documentation regarding certification, quantities, transport, and delivery aligned with data to EASA/UDB
- Establish clear MRV protocols for GHG savings and sustainability metrics
- Use third-party verification for data accuracy
- Publish annual sustainability reports

**7. Economic and regulatory alignments**

Buyers should examine economic and regulatory factors:

- Aligned, communicated, and prepared in relation to EU and national mandates
- Subsidies or tax advantages in the EU or member states
- Quota obligations in the EU's ETS (Emission Trading System)
- RefuelEU Aviation's increasing SAF requirements (from 2% in 2025 to 70% in 2050)
- Advocate for standardized and improved SAF definitions and certifications

**8. Economic viability, accessibility, and scalability**

- Explain SAF use in an economically, future and sustainable perspective
- Get hold of prices, suppliers, qualities, sustainability angles, media follow-up and more
- Promote public-private partnerships to fund SAF projects
- Be aware, where relevant, of the infrastructure for SAF blending and distribution

**9. Public Awareness and Collaboration**

- Build awareness and foster collaboration among stakeholders.
- Campaigns to promote SAF's benefits.
- Engage with airlines, airports, and passengers on SAF adoption.
- Share best practices across the industry through forums and other events
- Encourage government incentives and subsidies.
- Encourage private and public investments in sustainable solutions

**10. Risk Management and Resilience**

- Address risks related to feedstock availability, market volatility, and regulatory changes
- Address risks related to feedstock sustainability and media, political, NGO's and researchers' views
- Develop risk mitigation strategies (e.g., diversified feedstock sources)
- Advocate for sustainability-, feedstock- and production-improvements
- Monitor regulatory landscapes and adapt quickly
- Ensure business continuity through resilient supply chain planning

### 3.9.2 Considerations in the SAF landscape

- Partnerships with SAF producers, suppliers, and developers to secure reliable supplies
- Review the regulatory landscape and incentives related to SAF adoption
- Value and accountability for emissions reduction within the organization (scope 1-3)
- Visualize the demand for SAF within your operations
- Evaluate the various types of SAF available and their environmental benefits
- Internal stakeholders who could play useful roles in a SAF strategy
- Analyse market trends and forecasts for SAF options, pricing, and availability
- Physical fuel and/or investments in SAF developments and buying SAF certificates
- Decide emission reduction targets and timeline to manage the strategy
- Potential external partners and collaborators related to the SAF value chain
- Continuous innovation and technology development
- Pilot innovative projects, research, and development to improve SAF options
- Invest in/sign up for advanced biofuel and synthetic fuel technologies
- Collaborate with universities, research institutions and developers

### 3.9.3 Additional comments

Dealing with the many ordering and purchasing issues can be daunting. The immaturity of the market, the few manufacturers, the lack of experience, and the resulting widespread uncertainty about prices, sustainability, and certifications probably mean that many do not go into detail and therefore choose to postpone or address the many questions and issues pragmatically. Some SAF buyers will probably be satisfied with information and assessments from the suppliers. Therefore, the requirements for supplier roles should be clarified so that, as responsible suppliers, they can address relevant questions and communicate accurate information about the products. This requirement is, of course, also aimed at manufacturers, who are primarily responsible for data and certifications related to the products and who deliver the primary data to the suppliers. Furthermore, although it is not particularly widespread, some manufacturers also seem to be able to perform the supplier's tasks.

From the buyer's perspective, price is traditionally crucial, and since any SAF so far has been significantly more expensive than conventional fuel, any purchase of SAF is an additional challenge not only as a complex matter to handle but also as a major financial challenge.

The content of the reporting requirements for the suppliers that have now been established through RefuelEU Aviation can be a great help in the procurement processes as routines and experiences as well as dialogues and collaborations are developed as larger market shares are gained, price structures exposed to competition are created, that the market mechanisms begin to work, and that knowledge of sustainability criteria takes root among the actors.

#### 3.9.4 SAF status and forecast

So far, we have not seen the breakthrough in SAF production that we would like. Globally in 2024, SAF production accounted for only 0.53% of total aviation fuel consumption. In Europe, it appears that the use will reach approximately 2% required by the mandate by 2025. This finding is based on analyses and reports from IATA, SkyNRG, ACI/ICF, FuelsEurope and others, including dialogue with fuel suppliers. - But what does the future hold? A SAF forecast can be a comprehensive and uncertain undertaking. Most uncertainties stem from the fact that expected plant launches may be dropped or postponed, which has happened many times. However, several analyses have been conducted of the SAF supply situation from where we are today in 2025, to 2030, and to 2050. If we stick to European conditions, it is the general assessment that the decided mandates can be achieved in both 2025 and 2030 regarding the bio SAF part, whereas it is very uncertain whether it will be possible to establish plants and produce eSAF to a scale equivalent to 620,000 tonnes needed to meet the 1.2% eSAF requirement in 2030/32.

It is estimated that, in the EU, approximately 1 million tons of SAF will be available under the 2% mandate in 2025, and this demand is expected to be met. In 2030, the 6% EU mandate corresponds to approximately 2.7 million tonnes/year.

Also, regarding the global development, SkyNRG & ICF's 2025 market report estimates a SAF capacity of 18.1Mt in 2030, including the EU part, with a global demand of approximately 15.5Mt under "current trends", which also points to excess supply. This is based on existing and announced plants.

EU countries should then be on track to meet the SAF mandates in 2025 and 2030. Capacity is expected to exceed demand by approximately 0.5–1.2Mt/year in 2030. However, the market balance is vulnerable to project delays and regulatory instability. To maintain momentum in the future, increased production of advanced SAF types (PtL, ATJ), as well as policy certainty and incentives, are crucial.

HEFA (Hydroprocessed Esters and Fatty Acids) is dominating the SAF portfolio in 2025, accounting for 99% of SAF in 2023[102]. and is expected to account for 80-85% of capacity in 2030. Unless there is an immediate and extensive expansion of European production facilities, most supplies will come from Asia, primarily China. With the adopted political goals for SAF in Asian countries, competition will lead to higher prices, further supporting decisions in favour of European plants.

The HEFA technology offers several advantages: it is relatively simple. UCO and animal fat are energy-dense raw materials with a high content of $CO_2$. However, the success of HEFA has also created several challenges. The demand for used cooking oil (UCO) exceeds supply within the EU, increasing dependence on imports and, at the same time, motivating producers outside the EU to refine and export finished fuel rather than simply supplying raw materials.

One of the consequences is that HEFA, in practice, exclude other technological paths to SAF. A potential investor in a plant type based on lignocellulosic waste resources will face higher technology risks and production costs, without achieving higher revenues than with an HEFA plant. This imbalance between societal benefits and private economic risk has led to limited investments in alternative technologies to HEFA in the EU.

In addition, UCO and animal fat have other markets, especially diesel users, but there is also a limit to how much is available over a few years. The question of whether fraud and scams also occur in connection with the use of UCO is examined in sections 3.7.1 and 3.7.2.

T&E believes that there should be a separate ceiling on UCO for aviation in Europe of 2% and thus finds the adopted ceiling of 1.7% for all transport insufficient.

Since HEFA manufactured SAF primarily using UCO, which is dominant, it is relevant to examine the availability of UCO. As a starting point, on a global level, this market spans many borders, whether as a raw material or as a finished, processed fuel product, including SAF. As shown in the global overview below, according to ICF metrics, many other factors also play a role in the development path that can be chosen.[103]

[102] ACI: European SAF Industrial Policy, 2025, page 13
[103] IATA, SkyNRG, ACI/ICF, FuelsEurope; European Fuels Industry: on track to meet current SAF mandate and exceed 2030 targets, May 2025

| Metrics | EU | US | China | Description |
|---|---|---|---|---|
| Access to UCO feedstock | ◔ | ◑ | ◕ | Europe collected 0.8 Mt UCO in 2023, compared to 1 Mt in the US and 3.4 Mt in China |
| Cost of electricity | ◔ | ◑ | ◕ | EU average electricity price of $0.24/kWh, compared to $0.18/kWh in the US and $0.07/kWh in China |
| Cost of natural gas | ◔ | ◕ | ◔ | EU average natural gas price of €0.55/m$^3$, compared to €0.13/m$^3$ in the US and €0.47/m$^3$ in China |
| Low-carbon electricity | ◕ | ◑ | ◔ | EU average electricity emissions intensity of 244 gCO2/kWh, compared to 370 gCO2/kWh in the US and 581 gCO2/kWh in China |
| Construction costs | ◑ | ◑ | ◕ | EU and US construction costs are similar, and between 70%-130% greater than in China |
| Refinery expertise | ◕ | ◕ | ◕ | The EU refines 12 mmbpd, compared to 18 mmbpd in the US and 19 mmbpd in China |
| Permitting simplicity | ◑ | ◑ | ◕ | Higher backlog of renewable projects in the EU compared to the US and China |

*Figure 32 Comparing seven metrics for sustainable fuel developers in the EU, US, and China* [104]

In the next illustration, ICF estimates the size of the HEFA share and the growth rate. It is important to note that *"ICF expects that by 2030 HEFA SAF volumes will plateau as feedstock becomes constrained"* - ICF Analysis, 2025 [105]

[104] ACI: European SAF Industrial Policy, 2025, page 15
[105] ACI: European SAF Industrial Policy, 2025, page 9

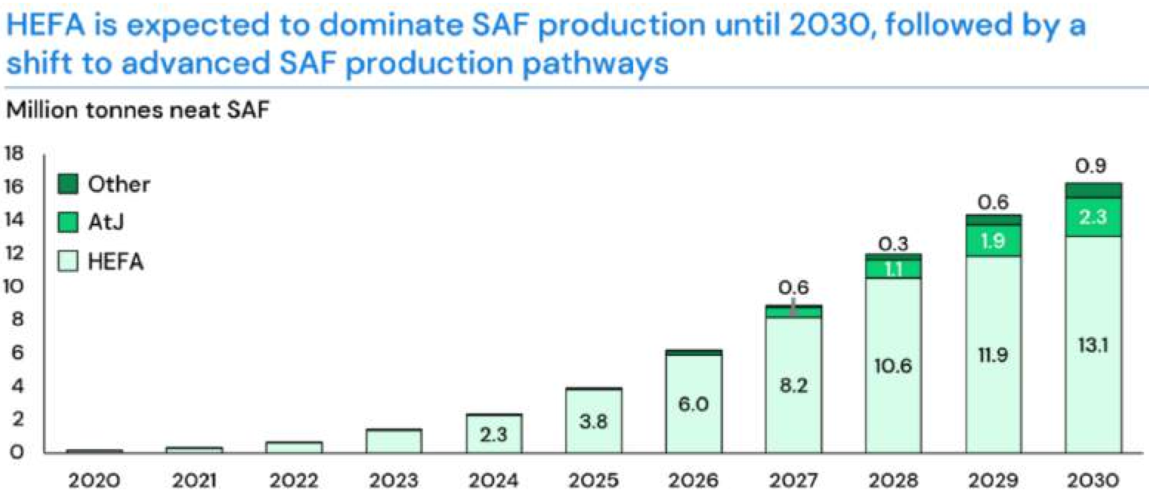


*Figure 33 HEFA expected to dominate SAF production*

There are several analyses of the availability of feedstocks based on UCO and animal fat. Stratas Advisors has reviewed the collected quantities and the potential. If we look only at Europe, the availability of UCO is approximately 55% of the total potential. The collection experience is relatively well developed, and the total quantities amount to 924 KT, while the potential is estimated to be 1669 KT. Spain, Germany, Italy, and the UK collect the most considerable quantities, as can be seen from the bar graph below of all the European countries:

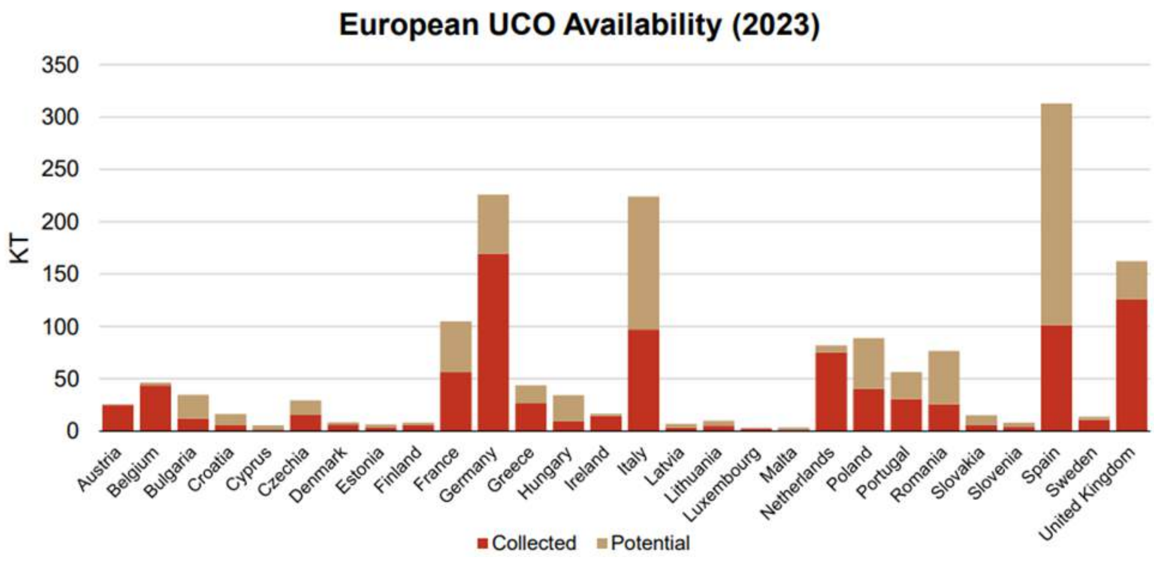


*Figure 34 European UCO Availability, 2023* [106]

Notice: Potential volume estimates represent the theoretical collectable volumes

[106] Stratas Advisors: UCO Imports: Unfair Competition with EU UCO Industry?, 2024, page 9

Compared with European UCO volumes, the potential in Asia is estimated at around 8,409 KT in 2023, of which approximately half has been utilised.

As for biomass and household waste, much of it is already used in existing value chains, including for recycling, composting, and biogas production. Similarly, agricultural residues such as straw and manure are often used for soil improvement, animal bedding, or feed. These existing uses reduce the availability of residual biomass for producing sustainable aviation fuel (SAF), thereby limiting the deployment of SAF from advanced biofuels. The same challenges apply to other types of biomass-based fuels.

The use of UCO as a feedstock for sustainable fuels raises both environmental and sustainability concerns. Many countries and researchers have expressed scepticism about the risk of fraud, for example, in reported cases where new (virgin) oil is mixed with UCO to "artificially" increase the declared UCO quantities. A practice that undermines the credibility of sustainable fuel schemes.

In addition, there is a significant sustainability problem in international trade flows. Exporting countries may choose to use palm oil to meet their own biofuel demand, while exporting UCO to, for example, Europe. Similarly, countries that traditionally use UCO for animal feed or other purposes may choose to export the oil and use palm oil domestically instead. These practices raise serious environmental concerns. They can lead to indirect land-use changes and, to an even greater extent, contribute to increased deforestation, especially in Asian countries where palm oil production is concentrated.

The limited availability of the most easily convertible feedstocks necessitates the use of alternative solutions, including synthetic fuels produced from renewable energy for hydrogen production and carbon capture. The use of waste products from households and industry will also be an essential raw material, but requires significant development, decision-making, and investment initiatives to ensure the realisation of new plants that can utilise these resources. Alcohol-to-jet (AtJ) is challenging to see as a significant and widespread option because it is based primarily on raw materials, i.e. food products, that are not approved for use as fuel in Europe. - Many of the advanced biofuels listed in Annex IX, Part A, of RED III are still at the development stage and face significant technological and economic barriers, which could be very limiting for the possibilities of large-scale production.

### 3.9.5 SAF market in EU 2025 – 2030

In early July 2025, WP2, inspired by inputs from the organization FuelsEurope, summarized the SAF status and looked ahead half a decade. This gives the following picture of the SAF situation, mid-2025:

Europe's SAF production is mainly from HEFA facilities at Neste (Porvoo, Rotterdam), Eni (Gela), TotalEnergies (La Mède), Repsol (Cartagena), and St1/SCA (Gothenburg), with additional volumes from co-processing at refineries by TotalEnergies, Repsol, BP, Shell, Eni, Cepsa, ExxonMobil, and Phillips 66.

Predictions for 2030 indicate that SAF production will remain dominated by HEFA technology, driven by new biorefineries, refinery conversions, co-processing, and capacity expansions. Key projects include TotalEnergies' Grandpuits conversion and La Mède expansion, Neste's Rotterdam expansion, Eni's Livorno conversion, and the Porto Marghera expansion, part of Eni's plan to convert refineries into biorefineries and boost SAF production by 2026. Spain has several plants under construction or in the planning stage. Expected to become a leader in SAF production within a shorter period. Repsol Puertollano and Moeves La Rábida refinery are examples. Co-processing is also being expanded at sites such as TotalEnergies Leuna and Galp Sines in France. (See more regarding selected European countries in section 3.9)

New technologies (e-SAF, alcohol-to-jet and biomass-to-liquids) are under development, but as discussed elsewhere in the report, are still at pilot or early commercial stages. The most advanced e-SAF project to date is INERATEC's 2.5 kt/a Era One plant in Frankfurt, inaugurated in May/June 2025. (see 1XXX) According to their own announcements, in 2026, Repsol, Petronor and Saudi Aramco will start an e-fuels plant in Bilbao with a capacity of 2 kt/a. Many industrial-scale e-SAF projects have been announced, but few are at an advanced stage of development; the most advanced are the Arcadia eFuels project ENDOR (see separate section), the Norwegian e-fuel in Mosjøen, the Alpha plant, and the Verso Energy project DEZiR. It is noteworthy that no industrial-scale e-fuel project has yet reached a financial investment decision in Europe. See more about this in the sections on Project SkyPower and Green Power Denmark. As with the e-fuel projects, the leading French bioSAF initiative, Elyse Energy's BioTJet, is still pre-FID.

For global SAF producers' schedules, quantities, and technologies, refer to our SAF Map at www.nisa.dk. The overview is updated but may contain uncertainties, as it relies on producer information from PRs or public announcements. eSAF topics are discussed in more detail later in this report.

**ICF and SkyNRG:** In spring 2025, they published a joint analysis of the opportunities ahead: the SAF market outlook 2025.[107] As shown below, optimism is expressed about the estimated SAF volumes for the European market, but essential preconditions for the start-up of new plants must be met.

Hereby conveying the main conclusions from their analysis in this section on the status and forecasts of SAF market trends in Europe:

[107] SkyNRG, SAF Market outlook, 2025

*"Looking ahead, a supply demand shift is coming. The mandated SAF demand in the EU and UK is expected to reach approximately 4 Mt (1.3 Bgal) by 2030 under the Current Trends demand scenario. Based on current announcements, SAF production capacity in the EU and UK is expected to reach 3.8 Mt (1.3 Bgal) by 2030, which means it is just 0.2 Mt (0.07 Bgal) below projected demand. However, only 30% of these projects are currently operational or under construction, and the gap may increase if many of the announced projects cannot reach financial close and complete construction and commissioning in time. This could increase Europe's reliance on imports. Mandated demand is set to triple to 12 Mt (3.9 Bgal) by 2035, requiring a rapid and steep ramp up of capacity and supply post-2030"* - SAF market outlook 2025 [108]

*"Supply of e-SAF remains in early stages of development, with 0.15 Mt (0.05 Bgal) of capacity in advanced planning and significantly more in feasibility stage. This is below the estimated minimum requirement of 0.6 Mt (0.2 Bgal) by 2030 and 2.4 Mt (0.8 Bgal) by 2035. This means that, considering project development timelines of 3 – 4 years, financial investment decisions will have to come in by late 2026 to have sufficient certainty that ReFuelEU sub-targets can be met"* - SAF market outlook 2025 [109]

## 3.10 Nordic and European SAF producers

The Nordic region is home to a growing number of SAF producers, working with both bio-based and synthetic production processes. The following is a status of the producers that are most prominent in the market, including current and announced upcoming ones. In continuation of the review of Nordic producers, the current SAF situation in selected European countries is reviewed.

### 3.10.1 Arcadia eFuels


[108] SkyNRG, [SAF Market outlook](), 2025, page 6
[109] SkyNRG, [SAF Market outlook](), 2025, page 6

Arcadia eFuels in Vordingborg. In May 2025, they completed their Front-End Engineering Design (FEED): Arcadia eFuels[110]

Preparing to complete FID, the project includes partners such as Sasol, Topsoe, BNP Paribas and KGAL. (See section 4.6 for more information about Arcadia).

### 3.10.2 ST1

Location: Sweden / Goteborg

Capacity / eSAF: 68-90 Ktpa

Technology: HEFA

Production year: 2024

Status: Producing

In the fall of 2024, Finnish/Swedish St1 started SAF production based on HEFA, i.e. primarily used cooking oils, tall oils from SCA (Svenska Cellulosa Aktiebolaget) and fat from dead animals, but with a larger local or European share than the dominant SAF producers who use Asian UCO. Total capacity 200kt, of which SAF 80/90kt. St1: A year of SAF – Welcome on board, 2025.

The company is also actively involved in several new developments within the RFNBO space with renewable fuels of non-biological origin (RFNBO). Together with partners, the development of the most suitable facilities in Sweden is being prepared.[111]

| | | | |
|---|---|---|---|
| Capacity/eSAF: 100 Ktpa | Technology: FT. | Prod: mid 30'es | Status: Feasibility |

Another biofuel project in the horizon:
St1/SCA BioOstrand: FID 2027/2028, prod. 2032/2033. Biorefineryostrand.com [112]

[110] Arcadia, Arcadiafuels.com
[111] St1: One year of SAF – Welcome on board, 2025
[112] St1/SCA BioOstrand

### 3.10.3 Preem

Location: Sweden / Lysekil

Capacity / SAF: 500 Ktpa

Technology: HEFA

Production year: 2029

Status: Planning phase

Sweden's largest oil refinery Preem has decided to reconstruct its Lysekil facility to produce SAF in the future. Swedish Export Credit (SEK) is financing Preem's investment in the conversion of its existing refinery in Lysekil with a EUR 121 million credit facility, with an 80 per cent green guarantee from the Swedish National Debt Office.

Preem's first investment and conversion is expected to be completed this year with a renewable production capacity of approximately 1 million cubic meters. To further accelerate conversion, SEK is also financing Preem's next investment, which will make Preem the largest producer of SAF and renewable diesel for road transport in Northern Europe. Preem is reducing its fossil production capacity accordingly. Read more about Preem, Preem.com [113]

### 3.10.4 Project SkyKraft

Location: Sweden / Skellefteå

Capacity / eSAF: 100 Ktpa

Technology: FT

Production year: 2030

Status: Project plan

[113] Preem

Further north, SkyNRG and Skellefteå Kraft are collaborating on Project SkyKraft: An eSAF project in northern Sweden. Access to nearly 100% renewable energy supplied by Skellefteå Kraft from hydro and wind power. Also, the region has the industrial scale to provide biogenic $CO_2$ and thus enabling continuous and cost-efficient eSAF production: SkyNRG.com [114]

### 3.10.5 Neste

Location: Porvoo, Rotterdam, Singapore

Capacity/eSAF: 1,5 mio. tons/year

Technology: HEFA

Production year: 2023/2024

Status: Producing

Neste is the world's largest producer of SAF. Production takes place at refineries in Rotterdam, Singapore and Porvoo (Finland). SAF is produced using HEFA (Hydro processed Esters and Fatty Acids) technology, which uses waste and residual resources such as used cooking oil and animal fat. Production in Rotterdam began in 2023–2024 and can deliver up to 500,000 tons of SAF annually.

Globally, Neste has a capacity of approximately 1.5 million tons of SAF/year in 2025, with plans to increase to 2.2 million tons/year by 2027. Neste does not disclose the source of its raw materials. SAF products from Neste are based on used cooking oil, animal fat waste, and various wastes and residues from vegetable oils. Neste.com [115]

[114] SkyNRG
[115] Neste

### 3.10.6 Projekt ALBY/Norsk e-Fuel

Location: Sweden / Ånge

Capacity / eSAF: 80 Ktpa

Technology: FT

Production year: 2032

Status: Feaseability

Norsk e-Fuel, in partnership with Prime Capital, is to produce SAF in Sweden. With support from renewable energy company RES, the companies will develop "Project Alby", an industrial-scale e-Fuel plant. The project is located approximately 370 km north of Stockholm, in Ånge, and benefits from low electricity prices thanks to the extensive availability of renewable energy in the area. Production volume 80,000 tons of eSAF: norske-fuel.com [116]

**Norsk e-Fuel** is simultaneously planning similar eSAF facilities in Norway (Project Mosjøen) and in Finland (Projects Imatra and Rauma). Boeing is key partner and investor in the project. Avinor and local authorities support the project in Norway.

### 3.10.7 Nordic electrofuel

Location: Norway / Porsgrund

Capacity / eSAF: 8 Ktpa (Pilot)

Technology: FT

Production year: 2027

Status: Feaseability

[116] Norsk e-fuel

A Norwegian company with Fischer-Tropsch technology. Has several advance agreements and many LoI's in Norway and the Middle East. According to their website, the plan is to build the world's first commercial PtL or eSAF plant in Herøya in Porsgrunn, Norway. Using renewable electricity, hydrogen, and $CO_2$ to produce SAF. Carbon source is blast furnace waste gas from a local Ferro/Silicon-Manganese plant. A relative greenhouse gas (GHG) emission avoidance above 99% is expected, compared with the reference scenario: nordicelectrofuels.no [117]
A demo, and production plant leading to further full-scale plants.

### 3.10.8 Fjord PtX

Location: Denmark / Aalborg

Capacity / eSAF: 1000 Ktpa

Technology: FT

Production year: 2030

Status: Planning

A Partnership between Aalborg Forsyning (Norbis Park), Nordværk and Copenhagen Infrastructure Partners (CIP). With commissioning scheduled for 2029, the plant is expected to be ready for production in 2030.

The location of the plant is right next to Aalborg Forsyning, close to the Port of Aalborg. Splitting of water into hydrogen based on local wind energy and 330,000 tons of $CO_2$ annually from waste incineration at RenoNord, equivalent to the $CO_2$ emissions of 17,000 Danish households. The plant's excess heat contributes to reducing $CO_2$ emissions by approximately 13,500 tons, which are replaced by emission-free district heating. Fjord PtX will contribute 200-400 MW to the EU's target of 40 GW hydrogen electrolysis in 2030. The production plant is expected to cover approximately 20 ha, equivalent to 26 football fields.

Construction work from 2026: fjord-ptx.dk [118]

[117] Nordic electrofuel
[118] Fjord PtX

### 3.10.9 European Energy and Metafuels

Location: Denmark / Padborg

Capacity / eSAF: 825 Ktpa

Technology: MtJ

Production year: 2030

Status: Heading FEED

Plant under preparation, subject to expected ASTM approval, methanol to jet, plant location in South Jutland. Swiss Metafuels AG has entered a partnership with the Danish development company European Energy to establish an eSAF plant.

The project involves the construction of an eSAF facility in connection with a future Power-to-X facility, where European Energy produces the hydrogen. Metafuels announces that it will produce approximately 12,000 liters of eSAF per day. Metafuels' technology is called "Aerobrew".

European Energy has inaugurated the first hydrogen plant: Europeanenergy.com [119]

### 3.10.10 Verso and City of Oulu

Location: Finland / Oulu

Capacity / eSAF: 80 Ktpa

Technology: MtJ

Production year: 2026

Status: Project planning

[119] European energy and metafuels

In February 2025, French Verso Energy and the City of Oulu in February 2025 signed a co-operation agreement on the production of eSAF. The city of Oulu is expanding its hydrogen production and has access to biogenic carbon.

Verso Energy will provide the technology to convert hydrogen into a sustainable jet fuel. Like other MtJ projects, it is subject to obtaining the necessary approval from the ongoing and independent ASTM process. ouka.fi [120]

### 3.10.11 Haffner Energy and IðunnH2

Location: Iceland / Keflavik

Capacity / eSAF: 65 Ktpa

Technology: MtJ

Production year: 2028

Status: Project planning

A 300MW e-SAF facility is being developed near Keflavík International Airport, aiming to produce 65,000 tons of SAF annually. The project is expected to cover approximately 15% of Iceland's projected jet fuel demand.

Green hydrogen produced from Iceland’s renewable energy sources (wind, geothermal, and hydropower) and biogenic carbon, sourced from Haffner Energy’s biocarbon gasification technology will be used. The project is based on close collaboration among producers, the airport, an airline, and authorities, with government support.

The project is distinguished by its physical proximity to the main airport, leveraging existing infrastructure and market connections. Icelandair has previously committed to using three-quarters of the annual production. Idunnh2.com [121]

[120] Verso and city of Oulu
[121] Idunnh2

### 3.10.12 Liquid Sun


This pilot project in Finland aims to establish a value chain collaboration to produce synthetic aviation fuel. The project is led by Liquid Sun, which has developed a low-temperature electrolysis technology to convert biogenic $CO_2$ and renewable hydrogen into (eSAF). Project partners include Finnair, ABB, Fortum, and Finavia.

The plant will be established in Espoo and is expected to be operational in autumn 2025 as the first pre-commercial pilot of its kind. The initiative will build knowledge and processes that can be scaled globally and secure a future supply of domestically produced eSAF. Finland has large amounts of biogenic $CO_2$ from the forest industry and biogas plants.

The project is supported by collaboration across the entire value chain, and the initiators estimate that it can be a strength for both energy security, grid balance and the green transition of aviation. Liquidsun.co [122]

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[122] Liquid Sun

### 3.10.13 Map of projected EU+EFTA SAF facilities in 2030/optimistic scenario

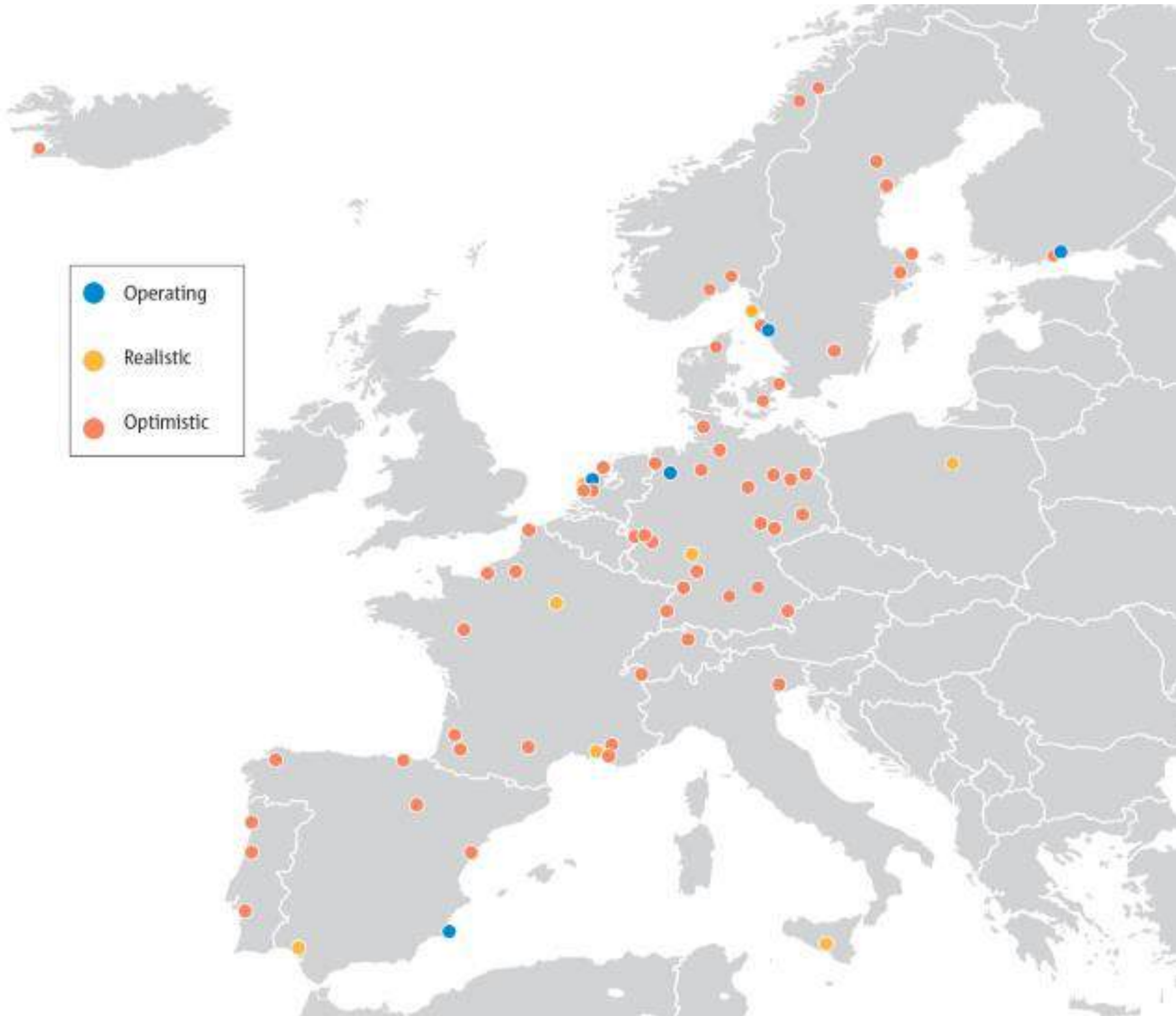


*Figure 35 European SAF producers – Optimistic scenario* [123]
*The textual review of producers is not coordinated with the SAF facility map from EASA.*

### 3.10.14 Status of SAF and eSAF in Italy (2025)

Like most European countries, Italy has, in recent years, focused on sustainable aviation fuels (SAF) as a key element of the aviation sector's green transition. The national aviation authority ENAC has drawn up a SAF Roadmap, which highlights the need for clear policies, incentives, and

[123] EASA, European Aviation Environmental Report, 2025, page 144

coordination among authorities, airports, airlines, and fuel producers to meet the European requirements for ReFuelEU Aviation.[124]

On the production side, Enilive (formerly Eni) is one of the leading players. The company has put its plant in Gela, Sicily, into operation in 2025 with a capacity of around 400,000 tonnes of SAF per year. It plans to expand to around 1 million tonnes per year in 2026, with further scaling up towards 2030. The raw materials are primarily waste and residual products such as used cooking oil and animal fat.[125]

**Several commercial agreements have been concluded:** easyJet has agreed to receive SAF from Enilive, including a Letter of Intent to purchase approximately 30,000 tonnes of SAF in the period 2025–2030. Ryanair has agreed with Enilive to supply up to 100,000 tonnes of SAF. In the same period, DHL Express Italy, in collaboration with SEA (Milan airports) and Enilive, has conducted test flights with a 20% SAF blend on 28 freighters departing from Milan Malpensa.

**eSAF:** However, when it comes to electrofuels (eSAF/PtL), Italy is still at a relatively early stage. Most initiatives focus on bio-SAF. At the Saras refinery in Sarroch, Sardinia, a green hydrogen project is underway with Enel Green Power to produce green hydrogen for refining processes. It includes a 20 MW electrolyzer powered by renewable energy to produce green hydrogen for decarbonizing refinery operations, particularly hydrogen-intensive processes. Saras is also collaborating with NextChem (MAIRE) on a pilot plant for e-SAF, using low-carbon hydrogen and captured $CO_2$ to produce synthetic fuels, with an innovative NX CPO technology (Catalytic Partial Oxidation, which enables syngas production) to maximize carbon efficiency. Both projects are supported by European and national funding frameworks. The company has signed contracts with Paul Wurth S.A., a subsidiary of the SMS Group, and Norsk e-Fuel AS for a license and engineering design package for the technology to be used in the first industrial-scale plant to produce SAF from green hydrogen and biogenic $CO_2$ in Mosjøen, Norway (see 3.10.5). Experts point out that the development of eSAF requires both large amounts of cheap renewable energy and $CO_2$ sources, as well as significant investments, which means Italy is currently lagging, for example, the Nordic countries, Spain and Germany.

Several analyses focus on challenges related to raw material availability and economic viability. Waste streams are limited, and large-scale production requires a stable policy framework, significant long-term investments and incentives if Italy is to contribute significantly to the EU's overall goal of climate-neutral aviation. [126] [127]

[124] ENAC, Italian Civil Aviation Authory, Cos'è l'ENAC, 2023

[125] Adnkronos English, Italy: Eni biofuel unit starts producing sustainable aviation fuel for Europe, January 2025

[126] ENAC (Italian Civil Aviation Authority) Una roadmap per i Sustainable Aviation Fuels in Italia – Percorso dell'Enac per la definizione di SAF policy

[127] NOTE: Prof. Mirko Morini, University of Parma has reviewed and contributed to the section on Italy

### 3.10.15 Status of SAF and eSAF in Spain (2025)

Spain is well-positioned to meet domestic SAF demand soon and could become a leading SAF producer in Europe, with major projects underway. While eSAF development is in its early stages, some initiatives are underway to meet the EU's synthetic fuels targets. However, there are still economic and technological challenges to overcome to realize planned projects.

**Biofuels:** According to Moeve (formerly Cepsa), the country is on track to have seven plants, primarily based on HEFA technology, which are expected to be operational in the period 2025–2030.[128]

Repsol and Apical Group have started construction of Southern Europe's largest biofuel plant in Andalusia, which is expected to produce 500,000 tonnes of SAF annually from 2026. This project is part of a larger strategy to produce 800,000 tonnes of SAF annually by 2030.

IAG (International Airlines Group), the parent company of airlines Iberia and Vueling, has signed Spain's largest voluntary SAF purchase agreement with Repsol. The deal aims to meet the EU's 2% SAF requirement by 2025, according to Biofuels International. Furthermore, the two airlines have committed to using 10% SAF by 2030 and to reaching net-zero emissions by 2050.

**eSAF:** Spain's geography and energy profile make the country attractive for PtX investments: massive solar and wind potential, access to $CO_2$ from industry, and a strategic location as a fuel hub for European and transatlantic aviation. Spain has established a hydrogen strategy, with green hydrogen production as a national priority. The combination of green hydrogen and $CO_2$ capture, therefore, points to eSAF as a logical next phase in the continued production of bio-SAF.

Moeve and Zaffra, a joint venture between Sasol and Topsoe, have signed a letter of intent to develop an eSAF plant in southern Spain, near the Andalusian Green Hydrogen Valley project. This collaboration aims to meet the EU target of 1.2% of SAF as synthetic fuel by 2030.[129] [130]

### 3.10.16 Status of bio SAF and eSAF in Germany (2025)

With the EU's ReFuelEU Aviation mandate of 2% blending, Germany faces a major challenge. All fuel suppliers supplying jet fuel to EU airports must ensure that at least 2% of their fuel supply is sustainable in accordance with EU criteria. In Germany, this means that suppliers such as Mabanaft Deutschland GmbH, Shell Deutschland GmbH, OMV Deutschland, TotalEnergies, VARO Energy, BP/Air BP and Kuwait Petroleum Aviation are legally obliged to meet the quota. The German aviation market consumes around 9 million tons of jet fuel annually, which means

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[128] Moeve Global, The new sustainable aviation fuel industry has the potential to (...) provided it's prioritized as a State policy, November 2024

[129] Moeve Global, The new sustainable aviation fuel industry has the potential to (...) provided it's prioritized as a State policy, November 2024

[130] Blanca de Ulibarri, EU LCA Project Manager, has reviewed and contributed to the section on Italy

the 2% requirement is approximately 180,000 tons of SAF for 2025. As domestic SAF production remains limited, most demand in 2025 will be met by imported bio-SAF, primarily HEFA-based.[131]

So far in the autumn of 2025, Mabanaft has documented concrete SAF deliveries to Frankfurt Airport, where it has delivered over 1,000 tons to airlines such as the Lufthansa Group and Singapore Airlines since January 2025 (safinvestor.com, 2025). Other suppliers on the EU's ReFuelEU list are obliged to deliver SAF, but concrete public information on quantities delivered in 2025 is scarce. This applies to Shell, OMV, TotalEnergies and VARO, among others, where production and deliveries in 2025 are primarily planned or in a pilot phase, and major German projects such as Haltermann Carless' ATJ plant in Speyer are not expected to deliver significant quantities until 2026/27. The Haltermann Carless project has been on hold since April 2025 and is therefore highly unreliable; however, Total Energies (Leuna, 50,000 t/y, 2026) and the Holborn Refinery (Hamburg, 110,000 t/y, 2028) have announced relevant quantities of bio-SAF for the coming years. In addition, BP produces unknown quantities of biofuel at its Lingen refinery.

In 2021, several federal ministries, together with the German Aviation Association, published a roadmap aiming for a total production of 200,000 tons of Power-to-Liquid fuels by 2030. The German Aerospace Center (DLR), supported by the Federal Ministry of Transport, is developing the Power-to-Liquid Fuels (PtL) technology platform in Leuna, Saxony-Anhalt. According to the players involved, it will be the world's largest PtL research and demonstration facility with an annual capacity of up to 2.500 t/y.

Smaller demonstration plants such as INERATEC ERA ONE in Frankfurt-Höchst will, when all three modules are installed, be able to produce up to 2,500 tons of e-fuels annually, primarily for testing and experience with PtL operation (see section 4.8). Larger PtL plants, including joint ventures such as HH2E/DHL/Sasol in eastern Germany and the Shell Wesseling project, are still in the planning or financing phase, with commercial production expected only from around 2028. This illustrates that in 2025 Germany will primarily rely on bio-SAF and imports to meet the ReFuelEU requirement, while scaling up eSAF will only become relevant towards the end of the 2020's.[132]

Although there are currently 21 e-fuels projects in Germany, only 3,500 t/y are expected in 2028, which will only change for 2030 if the plants of ConcreteChemicals, Hy2gen, and EDL reach the next project status (total 110,000 t/y). From 2028 onwards, it appears that the SAF quota can also be met in Germany with bioSAF.

[131] SAF Investor, MABANAFT BEGINS SAF SUPPLY AT FRANKFURT AIRPORT, April 2025
[132] Federal Ministry for Digital and Transport, ICAO State Action Plan on the Reduction of CO2 Emissions from Aviation for Germany, January 2025

Overall, 2025 marks a transitional phase for Germany, where the first concrete deliveries of SAF to national airports will take place, but where the full potential of synthetic fuels lies in the future. The national and international projects planned and launched in the second half of the 2020s will determine the extent to which Germany can contribute to the EU's long-term goal of sustainable aviation towards 2050.[133]

### 3.10.17 Status of bio SAF and eSAF in France (2025)

On the supply side, French players, primarily TotalEnergies, have been a primary national supplier and investor in building capacity for both bio-SAF and complementary production routes. Despite this, France is not yet able to produce the required 2% by 2025. TotalEnergies has announced plans to significantly increase its European SAF capacities in the coming years, aiming to reach up to 500,000 tons/year by 2028 through the expansion and conversion of existing refineries and the construction of new biorefining platforms. The planned investments are supported by commercial partnerships and by agreements with airlines and airport operators.

The vast majority of the available SAF volume in the short term remains bio-SAF (typically HEFA products derived from waste and residue streams), while commercially relevant quantities of eSAF (electrofuels/PtL) remain available only in demonstration plants. The French government has given political priority to supporting eSAF and forestry residue-based projects through investments under the “France 2030” framework, which includes funds (100m€ in 2025) to cover FEED studies and initial development of SAF projects. The support schemes aim to reduce early development costs and attract private capital to the projects.

At the project level, initiatives are planned: TotalEnergies and other industrial players are working on both the conversion of existing refinery capacity (co-processing and biorefinery conversions) and the development of new PtX solutions. West of Marseilles, the La Mède plant has started producing SAF in Sept 2025, and Grandpuits in Seine-et-Marne should be commissioned in early 2026.

French authorities are working to mobilise national industrial clusters and agricultural feedstock initiatives (e.g., development of intermediate crops and waste collection) to ensure both supply and sustainability in the production chain. These combined tracks – conversion of existing infrastructure and establishment of new PtL plants – should accommodate the rapid fulfilment of ReFuelEU requirements and the long-term build-up of eSAF capacity.

Despite the initiatives, France faces several significant barriers to rapid eSAF scale-up. First, PtL/eSAF requires large amounts of cheap, predictable renewable electricity and access to low-

[133] Dr. Sabine Leiser, CENA Hessen has reviewed and contributed to the section on Germany

emission $CO_2$ sources or direct air capture solutions to ensure the desired emission reductions. Second, the economic costs of eSAF in 2025 are significantly higher than those of traditional HEFA-SAF products, making eSAF dependent on market incentives, contracts-for-difference (CfD), guarantee schemes, or direct subsidies to ramp up. Finally, the establishment of a national eSAF industry requires a coordinated network of electrolysis infrastructure, transport, and storage, as well as action-oriented sales mechanisms (long commercial offtake agreements). These elements are still under development in 2025 (at European level and are expected to be reflected into the STIP) and are also fully parallel to the challenges in other countries.

On the demand side, French airlines and airport consortia have engaged in market development through agreements and partnerships. International and national airlines (including the Air France-KLM group, a strategic player in France/Europe) have entered into sales agreements and MoU's with producers to ensure early deliveries and build investor confidence. Furthermore, airport operators and port stakeholders have worked to adapt infrastructure for storage and logistics for SAF at major French airports. These initiatives are considered essential to creating an initial market that can reduce producers' sales risk. The realization of eSAF on a larger scale requires political incentives, access to large-scale renewable electricity and long-term sales contracts to make the financially heavy projects bankable.[134] [135]

## 3.11 St1-refinery started SAF production 2024

Let's briefly look at one of the few producers of HEFA-based SAF products in the Nordic market, based on dialogue with representatives from the refinery**.**

**Background and production facility:** St1's commitment to biofuel production was realized in 2024 after an extensive start-up phase as the Gothenburg Biorefinery, a joint venture with SCA (Svenska Cellulosa Aktiebolaget), St1 75% and SCA owning 25%. Operations started in April 2024. The biorefinery represents St1's most significant single investment of SEK 4 billion. It has an annual production capacity of 200,000 tons of renewable fuels, including Sustainable Aviation Fuel (SAF), renewable diesel (HVO), bio-naphtha and bio-LPG.

**Feedstock and flexibility:** The biorefinery is designed for flexible use of feedstock, enabling sustainable and reliable production. Key feedstocks include:

[134] References:

- Ministère Chargé Des Transports, Environmental Report 2022, 2022
- SAF Investor, UN SOU EST UN SOU: FRANCE ANNOUNCES $113M FOR SAF PROJECTS, April 2025
- T&E, The e-SAF market: Europe's head start and the road ahead, June 2025

[135] Steven Le Moing, Sustainable Aviation Fuel Program Mgmt., Airbus has reviewed and contributed to the section on France

• Used cooking oil and fatty food waste, supplied through St1-owned Brocklesby Ltd, a UK specialist in the recycling and refining of these feedstocks.

• Crude tall oil fractions (CTO), such as fatty acids, a by-product of kraft paper production, are supplied via the joint venture with SCA.

These two primary feedstocks are local/regional and account for more than 50% of the total feedstock volume, with the remainder purchased on the global market. Approximately half of the local/regional feedstock is UCO collected in the UK. St1 estimates that it uses a significantly lower proportion of feedstock from Asia than other producers. [136]

**Technology and process:** St1 SAF is produced using Honeywell's Ecofining™ technology, which has been commercially used since 2016 and is adapted to a wide range of feedstocks. In the process, oils and fats are hydrotreated to produce primarily SAF and diesel, which, according to ST1, enables high sustainability and $CO_2$ reduction. In addition, flexibility can help to secure or increase customer demand and sustainability requirements.

**Certification and emission impact:** All bio-based fuels from the Gothenburg biorefinery are certified under ISCC. According to St1, their SAF products are estimated to reduce life-cycle $CO_2$ emissions by around 80% compared to conventional jet fuel, thereby reducing annual $CO_2$ emissions by approximately 500,000 tons.

**Market adoption and customers:** A key example of market adoption is the agreement with the Norwegian Defence via the airline Norwegian, which will use St1 SAF to cover 15% of Norwegian's business travel from 2024 to 2028, supporting around 1 million trips. According to this agreement, the following are stated:

• The agreed SAF volumes will be refueled in Norway to ensure local supply and safety.

• SAF meets EU sustainability criteria and provides approximately 80% lower $CO_2$ emissions over the entire life cycle compared to conventional jet fuel.

**Supply and market introduction:** By mid-2025, St1 SAF will be introduced to Nordic airlines, other regional customers, and incoming international customers. Examples include Braathens Regional Airlines, Norwegian and SAS. The aim is to gradually increase availability, including airport access throughout the region, and support compliance with EU mandates and the voluntary market, where St1 is certified under the RSB Book & Claim system. While efforts to enter airports are progressing well at some larger locations, others have significant barriers to

[136] T&E, A study: 80% of Europe's 'used' cooking oil now imported raising concerns over fraud, Dec. 2023

entry despite the EU Ground Handling Directives. Examples could include agreements with operators who control the central infrastructure and that are not open to other fuel traffic. [137]

### 3.10.1 Access to fuel infrastructure

Given the challenges St1 has faced, access to central fuel facilities at EU airports – such as fuelling facilities and hydrant systems – could increasingly become a competitive issue. Many of the fuel handling activities are operated by joint ventures, where access is not provided through open supply agreements (also called throughputs) but only through the purchase of ownership interests. Fuelling facilities and hydrant networks are typically natural monopolies for safety, equipment, and space reasons, and, of course, for the inherent liability. When a joint venture controls these assets and access is granted only through equity or contractor pricing, new entrants may perceive that existing joint ventures control market access to some extent.

**Customer/competitor conflict:** If joint venture shareholders also sell fuel at the airport, they may be able to favour their own downstream activities, which could be perceived by companies such as St1 as a restriction of competition/abuse of a dominant position [138]

Entry barriers can be exacerbated by the way ownership and returns are structured but are still subject to regulatory control. The problem can also be perceived by newcomers as greater at smaller, regional airports not covered by the EU Ground Handling Directive (96/67/EC). For example, if an existing supplier has a long-term contract and thus possible exclusivity, this could hinder competition and the introduction of sustainable aviation fuels (SAF) if they come from smaller producers not part of the current set-up.

**Possible solutions** to reduce the challenges for new and/or smaller companies wanting to enter the market: 1. Regarding smaller airports with long-term contracts with single fuel suppliers, the possibility of more airports being covered by the ground handling directive should be considered, 2. Assessment of the possibilities for transparent access and agreements on total cost-based payments. 3. In the long term, it can be considered whether infrastructure ownership and fuel trading should be separated to prevent conflicts of interest. 4. Perhaps most importantly, access to SAF products should be prioritised so that the infrastructure positively supports the EU's climate goals.

**There are two main models** for organising fuel supply to airports: the **equity model** and the **throughput model.**

As just mentioned in the equity model, airlines or fuel suppliers gain access to the infrastructure by purchasing an ownership stake in the joint venture that owns and operates the fuel yard and

[137] Christian Janssen, Direc. Business Development Sustainability & Future Business St1 Sweden, has reviewed and contributed the section on St1

[138] GCR: European Union: Article 102 TFEU and the European Commission's 2025 Guidelines: what to expect…., 2023

hydrant system. This means that new players must buy in to gain access. The model ensures financing for the very capital-intensive facilities and gives the owners influence, operational reliability, and control of a critical part of the supply chain. It also creates a high barrier to entry. If the owners are also active fuel suppliers, conflicts of interest can also arise.

In the throughput model, the infrastructure is typically operated by a joint venture or operator, but access is granted under throughput agreements. Players pay a tariff per cubic metre or tonne of fuel delivered through the system, without having to purchase ownership stakes. In this way, all qualified suppliers can gain access on equal terms. The model promotes competition and makes it easier to introduce new fuels such as SAF. Still, it also means that the owners of the infrastructure receive a smaller direct return and therefore need transparent pricing and terms.

In short, the equity model is based on access through ownership, while the throughput model is based on access through payment per volume.

St1 and other newcomers see challenges with the equity model if they want to supply the airport directly. If trading is done through the Rotterdam market, the model is hardly decisive. Which of the two models is preferable in a holistic view is beyond the scope of this project to analyze. There may be several considerations and points of view, but: From a sustainability perspective, it should be emphasized that regardless of the model. The transition to sustainable fuels mustn't be limited or prevented by any model or access barriers!

### 3.11.1 SAF prices and costs

The price of SAF is, of course, one of the most decisive factors for all parties, not least because fuel accounts for around 30% of airlines' operating costs. In 2023, the average price of conventional jet fuel was around €816 per tonne, based on readily available data from Price Reporting Agencies (PRA), such as S&P Global, Argus Media and General Index.

When assessing the prices of SAF that meet the requirements of ReFuelEU Aviation, a distinction has been made between two categories: SAF with current market presence and SAF still under technological development, for which only estimates of production costs are available.

Among the commercially available SAF in 2023, only biofuels made from feedstocks listed in Annex IX, Part B, of the EU RED were available on the market. These had an average market price of around €2768 per tonne, according to relevant PRA indices. With a density of around 0.8 g/cm$^3$, this corresponds to approximately €1.02 per litre.

Estimated prices and production costs in 2023 for ReFuelEU Aviation eligible fuels:

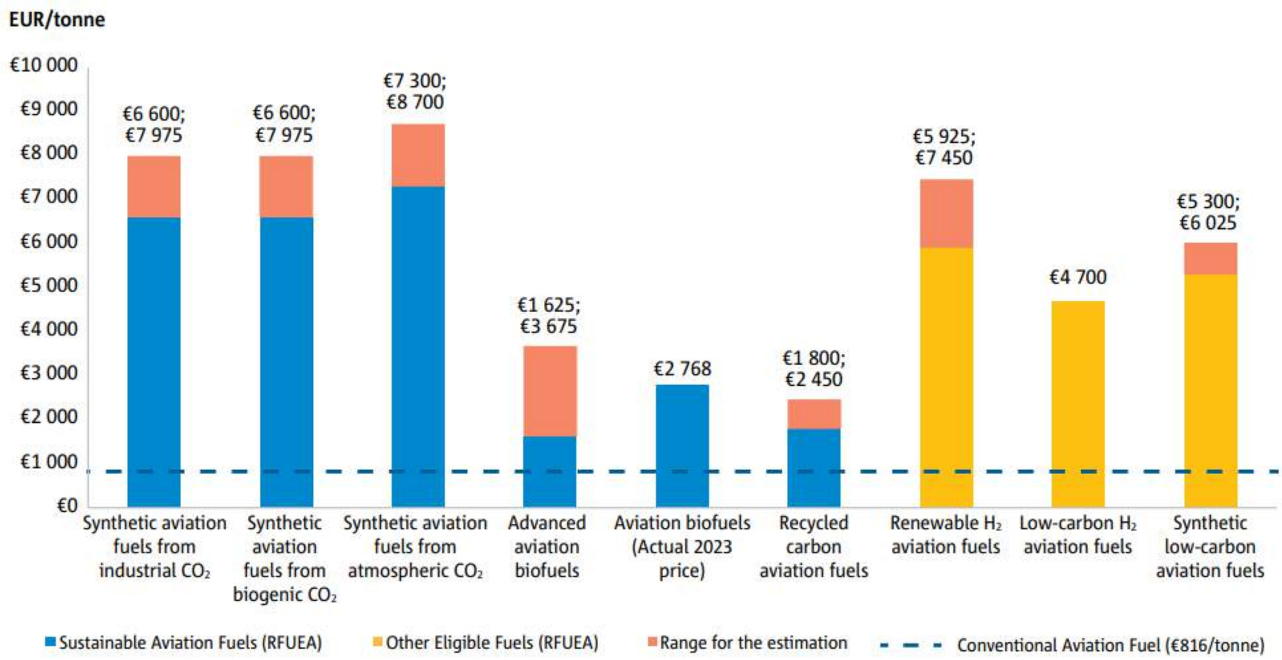



*Figure 36 Estimated prices and production costs* [139]

For SAF types that are not yet commercially available, production costs were estimated based on feedstock prices, energy consumption, and implementation costs. Prices here vary from around €1600 per ton for advanced biofuels to up to €8700 per ton for electrofuels (PtL).

The reference for this is the EASA Environmental report 2025 (see note 115), but other analyses and market inquiries show approximately the same results.

However, these costs are expected to decrease significantly as new production methods are scaled up and technologies mature. Particularly for PtL fuels, where energy costs are a significant price driver, regional differences in energy prices may have a substantial impact on where in Europe production will be most competitive in the future. Furthermore, well-exploited interactions and sectoral couplings with other users could significantly reduce prices. (See for example the analyses from AAU, “Renewable Aviation e-SAF Catalogue and system Impacts”. [140]

### 3.11.2 Policy SAF Toolbox-recommendations

We conclude this chapter with a series of recommendations to accelerate EU SAF production. In an analysis of the SAF challenges, ICF has made several recommendations. The report "European SAF Industrial Policy" from January 2025 aims to contribute to securing European

[139] EASA, European Aviation Environmental Report, 2025, page 147
[140] AAU, Renewable Aviation e-SAF Catalogue and Systems Impacts, 2024

competitiveness, with a focus on aviation, energy, and potential interactions, sector couplings, and related topics. We review the key recommendations in a policy toolbox (full report). [141]

**Overview:** Scaling up the production of sustainable aviation fuel (SAF) in the EU requires a coherent policy framework that improves market stability, reduces investment risk, and accelerates the deployment of advanced and synthetic SAF technologies. Clear, long-term regulatory signals are crucial to attract private capital and establish Europe as a global SAF leader.

**De-risking SAF investments requires market stability tools:** SAF price volatility undermines investor confidence. Mechanisms such as long-term off-take agreements, Contracts for Difference (CfDs) or Feed-in Tariffs can provide predictable revenues. The UK's revenue security mechanism for non-HEFA SAF offers a promising model.

**Carbon Contracts for Difference (CCfDs):** These reward producers for emission reductions, aligning support directly with climate benefits. Compensate producers for the carbon reduction gap by linking financial support directly to the emissions reduction potential of SAF. Germany's CCfD scheme for hard-to-mitigate sectors could be adapted to a European SAF model.

**EU-wide support schemes:** While national state aid tools exist under the CEEAG, an EU-level mechanism could reduce fragmentation and ensure fair competition across Member States.

**Access to tailored innovation fund:** The current ETS Innovation Fund rules disadvantage SAF projects due to high upfront costs and lower emission reductions compared to other sectors, such as the steel sector. A dedicated SAF funding stream and evaluation track would ensure fairer competition.

**Adjusted award criteria:** The criteria should favour projects that integrate early technologies, deliver cross-sectoral benefits (e.g., green hydrogen, CCU), and provide clear cost-reduction pathways. Increased emphasis on aviation projects would recognise the sector's decarbonisation challenges.

**Strategic importance factor:** SAF production increases the EU's energy security. Funding criteria should reward projects that reduce import dependency and enhance industry competitiveness.

**STEP prioritisation:** SAF projects should be prioritised under the Strategic Technologies for Europe Platform (STEP) to unlock more funding streams and attract private investment. A similar prioritization is recommended through the EU's Clean Industrial Deal and the upcoming

[141] ACI, European SAF Industrial Policy, 2025

Sustainable Transport Investment Plan (STIP) (according to SkyPower, Green Power Denmark and others).

**Lessons from Global Best Practice:** Countries such as the US, UK, Australia, and Japan have already allocated hundreds of millions in SAF project funding. The EU risks falling behind unless similar support mechanisms are deployed on a large scale.

**Recognition of renewable naphtha:** SAF co-products such as synthetic naphtha should be credited for their climate benefits. This improves the economics of SAF projects, as demonstrated by partnerships such as IKEA-Next.

**Food residuals and waste prioritisation:** Biogenic waste should be prioritised for SAF production over incineration. Updating the Waste Framework Directive to reflect this could free up MSW-to-SAF pathways, reduce landfill and support circular economy goals.

**Electricity access for synthetic SAF:** Synthetic SAF is very power-intensive. To ensure global competitiveness, EU SAF producers need access to electricity at reduced rates through tax exemptions or tax breaks.

**Concluding remark:** The EU needs to act quickly to establish market-based incentives and targeted financial support for advanced SAF production. A dedicated policy toolbox combining regulatory certainty, risk-sharing instruments, prioritisation of feedstocks and strategic access to finance is essential to meet SAF mandates and effectively decarbonise aviation.

#### 3.11.2.1 Case: Low aromatic

**Low aromatic fossil jet fuel**

During the ALIGHT general meeting in Rome in May 2023, the ALIGHT consortium discussed how to facilitate a long-term measurement campaign in CPH. The original assumptions of a stable supply of sufficient SAF quantities could not be met. Therefore, a satisfactory measurement campaign could not be conducted, which would have required a 20-30% SAF blend-in. During the project, there has been an evident shortage of SAF, and the small quantities available have been distributed through market mechanisms beyond the ALIGHT project's capacity. None of the possible actors who could acquire SAF would have either the authority to do so or the access to the quantities necessary for a measurement campaign. Therefore, it has been relevant to investigate whether there could be alternative options. An offshoot of the considerations was to investigate, if possible, the use of low-aromatic fossil fuels to measure the effect of lower aromatic content in the fuel, provided that sufficient quantities could be supplied. Conventional jet fuel typically contains 16-17% aromatics, and for a measurement campaign, the desired content should be approximately 8%. The aromatic content has effects on both local air quality and a significant climate impact on long-haul flights, both of which are further described in section 3.7.2 and WP3.3

The WP2 team was tasked with investigating the potential for sourcing low-aromatic fossil fuels from producers in the Nordic region or elsewhere in Europe.

The first step was to request that Air BP investigate whether access to low-aromatic jet fuel could be obtained through their network and contacts in the fuel market. The feedback from Air BP was that it was not possible, as there were no producers with the necessary technologies, supply, or storage capabilities.

The next step was therefore to form a network with Drivkraft Danmark (Industry Association for Fuels and Charges), BDL/Danish Aviation, CPH and a fuel supplier to discuss the possibilities and how to proceed. Through the network, it was found most realistic to primarily investigate the Nordics due to investments in certain technologies that could target specific aromatic content. In the Nordics, some advanced refineries are dedicated to producing MK-1 fuel for road transport in Sweden, under a mandate from the Swedish government. In discussions with several refiners/producers, our analysis revealed several findings to share:

Technologically, it was assessed that, even though MK-1 is produced, a transition to low-aromatic jet fuel could be feasible and that, by some actors, it was evaluated as not very time-consuming. Most advanced refineries do not have storage capacity for low-aromatic jet fuel and would therefore not be able to utilize the current storage capacity.

The refineries would need substantial orders to justify the transition economically and logistically. In addition, small quantities are difficult to certify (due to limited experience, network and sufficient storage capacity).

However, the refineries were interested in continuing the conversation about low-aromatic jet fuel in the future. As road transport electrifies, refiners may see low-aromatic jet fuel as a future business opportunity.

Many refineries lack the technology to target specific aromatic content and would instead purchase low-aromatic crude and blend it to achieve the desired aromatic percentage. This would also create storage and logistical problems, and thus cost problems, in the short term.

The WP2 team investigated the possibilities of the refineries Crossbridge Energy, Kalundborg Refinery, PREEM, ST1 and Sasol. These companies were assessed as having the highest probability of delivering the desired product, although none could provide it on time or at all for the measurement campaign.

With these findings, it had to be concluded that it was not feasible in the ALIGHT project to obtain the necessary quantities of low-aromatic jet fuel. Other aspects also made the initiative questionable or difficult to realize. Firstly, the financing issues had not been clarified, which could prove to be a showstopper unless relevant stakeholders could see their interest in stepping in. The subject was therefore not further discussed as no producers were ready.

Second, refuelling low-aromatic jet fuel on aircraft landing in CPH would mix with the fuel already in the aircraft's tank, reducing the value of the measurements. This could lead to only selected aircraft being involved, possibly with segregated refuelling, to achieve optimal effect on the desired measurements.

Conversely, the initiative was seen as enabling an interesting step towards alternative and improved solutions. There is a need to work with producers and refiners to promote low-aromatic fossil fuels. The main recommendation, based on what was observed, is that initiatives should be taken at the European and global levels to significantly reduce aromatic levels. Both the possibility of refining crude oil and the technologies to reduce aromatic content should be considered. This is outside the scope of the ALIGHT project but is nevertheless a key recommendation. Scaling up SAF will take a long time; therefore, aromatics in conventional fuels should be reduced to improve air quality and reduce the non-$CO_2$-related impacts of aviation.

The WP2 team has worked closely with the Danish Climate Partnership for Aviation to develop a common understanding of ways to reduce aromatics content in fossil fuels and to investigate the possibility of standardising aromatics content in jet fuel.

The Climate Partnership for Aviation submitted a recommendation on reduced aromatic content to the government in the spring of 2025. (See section 5.1.4) The same agenda can be found in the EU-established alliance RLCF, to which the WP2 team is also engaged.

Kalundborg Refinery announced on September 8, 2025, that it had produced the first quantities of low-aromatic fossil fuel and entered into an agreement with Airbus to test its operational effects. It has been agreed to deliver 45,000 litres for the purpose.

(also see section 5.1.4).

# 4 eSAF development and challenges

After a review of the fuel product supply routes, applicable regulations and certifications, storage, distribution and use at airports and aircraft refuelling, as well as thorough reviews of SAF sustainability criteria, the political framework conditions and what SAF's availability looks like, including which products are involved, how sustainable they are and how it should be handled in continuation of the EU's decisions on blending requirements, we have now come to look at SAF development projects.

When we assessed global perspectives on the continued development and expansion of biomass-based SAF products in 2019, it was clear that other technologies would also have to come into play to meet an increasing, sustainable, and climate-adapted demand for liquid fuels.

As mentioned in the project objectives, WP2 was to act as a link between the supplier (s) and end users, and to investigate two options for the necessary supply to the airport, considering product prices, delivery capacity, sustainability, and continuity. Furthermore, methods had to be developed, and quality, delivery, and quantities in the future SAF flow had to be organised. The latter was a huge challenge, since SAF in significant quantities was not available throughout the ALIGHT project period, except perhaps in the current and final project year, when it may be possible to obtain SAF in addition to what the mandates prescribe. However, the lack of physical quantities of SAF, reinforced by the COVID-19 crisis and the airlines' pronounced reluctance due to waiting for regulations from the EU, has meant that the expected quantities of SAF that were expected to flow into the airports and thus form the basis for handling and adapting SAF flows have not been realised. We have focused on the development of new SAF products, new fuels, approval processes and political initiatives that will promote the possibilities for aviation to become sustainable.

In the following, we will review possible new production and supply pathways, with a focus on PtX-based eSAF products that can be based on Fischer-Tropsch technology or on methanol that can be converted to jet fuel (MtJ) as soon as they are approved as pathways. The production technology-details will not be discussed in depth, but facilitation, encouragement and collaboration on initiation are closely linked to the subsequent delivery terms and circumstances. This has meant that we have looked into the primary challenges and most importantly prerequisites associated with these new methods and technologies and their development circumstances, including approval processes, final investment decision (FDI) and the political support options and perspectives, primarily from a Danish perspective, as this is where the activities are highly prioritized, but also so that it is recommendable and replicable in a broader European perspective.

## 4.1 Green Fuels for Denmark

WP2 has had a strong focus on the development of e-fuels, or eSAF based on PtX, PtL, MtJ, and other similar fuels (hereinafter referred to as e-fuels and specifically for aviation eSAF). An overview of the producers has been updated and can be found in section 3.10 and on *Global overview of SAF producers* at NISA's homepage.[142]

Our analysis revealed that e-fuels have, in recent years, gained huge traction due to their high sustainability potential and widespread application possibilities. The Project has been in regular contact with Danish, Nordic, and international e-fuel producers to assess progress across the various technology compositions. Overall, our findings show that the lack of access to renewable energy, particularly for producing hydrogen, and the subsequent price of that energy are a concern for most market participants. Also, our research indicated that another significant development is the shift in carbon acquisition from fossil to biogenic point sources. Changing feedstock priority is a positive step toward the sustainability of e-fuels, but it conflicts with other sectors' interest in the same feedstock and with the scaling potential. Our assessment reveals that, while biogenic feedstock may currently appear abundant, very few studies have comprehensively considered the scale of many industrial processes transitioning to PtX technologies that demand biogenic carbon.

Additionally, the political landscape is changing and adapting to the pressure to become net-zero over time. In Denmark, this has contributed to a political goal and intention to prioritise carbon capture storage (CCS) rather than using it for CCU, which greatly challenges the initiation and scale-up of e-fuels production.

From the start in 2019/20, based on the Grand Agreement, WP2 was determined to follow the newly established and large-scale project consortium Green Fuels for Denmark, as option number two as a SAF supply to the airport. An initiative that was new, promising and very much needed. The planned facility was to be located in the immediate vicinity of Copenhagen Airport. Perhaps most importantly, the established consortium consisted of large and relevant transport players, technology and energy providers, experts and the local political environment: Copenhagen Airports, A. P. Moller-Maersk, DSV Panalpina, DFDS, SAS, Everfuel, NEL, Molslinjen, Topsoe, COWI, the Municipality of Copenhagen, Denmark's Capital Region and Ørsted formed the first partnership of its kind, which combined leading competencies across the value chain, with the energy company Ørsted as the dominant driving force in the project. The plan was to establish a 1.3 GW electrolyser in 2030, powered by 2-3 GW of offshore wind from the Bornholm energy island, with the potential to replace >270,000 tonnes/y of fossil fuel consumption in 2030, equivalent to a 1.77% reduction in Danish $CO_2$ emissions and in the project's phase 3

[142] NISA, Global overview of SAF producers, 2025

would correspond to 30% of Copenhagen Airport's fuel consumption and a large proportion of truck and bus operations in Greater Copenhagen.

With the location of the facility in Copenhagen, the project should be seen in a larger regional context where several Northern European regions (i.e., Oslo, Gothenburg, Malmö, Copenhagen and Hamburg) should cooperate on solutions facilitating a green transformation through renewable hydrogen and also contribute to the district heating supply through surplus heat and sector coupling and thus be integrated with the energy system in Greater Copenhagen. The project's ambition was also to contribute to PtX development, and it would help demonstrate the potential for large-scale offshore wind development and its massive expansion, which would increasingly connect to more countries. In this process, Green Fuels for Denmark was the declared frontrunner.

**But that did not happen,** - of several reasons which we briefly will review here because the learnings are relevant for others and should also be seen in light of the difficulties that many other PtX and eSAF development projects are still struggling with today, and because we and the aviation sector saw the possibility that Green fuels for Denmark could become a leading actor, for example addressing SAF deliveries and solutions that do not depend on biomass resources, e.g. by linking supply targets to one or more electrofuels development projects. Therefore, from the start of the ALIGHT, contact was established with Green Fuels for Denmark project management, and, in addition, the ALIGHT partners SAS and CPH were part of the established consortium. The project preparations took up a lot of time in the first months and years, but the efforts gradually ebbed away. The leading causes are reviewed later.

At our request, Ørsted has provided the following reasons for withdrawing from the project:: *"The decision to step out of Green Fuels for Denmark follows our decision to de-prioritise our effort within e-fuels in Northern Europe and as such the project is no longer in line with our strategy… it is no longer the right fit for Ørsted since we are focusing on our core business which is wind energy with green hydrogen as a relevant and complementary technology."* - Ole Mathias, Head of Renewable Hydrogen, Ørsted, 2025 [143]

Before Ørsted concluded this, the plan was to develop a technological path that used the raw materials hydrogen and carbon to produce methanol, which, in parallel with the development process, had to undergo an ASTM approval process to be designated as a base product for producing SAF. In assessing the many reasons for stopping the development project, these barriers can be added to the official announcements:

**Long-term offtake agreements:** A production facility of this size requires significant investment, especially given uncertainty about whether the market is ready and able to offtake

[143] Ørsted, Ole Mathias, Head of Renewable Hydrogen, mail correspondence, 9. January 2025

the product. Due to being first movers in new technology, high interest rates (though fluctuating), high investments, and more, new e-fuel producers are in a fragile position to make significant investments, such as building an MtJ plant.

**Technological readiness – not there yet:** MtJ manufacturing relies on several proven technologies but bringing them together in a new facility would be challenging and potentially problematic. Also, ASTM approval was a factor that could take a long time, thus adding to the challenge.

**Ørsted halts historic production of sustainable jet fuel**

Ørsted has decided to shelve the plant that was to supply clean fuel for Denmark's first green air route in Denmark. The climate minister is disappointed.

**Regulation:** EU regulations regarding the off-take of products are lacking, and concrete financing models and support options for a necessary future SAF product, which is expected to be more expensive than conventional fuel and bio-SAF, are missing. National support for CCS, but not yet concrete for CCU, is a significant uncertainty factor.

**Infrastructure:** Insufficient confidence in access to renewable energy and carbon. Without a robust, visionary plan to build a flexible infrastructure system for hydrogen and carbon, the project could compromise future scaling.

**Location:** The physical location in the Copenhagen area was less suitable for connecting to future hydrogen pipelines supplying Germany than other parts of the country.

**Conclusion:** A very significant reason for withdrawing from the PtX development has also been a marked economic crisis. At the end of 2023, Ørsted had to write down the value of its assets by a gigantic amount. The reduction is justified in the announcement because Ørsted had been hit by several problems, particularly that several American offshore wind turbine projects could not be realised as expected.

In the autumn of 2024, when the decision to close the project was taken, ReFuelEU aviation had set an indirect guarantee that E-fuels would be supported on their way to the aviation industry.

However, this did not result in any of the commercial European stakeholders landing a final FID. As mentioned above, there are still many challenges and risks in deciding to produce e-fuels at the current stage. With prices estimated at 4-8 times those of conventional fuels, there is an obvious need for subsidies and financing models to play a crucial role in promoting e-fuels and enabling even smaller projects. As national policies aim to meet national targets and promote CCS, a state of indirect competition has emerged between e-fuel producers seeking to attract investors and the government subsidising competitive CCS development.

The explanations show that the current models for using carbon represent a significant barrier for e-fuel producers. Given the normative contract length for the airline’s fuel contracts, which extends for 1-2 years, expectations of long-term sales lasting 10+ years seem difficult, if not impossible, to meet. Subsidies, 3rd-party stakeholders seeking to reduce their scope 3 emissions, and other indirectly involved stakeholders can play a crucial role in increasing long-term certainty for producers. However, as the COVID-19 pandemic has shown, the aviation industry is highly susceptible to change, and the uncertainty around long-term operations is significant.

One more critical point is the unclear rules. Although ReFuelEU Aviation was a major step forward in promoting e-fuels, many questions remain. Soon, Member States will face deadlines for implementing the regulation in practice. Without clarity on how the rules should be interpreted and managed, as well as on the new systems that need to be put in place, e-fuel manufacturers lack usable guidelines for navigating anticipated industry developments. This is ultimately also crucial for how the airlines can comply with the politically determined goals and mandates.

## 4.1 Methanol to Jet (MtJ)

Our analysis shows that in recent years, global interest in obtaining MtJ approval has increased, leading several large fuel producers and technology developers to build test or pilot plants. There is strong confidence among the key players that MtJ will soon obtain the necessary ASTM approval, allowing methanol to be accepted as a basis for producing jet fuel. ASTM has responded by establishing a group process, which is a new approach from ASTM, in the ambition to speed up the approval process, among other things by having it proceed in a parallel process with several manufacturers simultaneously. Topsøe is one of four companies participating in the development work to get methanol approved. The producers have all delivered an agreed quantity to ASTM's approval process. A result is expected around the turn of the year 2025/26.

In parallel with the Green Fuels for Denmark project, the technology provider Topsoe, together with DTU, AAU, SkyNRG, NISA, and others, initiated an MtJ project within the MissionGreenFuels program, which is part of the Danish Innovation Fund.

The project "Methanol-to-jet fuel process development" is part of the decided focus on PtX as the enabler of technologies and future technological and commercial strongholds for Denmark. Through the activities planned in the project, the MtJ development project addresses both the need for aviation fuel production and Danish decarbonization targets, and it feeds into the EU Regulation on ReFuelEU Aviation towards sustainable aviation fuels and is therefore also relevant to ALIGHT WP2.

The objective of the MtJ project was through research and technical development led by Topsoe to create a pilot plant process design and construction to open the MtJ fuel pathway to produce aviation fuel to a level of maturity where the pathway is developed to TRL 5-6 and thereby create the necessary solid base for subsequent design to an industrially relevant scale.

Since the conversion of methanol to jet fuel is not an approved process, the project's objective is also to develop a strategy and commence ASTM certification of the MtJ for use in commercial aviation. As a part of the MtJ project, this task is led by SkyNRG.

The project will also provide a theoretical benchmarking of MtJ versus the Fischer-Tropsch route from a techno-economic perspective. This includes cost estimates with different manufacturing methods, led by Aalborg University.[144] As a relevant part of the ALIGHT WP2 activities, NISA has followed the MtJ technology development at Topsoe (lead) and participated in the work on the ASTM certification strategy and benchmarking report.

Our role has also been to follow the approval process as closely as possible and to coordinate and support initiatives along the way. Thus, both on behalf of the Nordic aviation players and as an integrated part of SAF's supply tasks in ALIGHT WP2, we have been in close contact with fuel producers and technology developers, especially regarding new and more sustainable products. From the beginning of the project, we also considered a broader perspective on the MtJ part of the national development project through participation in the aforementioned Green Fuels for Denmark.

## 4.2 ASTM MtJ approval process

Topsoe is actively involved in the ASTM approval process for the Methanol-to-Jet (MTJ) pathway. Collaborating with ExxonMobil, Honeywell UOP, and other stakeholders, Topsoe is contributing

[144] AAU, Renewable Aviation e-SAF Catalogue and Systems Impacts, 2024

to the ASTM Task Force, to evaluate and qualify MTJ as a Sustainable Aviation Fuel (SAF). The ASTM D02.0J AC724 Task Force is working on the approval process for the MtJ pathway.

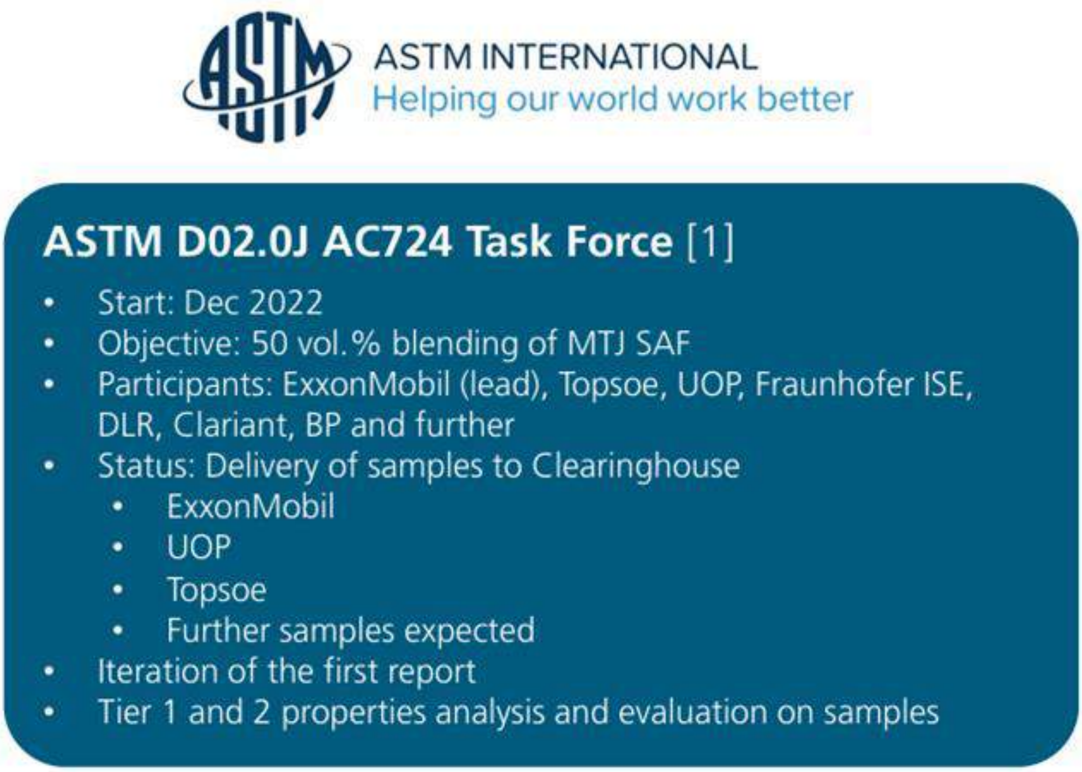



*Figure 37 ASTM D02.0j AC724 Task Force* [145]

To support this effort, Topsoe has been producing and supplying MTJ-produced fuel samples from their demonstration unit for testing under the ASTM D4054 evaluation process. These samples are essential for validating the fuel's quality, safety, and compatibility with existing jet engines. To facilitate evaluation, ASTM International's Aviation Fuel Subcommittee developed ASTM D4054, a Standard Practice that outlines the data the industry requires to effectively assess the composition and performance of a potential new product.

Topsoe has developed and tested the MtJet™ technology, which converts methanol into jet fuel. This technology will be capable of producing large-scale jet fuel at a later stage from renewable electricity, water, and $CO_2$, offering a comprehensive feedstock-to-fuel solution.

Furthermore, a parallel working group led by SkyNRG has prepared a “Fuel Specification & ASTM Qualification Strategy”. The work on this process focused on gaining insight into existing and

[145] ASTM D02.0J AC724 Task Force: Link

upcoming processes for SAF approvals and on preparing communications and feedback regarding the testing phases, mainly to avoid delays in final approvals.

**The approval processes**

Topsoe developed 3 samples of MtJ fuel, total of 40 gallons (±150 L). These Samples were sent to the US Clearing House for Tier 1 + Tier 2 analysis in mid-2023. Tests were conducted on Topsoe's product with blend-in percentages of 20% and 50% in the conventional fuel. Both Tier 1 + Tier 2 results demonstrate good compliance with ASTM specification requirements.

While ExxonMobil and UOP are preparing for approval of a 50% blend-in, Topsoe estimates that its product can reach the market faster with a 20% blend-in. This implies that Topsoe is aiming for a 20% blend-in through inclusion in a separate annex to D7566. This also means that there will be separate ballots for ExxonMobil/UOP's 50% blend-in and Topsoe's 20% respectively. It is expected that both MtJ pathways will be approved in 2026 the fourth quarter.

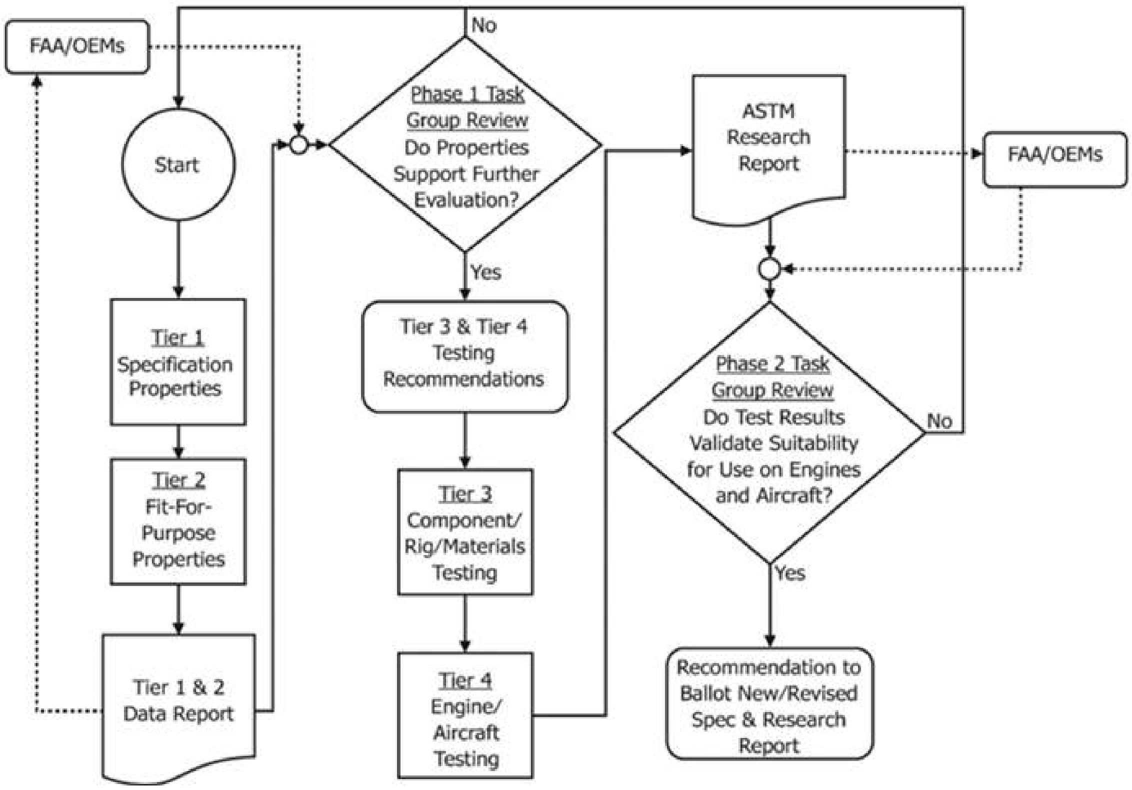



*Figure 38 ASTM approval process[146]*

[146] ASTM, D4054 Tiered Evaluation Process / Approval process

*The extensive OEM review on both MTJ routes is ongoing, and feedback is expected mid-2025*

The Green Fuels for Denmark project was an apparent reason for Topsoe to initiate the MtJ development. The relationship between the two development processes was established and served as the basis for state funding from the Innovation Fund.

## 4.3 Two primary production methods

Across Europe, some potential producers of eSAF based on methanol are awaiting ASTM approval. Current and future hydrogen producers see eSAF as one of the products that may become relevant to invest in. Methanol has more applications than eSAF for aviation. First and foremost, as a green fuel for shipping and as a basis for many chemical products.

E-methanol is produced via a syngas process. This syngas can then be further converted to SAF via the Fischer-Tropsch (FT) pathway or the Methanol-to-Jet pathway (currently undergoing ASTM D4054 qualification). The primary SAF production methods are illustrated below, with the two eSAF methods shown on the right.

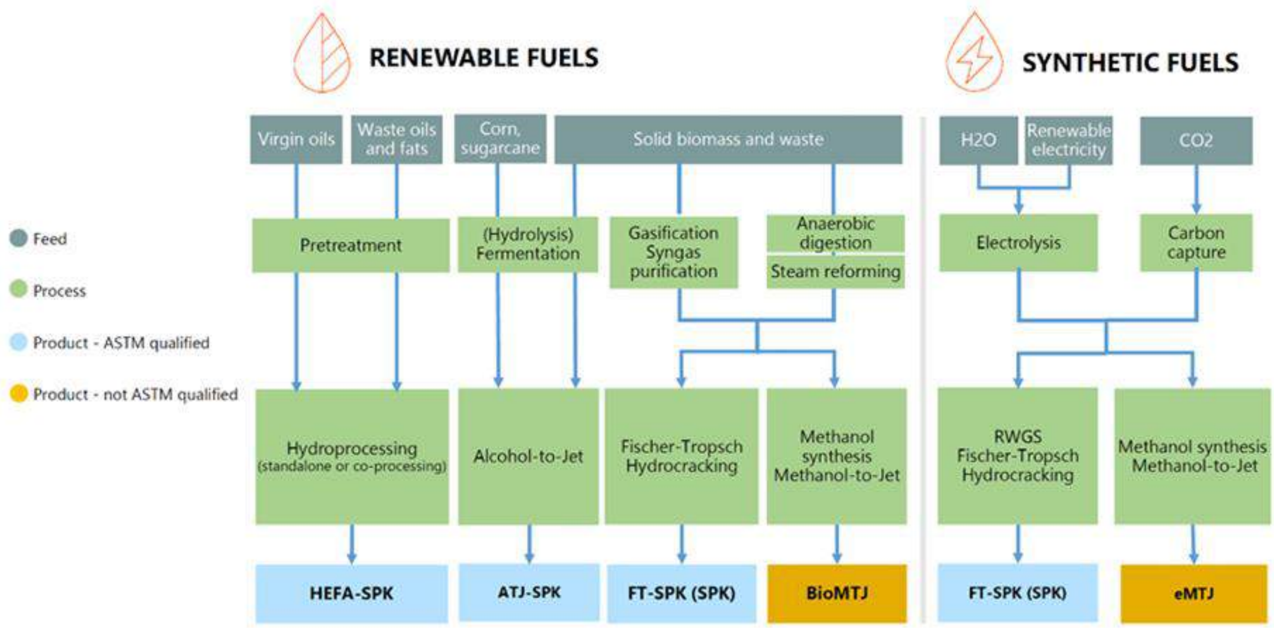



*Figure 39 Main SAF production pathways with similar building blocks* [147]

[147] ECAC, State Action Plan On CO2 emissions from aviation, 2024, page 44

## 4.4 MtJ projects

As with the previously mentioned eSAF project Green Fuels for Denmark, there is widespread ambition among some European manufacturers to establish plants to convert methanol into sustainable jet fuel. As discussed earlier, several large energy and technology providers are working to secure ASTM approval for methanol, a prerequisite for manufacturers to establish MtJ plants. There is, of course, a difference between a plant that will produce all process steps starting with hydrogen production, and a plant established to convert methanol into jet fuel and thus chooses to purchase sustainable hydrogen and $CO_2$ or carbon.

When we in ALIGHT WP2 examine the assumptions and proposals of the eSAF perspectives, we aim to show which possible solutions are linked to the goals of increasing SAF access and sustainability, and to assess how challenging they are compared with other long-term options for SAF production. We have noted the quantitative limitations and sustainability challenges associated with biomass-based products, especially HEFA products derived primarily from UCO. FT based on MSW is also a very limited resource in the Nordic countries and not least in Denmark, where the lighthouse airport is based. Waste products from both households and industry are, to a considerable extent, already utilised for other purposes. Other options are undoubtedly available in countries such as the UK and several southern European countries, where such waste streams have not been used for heating. Alcohol to jet fuel is a third option that undoubtedly has potential due to the several feedstocks that can be developed for the purpose, but while the Alcohol to Jet product can be produced with or without aromatics, the GHG reduction potential is relatively low, estimated at 40-70%.

It is essential to outline the potential of eSAF and consider its long-term implications. Partly because there is the possibility of expanded access to feedstocks in the form of renewable energy and carbon, and partly because both aviation players and politicians, as well as several NGOs and several other market players, point to these technologies, methods, and resource uses.

Thus, several PtX-based eSAF projects are in the pipeline. In Denmark alone, there are three or four plants under preparation, and across Europe, at least 30 plant projects are underway.

Below, some of the projects furthest advanced in preparation are reviewed, with two examples of possible plants that use the MtJ method and three that use the Fischer-Tropsch method.

### 4.4.1 Power2X partners with Honeywell to implement MtJ technology

Dutch company Power2X has entered into a strategic agreement with technology company Honeywell to use the company's eFining™ technology to convert green methanol into sustainable aviation fuel (eSAF) at a future electrofuel plant in Rotterdam. According to the Dutch company, the project represents a significant contribution to establishing a European supply chain for low-carbon synthetic fuels. It supports the green transition in the aviation sector.

The Rotterdam plant, planned as a large-scale production and storage unit in the port area, will use locally produced green hydrogen as well as imported methanol made from green hydrogen and biogenic $CO_2$. These components are used as raw materials in the production of electrofuels (eFuels) – a class of synthetic fuels that can replace part of the fossil fuel consumption in the transport sector. By combining renewable hydrogen and $CO_2$, eMethanol is produced, which is then converted via the eFining process into eSAF or other synthetic, so-called "drop-in" fuels that can be used in existing infrastructure without technological adaptations.

The upcoming plant is expected to produce over 250,000 tonnes of eSAF annually. This will make the plant a key player in implementing the EU's ReFuelEU Aviation regulation, which requires a gradual increase in the use of sustainable aviation fuel, including eSAF, from 2030. According to the project's backers, the plant could cover up to 40% of the expected European demand for eSAF when the project is commissioned at the end of this decade.

Honeywell's eFining technology will enable efficient and large-scale conversion of methanol to eSAF with significantly lower emissions. According to the company, the technology can reduce greenhouse gas emissions by up to 88% compared to conventional jet fuel. Honeywell has already licensed its solutions to over 50 production sites globally and expects these sites, when fully operational, to collectively produce over 60 million litres of renewable fuel per day.

With this collaboration, Power2X and Honeywell seek to contribute to the development of next-generation energy technologies that will support aviation's reduction of $CO_2$ emissions and, at the same time, become a significant part of a European value chain for electro-based fuels.

### 4.4.2 European Energy and Metafuels

Another project in preparation, dependent on the expected ASTM approval of methanol-to-jet, is taking place in Denmark. Swiss company Metafuels AG has entered a partnership with European Energy to establish a synthetic sustainable aviation fuel (eSAF) production facility in southern Denmark. The project involves the construction of an eSAF facility in conjunction with a future Power-to-X facility that European Energy plans to build in the area. When completed, the facility is expected to produce approximately 12,000 litres of eSAF per day.

The initiative is part of a broader effort to enter the market to support the aviation sector's climate goals. Metafuels' technology, called "Aerobrew", is scalable and based on the conversion of sustainably produced methanol into jet fuel. Metafuels says the technology offers high energy efficiency and a very high carbon conversion rate to jet fuel. Overall, it can result in up to 90% reduction in greenhouse gas emissions over the fuel's life cycle compared to conventional jet fuel.

European Energy is currently developing a Power-to-X facility in Southern Denmark, planned to have a capacity more than three times that of the Power-to-X facility in Kassø, which opened in 2024. According to European Energy, the Kassø plant is the world's first large commercial e-methanol plant.

The large amounts of electricity for the electrolysers and all other processes are supplied from nearby solar panel and wind turbine plants. The biogenic $CO_2$ is supplied from the company's carbon capture technology in southern Denmark via a new $CO_2$ liquefaction facility at Tønder Biogas, one of the largest biogas plants in Europe. This facility will capture, purify, and liquefy biogenic $CO_2$. It has the capacity to produce 48,000 tonnes of liquefied $CO_2$ annually.

As with all other eSAF projects, implementing the plans requires clear security for the eSAF products to be sold on the European and national markets. [148]

## 4.5 Synthetic eSAF from Arcadia eFuels

In this project, we have established solid options for insight into the development process for an eSAF production plant with Arcadia efuels, which will be based on Fischer-Tropsch technology. WP2 has, through long-term collaboration and interviews, followed Arcadia E-fuels from the original idea to the point where they are considered close to an FID with potential investors, as of May 2025, when the company completed the Front-End Engineering Design (FEED).

**Arcadia eFuels**

Arcadia e-fuels is an upcoming e-fuels producer with planned production start in 2029 at Masnedø, south of Zealand, Denmark.

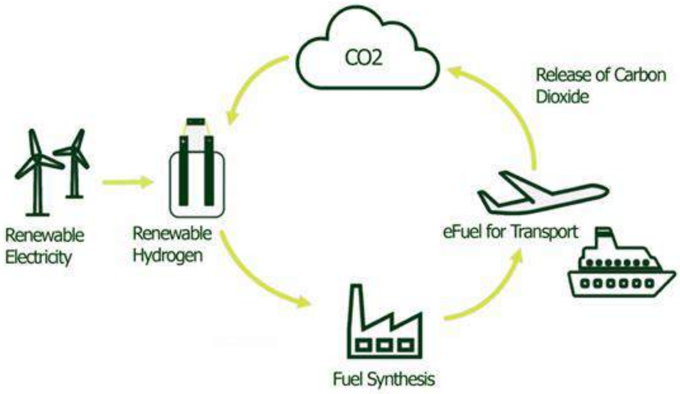
The company started with a small team of people coming from the oil industry and technology providers. With many years of experience, they have collected the necessary skill set to plan and execute the construction of an e-fuels facility in Denmark.

The chosen technology is the proven Fischer-Tropsch process, which benefits from a long history of application and already approved ASTM certification. The other technologies involved should be purchased from Topsoe and other technology providers to ensure proven

[148] Søren Knudsen Kær, Director, Head of Technology, European Energy, has reviewed and contributed to this section

applicability. Although the technologies have been operational separately, this is the first time they are operating together in a single facility.

The following steps involved hiring a French oil and gas engineering company to design the concrete plant in a pre-feed setting, outlining the specifics of both construction and operation to be planned and designed.




This process took 15 months and had several coordination steps with the engineering team and Arcadia to ensure a high-quality planning phase.

Meanwhile, Arcadia planned the location and feedstocks such as water, power, and $CO_2$, conducted environmental impact assessment, and more to secure the necessary framework for the production facility. The choice was set on the small island of Masnedø, in the Vordingborg area south of Zealand, which benefits from being connected to a harbour for logistics and accessibility, and from carbon from biogenic sources near the Arcadia facility.

As the planning for the production facility fell into place, Arcadia eFuels hired BNBP, a major French bank, to upgrade the documentation and visualization for further communication and collaboration with new investors. To attract investors going forward, according to Arcadia, this was a necessary step to provide legitimacy and assurance that all documentation was handled and presented to a high international standard.

Arcadia described the process of concentrating decision-making within a small team and hiring an external consultancy for specific tasks as creating high levels of agility to adapt quickly to the company. Arcadia itself describes this as an essential mechanism for venturing into new technological territory, enabling them to make changes, both small and large, without losing much momentum.

As the planning phase has progressed to the point where construction is ready to begin, there is still a need for further funding. The final financing stretch should complete the Final Investment Decision (FID), which signals a turning point toward realising the project and provides the necessary security to sell the manufactured SAF products.

## Challenges Arcadia faces

**Regulatory frameworks:** Arcadia found that the new EU delegated act caused problems due to its location in Southern Denmark, which is a requirement for exemption under the new delegated act. This means that further work is needed to negotiate advantageous power purchase agreements with renewable energy distributors.

**National political targets compete with feedstocks:** A vital feedstock for e-fuels is access to $CO_2$ or carbon. In the Danish national climate policy, the priority is set on carbon capture storage, with most subsidies targeted at industry sectors that can store the carbon, CCS. The purpose is to meet the national emission targets for 2030. This disposition challenges upcoming e-fuel producers such as Arcadia, thereby indirectly competing with the national prioritised topic for sufficient feedstock. Without subsidies and a lower priority for carbon use in industry, there is a risk of significantly increasing the price of $CO_2$, thereby compromising the attractive business case for E-fuels.

**Lack of long-term off-take agreements:** Although ReFuelEU Aviation creates incentives to purchase e-fuels, there is no guarantee of long-term, reliable sales without long-term, binding contracts. A typical contract between airlines and suppliers lasts 1-2 years, which is insufficient security for investors seeking certainty of return on invested funds. Without additional support schemes, subsidies or third-party guarantees to reduce the risk in a business case to attract investors, other means must be used to ensure competitive prices and offtake, to attract subsequent players in the supply chain, which would typically be fuel suppliers and airlines, as well as other potential end users. This deadlocked situation calls for alternative financing models, or investment platforms, that can help bring the necessary FID onto safe ground. More on this topic in later sections, where the main elements of some specific financing models are reviewed. The latest update is that in May 2025, Arcadia eFuels was able to complete its Front-End Engineering Design (FEED), enabling Project ENDOR in Vordingborg, Denmark, to reach Final Investment Decision (FID) [149] [150]

In addition to the plant in Denmark, Arcadia eFuels is also planning similar plants in Teesside, United Kingdom and Portland/Corpus Christi, Texas, USA.

[149] Arcadia: Arcadiaefuels.com

[150] Martin Nielsen, Plant manager, Arcadia eFuels, has reviewed and contributed to the section on Arcadia

*Figure 40 Designated and approved construction of the Arcadia plant, located in Masnedø near Vordingborg* [151]

## 4.6 Fjord PtX by CIP

Fjord PtX is a Danish Power-to-X (PtX) project under development by Copenhagen Infrastructure Partners (CIP) that aims to produce synthetic Sustainable Aviation Fuel (SAF) as an eSAF using green electricity and captured $CO_2$. CIP plans to start construction of the plant in 2026 in Norbis Park near the northern Jutland city of Aalborg. The plant is expected to be operational in 2030.

**Key facts about Fjord PtX**

The plant is expected to produce up to 90,000 tonnes of SAF annually, which corresponds to approximately 110 million litres of production capacity. This is a fuel volume that is 3 to 4 times larger than the consumption of all current Danish domestic aviation. This production volume is based on approximately 330,000 tonnes of $CO_2$ captured and recycled annually.

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[151] Arcadia: Arcadiaefuels.com

Denmark is divided in two electricity price areas (bidding zones). Fjord PtX plant is in the DK1 bidding zone. The zone is expected to reach above 90% renewable content by the time Fjord COD's (Commercial Operation Date), enabling RFNBO compliance through direct grid power sourcing. A 400 kV substation is located next to the plant, allowing connection to the grid.

One of the primary $CO_2$ capture sources is the waste incineration plant Nordværk. The amount of $CO_2$ used corresponds to the emissions from approximately 17,000 Danish households, calculated as an average.

Fjord PtX is in the industrial area, Norbis park, next to Aalborg Forsyning. The manufacturing process generates a large amount of surplus heat, which, thanks to a carefully planned sector coupling, should be able to supply 11,000 households in the Aalborg area with district heating.

The plant benefits from direct port access, allowing for easy import of machinery and equipment in the construction phase and import of $CO_2$ and export of eSAF when production commences.

Additional land is available in close proximity to the plant, enabling scaling up production as the eSAF markets grow.

**Technology and Sustainability**
Fjord PtX will use electrolysis technology on an industrial scale to produce green hydrogen from renewable electricity. This hydrogen is combined with $CO_2$ captured from waste incineration to produce eSAF. The project will also utilize technical water from Aalborg's wastewater treatment plant.

In addition, the Fjord PtX project, led by Copenhagen Infrastructure Partners, has decided to use Fischer-Tropsch (FT) technology as a central part of the eSAF production process. FT is a well-proven and mature technology that has been used on an industrial scale in other industries. Experience shows that FT technology is suitable for converting synthesis gas from non-fossil sources. The fuel product can be used as an approved drop-in SAF in existing aircraft and equipment. It can be used within existing ASTM approvals up to 50% blend-in and, in the future, is expected to be approved for higher blend-in rates, even up to 100%.

**The project's primary technology elements**
**Green hydrogen production:** Using electrolysis powered by renewable energy (e.g., wind and solar), green hydrogen is produced by splitting water into hydrogen and oxygen.

**Water for splitting:** By purifying wastewater for use as technical water, access to a water resource is established that does not affect access to drinking water and similar uses.

**$CO_2$ capture:** The $CO_2$ is captured locally – primarily from waste incineration at Nordværk in Aalborg, and with additional sources of biogenic $CO_2$ available in proximity to the plant.

**Synthesis gas (syngas):** The hydrogen and $CO_2$ are converted into synthesis gas (a mixture of $H_2$ and CO) via a reverse water-gas shift (RWGS) reaction.

**Fischer-Tropsch synthesis:** The synthesis gas is fed into an FT reactor, where it is converted into long hydrocarbon chains using a catalyst – i.e. synthetic liquid fuels that can be refined into eSAF.

**Refining and upgrading:** The unfinished FT product is refined into aviation fuel that meets ASTM standards for use in civil aviation.

**Excess heat:** The production of eSAF results in excess heat, which is used to contribute to Aalborg Municipality's district heating.

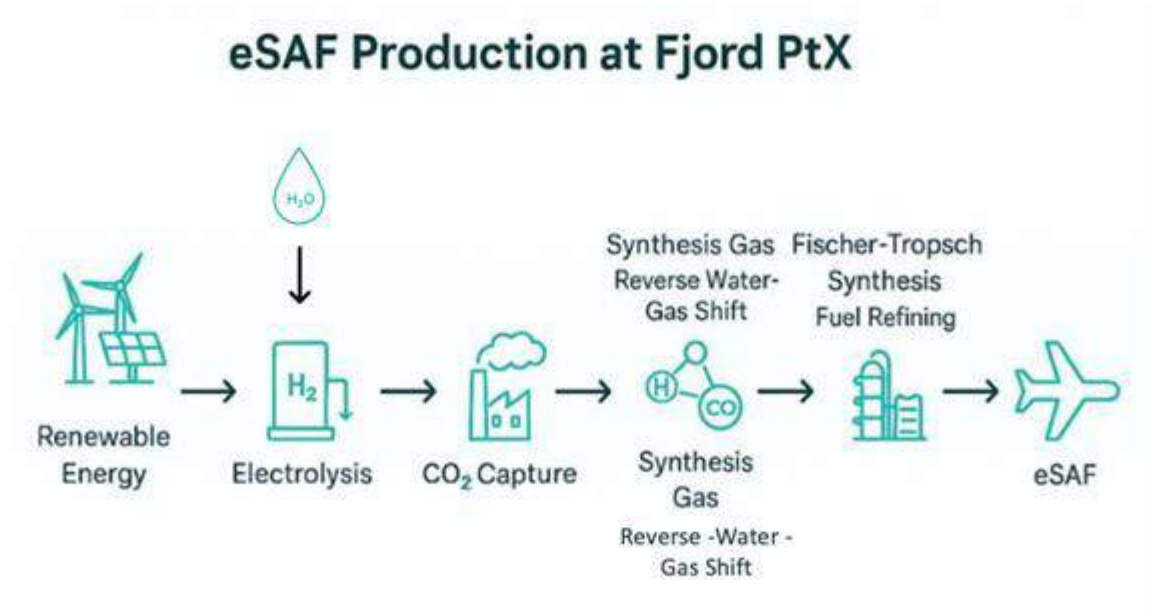



*Figure 41 eSAF Production at Fjord PtX* [62]

**Collaboration with technology partners:** Although CIP has not yet publicly named the specific FT technology supplier for Fjord PtX, the company typically collaborates with recognized technology partners such as Topsoe (for upstream electrolysis and RWGS) and possibly licensees of FT processes such as Shell, Sasol, Velocys, or EMG (Emerging Fuels Technology) depending of course on terms, scale and design.

**Investment and employment:** The project is estimated to represent an investment of +2 billion euros and is expected to generate several tasks and products from subcontractors, and in addition to creating up to 200 permanent jobs associated with the eSAF plant when it is in production.

As with other potential eSAF producers, the CIP and Fjord PtX project faces the challenge of breaking the link between short-term investment willingness and long-term strategic investment, which can help ensure future sales of the plant's products.

**Strategic partners:** In November 2024, CIP entered partnerships with SAS, Copenhagen Airport, and Aalborg Airport to support the development of Fjord PtX. These partners work together to promote Danish production of eSAF and to support both the Danish climate goals of fossil-free Danish domestic air traffic and the goals of the ReFuelEU Aviation Regulation, which, based on a 1.2% blend in 2030-32, requires a gradual increase in the integration of eSAF to achieve net-zero emissions in aviation by 2050.

**Fjord PtX's plans:** The company is positioned to become a frontrunner in eSAF production in the Nordics and thus a potentially central player in Denmark's strategy to reduce $CO_2$ emissions from aviation. With the necessary political support and clear framework conditions, the company believes that the project can contribute significantly to Denmark's green transition and thereby create a more sustainable foundation for the aviation of the future, and in the longer term, through expansion and new projects, become a contributor to RefuelEU Aviation's climate goals for aviation.[152]

## 4.7 INERATEC's ERA ONE – A breakthrough for industrial e-fuel production

Midsummer 2025 finally made it possible to welcome the first eSAF production plant in Europe. At the end of June 2025, ERA ONE, a groundbreaking Power-to-Liquid (PtL) plant, was declared production-ready by INERATEC and officially inaugurated in Frankfurt-Höchst, Germany. The plant is the largest commercial plant of its kind in Europe to date and represents a significant technological and climate-friendly advance in the production of synthetic, climate-neutral fuels – so-called e-fuels. (The German NGO "Atmosfair" was the first to build a small-scale e-kerosene plant in 2023, but not with further expansion.) [153]

With an annual production capacity of up to 2,500 tons, ERA ONE will eventually enable large-scale production of electronically produced sustainable aviation fuel (e-SAF), e-diesel and e-chemicals.

The plant's production process uses biogenic $CO_2$ in combination with locally produced green hydrogen in the industrial area around Frankfurt-Höchst. $CO_2$ is captured from a biogas plant

[152] Sune Petersen, Senior Commercial Manager, CIP, has reviewed and contributed to the section on Fjord PtX

[153] Atmosfair, Atmosfair fair fuel standard

that recycles waste, and hydrogen is a previously unused byproduct of chlorine production. These components are converted via a synthesis process into a synthetic crude oil product, which is subsequently refined into usable drop-in fuels such as eSAF and basic chemical products. According to ERA ONE, this method is the most effective technology for accelerating the transition to climate-neutral mobility, especially in aviation.

The ERA ONE plant is also designed as a modular prototype, enabling the plant to be replicated and scaled quickly and cost-effectively, the company informs. This design strategy aligns with INERATEC's ambitions to scale up production significantly by 2030 and thus contributes to the EU's overall climate goals and the implementation of the ReFuelEU regulation. The announced volume of 2,500 tons per year does not go far, about 30 flights across the Atlantic if only SAF is used. With a 5% blend-in to just over four flights every day across the Atlantic. But the commissioning of the plant could mark a landmark beginning, providing a foundation of experience and inspiration for expansions and subsequent projects.

According to ERA ONE, the project has been realized through close interaction between public and private investors and has provided important experience for further processes and additional initiatives. It has received financial support from, among others, the European Investment Bank (EIB), Breakthrough Energy Catalyst and the German Environmental Innovation Programme (Umwelt Innovations Programm). This multi-stranded funding structure underlines the strategic importance that both public authorities and private investors attach to ERA ONE in the green transition of the transport and energy sectors. It is based on the recognition that partnerships are needed to address both the initial and long-term financial challenges associated with the projects. (See more in sections 5.2.2 and 5.2.3).[154]

## 4.8 Bio-methane and e-methane as a basis for future SAF

In addition to the well-known SAF pathways based solely on $CO_2$ and green hydrogen ($H_2$), there is **a third option**: Production of eSAF with methane as an intermediate. Researchers point out that both biomethane and synthetic methane (e-methane) can be used effectively for SAF production and, at the same time, provide significant systemic benefits. As an alternative to the current eSAF production based solely on $CO_2$ and green hydrogen ($H_2$), a methane-based approach can be used, with e-methane (synthetic methane) or bio-methane serving as the feedstock. Proposals for this have been prepared and can be read in more detail in Appendix 9.3[155]

[154] Ineratec: ineratec.de
[155] Henrik Wenzel, Professor, Department of Green Technology, SDU

# 5 National aviation policies

## 5.1 Aviation policy initiatives – Denmark

The Danish Parliament has decided to introduce a passenger tax starting 1 January 2025. Half of the passenger tax is planned to be returned to the aviation industry as support for a transition to a more sustainable aviation sector in Denmark. It is up to the regulatory authorities to ensure the agreed support is implemented. Initially, the authorities were tasked to establish a tender process for a Danish domestic route. In a subsequent, partly parallel phase, the Danish Climate Agency will establish a process over the next 5-6 years to use the approved support funds for development initiatives that will help make all Danish domestic aviation independent of fossil fuels by 2030. If new technology is available and feasible, support can be allocated to the development and/or commissioning of, for example, electric aircraft**.**

As in most countries, aviation plays a significant role in transport infrastructure, in connecting countries, in trade and business, in outbound and inbound transport and tourism, and as a social and employment factor for many people. Domestic traffic is extensive in relation to the size of the country. When Greenland and the Faroe Islands are not included, all routes can be covered within 250 km or less. There are nine commercial airports in Denmark, four of which are international. In addition to being the largest airport in the Nordic region with over 30 million passengers annually, by far the largest and virtually all domestic flights arrive or depart at CPH. Only a small part of this is Danish domestic traffic.

Although domestic air traffic is not large, it still plays a significant role for users and airlines in public debate, and its climate impact has often been criticised. Domestic flights play a minor but essential role in linking the various parts of the country. Many critics, however, believe that the country is not so large that travel between the regions should not be possible by other means of transport that emit less. Supporters of aviation find it necessary and valuable because it enables job transport, is faster than trains and cars, connects regions of the country, and facilitates international travel.

### 5.1.1 Climate Partnership for Aviation

In 2019, the Danish government initiated a wide range of climate partnerships across the most climate-impacting sectors in Denmark, including energy, agriculture, housing and construction, life sciences and biotechnology, manufacturing, waste and water, and aviation. The climate partnerships were established in collaboration with the business community to strengthen the green transition and support Denmark's climate target of a 70% reduction in greenhouse gas emissions by 2030.

The climate partnership for aviation included significant actors and is established as a cooperation forum between interest organizations, airlines, airports, trade unions, experts, and knowledge organizations, among these ALIGHT partners CPH, SAS and NISA, with the declared objective of contributing to the fulfilment of Denmark's overall climate objective of 70% $CO_2$ e reduction by 2030 compared to 1990.

To achieve this, the technological and operational options were analyzed, including aircraft and equipment renewal, operational improvements, and, not least, the establishment of a supply chain for sustainable aviation fuels (gas-to-liquid and PtX). The Climate Partnership came up with several proposals, including three central initiatives and recommendations:

**1. National Climate Fund for Aviation:** Launching a national fund to create a market for sustainable aviation fuel by financing the price difference between conventional aviation fuel and sustainable aviation fuel. The purpose of the fund was to facilitate a robust platform for investors to engage in production facilities, including wind power plants (for green H2). The most far-reaching element was that the fund was to be financed by a climate contribution (20–30 DKK) from each passenger departing from Danish airports.

**2. A national blending requirement for sustainable aviation fuel:** Setting national blending levels to support research, development and supply of sustainable aviation fuels and reducing $CO_2$ emissions from aviation. Levels were to be subsequently determined and adapted to the structure of the climate fund.

**3. National master plans for green electricity + carbon capture**: A national master plan for expanding green energy production capacity for hydrogen production, allocating biogas as an interim carbon source and overall, for carbon consumption and storage as a feedstock for PtX.

### 5.1.2 The government's model

Several factors led the government to adopt a model different from the one proposed by the aviation climate partnership. First, there had been a change of government that resulted in a majority government between three parties, secondly, the political pressure for a passenger tax had grown, and, not least, the Prime Minister chose in her New Year's speech in 2022 to put forward the ambition of a green Danish domestic route by 2025. An ambition that was put forward at a time when the flagship project Green Fuel for Denmark was in a start-up phase and therefore a possible future solution that could deliver SAF and benefit the energy sector in Denmark (see section 4.1).

Against this background, the majority in the Danish Parliament decided to introduce a national passenger tax from 2025. The tax applies to all passengers departing from a Danish airport and does not apply to passengers departing airports in Greenland or the Faroe Islands. The tax rates are graduated based on the destination of the flight, as per table

| Tax rates in the national passenger tax (DKK per flight, current prices) | | | | | | |
|---|---|---|---|---|---|---|
| | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| **Intra-europe, incl. domestic** | 30 | 30 | 30 | 40 | 40 | 50 |
| **Medium length flights** | 250 | 260 | 270 | 280 | 300 | 310 |
| **Long flights** | 300 | 320 | 340 | 350 | 390 | 410 |
| **Average** | 70 | 72 | 75 | 85 | 90 | 100 |
| **Notes:** The average is rounded to the nearest 5 DKK except for 2026, where it is rounded to the nearest 2 DKK. Tax rates are subject to price-indexation after 2030. | | | | | | |

*Figure 42 National passenger tax, Denmark [156]*

Approximately 50% of the revenue generated from the passenger tax is planned to be allocated to support the green *(green is used by governments and authorities in the sense of more sustainable)* transition of the aviation sector. Specifically, a total of approximately DKK 3.500 million has been allocated to the following initiatives:

- Enable the establishment of a green domestic route in 2025 (DKK 800 million)
- Enable fully green domestic aviation from 2030 (DKK 1.550 million)
- A funding pool to support the green transition of aviation (DKK 1.100 million)

The specific allocation of these funds has not yet been finally decided. Allocation will be subject to decisions by the political parties behind the agreement to introduce the passenger tax. The funding aims, among other things, to bridge the current price gap between fossil aviation fuels and technologies that enable green flights, e.g. SAF, hydrogen, and electric aircraft. By bridging the price gap, the contribution from the passenger tax shall help stimulate the development and adoption of these green technologies within the aviation sector.

[156] Skatteministeriet, Vejen til grøn luftfart, 2023

#### 5.1.2.1 Overview of Danish Green Aviation Programs

| Program | Period | Funding | Responsible Authority |
|---|---|---|---|
| Green Domestic Routes (1st Tender) | 2025–2027 | DKK 0.5 billion | Danish Civil Aviation Authority |
| Green Domestic Routes (2nd Tender) | 2028–2029 | DKK 0.3 billion | Danish Civil Aviation Authority |
| Fully Green Domestic Aviation 2030 | 2027–2033 | DKK 1.5 billion | Danish Energy Agency |
| Green Transition of Aviation | 2025–2033 | DKK 1.0 billion | Danish Energy Agency |

*Figure 43 Danish Green Aviation Programs* [157]

In continuation of the decision of the majority of the Danish Parliament and based on the experiences from the cooperation in the Climate Partnership, the aviation sector and network chose to accept invitations from national agencies to participate in several meetings on the above legislative adjustments and implementation of the decisions. This included processes for dialogue meetings, with the opportunity to comment and propose adjustments to the authorities' attempts to implement changes in the aviation sector. The consultation processes were established in two main tracks: one concerning the decision to establish a green domestic route under the leadership of the Danish Transport Agency, and the other, under the leadership of the Danish Climate Agency, regarding the use of support funds for the necessary transformation of aviation. The reason for this division into two tracks is that route and traffic issues are regulatory matters under the Ministry of Transport, while matters involving electricity, hydrogen, and other forms of energy are regulatory matters under the Ministry of Climate. Since both tracks involve state revenue collected through passenger taxes, projects are also anchored in the Ministry of Taxation.

### 5.1.3 Tender Model for Green Domestic Route

The Danish Transport Agency was tasked with preparing a public tender for the operation of a fully green domestic route. The tender required airlines to use 100% SAF or equivalent green

[157] Skatteministeriet, Vejen til grøn luftfart, 2023

fuels. The financial support from the passenger tax includes coverage of the green premium (the price difference between fossil jet fuel and SAF) and, potentially, public service obligations (PSOs) to ensure continuity. The scheme must comply with EU state aid rules and is subject to prior notification and approval by the European Commission's DG COMP (Directorate-General for Competition). This means that the support scheme is subject to competition and should be awarded to airlines that commit to at least 20 green flights per week. According to the tender, the support should cover the additional cost of using sustainable aviation fuel (SAF), with a cap of DKK 10,000 per ton of $CO_2$ displaced.

The government's submission emphasizes that the support is technology-neutral, "taking into account, among other things, global climate effects, including ILUC effects (Indirect Land Use Change)", which ensures that it is not possible to import a fuel for which the climate effects in the country of origin have not been accounted for.

There is also no possibility of receiving support for the so-called »First Generation Biofuels«, i.e., fuels based on food products such as sugarcane and palm oil. It is also emphasized that support in the proposed scheme is in addition to the SAF blend-in mandates adopted by the EU.

The most controversial thing in the proposal, however, is that the government wants the planes to use fuel according to the so-called »drop-by-drop principle«. In practice, this means the aircraft must physically fly with an amount of SAF that corresponds to the energy requirement for the route, but there may still be fuel in the tank from previous flights. This setup requires separate refuelling, which in turn requires separate tanks and supplies, all of which entail significant additional costs. The requirement for 100% SAF (in the sense of SAF/SATF drop-in; see section 1.3.8) was formulated with the expectation that the product would be approved before startup. Since this cannot be achieved, the route will be put out to tender with the highest possible SAF blend-in for the period 2025-2027.

In the period 2028-2029, 100% green fuels will be required if the ASTM approval standard is in place. Furthermore, there will be stricter sustainability requirements with a focus on e-fuels or electric aircraft, so the tender will prioritize these over bio-based SAF, if the new options are available on the market.

Many aviation players have been critical of the tender model, among other things, because a segregated solution would be unnecessarily expensive. Therefore, a mass balance model would have been preferred. The future competitive consequences of the model are unknown, and the price of the achieved climate benefits is not sufficiently documented. It has also been stated that the financial resources for this green route could be better used if they were invested in the development and production of eSAF in Denmark. The political majority and, consequently, also the Danish Transport Agency have maintained the basic principles of the proposal, which are incorporated into the executive order for a green route in Denmark.

12. August 2025, the Danish Transport Agency published a tender process for the establishment of a domestic "Green route" in the form of a support scheme for SAF in domestic aviation, approved by the European Commission. The deadline for submitting offers set to 29 September 2025 at 13:00. The official tender version was published on Tender Electronic Daily and can be found at The European Union; *516185-2025 Konkurrence vilkår.* [158]

The authorities expect that the operational start-up can take place no later than 30 April 2026. It is also stated in the conditions that if an ASTM approval is available that allows a higher blend-in than 50% before 1 July 2026, the process will be suspended from 31 December 2026. This must be notified by the operators six months in advance. In that case, a new tender process will be established for 2027 with new criteria for a higher SAF blend-in.

Four dialogue meetings with all relevant aviation-sector stakeholders and many bilateral meetings with key stakeholders have been held. Many aviation stakeholders have previously commented that the primary focus, financially and in decision-making, should be on building national production of eSAF that better aligns with sustainable aviation development.

Seen in a broader context, with perspectives on the joint process involving relevant actors and on the many challenges the task entails, it can be appropriate and valuable, in terms of learning and experience, to be updated on the effects and significance the proposal may have. The most essential elements of the model are reviewed here:

**1.** In its national aviation strategy, the government has recognized the need to support the development and use of sustainable fuels

**2.** Funds for a green domestic route are found through the introduction of a passenger tax

**3.** The Danish Transport Authority organized a tender for a green domestic route that should demonstrate the practical application of fossil-free aviation and create demand for SAF, divided into two phases 2026-2027 and 2028-2209.

**4.** The strategy was aligned with the EU's climate and energy policy objectives, including ReFuelEU Aviation, which requires a gradual increase in the SAF share in European aviation, and REDIII, which sets sustainability criteria and traceability obligations

**5.** Participation in the scheme is voluntary, and the use of SAF is in addition to the mandates decided in the EU

**6.** The tender must be notified and approved by the EU Commission's Directorate-General for Competition (DG COMP), ref. the rules for State Aid for Climate, Environment and Energy

[158] The European Union; *516185-2025 Konkurrence vilkår*

(CEEAG). This involves an assessment of proportionality, transparency and necessity. Competition rules may well be a significant obstacle to the best sustainable solutions

**7.** The tender must (soon or later) result in a flight route that operates 100% with fossil-free fuels (SAF or electric) and will be open to airlines that meet specific climate/environmental requirements. (100% has subsequently been changed to "as high a blend-in as possible")

**8.** The model must address the existing price differences ("green premium") between SAF and conventional fuel. Therefore, the financing must enable a market introduction, for example, through state aid, green innovation funds or public-private partnerships. Funds, innovation projects and partnerships have been proposed for use, but the Danish Transport Authority has rejected this

**9.** Implementation requires a robust system for monitoring, reporting and verification (MRV), including the use of the Union Database (UDB) to ensure documentation of sustainability and fuel quantities delivered. National authorities will have a central role in data collection and control.

**10.** The model can potentially function as a demonstration project and source of inspiration for other member states and ICAO states. It combines targeted public support with market-based mechanisms and strong regulatory anchoring. A model like this can demonstrate:

- Technological test platform: For SAF products, fuel infrastructure and new aircraft types.
- Policy laboratory: For new forms of cooperation between government, aviation and the energy sector.
- Market formation: Business models and incentives for investment in SAF.
- Climate impact: Real, but moderate, contribution to national and EU climate goals.
- Institutional learning: Data, supervision and systems that can be used for scalable solutions.
- Opportunity for dialogue on critical elements, with a few examples mentioned here:
- Greater greenhouse gas reduction could be achieved with the mass balance principle!
- Greater long-term gain could be achieved by investing support in development projects such as eSAF.
- Criticism of SAF based on UCO from Asia should be countered by reducing or avoiding it in the tender documents. Clarity in the sustainability criteria regarding prices, quantities, and competition!

As mentioned, many aviation stakeholders have been sceptical of several aspects of the tender documents for the green route. Fifteen consultation comments have been submitted to the Danish Transport Authority, and the critical objections have been presented and discussed during the process. Despite extensive industry criticism and scepticism, there is broad recognition of how the model development and process have been handled through dialogue and meetings. What individual stakeholders, primarily the airlines, do in response to the tender itself was their own internal decision, and any offer should be submitted in accordance with legal and competitive rules.

The model's assessment and perspective is that public support, in this case from the passenger tax, can accelerate the development and market introduction of more sustainable aviation at a time when commercial incentives are still weak. Particularly valuable may be the potential of the national model to build on EU political goals and EU regulations. Suppose others want to promote development: a similar instrument, a publicly supported proposal, a selected mode or technology, or a development project. In that case, this initiative can serve as a testing and learning platform with the possibility of adaptations and gradual scale-up.

However, the prerequisite is close coordination with national climate targets, EU state aid rules, and transparent control mechanisms, including consideration of alternatives to the tender model. The Danish plan for a green domestic route can serve as a model for other countries seeking to combine climate policy, technological innovation, and market support within an overall framework. The tender model and its institutional anchoring can be considered a pragmatic and ambitious approach to the green transition in aviation.

### 5.1.4 Green transition of aviation and green domestic 2030

The second part of the decision that Danish aviation must be transformed to become sustainable concerns a pool for green transition.

The pool for the transition of aviation is initially formulated relatively broadly and, as stated in the agreement text, can be used for the green transition of international flights from Denmark, including to Greenland and the Faroe Islands. It can also be used to blend sustainable aviation fuels such as PtX/eSAF, or other fuels such as electricity or hydrogen, to reduce the aromatic content in fossil fuels, or, as stated in the text, potentially for other initiatives not mentioned in the agreement.

There are several reasons for the broad descriptions. First, the support funds can primarily be used as passenger taxes are paid. Second, the government has not clarified which areas of aviation this pool should fit into the national energy policy. The Danish Climate Agency has therefore been asked to initiate initial analyses of the possibilities and to involve stakeholders, who in practice are fuel producers, suppliers, airlines, airports, relevant organizations, as well as a few knowledge institutions, researchers and specialists.

In the initial phases, several industry and dialogue meetings have been held, focusing on the current market and potential initiatives in this area.

The Danish Climate Agency has initiated dialogues with the EU Commission regarding the legislative preparatory work that must be in place before the implementation of the financial support pools. The plan, as presented by the Danish Climate Agency, is to open the final subsidy model during 2025

So far, spring 2025, three possible models have been presented for use in applications for financial support funds with the following preliminary principles:

| **Model A:** | **Model B:** | **Model C:** |
|---|---|---|
| **Support for the purchase of green fuels for international aviation** | **Support for the production of PtX aviation fuel (e-SAF)** | **Support for development and demonstration projects with low-aromatic aviation fuel** |
| • Number of tender rounds not determined: Technology-neutral tender<br>• Expected to be only one bidding round: Fuel producers/suppliers<br>• Possibility of priority for electricity, hydrogen and PtX/eSAF<br>• Mass balance principle applied<br>• Tender cap over maximum subsidy.<br>• Criteria: Lowest price per ton $CO_2$ e reduced? – Sustainability as defined by EU REDII/III<br>• Penalty for failure to fulfil obligations | • Tender design to be developed<br>• It must be clarified what is being bid for.<br>• Request for support for the production of PtX/eSAF in DK<br>• Who can participate in the tender process?<br>• PtX producers and others?<br>• What is being bid for, framework for cost, time, quantities, who etc?<br>• Quantity of e-SAF, what are the total benefits, co-production etc.<br>• Award criteria: Ex price per quantity of e-SAF produced? Climate reduction etc. | • What is being offered?<br>• Development and demonstration projects through the Energy Technology Development and Demonstration Program (EUDP)<br>Special fund for projects concerning low-aromatic aviation fuel<br>• Who can bid? Companies, researchers, consortia<br>• What is being offered? Projects with low aromatic aviation fuel<br>• Documentation of effects on particle emissions related air quality |

*Figure 44 Three possible models for use in applications for financial support*

Several dialogues have been held on these possible models with the participation of aviation stakeholders, including organizations and government representatives. For each model, the authorities have invited stakeholders to answer questions on feasibility, establishment period, support needs, and timeframes for financial support. The topics have been discussed at different levels and between the possible initiatives. The aviation industry, through the Climate

Partnership for Aviation, has chosen to follow a call for proposals for the use of financial support funds related to the models. Two proposals have been submitted to the Minister for Climate:

*"Denmark has very fruitful conditions for establishing a production of SAF (e-SAF and advanced bio-SAF). As a green frontrunner nation, Denmark should support production of SAF in Denmark, which in turn will push forward the green transition of the aviation sector as well as creating green jobs, know-how and growth in Denmark. This will require a shift in the current political focus om carbon capture and storage (CCS) to an equal focus on carbon capture and usage (CCU). Across Europe several projects (50+) on producing SAF are struggling to get financial investments decisions. Main reason is that airlines cannot agree to 15 years+ agreements on fuel which producers typically must have to secure their investment. To close the gap between producers and buyers, the risk profile must be changed in order to secure an acceptable level of risk for all actors in the supply chain. This calls for government involvement"* – Climate Partnership for Aviation, September 2024.[159]

**SAF recommendations:** The Climate Partnership for Aviation encourages the government to **1.** Support the establishment of a Danish production of SAF to boost the green transition of the aviation sector and to follow the government's ambitious targets for green domestic aviation and for Denmark as a green frontrunner nation, **2.** By establishing a pool of 987 million DKK for SAF production based on criteria that could lead to Danish SAF production, preferably with a Danish value chain and key actors, **3.** Thereby, de-risking relevant SAF projects in Denmark by engaging in risk sharing with central actors in the value chain.

**Low aromatic recommendations:** Research and tests show that a reduced content of aromatic compounds in jet fuel can significantly reduce aviation's non-$CO_2$-related climate impacts and particle emissions in and around airports. Low-aromatic jet fuel can therefore be a promising option for the green transition of aviation.

However, a gradual reduction in the aromatic content of jet fuel will pose significant challenges, especially given airlines' existing purchasing strategies, reliance on international supply chains, and Denmark's relatively limited total fuel volume. Against this background, establishing an independent Danish supply chain seems complicated in practice.

A more sustainable strategy will therefore require a coordinated European approach, in which EU and EEA countries ensure sufficient volumes and common standards to address the complex supply challenges. Denmark can play a key role in this regard by both working for common legislation at EU level and by testing practical solutions nationally that can demonstrate the possibilities for reducing the aromatic content.

[159] Danish Climate Partnership for Aviation, Recommendations to the pool for green transition, Sep. 2024

In this context, the Climate Partnership for Aviation has recommended three specific initiatives to the government:

**1.** To initiate an analysis of how a feasible supply chain for low-aromatic jet fuel can be established, with a budget framework of approximately DKK 5 million.

**2.** To allocate approximately DKK 135 million. In the period 2027-2033 (or earlier, if technically possible) to reduce the aromatic content in jet fuel used at Danish airports.

**3.** Denmark is actively working in the EU to ensure that the aromatic content in fossil jet fuel distributed to European airports is gradually reduced to, for example, 8 per cent by 2033 [160]

As a result of the initiative, Kalundborg Refinery produced the first litres of low-aromatic jet fuel on 8 September 2025 and partnered with Airbus to test its use. The goal is to lead this development and advocate EU regulations to reduce aromatic content. Lowering aromatics in fossil fuel is a short-term transition, while parallel efforts focus on developing fossil-free eSAF from large-scale PtX plants as a long-term solution.

### 5.1.5 The perspectives and the further course of decisions

The perspectives of the decisions and the transferability of Denmark's integrated policy design – spanning tax, financing, industry dialogue and innovation – offer a replicable model for other regions or countries. The strategic mix of supply-side and demand-side incentives, combined with stakeholder engagement and EU compliance, can be interpreted as a valuable model for the further development of sustainable aviation.

The domestic target for 2030 is both a symbolic and practical milestone that can demonstrate the viability of the decisions and tools taken. At the same time, the broader policy architecture enables scalable transformation across the aviation sector and can offer valuable insights to nations aiming to design more sustainable transition frameworks for aviation.

The described approach exemplifies how public-private collaboration, regulatory initiatives, and (the intentions of) technological investments can converge to accelerate decarbonization in sectors where change is needed.

The aviation parties have been involved and have agreed to the overall goals and guidelines. This does not mean agreement on the details, especially not the way in which the green route in Danish domestic was organised. As the employer representative on behalf of airlines and airports, Danish Aviation has proposed postponing the ambition of a green domestic route until the regulation allows flying on "pure green fuel" and that the financial instruments be managed

[160] Danish Climate Partnership for Aviation, Recommendations to the pool for green transition, Sep. 2024

into only one pool to get the greenest aviation for the money, e.g., to create Danish production of sustainable fuel.

**The result**

Shortly before the deadline for this report, the Danish Transport Authority announced the results of the completed tender process**. Oct. 14, 2025:**

The airline Norwegian won the tender for the domestic route Aalborg - Copenhagen in the support period from March 1, 2026, to December 31, 2027, with at least 40 per cent sustainable aviation fuel on the flights. This was done with an offer price of DKK 8,705 per ton of CO2 saved (EUR 1,166). The Norwegian low-cost airline has calculated that it expects to reduce CO2 emissions on the route by 6,700 tons. This will trigger a little over DKK 58 million in subsidies, financed by the introduced passenger tax. (EUR 777,000)

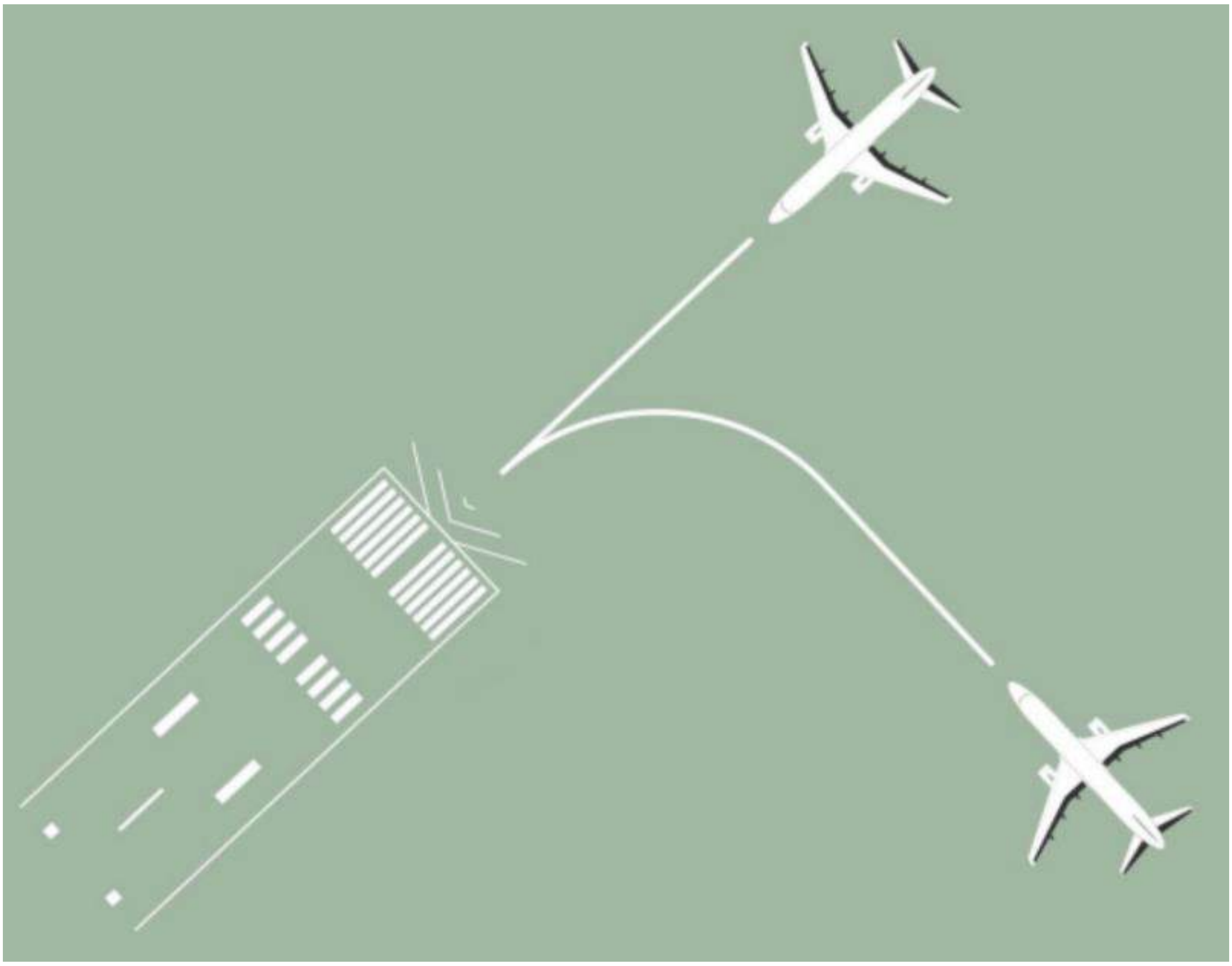
Norwegian plans a total of 3,541 flights during the period, which corresponds to approximately 160 per month. With the offer price of DKK 8,705 per tons of CO2 saved, it was the lowest of the two offers received.

The agreement means Norwegian will operate the one-way route from Aalborg to Copenhagen Airport with a 40-50% SAF blend. The segregated refuelling arrangement has been established with a truck tanker at Aalborg Airport without major changes to the infrastructure, more like an additional option. Norwegian informs that the deal with the supplier includes that the SAF product is manufactured at the St1 refinery in Gothenburg. St1 delivers the blended product to DCC Shell Aviation, which is responsible for transportation and delivery to the airport.

The aviation industry, including Norwegian, preferred a mass balance over the decided drop-to-drop model, which could be established for a significantly smaller amount and on more routes/returns, potentially also with more airlines participating.

As inspiration and as possible replication, be it in whole or in part, there are a number of topics that can be considered and perhaps decided upon. The process in the Danish political proposal includes a pit stop midway with possibilities for changes in the tender and in the conditions. The authorities will develop a proposal on this.

The process has given rise to considerations among relevant actors. A framework for this could be a review of the Danish initiatives, experiences and potential perspectives, as well as reviewing the subsequent checklist.



##### 5.1.5.1 Step-by-step implementation model

**Step-by-Step: Implementation Model**

National sustainable aviation proposal – A transferable model
Objective: To demonstrate and promote a way to a more sustainable aviation through private end public support. Based on the Danish government's aviation policy decisions 2024

| Step | Element | Description |
|---|---|---|
| **1** | Political anchoring | Identify sustainable aviation as a strategic objective in national climate plans or aviation strategies |
| **2** | Definition of tender/project | Define route or technology, SAF/eSAF (electric-long term), climate emission reduction requirements, and minimum share of future operation |
| **3** | Financing model | Clarify financial needs and identify support mechanisms: direct subsidies, charges, green fund, public-private partnership |
| **4** | EU approval | Prepare state aid notification and engage with the EU Commission (DG COMP) – follow CEEAG rules |
| **5** | Execution and partnership | Enter agreements with airlines, fuel producers, providers, airports, authorities, researchers, and specialists |
| **6** | MRV and traceability | Implement Monitoring, Reporting, and Verification (MRV) systems and include the use of the Union Database (UDB) for fuel traceability |
| **7** | Evaluation and learning | Set up ongoing evaluation to support scaling up and transfer of knowledge national and internationally |

#### 5.1.5.2 Checklist, national implementation

| Checklist, national implementation | |
|---|---|
| **Area** | **Key question** |
| Strategy | Is a future sustainable aviation anchored in national objectives? |
| Market | Are there operators, producers, and suppliers ready to participate? |
| Legislation | Is the national legal framework compatible with public tenders, project implementation models etc.? |
| Other aspects | Be aware of criticism and scepticism regarding SAF sustainability content etc. |
| Financing | Is there clarity on cost options, coverage and sources of funding, subsidies or? |
| EU Approval | Has the model, tender or project been notified and approved by the EU (DG COMP)? |
| Infrastructure | Is SAF availability, quality, certification, refuelling and logistics infrastructure in place, available or planned? |
| Data & MRV | Are there systems for monitoring and verification (MRV/UDB)? |
| Communication | Is the purpose clearly communicated to citizens and industry, media/PR? |
| Scaling Up | Are there plans for learning and replication to other airlines, airports, routes? |
| Technology development | Preparation of developments, investments, and prioritized areas of focus (SAF, eSAF, electrification etc. |

Key Roles

- **Civil Aviation Authority** – tender process, approval, oversight
- **Ministry of Transport, Climate, Tax** – climate goals, traceability, EU liaison,
- **Airline operator** – technology, operations, data
- **Fuel producer** – SAF delivery, frames for cost, amount, time and certification
- **Airport/fuel handlers** – infrastructure and fuel handling
- **European Commission** – approval of state aid and integration into the Union database (UDB)
- **Knowledge institutions** – Research and specialists
- **NGO's** – with aviation-, policy- and sustainability-knowledge

*Figure 45 National implementation / Key roles* [161]

Potential Benefits of Implementation

- Demonstration of climate action in practice
- Promotion of new technologies and value chains
- National transition laboratory
- New industry- and job options
- Value creation and impact
- Creation of demand for SAF, specific SAF products and their climate benefits
- Inspiration for others, sectors, and neighbouring countries

*Figure 46 Potential benefits of (national) implementation* [162]

[161] Danish Climate Partnerships, National implementation / Key roles, Climate Partnership Playbook
[162] Energistyrelsen. Danmarks globale klimapåvirkning - Global afrapportering (GA24): International transport. Apr. 2024:

## 5.2 Why aviation needs eSAF

The combination of high energy prices and fierce global competition, especially from China and the US, is putting pressure on European competitiveness. At the same time, it is crucial to maintain and strengthen the commitments to ensure a more sustainable future. If the associated goals are to be achieved, resolute action must be taken with ambitious political initiatives to support a green industry that is both competitive and strengthens the energy security of the EU and the member states.

### 5.2.1 Why eSAF is crucial – despite its high energy consumption

A critical point of view on a large-scale investment in eSAF is that it requires significant amounts of electricity, primarily because it is produced by combining green hydrogen from electrolysis with a carbon source via synthesis processes such as Fischer-Tropsch or methanol conversion, when approved as a pathway for jet fuel production. This makes it one of the most energy-intensive forms of fuel production. Yet eSAF is central to the development of aviation sustainability, for the following reasons:

**1.** Drop-in compatibility
Like other approved SAF alternative jet fuels, eSAF is chemically identical to fossil jet fuel and can be used directly in existing aircraft engines and airport infrastructure without any adaptations other than those required for blending.

**2**. Long-term climate impact
When produced with renewable electricity and biogenic/atmospheric carbon, eSAF can provide nearly climate-neutral use. This means that aviation with eSAF achieves greater emission reductions than other SAF products.

**3.** Scalability and security of supply
Although energy demand is large, the technologies behind eSAF are scalable and can use nationally or European-produced electricity and carbon, thereby reducing dependence on imported fossil energy and Asian biomass/UCO and increasing energy sovereignty.

**4.** Regulatory drive and targets
ReFuelEU Aviation sets minimum targets for synthetic fuels from 2030 onwards, which will make eSAF a legal and political necessity. Ignoring eSAF would be ignoring the EU's green legislation and climate goals.

**5.** The energy demand is huge
By 2050, eSAF production will require approximately 610 TWh of electricity, equivalent to 12% of the expected total EU electricity production. This is a considerable amount, but it should be possible if the production is planned as part of a broader energy policy and strategy for expanding renewable energy.

**6.** Possibility of sector integration
The production of eSAF can be coupled with the development of Power-to-X technologies, storage and electrification in other sectors, as well as surplus heat for heating purposes. This makes eSAF part of the overall green transition, not an isolated niche product.

**7.** Power storing options and flexibility:
Provides the possibility of storing surplus electricity as liquid fuel. Many applications, including use as buffer storage in situations with a shortage of renewable energy.

**8.** Lack of alternatives
Other SAF products based on biomass and waste products have an upper limit on how much feedstock is available. Access to eSAF feedstocks is a challenge, but expanded renewable energy resources can enable access to the necessary raw materials. Access to eSAF raw materials is a challenge, but expanding renewable energy resources offers better opportunities to obtain them. Other alternatives, such as electric, hydrogen and hybrid aircraft, will enter the market in the coming years and may play a significantly increasing role in the slightly longer term.

In general terms, eSAF is produced using hydrogen (H2) and carbon/carbon dioxide ($CO_2$). In accordance with EU legislation, according to the following criteria:

- The energy content of the fuel produced must come from renewable electricity
- The hydrogen is produced by electrolysis of water powered by renewable energy or nuclear electricity
- $CO_2$ can be recycled from bioenergy (so-called biogenic carbon), industrial emissions or captured from the air (through Direct Air Capture)

*NOTE: The so-called "e-biofuels" can come into play (sometimes referred to as Power-and-Biomass-to-Liquid (PBtL) fuels). These are produced by co-processing a synthetic gas derived from biomass gasification and hydrogen from renewable electricity, enabling the co-production of biofuel and e-fuel. Confirmed by the EU European Commission, Q&A, question 45.* [163]

[163] European Commission, Mobility & Transport. Frequently Asked Questions on the interpretation (...) for sustainable air transport

Energy balance for eSAF – input vs. output. eSAF (via PtX/PtL). It is a very energy-intensive process to produce PtX-based eSAF. With current technology, the overall system efficiency of eSAF when using electricity is typically 10–15% in a "tank-to-wake" calculation. For every 100 kWh of renewable electricity, only approximately 10–15 kWh of usable eSAF energy is produced after accounting for the entire process chain. Several development projects are working on the energy challenge. Among others, OXCCU's $CO_2$ F-T process exhibited approximately half the capital costs of conventional SAF production methods, such as Methanol-to-Jet (MTJ) or Reverse Water Gas Shift Fischer-Tropsch (RWGS+FT). The developers predict a 25% reduction in Fuel Costs: OXCCU's process enables SAF production at roughly 25% lower cost per ton compared to traditional RWGS+FT methods, making e-SAF more economically viable. [164]

eSAF is energy intensive, but probably also the most promising technology for sustainably decarbonizing the aviation sector. The high energy demand should be met through a massive expansion of renewable energy and through innovative, intelligent sector integration. Furthermore, PtX products can be scaled globally and stored and transported in liquid form, allowing for flexible use.

The EU has recognised the potential of eSAF in political initiatives such as ReFuelEU Aviation and the 2040 Climate Target. Fuel suppliers in the EU must deliver 1.2% e-SAF in 2030/31 and 5% in 2035, respectively, to be on track towards the necessary long-term reductions. If production is not established and scaled up in a well-planned manner, the EU and aviation risk will be left without usable solutions and alternatives when biomass, residual waste, and other production routes are insufficient.

Despite the central role eSAF will play in achieving the EU's targets, no company has yet made a final investment decision to build a production facility. Furthermore, most major fuel suppliers have not announced that they are actively involved in such projects. This must be considered very worrying, especially given the ReFuelEU requirement to deliver 600,000 tonnes of eSAF by 2030. Failure to meet this target could lead to fines for suppliers and, in turn, significant additional costs for both airlines and European consumers. In this context, it may be relevant to call on producers, especially major oil companies, also to be responsible for developing and producing the required SAF volumes.

[164] Oxccu, New Techno-economic report shows path to cost-effective, scalable sustainable aviation fuel, SAF. Jan. 2025

To change the current situation, meaning getting decisions and investments off the ground, many players have pointed to the need to create an attractive, solid financing structure. Although there is strong interest in equity investment, the lack of certainty about product sales and, thus, future revenues represents a serious barrier to obtaining the billion-euro loans and investments required. This uncertainty is mainly due to price and market fluctuations, uncertainty about new technologies, lack of infrastructure and uncertain raw material availability. Several actors state that if rapid and targeted action is not taken, there is a risk that production will be too slow relative to the set targets and that eSAF production will instead be established outside Europe. It may help suppliers meet their delivery responsibilities that, as with HEFA products now, eSAF can be sourced from Asia, but this is hardly good for the trade balance or the EU's goal of energy sector self-sufficiency.

The EU's Clean Industrial Deal and the upcoming Sustainable Transport Investment Plan (STIP) could be an essential opportunity. The Industrial Deal aims to lower and stabilise energy costs by installing 100 GW of renewable capacity by 2030. This creates better conditions for eSAF projects to become profitable, especially and initially in countries with electricity grids dominated by green power, and where the infrastructure has, or can be provided with, sufficient capacity to handle increased electricity demand. The plan also proposes that tax rules be targeted so that polluting conventional jet fuels are no longer favoured. This is a much-needed measure as continued subsidies for fossil oil production are not in line with the EU's climate goals.

Furthermore, there is increasing demand for cleaner products – for example, through increased use of renewable hydrogen. The existing European Hydrogen Bank has not yet proven effective in supporting the development and production of eSAF, underscoring the need for additional risk-reducing initiatives. In addition, over €100 billion will be mobilised for the green industry, including through the ETS and the InvestEU fund. It has been assessed that the current reliance on voluntary national contributions from the ETS could risk diluting the effort. It is therefore proposed to strengthen InvestEU' s risk-bearing capacity so that it can also target eSAF projects that have not yet received support.

For eSAF projects, access to renewable electricity for hydrogen production and to captured $CO_2$ is central, and as global climate demands intensify, the fight for these resources will intensify. This could be facilitated if the EU adopts a plan for the future expansion of security of supply and production. The upcoming Sustainable Transport Investment Plan should prioritise support for fuels best suited to reducing emissions in aviation and shipping. To accelerate development, eSAF must be made a strategic priority, and revenue security for eSAF investors should be created, for example through a government intermediary. Proposals such as these aim to build confidence that the necessary investment decisions are made, and production begins in time to meet the 2030 targets.

Some stakeholders recommend using the H2Global mechanism to establish revenue security through long-term contracts between producers and a publicly supported intermediary, which can also receive ETS revenues. Project SkyPower has calculated that if just 20% of ETS revenues in the period 2031-2040, equivalent to 3 billion euros, are channelled into this mechanism, it could finance 300,000 tonnes of e-SAF over 10 years, paving the way for 3-5 full-scale projects.[165]

However, as this mechanism can realistically only be in place in 2027, a transitional arrangement is also needed that can give leading projects access to temporary support earlier. Also, a state-guaranteed financial security scheme is necessary to ensure payment capacity in the event of production failures or supply chain problems. It is indicated that this could be handled through the European Investment Bank EIB or InvestEU.

If these policy interventions are implemented, Project SkyPower and other stakeholders find that private investors and businesses will be ready to accelerate the development of eSAF and thereby contribute to Europe's development of a more sustainable aviation. If these critical prerequisites are not met, it may be difficult to see how a path can be created to ensure the technological advances needed to meet the agreed mandates and objectives in both the short and long term.

### 5.2.2 e-SAF: A strategic opportunity for the EU's energy policy goals

Project SkyPower is an initiative to promote the opportunities to produce eSAF in Europe. Several CEOs lead the initiative from key parts of the value chain, including eSAF developers, manufacturers, investors, end users, and related actors. Related to partners in ALIGHT and NISA's membership and network, CEOs from SAS, CPH, Airbus, SkyNRG and KLM/Air France participate. Project SkyPower has set itself the goal of paving the way for the first large-scale e-SAF plants to reach final investment decision by the end of 2025, among other things by setting up financing models and by putting pressure on key decision-makers.

As the EU works to strengthen its domestic industry, increase energy security, create valuable jobs and take a global leadership position in cleantech, electro-based sustainable aviation fuel (eSAF) could become a key strategic opportunity. In addition to contributing significantly to aviation's climate goals, eSAF could, as reviewed earlier, also support several key European priorities.

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[165] Project SkyPower, 50+ companies call (...), June 2025

According to SkyPower, players across the aviation value chain are ready to realise eSAF projects in Europe. Many airlines are actively negotiating future purchase agreements, financial institutions are identifying investment and risk hedging opportunities, and technology suppliers are collaborating on scale-up. Mainly because it is recognised that the need exists. It is pointed out that with the right political decisions, the EU can help secure both the green leadership position and a transition to a competitive, and in the long term, a more sustainable aviation sector.

To date, around 30-40 eSAF projects have been announced in Europe, totalling a production capacity of 2 million tonnes per year. Yet no one has reached a Final Investment Decision (FID). It is highlighted that eSAF development and production can both deliver industrial benefits and help the EU achieve energy independence. In terms of climate, the long-term potential is a reduction of 400 million tons of $CO_2$ e, and eSAF production could have spin-off effects to the benefit of other areas, such as shipping and the chemical industry, as well as sector couplings with other energy supply areas.

To bring the first e-SAF projects to FID, Project SkyPower believes targeted political action is needed. It is noted that several players in the energy sector, including project developers and the aviation industry, are already underway but are being slowed by three key barriers: lack of revenue security, perceived regulatory uncertainty, and a lack of project risk taken in connection with new technologies. To accelerate the private sector's engagement, five political initiatives are proposed:

### 5.2.3 Five policy measures to secure investments in e-SAF

**1. Recognise e-SAF as a strategic priority:** Project SkyPower propose that eSAF be incorporated into the EU’s Clean Industrial Deal and the upcoming Sustainable Transport Investment Plan (STIP). A clear policy priority will send a strong signal to the market, encourage investment, and facilitate the transition from innovation to commercial operation.

**2. Establish a market intermediary supported by ETS revenues:** ETS revenues from aviation should be reinvested to capitalise a publicly supported intermediary that can enter into long-term purchase agreements with producers and shorter-term resale contracts with buyers. This will create revenue security for producers and price predictability for airlines and is a key prerequisite for achieving FID. Such a mechanism, e.g., via Hintco[166] and the H2Global structure, should operate under multi-year contracts and cover price differences through a contracts-for-difference model. An initial capital of €3 billion could support annual production of 100-300 kt and up to half of the ReFuelEU requirement for 2030/31.

**3. Create a transitional arrangement until the market intermediary comes into force:** To avoid delays and uncertainty among first movers, the Commission should guarantee that the earliest projects will have priority access to the new support scheme when it comes into force. This is crucial so that projects applying for FID in 2025-2027 can deliver before the first ReFuelEU deadlines in 2030/31.

**4. Provide long-term regulatory clarity:** Investors are demanding greater certainty about future requirements and criteria. The Commission should clarify in 2025 the consequences of a potential supply shortfall on eSAF in relation to the 2040 climate targets. At the same time, a grandfathering mechanism should be established to protect early investments, and Member States should publish clear, harmonised penalty systems for non-compliance with ReFuelEU in Q1/2025.

**5. Address supply risks through state guarantee schemes:** Large eSAF projects depend on access to green electricity and $CO_2$ resources that often require the construction of new infrastructure. Delays in this create "project-by-project" risks. According to Project SkyPower, the Commission should establish a financial guarantee scheme that ensures loan repayments and, if necessary, minimum returns to investors in the start-up phase. Strict access criteria can minimise the take-up of this support. In addition, the EU Innovation Fund should be further opened to eSAF, and blended finance instruments such as EU-Catalyst should be used to mobilise private capital. [167]

Project SkyPower finds that kick-starting the e-SAF industry in 2025 will put the aviation sector on track to achieve significant emissions reductions by 2050, benefiting the EU.

SkyPower argues that the EU has a unique opportunity to lead the global e-SAF industry by simultaneously increasing energy security, industrial competitiveness, and climate leadership. However, if it does not act, it risks missing its 2030 RFEUA sub-mandates, delaying critical progress on climate targets and losing ground to international competitors on e-SAF development.

[166] Hintco, Hintco.eu
[167] Breakthrough Energy, Breakthrough Energy Catalist Partnership, Accelerating the Deployment of Emerging Climate Technologies in the EU

The Clean Industrial Deal (including its announced STIP, the Industrial Decarbonisation Bank, the increasing investment-carrying capacity of Invest EU, etc.) are positive critical opportunities to place e-SAF as a strategic priority and establish a clear roadmap to meet the 2030 mandates.


A decisive action in 2025 will determine whether the EU puts the aviation industry on the right track towards climate goals and positions itself to capture a share of a potential 350+ billion EUR global e-SAF market. [168] [169]

Project SkyPower stresses that with targeted support in the critical early years, the EU can lead the development of this technology on a very large scale.

Central to the call and proposals from Project SkyPower is the model of double-sided auctions through a uniform sales price-setting. A model that is intended to play a role as a bridging mechanism for the entire support concept to be launched.

As mentioned, the model has been proposed previously and partially used through Hintco[170] and the H2Global initiative.

[168] Project SkyPower: Five policy measures to secure investments in e-SAF, march 2025
[169] Project SkyPower, 50+ companies call (...), June 2025
[170] Hintco, hintco.eu

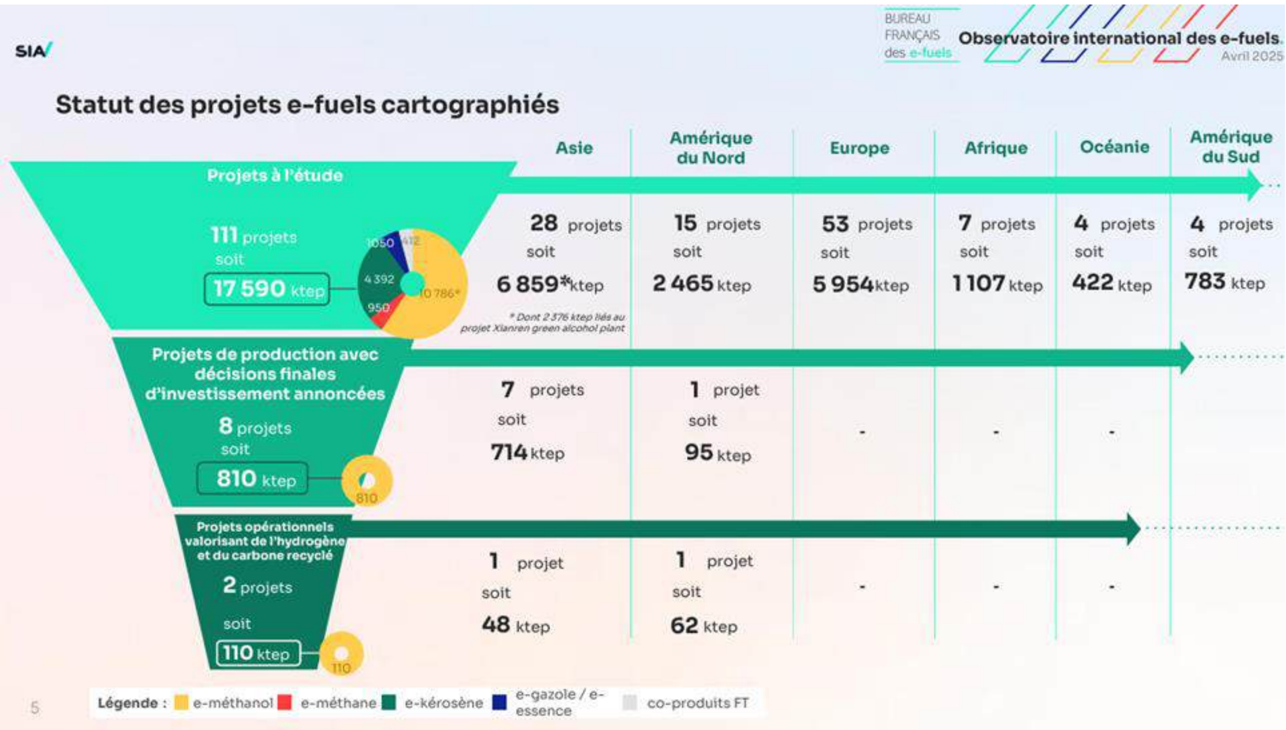



*Figure 47 Global overview of eFuel projects* [171]

As shown in the figure above, there are more than 100 eFuel projects in preparation globally, of which over 50 are in Europe, and approximately 30 are expected to be able to produce eSAF. In contrast to Europe, which has none yet, China (Asia) has 7 projects that have undergone an FID and are, in principle, in the process of building plants. As shown above, there are many barriers to launching new eSAF plants. The biggest resource challenges are power volumes and energy supply.

### 5.2.4 Electricity demand for eSAF under ReFuelEU Aviation

We have previously described hydrogen and carbon as the central components of eSAF manufacturing. High targets for PtX-based eSAF require large amounts of renewable energy to produce hydrogen. According to calculations from Green Power Denmark,[172] over 100 TWh of green electricity will be made in Denmark in 2030. PtX will require a minimum of 20-30 TWh of electricity consumption in total to meet the PtX strategy, of which PtX aviation fuels alone are expected to account for around 10 TWh. To meet the PtX strategy, investments in renewable energy production plants of over DKK 100 billion are required, as well as over DKK 30 billion for PtX plants in Denmark.

[171] Bureau Francias des e-fuels: Illustration from: La course mondiale aux e-fuels est lancée, April 2025
[172] Green Power Denmark, Grøn omstilling af luftfarten med PtX-brændstoffer, 2022, page 14

In the context of the European Union's climate and energy objectives, the implementation of ReFuelEU Aviation plays a central role in decarbonising the aviation sector. The regulation includes binding minimum sub-targets for the use of synthetic aviation fuels (eSAF) beginning in 2030 and increasing towards 2050. Meeting these targets will require a significant increase in the production of renewable electricity, a prerequisite for large-scale production of eSAF via Power-to-Liquid (PtL) pathways.

ReFuelEU Aviation currently does not include specific provisions to ensure the necessary deployment of renewable electricity for synthetic fuel production.

By 2030, the expected electricity demand for eSAF production is approximately 1.4 TWh, rising sharply to 81 TWh by 2040 and ultimately reaching 610 TWh by 2050, in line with the full deployment of the synthetic fuel mandate. While electricity currently accounts for only a minor share of aviation sector energy needs, the anticipated scale of the transformation implies a substantial shift in electricity use.

The 2030 and 2040 electricity requirements correspond to 0.04% and 1.7%, respectively, of the EU's projected total electricity generation for those years. These levels appear manageable within the existing framework. However, the anticipated growth between 2040 and 2050 is exponential. The 610 TWh needed in 2050 is equivalent to the total volume of renewable electricity capacity added across the EU between 2005 and 2022. It also represents approximately 22% of current renewable electricity production and 12% of the projected total EU electricity output in 2050. [173]

Importantly, this electricity must be both additional and sourced from renewable energy to ensure the environmental integrity of eSAF. Despite the importance of this issue, ReFuelEU Aviation does not include specific provisions to provide the necessary deployment of renewable electricity for synthetic fuel production. To accurately reflect the implications of synthetic fuel deployment, EU fuel mix modelling and energy strategies must include corresponding renewable electricity capacity planning, which emphasizes the need for aviation's fuel/energy needs to be fully integrated into both national and EU energy policy.
The production of eSAF requires early investments, as the ramp-up in capacity must begin immediately to ensure compliance with ReFuelEU Aviation targets from 2030 onward. In addition to the electricity needed for eSAF production, it is also essential to account for renewable electricity inputs into the production of green hydrogen used in refinery processes for bio-based jet fuels. Although often overlooked, this demand is non-negligible and must be integrated into broader assessments of the sector's decarbonisation pathway.

[173] FCA, Technical report, ReFuelEU Aviation's Targets: A Feasibility Assessment, Sep. 2024

With the enormous need for electricity, the expansion of renewable energy plants and installations is crucial, not least because there will be limited access to other feedstocks and resources for future SAF needs. Competition for electricity resources is increasing as more energy-consuming activities are electrified.

**Airports and RE:** It may therefore also be relevant to ask whether energy utilization at airports is sufficient. Airports often have large areas that are not utilised but mainly serve as buffer zones for safety, traffic, and access conditions. Some airports are in the process of expanding their utilization, and some are considering it. Given the large amounts of TWh required, airports' contribution is not significant, but as electricity production increasingly serves aviation, it is relevant to assess whether the potential for electricity production has been fully utilised not least in countries and areas where other areas for solar and wind are under severe pressure and perhaps even under criticism for expansion due to visual nuisance to the landscape.

In addition, there is a growing demand for cleaner fuel products to improve air quality, among other things, which, in the long term, can be achieved through increased use of renewable hydrogen.

There is a need for thorough analyses of the potential to make decisions that maximise the contribution to the green transition.

Production and consumption of green electricity are mutually dependent, and therefore, the framework conditions for the entire value chain from renewable energy plants to electricity and hydrogen infrastructure must be optimized. Decisions on this should also preferably be made in a context and time perspective that matches the set goals. Self-sufficiency in energy and fuel would be optimal. Could it be near or at the airport? Questions that weigh heavily are how large the plant should be and its geographical location, both in relation to raw materials and power availability on the input side, and to possible synergy effects on the output side. In addition, of course, how the main products can either be transported for use by the end user or for further processing by an intermediary. A location close to shipping access is often preferred. Geographic location is also vital for regulatory approvals. For example, whether the facility is an expansion of an existing energy/refinery, e.g., in an area pre-approved for chemical production, or a new location where all approval processes must be done from scratch. (See further considerations in section 5.4 regarding the airport's role)

### 5.2.5 Carbon needed

Access to carbon sources is also a critical factor that should always be included in planning and decision-making processes. Biogas plants and other plants that produce carbon as a byproduct are the most obvious. In the long term, direct air capture (DAC) is also expected to become a necessary and crucial carbon source. The need for carbon will be enormous in the coming decades. This is because the capture of biogenic carbon serves both as a means of achieving negative emissions via CCS (carbon capture and storage) and of converting transport, shipping, and aviation to PtX fuels via CCU (carbon capture and utilisation). In addition, the carbon potential from point sources, such as industrial facilities and biomass power plants, will decrease in the coming years as processes are streamlined and existing plants are expected to be phased out.

Projections indicate that in the future, there will not be enough green carbon to cover all needs for both CCS and CCU. Green carbon must be used where it provides the most value. Therefore, the combined efforts of aviation nationally, at EU level and globally are essential.

For eSAF to be considered climate neutral and recognised within the framework of EU regulations, including ReFuelEU Aviation and the Renewable Energy Directive (RED III), this $CO_2$ must not originate from fossil sources, but from sustainable and verifiable non-fossil sources.

Today, the primary carbon sources that can potentially be used for eSAF production are biogenic carbon from biomass plants and biogas upgrading, Carbon captured from waste incineration of biogenic content, and Direct Air Capture (DAC). Carbon from power plants or other industrial sources can be used in RFNBO production and counted as zero emissions until 2036. DAC is still at an early stage of development and is characterised by both high costs and low energy efficiency. It is important to note that many existing industrial point sources of carbon, particularly those from fossil processes, will gradually be reduced in line with stricter climate requirements, implying a future decline in the availability of carbon from these sources.

The challenge is also exacerbated by the growing demand for carbon in other sectors. In addition to synthetic fuels for aviation and shipping, carbon is expected to play a key role in other Power-to-X technologies, in the production of low-carbon plastics and in negative emissions technologies. This will inevitably lead to increased competition for the limited supply of sustainable carbon ($CO_2$), which is expected to create shortages and raise the cost of eSAF production.

Carbon is not only a technical resource but also a strategic scarcity factor. Meeting the ReFuelEU Aviation target for synthetic aviation fuels from 2030 onwards will require not only scaling up electrolysis capacity and green power generation, but also a coordinated focus on establishing carbon supply chains. This will involve building infrastructure to capture, clean, and transport carbon ($CO_2$), as well as strengthening political efforts to define clear, sustainable standards for acceptable sources under EU certification systems.

Against this background, the need for accepted carbon must be developed as an integral part of the EU's overall strategy for renewable energy and decarbonisation of the transport sector. Future policy frameworks should therefore accommodate investments in biogenic carbon capture and DAC technologies, create incentives to allocate resources to high-value applications such as eSAF, and ensure that competition for carbon does not undermine the climate benefits of synthetic fuels. It should be added that in Denmark, further proposals have been made regarding the aforementioned dual financing model. We will return to this, but first, we will review perspectives on using captured carbon for purposes other than eSAF.

## 5.3 Carbon storage and/or usage

Not all researchers working on the applicability of limited energy resources consider PtX-based eSAF solutions for aviation the most obvious, precisely because the energy consumption of the manufacturing process is so high compared to other applications.

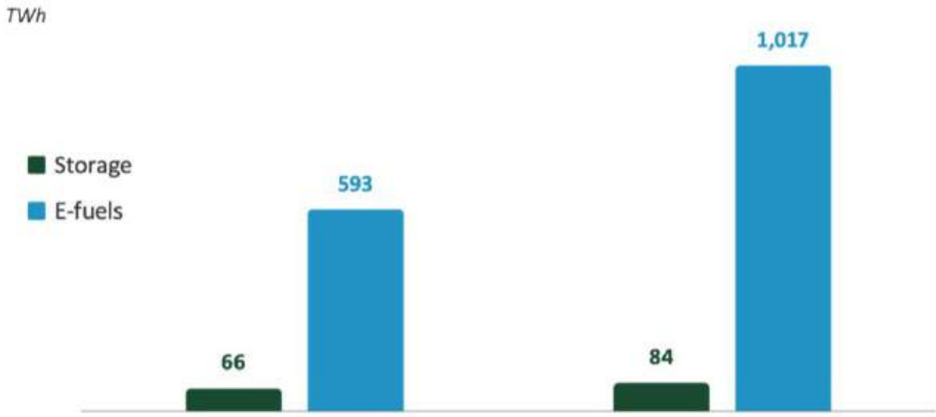
Many calculations have been made about this, and the latest comes from one of Denmark's leading climate think tanks, Concito, which, for example, in the report "eFuels or storage" has calculated that carbon storage using Direct Air Capture will be far more efficient to use for storage than for use when it comes to aviation, because the captured carbon must be converted into jet fuel using hydrogen and thus large amounts of electricity for splitting water. [174]

Their analyses compare the cost-effectiveness of storage and e-fuels and assess how $CO_2$ capture and clean electricity can be used most efficiently to maximize climate benefits. Based on this, Concito provides some policy recommendations on how the aviation sector can contribute to the EU's climate goals in a cost-effective, scalable, and sustainable way. The main findings and policy recommendations are expressed in points in the following overview:

[174] Concito, efuels or storage. How to make the most of clean electricity and captured co2, march 2025


*Figure 48 Electricity demand for $CO_2$ -storage and carbon-based e-fuels in 2040 and 2050* [175]

[175] Concito: efuels or storage. How to make the most of clean electricity and captured co2, marts 2025

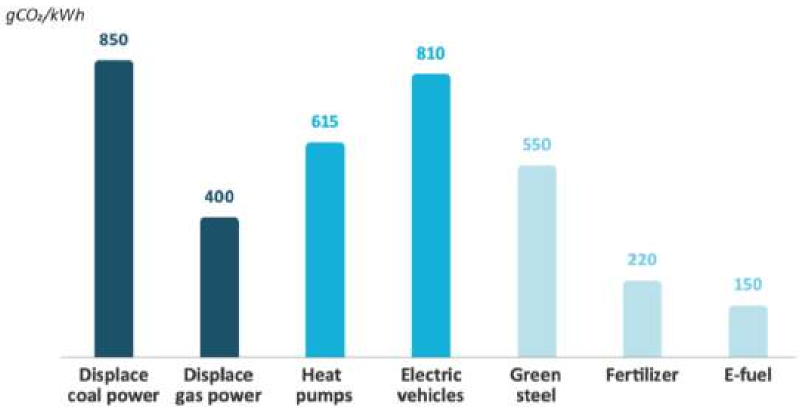



*Own calculations assuming offshore storage and a 50 % conversion efficiency of electricity to e-fuels. Based on data from the EU Commission's Industrial Carbon Management Strategy and the Impact Assessment of the EU Commission's proposal for 2040 climate target*

*Figure 49 Climate impact of using clean electricity to displace fossil energy for various purposes* [176]

Concito finds that the climate impact of using clean electricity to displace fossil fuels for various purposes is much higher than that of eSAF. This is evident from the figure above, which shows the calculations underlying the EU Commission's impact assessment of its proposal for the 2040 climate target.

According to Concito, the use of renewable electricity is far more advantageous for other purposes, for example, heat pumps, electric cars, and especially to replace coal power, as shown in figure 49.




*Coloring represents the type of displacement: Dark blue = Electricity generation, blue = direct electrification, and light blue = indirect electrification. The production of green steel with clean hydrogen (through the so-called $H_2$-DRI-EAF technology) provides over three times more climate benefit than e-fuels. If e-ammonia is used to displace fossil-produced ammonia for fertilizer production, the climate benefit is about one and a half times greater than displacing bunker oil for ships. Source: Agora Energiewende and own calculations.*

*Figure 50 Climate impact of using clean electricity to displace fossil energy for various purposes* [177]

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[176] Concito: efuels or storage. How to make the most of clean electricity and captured co2, marts 2025

[177] Concito: efuels or storage. How to make the most of clean electricity and captured co2, marts 2025

Concito does not rule out the use of eSAF but points out that a political opportunity should be created for aviation to choose to pay for storage instead. According to Concito, the benefits of using electricity are much greater outside aviation. This is, of course, thought-provoking. The argument can be followed at a very general level, provided that the calculations are completely solid. However, if the proposal were followed and the main emphasis were placed on paying for storage, aviation risks would be placed significantly worse than those in other sectors in achieving and implementing sustainability goals.

To this, aviation stakeholders will likely object, pointing out that it will mean a much slower path to aviation becoming sustainable if it continues to fly on fossil fuels while offsetting emissions elsewhere. It would also mean a deterioration in the possibility of reducing non-$CO_2$ emissions. Even if the calculation of storing $CO_2$ rather than using it in aviation is correct, the perception of an aviation sector that is not contributing optimally can lead to a worse reputation and, in turn, worse competitive conditions. Airport employees and airport neighbours would also miss out on improved air quality if the compensation method were to become prevalent.

The discussion is nevertheless interesting and has been addressed in several contexts. Given the objectives of aviation, it could be considered not contradictory. The proposal for CCS should best be seen as one of the methods that can be developed to play a role in the future, as a supplement, preferably in conjunction with the best possible utilisation of scarce feedstock resources, to reduce climate impact.

Various transitional arrangements should be analyzed, and, with great appeal, long-term, feasible, and advantageous models should be examined, along with their advantages and disadvantages. To the extent that CCS can be developed and used on a large scale with a much greater reduction in climate impact at a lower cost, then it will be relevant to implement it in international emission trading systems such as ETS and in ICAO's CORSIA and in other, including voluntary, systems for aviation and other sectors. eSAF and carbon removal should not be treated as either-or. Each path has its own primary purpose. e-SAF can reduce aviation emissions and thereby accelerate Europe's industrial transition. At the same time, carbon removal (CDR) should primarily be used to reduce emissions that are generally more diffuse and difficult to avoid.

### 5.3.1 CDR

Carbon dioxide removal (CDR) systems are among the options under consideration, and several stakeholders have participated in these efforts. There are good reasons to include the topic in considerations and in further reviews.

Carbon Capture and Storage (CCS) may become an essential tool in the fight against climate change. They can also be recognised as an instrument in emissions trading systems under certain conditions. In the EU's Emissions Trading System (EU ETS), it is already possible to count permanent storage of $CO_2$ as a valid emission reduction. This applies provided that the carbon dioxide is captured and stored in accordance with the requirements laid down in the EU's CCS Directive (Directive 2009/31/EC), including the use of approved geological storage sites and documentation of storage integrity, i.e., that emission data is verified and monitored (Commission Regulation 2018/2066).

For example, if a Power-to-X plant uses CCS to capture and store process-related $CO_2$, this can be counted as a reduction in the actor's emissions under the EU ETS.

Currently, the CORSIA system does not explicitly approve CCS as a way to produce offset credits. CORSIA only allows the use of offset projects from programs approved by ICAO's technical bodies, primarily area-based projects, renewable energy, and energy efficiency. However, there is increasing attention to the need to include technology-based carbon removals, such as DAC, as potential future offset mechanisms under CORSIA. ICAO has therefore initiated work to develop technical requirements and methods for "carbon removals". Both the ETS and ICAO emphasise the need for permanent and fully monitored $CO_2$ storage.

The aviation consultancy firm SimpliFlying finds that aviation must necessarily adopt carbon removal technologies, such as Direct Air Capture and Bioenergy with Carbon Capture and Storage, to meet climate requirements and its own goals, including addressing emissions that cannot be reduced directly. [178]

Carbon removal, like PtX/eSAF, is still an immature technology with high costs and limited capacity. It is pointed out that competition for access to removal capacity may increase rapidly and that it may therefore be crucial to secure access to future carbon removal capacity. The aviation industry should enter into long-term purchase agreements to help scale the technologies and reduce prices over time.

The report from SimpliFlying calls for regulatory mechanisms such as CORSIA and EU ETS to incorporate and recognise carbon removal fully and to provide incentives for investment, under the earlier mentioned central assumptions.

**Carbon storage and its relevance to aviation.** Carbon storage – defined as the capture and long-term storage of $CO_2$ – must be considered an essential pillar of the global climate effort, and perhaps especially for aviation, where direct electrification or full decarbonization is difficult. Here follows a brief overview of carbon storage, its technical characteristics and possible significance for aviation’s path towards net-zero emissions.

[178] CORSIA: The Role of Carbon Removals in Decarbonising Aviation by SimpliFlying - Issuu

**Categorization of carbon storage.** Carbon storage comprises two steps: capture and storage. Both steps can be done via biological, geological, or technological methods. Many storage methods combine technologies across these categories —for example, biological capture and storage in geological structures, as seen in Bioenergy with CCS (BECCS).

**Combined solutions and CCS in aviation.** A particularly relevant CCS system for aviation is BECCS, in which biomass is used for energy or biofuel production and the captured $CO_2$ is stored geologically. BECCS can create negative emissions by storing $CO_2$ collected during biomass growth and production. Captured $CO_2$ can be used to produce synthetic jet fuel (eSAF), enabling a closed carbon cycle with no new net emissions. Even with full deployment of SAF, aviation will still emit some $CO_2$. CCS can address residual emissions that cannot be avoided immediately. Some companies, such as Microsoft, have committed to removing all their past emissions through CCS.

**Barriers and risks.** The biggest challenges for CCS are economic and technical. Capture and storage is expensive – especially DAC, which is currently estimated to cost up to USD 600 per tonne of $CO_2$. Economic viability likely depends on political incentives and precise regulation.

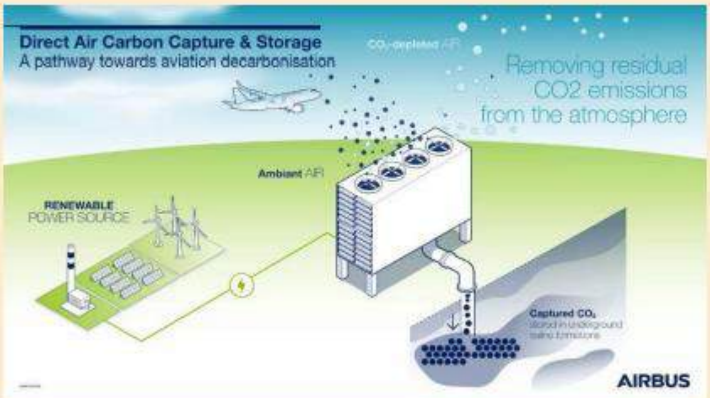
**Political regulation and prospects.** CCS is increasingly the subject of political and market interest. The International Emissions Trading Association (IETA) has published criteria for certifying CCS as carbon credits.

In the future, CCS is expected to play a role in systems such as the EU ETS and ICAO's CORSIA. Although not yet mandatory, it is increasingly likely that aviation could be required by law to use CCS as part of a net-zero strategy. It is important to emphasise that CCS should not be seen as a substitute for emission reductions, but as a necessary complement to decarbonization in difficult sectors such as aviation. Technological maturity and political support are crucial for scalability. For aviation, CCS could be necessary both as a feedstock for eSAF and as a solution to residual and historical emissions.

## STAKEHOLDER ACTIONS

### Airbus Carbon Capture Offer (ACCO)

Airbus developed ACCO with the aim to bring to the aviation industry high-environmental integrity, scalable and affordable carbon dioxide removal credits [21]. ACCO looks to support the management of the remaining and residual $CO_2$ emissions of aircraft with the latest carbon removal technologies.




As a first step, Airbus partnered with 1PointFive for exploring direct air carbon capture and storage solutions for the aviation industry. In particular, 1PointFive is developing a large-scale facility expected to capture 0.5 million tonnes of $CO_2$ per year starting in 2025. Airbus has committed to purchase 400 000 tonnes of $CO_2$ removals. This initiative aims to support efforts for decarbonising and mitigating Airbus' Scope 3 emissions from the use of its sold product, and also contributes to the larger efforts already underway across the aviation industry.

*Figure 51 Stakeholder Actions / Airbus Carbon Capture Offer [179]*

## 5.4 The role of airports in CDR

There has not yet been much analysis of the role airports can play in this regard. But it may be worth considering whether an airport can either interact with primary actors, such as airlines and their customers, to acquire climate credits through carbon removals, and/or independently set up procurement programs, partner with companies that handle this type of work, or do so in other ways. It is a new concept for the aviation sector, but since credits are already available, it can at least be included in current considerations, or even advance purchases or agreements in advance.

Airports can play a relevant and active role in the development and implementation of carbon removal solutions ($CO_2$ removal), both as infrastructural hubs and as actors with their own climate goals. Here are some key roles that airports can potentially fill, concrete options, including some considerations and initiatives:

[179] Airbus + EASA: STAKEHOLDER ACTIONS, Airbus Carbon Capture Offer (ACCO)

**Facilitator and/or host of technological $CO_2$ removal**

Airports often have access to large areas and infrastructures that can be explored for the location of carbon removal technologies, e.g.:

- Direct air capture (DAC) plants, which extract $CO_2$ from the atmosphere and store it geologically or recycle it.
- Power-to-X plants in combination with DAC, where captured $CO_2$ is used as a feedstock for eSAF. As mentioned in section 1.10, Düsseldorf Airport are involved in a plan to establish a "DAC to SAF" facility at the airport. (Read considerations in: Prism Sustainability, *Direct Air Capture Integration in Airport Infrastructure → Scenario*)[180] A similar project is under development at Dublin Airport (See *Trinity's groundbreaking carbon capture tech* from Trinity College Dublin).[181]
- Heat and power integration: Airports with district heating or surplus energy (e.g., from solar cells or biogas plants) can provide energy sources for carbon removal processes.

**Partner in eSAF production and CDR certification**

- Captured carbon from DAC can be used locally or regionally to produce electrofuels (eSAF), which airports can partner or help promote.
- Airports can enter partnerships with suppliers of SAF and carbon removal to document $CO_2$ reductions and obtain certified carbon removal credits.
- In the longer term, airports can act as aggregators of carbon removals for use by airlines, e.g., under the EU ETS or CORSIA.

**Climate compensation and own emission reduction**

- Airports emit $CO_2$ through operations, energy, and transport. Own use of carbon removals can be part of the airport's net-zero strategy, mainly to deal with residual emissions
- It is possible to invest in certified carbon removal projects as part of climate-responsible operations and marketing

**Catalyst and showcase for innovation**

- Airports have high visibility and can act as a demonstration platform for new $CO_2$ removal initiatives or technologies to passengers, authorities and the business community

[180] Prism Sustainability: Direct Air Capture Integration in Airport Infrastructure → Scenario, Sep. 2025

[181] Trinity Collage Dublin, Trinity's groundbreaking carbon capture tech, July 2025

- Airports can be early adopters and attract companies that want to test or demonstrate carbon removal on a large scale

**Political and regulatory bridge-builder**

- As infrastructure owners and transport hubs, airports can engage in dialogue with authorities and industry organizations on framework conditions and incentives for carbon removals
- Airports can help promote standards and transparency in the use of carbon removal within the aviation supply chain

**Examples and further perspectives**

Heathrow Airport, for example, has announced an interest in collaborating on carbon sequestration in combination with SAF.

Copenhagen Airport (CPH) has identified residual emissions – those where reductions are still possible – as a critical challenge in its climate action plan. The airport aims to reduce its operational emissions (Scope 1 and 2) to or below 10% of 2019 levels by 2030 and eliminate it by 2050. To address residual emissions, CPH explicitly incorporates carbon removal credits into its strategy, marking a shift from traditional $CO_2$ offsets that solely remove $CO_2$ through agroforestry and potentially technological means. This approach is part of CPH's broader sustainability roadmap, which involves deep decarbonisation measures – such as switching to renewable energy, phasing out natural gas, electrifying land vehicles and machinery, implementing heat pumps and installing solar panels and battery storage systems. Carbon removal credits can serve as a bridge, enabling CPH to credibly claim net-zero operational emissions.

CPH also plans to develop its offset portfolio over time by investing in nature-based offsets (e.g. agroforestry projects in Nepal and India), while gradually shifting to more permanent, measurable and reliable $CO_2$ removal technologies.

By adopting an explicit strategy for residual emissions, Copenhagen Airport not only aligns with its Net Zero 2030–2050 roadmap but is also in the forefront among airports implementing carbon removal, increasing its credibility and potentially influencing regulatory frameworks and industry best practices.

CDR may lie on the periphery of a SAF development strategy, but it remains a relevant topic that can help SAF along its path. This means both an opportunity to reduce climate impact through investments in carbon storage and as part of the effort needed to secure assets in facilities that can deliver climate reductions and eSAF. If an airport is interested in going deeper into considerations, for example, DAC, a starting point for the preparatory assessments can be based on the questions and topics below. The decision matrix shown assumes that the airport wants to assess a possible location for a DAC facility.

**Airport engagements**

Active role in development and implementation of carbon removal solutions, both as infrastructural hubs and as actors with own (or shared) climate goals

Facilitator and host of technological $CO_2$ removal
- Airports often have access to large areas and infrastructures that can be explored for the location of carbon removal technologies; PPP etc
- Power-to-X plants in combination with DAC, where CDR is used as a feedstock for eSAF
- Heat and power integration: Airports with district heating or surplus energy, e.g. from solar cells or biogas plants) can provide the necessary energy sources for CDR

Partner in eSAF production and CDR certification
- Help to promote carbon capture - partnerships with producers/suppliers of SAF and carbon removal
- Document $CO_2$ reductions and obtain certified carbon removal credits

Climate compensation and own emission reduction
- Own use of carbon removals can be part of the airport's net zero strategy
- Possible to invest in
- Certified carbon removal projects

Catalyst and showcase for innovation
- Dusseldorf and Dublin airports

Political and regulatory bridge-builder

**Considering DAC Facility Placement- Decision Matrix**

| Criterion | Near runway | Elsewhere at airport |
|---|---|---|
| $CO_2$ concentration (efficiency) | Marginal gain (450–500 ppm) | Normal background (420 ppm) |
| Symbolic value / branding | Very high – strong visibility | Moderate – less visible |
| Logistical integration | Short chain, but complex area | Good integration with energy zones |
| Safety and regulatory conditions | Highly challenging, ATEX, safety | Restrictions, but far fewer |
| Air quality / operations | Issue: $NO_x$ and particulates (UFP) | Cleaner air, lower operating costs |
| Renewable energy availability | Topic: Sufficient renewable energy | Easier access to renewable energy |
| Space and scalability | Limited: Space, noise, regulation | Ample space, higher scalability |
| Involvements PP + local community | | |

## 5.5 National eSAF financing model

Initiatives can also be taken at the national level that align with climate goals, address the need for alternative aviation solutions, and develop financing models to overcome the deadlock caused by a lack of investment decisions. This initiative has been taken in continuation of the previously described political decisions in Denmark, where the aviation industry, through the Climate Partnership for Aviation, has submitted proposals for the use of the support funds arising from the adopted passenger tax. But other actors have also been involved in efforts to find solutions for eSAF production. Green Power Denmark is one of them. The organisation has 1,500 members and represents the energy industry, large and small owners, installers of energy technology, and companies that operate the Danish power grid and are energy traders. It is therefore natural to review their analysis and recommendations here in a Danish context, with clear overlap with Project SkyPower's European recommendations.

Green Power Denmark has also submitted a consultation response to the EU Commission's proposal on allocating ETS allowances to green fuels, specifically to allocate 20 million EU ETS allowances to support the use of green fuels in aviation.

In its consultation response, Green Power Denmark supports the 20 million EU ETS allowances set aside to promote the use of SAF, but notes that these allowances are expected to be fully used by 2028. This means that the allocated allowances will only support the use of SAF in the very short term, and thus only bio-SAF. Therefore, Green Power Denmark proposes extending the period and that more funds be allocated because: *"To finance an e-SAF facility, the project developer needs to demonstrate that the debt is serviced over an offtake period of at least 10 years. On the other hand, commercial aircraft operators are unable to enter offtake contracts for longer than 1 year due to the economic situation in the aviation sector and their credit ratings. Green Power Denmark recommends that the Commission investigate the possibility of implementing other support mechanisms that both incentivize the use of e-SAF as well as it enables e-SAF producers to reach final investment decision......If e-SAF is to be available in 2030 when the mandate begins, e-SAF producers must reach final investment decision by the end of 2025. This means that the new framework conditions and support mechanisms must be in place by fourth quarter of 2025"* - Green Power Denmark[182]

The recommendations from Green Power Denmark are based on the assessment that Denmark has significant potential to become a leading player in Europe in the production of eSAF via PtX. There are good opportunities to combine large amounts of renewable energy with

[182] Green Power Denmark. … contribution to the open consultation on the draft delegated (...) in the aviation sector, dec. 2024

the ability to capture biogenic $CO_2$, the two essential components of eSAF production. In addition, Denmark has several globally leading companies with the ambition and technical expertise to drive this transition forward, Green Power Denmark points out.

**Economic barriers and the need for government facilitation**

Despite this potential, there are obstacles stemming from the gap between manufacturers' needs and the aviation industry's contractual practices. Manufacturers require long-term purchase agreements to ensure financial sustainability and meet investment decisions (FID), while airlines and fuel suppliers traditionally enter short-term contracts. The result is a risky situation that must be managed, and here the government as a market facilitator could play a crucial role. A state actor that temporarily assumes the risk can provide eSAF producers with the necessary guarantees to make FID and bring the first projects to life, as Green Power Denmark, like Project SkyPower, points out as a crucial step.

**Regulatory timing and necessary framework**

The EU's ReFuelEU Aviation requires eSAF use from 2030 with a gradually increasing minimum share, but these requirements alone do not create investment security. Despite many uncertainties, producers should make FID's before the end of 2025 to ensure delivery in 2030. Therefore, Green Power Denmark calls on the state to establish a targeted support policy and the necessary regulatory framework as soon as possible.

In December 2023, the agreement "Green Aviation in Denmark" allocated approximately DKK 1.1 billion for the green transition in the aviation sector. Green Power Denmark recommends that the funds be prioritized for pilot auctions for eSAF production. By using the double-sided auction mechanism – inspired by the German H2 Global model and already approved by the EU – the state can act as an intermediary, enabling long-term contracts with producers (e.g., 10 years) and shorter agreements with buyers (e.g., 1 year). This way, the most significant risks for both producers and buyers are covered, without requiring a fixed reference price for eSAF.

According to Green Power Denmark, this mechanism can be continuously adapted to market developments: support levels can be adjusted in line with market prices and regulations. Over time, the need for support is expected to decrease, among other factors, as fuel prices rise and taxes on fossil fuels become stricter. In the period 2025–2030, the eSAF price is expected to be 30–40 DKK/kg. With a budget of 1.1 billion DKK, this means that Denmark can finance approximately 27,500–36,500 tons of eSAF, equivalent to, for example, domestic flights in Denmark.

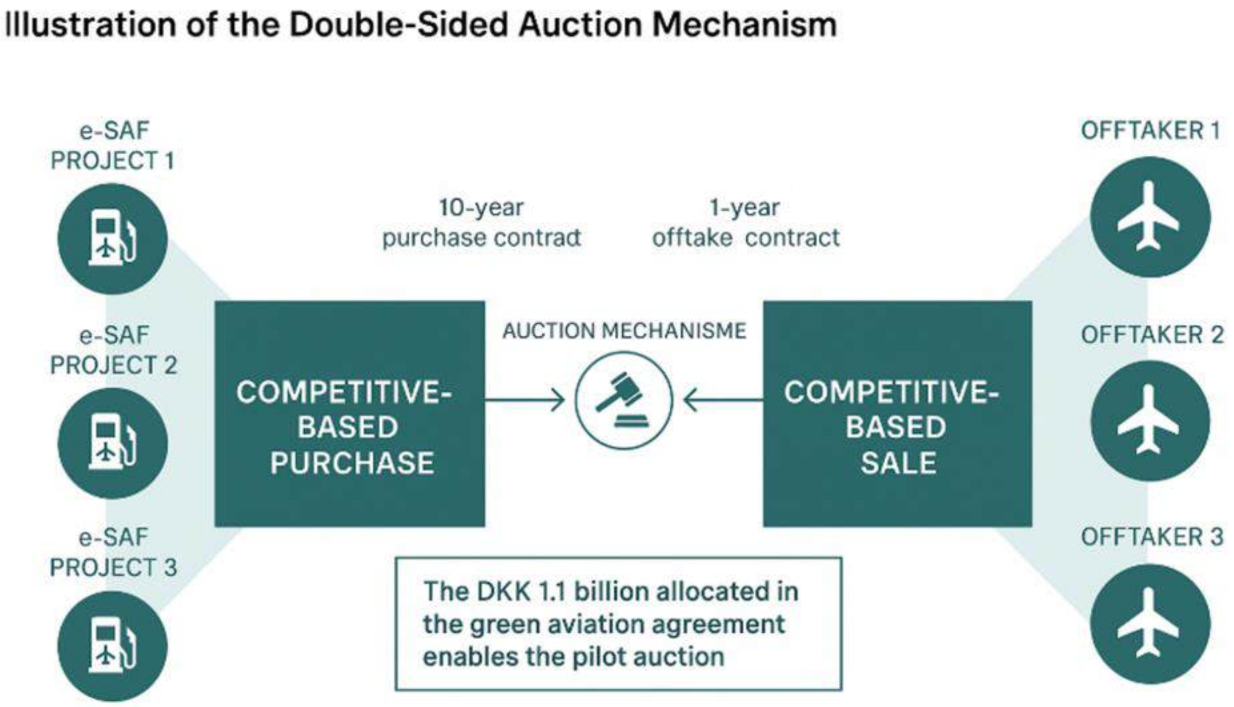



*Figure 52 Figure 53 Double-sided Auction Mechanism* [183]

In the first auction, e-SAF is purchased at a fixed price in a long-term purchase contract, e.g., 10 years. A long-term contract provides the producer with financial security, ensuring FID. In the second auction, e-SAF is sold at a fixed price in a short-term sales contract. The sales auction is repeated, e.g., 10 times at 1-year intervals. A short-term contract allows the sales price to buyers to be adjusted to developments in the fuel market and applicable regulations. This is also reflected in the expected level of support.

However, if Denmark wants to secure long-term, large-scale eSAF production, the allocated funds are insufficient. Therefore, ETS funds from aviation, expected to bring approximately DKK 685 million annually to a country like Denmark after the phasing out of free allowances in 2026, should be earmarked for eSAF support. Green Power Denmark recommends such earmarking to ensure continued investments.

**Wind power, PtX strategy and export potential**

Denmark's ambitious PtX strategy (4–6GW electrolysis capacity by 2030) is supported by a massive expansion of wind power, including offshore islands with up to 14GW capacity.[184]
In addition, funding from the latest PtX tender process (1.25 billion DKK, awarded to six projects with over 280MW of electrolyser capacity) supports increased production of green hydrogen and e-fuels. [185]

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[183] Green Power Denmark. Grøn omstilling af luftfarten med eSAF. Dec. 2024
[184] IEA. Energy Policy Review. Executive summary, Denmark 2023
[185] Energistyrelsen, Offshore wind farms tendered towards 2030.

The government's transitional scheme for PtX certification ensures that e-SAF from Danish plants can be documented as EU-compatible from day one.

Green Power Denmark assesses that, overall, these initiatives lay the foundation for a robust infrastructure and a domestic market for e-SAF, both of which can support the aviation sector and create export opportunities. Investment-intensive transitions require targeted support and long-term planning. To ensure realization before 2030, Green Power Denmark recommends early implementation of support schemes based on pilot auctions and support from the ETS and the "Green Aviation" pool, and that the state assume the role of market facilitator to take on the initial risk while the market matures.

Combined with the adopted mandates in the EU, the national aviation goals, and the strategic use of support and regulation, must help to create the necessary volume and price development for SAF to become competitive over time, for the benefit of both climate and industry. The conditions differ, but the recommendations from Green Power Denmark can be considered by many, as evidenced by the overlap between the recommendations' basic principles and those put forward by Project SkyPower.[186]

[186] Green Power Denmark, Grøn omstilling af luftfarten med eSAF, Dec. 2024

# 6 Aircraft of the future, mobility in the air and new propellants

The development of and increased access to SAF is crucial for aviation for many years to come. Since the start of the ALIGHT project, it is even clearer today that other energy- or fuel types are also on the way. Electric, hydrogen and hybrid aircraft are under development in many countries. From the start of the project, activities regarding new energies, new propellants and future aircraft concepts have been included. A broad range of partners have collaborated on "Future Aircraft Stands Conceptual Design" in WP5 Task 5, leading to a comprehensive study of future conditions at airports and, naturally, a review of which aircraft types are predicted to become operational in the coming years.

Along the way, the EU Commission, the former PO (project officer), and the ALIGHT evaluation team have also called for assessing and promoting the development and use of future aircraft powered by electricity and hydrogen. At the EU level, the Commission has established AZEA (Alliance for Zero Emission Aviation), which is working to prepare for the entry into service of zero-emission aircraft by advancing infrastructure, regulation, and practical/technical solutions. Recognising the importance of this topic, WP2 has included it as a natural part of determining which solutions the airport should be aware of in the future. To ensure qualified input from others, this has also led to active participation in two of the AZEA working groups established under that auspice.

Similarly, both NISA and CPH have participated in the Nordic Network for Electric Aviation (NEA), which, together with partners from airlines, airports and two Nordic electric aircraft manufacturers, has focused on possible routes, regulations, infrastructure, simulations and charging conditions.

The figure below provides an overview of aircraft developments and their announced entry-into-service (EIS) dates. AZEA expects the following entry-into-service dates, based on aircraft size and design approach. By 2030: General aviation, eVTOLs, and regional air mobility aircraft will enter the market. By the late 2030s, Larger regional and single-aisle hydrogen-powered aircraft developed for mass-transit short-haul markets will follow. • From 2040+: Potential hydrogen-powered longer-range aircraft. Note: Certification times depend on several factors, such as the maturity of the applications received and the volume of applications to be handled at a given time.

**AZEA expects the following entry-into-service dates:**

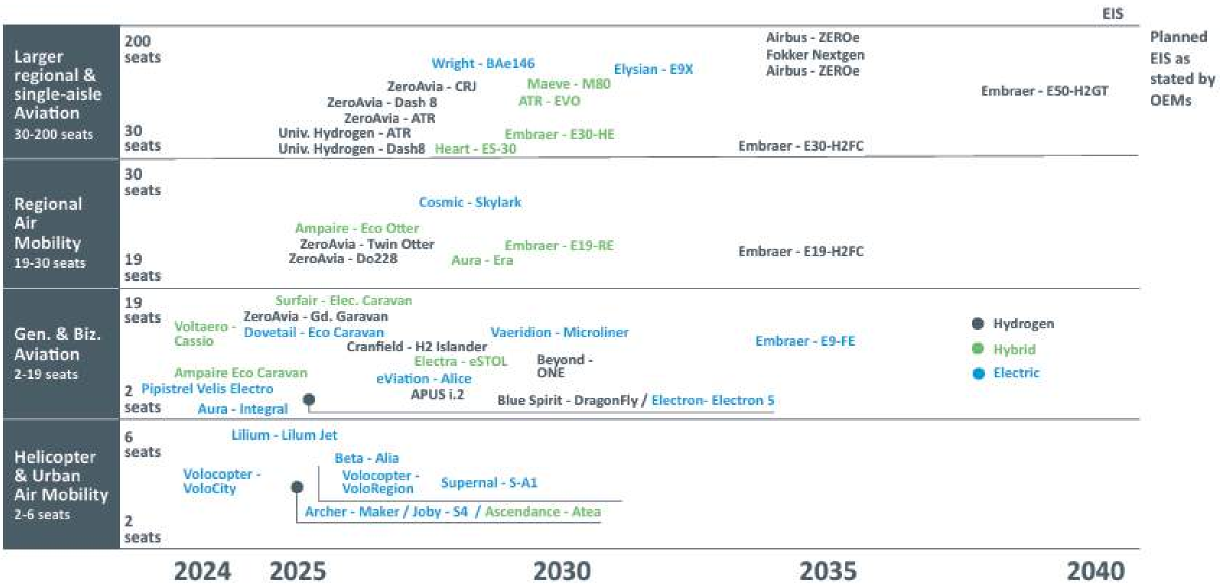


*Figure 54 Overview of expected into-service-dates by AZEA [187]*

Developing the necessary infrastructure for charging or refuelling these future aircraft has been a significant challenge. In the ALIGHT project, there is a defined focus on CPH as a lighthouse airport, with Vilnius, Rome, and Warsaw as fellow airports, but several other airports with potential connections are relevant for preparations and future decision-making. Because the aircraft, as is the nature of the matter, will have to fly back and forth between several airports. Our analysis therefore indicates that these must be able to offer facilities and capacities across several areas that meet the requirements and needs of the new users. Complexity in the layout and expansion of the airport stand, and not least previous layout plans and investment decisions, indicate that the adjustments may take a long time. Access to the necessary charging current can be an obvious example of this, depending very much on how it is prepared.

Furthermore, our findings suggest that airports will need to invest in charging and/or hydrogen refuelling stations. This may include access to relevant and necessary battery and hydrogen technology. Improving the energy density, safety and lifetime of batteries and fuel cells is essential to achieve viable range and efficiency for these aircraft. Another issue that needs to be addressed may be weight and efficiency, as electric and hydrogen propulsion systems often have additional weight compared to traditional aircraft and equipment, especially in relation to the number of passengers per aircraft. Balancing this with energy efficiency may be a critical design consideration for some areas and actors. For these and many other reasons, we believe it is crucial to develop and adapt aviation regulations and safety standards, and to plan and

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[187] AZEA: Future propellants entry-into-service dates, June 2024

adapt as many aspects as possible to accommodate these new technologies for widespread use. What is also essential is that developments can deviate significantly from predictions. New battery technologies with lower weight per kW are constantly being developed, and hybrid technologies are gaining ground. They may become central to many types of aircraft, and, as shown recently, progress in hydrogen aircraft has not been as predicted a few years ago.

# Excerpt

## 6.1 Future Aircraft Stands Conceptual Design Report

In WP5 Task5.5, for the report Future aircraft stands, we have prepared a reporting platform detailing the elements and prerequisites that will become relevant for airports in near future.

The report addresses the design of the aircraft stand of the future – the operational area at the gate or apron where aircraft are parked, refuelled and serviced. The report focuses on how stands can support electric, hydrogen-powered and hybrid aircraft as well as fully electrified and autonomous designs.

The report has two main objectives. Firstly, the aim is to present several generic aircraft stand designs that can be realized at a specific airport in accordance with the local master plan and gate strategies, which are explained and visualized. Aircraft stands require ground support, which is why there is also a focus on the implications for ground support regarding the electrification and autonomous development of existing and new GSE (Ground Support Equipment) at the aircraft stand.

The second main objective of the report is to propose guidelines for key stakeholders on how to accelerate the transition regarding the aircraft stand. The chapter "How to make it possible" therefore contains several topics for selected stakeholders with practical recommendations in the short, medium, and long term.

The methodological approach of the report is based on four conceptual blocks:

1. Infrastructure study (electrification and hydrogen)

2. Pushback and taxiing study

3. Analyses of announced alternative propulsion technologies from manufacturers

4. Concept development of five stand typologies

The methodology combines technological projection, business case analysis, safety standards, and physical design optimization to define flexible, scalable stand solutions. The starting point is ICAO Code B/C aircraft, which constitute most of the European passenger traffic.

Electrification of aviation is expected to take off first on short-haul and regional routes up to 1500 km, as limitations in battery energy density and weight continue to limit the range of larger aircraft. Even with significant technological advances, such as a tripling of energy density, it is estimated that electric aircraft will only cover a fraction of the total expected growth in air traffic. The first 9 to 30-seat electric aircraft are expected to be on the market around 2030. Commercial electric narrow-body aircraft are likely to be introduced during the 2030s, in parallel with hybrid electric solutions for longer routes.

Battery-electric aircraft will require fast charging of up to 3 MW per aircraft to match traditional turn-around times. This implies major investments in airport power grids and supporting infrastructure, including the potential for mobile battery banks for flexible energy distribution. These mobile units can be charged during off-peak periods, thereby mitigating peak loads on the power grid.

Hydrogen technologies are divided into two main categories: gaseous hydrogen ($GH_2$) and liquid hydrogen ($LH_2$). $GH_2$ is technologically simpler to implement, but has lower energy density, which limits range. $LH_2$ allows for longer flights, but requires cryogenic storage at -253°C, advanced materials and new refuelling procedures to avoid evaporation and leaks. Commercial phasing-in of hydrogen aircraft in the narrowbody segment is not expected until 2035–2045.

SAF (Sustainable Aviation Fuel) is expected to become increasingly dominant on intercontinental routes by 2050, as both existing aircraft and large widebody aircraft will continue to rely on liquid fuels and engines for many years to come.

## Stand Design – Generic Concepts

The report introduces five generic stand types that can be adapted to local master plans: (1) All-propellant stands, which support all current and future fuels and technologies, (2) dedicated electric stands optimized for battery-electric aircraft, (3) hybrid SAF-electric stands, (4) hybrid hydrogen-electric stands, and (5) wide-body hydrogen MARS (Multiple Aircraft Ramp System) stands designed for possible future intercontinental $LH_2$ operations.

All-propellant stands represent the maximum technological complexity and also flexibility. They are equipped with fixed and mobile charging points, hydrogen refuelling zones with safety distances, integrated GPU and PCA systems, and service roads both in front of and behind the apron area. Such a layout can be gradually simplified depending on local needs.

Dedicated electric stands focus on high charging power and flexibility in the location of connection points, as future electric aircraft may vary in design. Mobile battery units enable charging without direct dependence on grid capacity. Hybrid stations combine electric functions with either SAF or hydrogen, creating a bridge technology towards 2050.

Wide-body hydrogen stations are a future scenario where large $LH_2$-powered aircraft are refueled via integrated pipelines and cryogenic infrastructure. Safety zones and containment systems for potential leaks are key elements.

**Ground Support Equipment – electrification and cybersecurity**

Electrification of Ground Support Equipment (GSE) is already underway at many European airports. GPUs, PCA units, pushback tractors, baggage handling equipment and passenger stairs can all be converted to electric operation. This reduces emissions and noise and improves the working environment in the apron area. However, it requires significant investments in charging infrastructure and in expanding the internal power grid.

Autonomous GSE systems are expected to be deployed in phases, starting with semi-autonomous solutions, followed by full autonomy for standardized tasks. Pushback tractors are obvious candidates for early autonomous deployment because they operate in controlled environments.

Cybersecurity is a critical component of the operation of autonomous GSE. Threats such as hacking, signal jamming and data manipulation require robust security measures, including encryption, redundant systems, access control and continuous monitoring.

**Safety, standards, and regulations**

To enable a smooth transition to electric and hydrogen-powered technologies, the report calls for the development of global standards for charging, refuelling and safety procedures. Harmonized certification requirements should be established, including specific guidelines for handling high-voltage systems and cryogenic hydrogen storage.

Regulators are encouraged to adjust landing fees to favour low-emission aircraft and to allow flexible testing environments for new technologies. Training and certification of personnel in handling batteries and hydrogen are essential for safe operations.

**Implementation strategy**

The implementation strategy is divided into three stages: No-regret moves (now–2030), where low-risk actions are implemented immediately; Add to plans today (2030–2040), focusing on major infrastructure adaptations; Experiment today to create the future (2040–2050+), which includes pilot projects for future technologies.

In the short term, the establishment of dedicated electric stands, investment in electric and autonomous GSE, and preparation of hydrogen operations with safety zones are recommended. The medium term involves the phasing in of hybrid stands, network upgrades and standardization of interfaces. Long-term focus must be directed towards the potential for $LH_2$ infrastructure and large-scale implementation of autonomous systems.

The report concludes that the aircraft stand of the future is a key strategic component in the green transition of aviation. With modular, flexible designs, electrified and autonomous GSE, infrastructure capable of handling electric and hybrid aircraft, and the gradual rollout of hydrogen infrastructure, significant environmental, operational, and economic gains can be achieved. Cross-sectoral cooperation and a balanced innovation culture that must necessarily be thoroughly prepared and developed in line with requirements, needs and opportunities, are all crucial to realizing the vision towards 2050.[188]

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## 6.2 Checklists for action plans

Based on the work prepared in connection with the aircraft stand report and based on the work on the subject, including our participation in AZEA and NEA, we will review suggestions and checklists for action plans for airports and relevant actors who are considering preparing for the aircraft of the future - including a proposal to establish a stakeholder network for the implementation of, initially, national or regional, infrastructural preparations.

In the ALIGHT project and at the conferences and workshops held, it has been discussed how the activities can be continued to help ensure that the infrastructural prerequisites are in place when the new aircraft types arrive. In the following, challenges are presented in several subject areas that must be included and prepared for further work. There are tasks throughout the supply chain that concern many actors.

In the current situation, many questions are challenging to clarify. Airline operators and other initiators are waiting for manufacturers to come up with attractive solutions, airports, operators and manufacturers are waiting for regulations and guidelines from legislators and authorities and many airports would like to play an active role to prevent being overlooked if they are not ready and because specific necessary changes and energy supply prerequisites can take a very long time to put in place. Through both AZEA and NEA, work has been done on these extensive prerequisites. In this project, the focus is on the role and tasks of the airport, which, for example, in connection with the preparation of electric and/or hybrid-electric aircraft, create many considerations, obligations, discussions and decisions. Many of the same elements apply when receiving pure electric aircraft as with hybrid-electric ones, however, depending on

[188] ALIGHT, Future Aircraft Stand Conceptual Design, March 2025

whether integrated solutions or remote stands are chosen, and whether stands can be arranged so that multiple energy types can be used.

The following outlines several areas that must be processed, partly separately and also in integrated contexts. For practical purposes, a brief description of the topics follows. After each topic, a reference is made to a checklist in the appendix, starting with electric and hybrid aircraft and then hydrogen.

## 6.3 Electric aircraft

The first aircraft categories requiring electric charging are expected to be eVTOLs and general aviation aircraft RAT/RAM (Ram Air Turbine/Regional Air Mobility) platforms, with a planned phase-in period of 2028/30–2035. In the years after that, smaller general aviation aircraft and turboprop aircraft may also switch to fully electric propulsion. However, electric propulsion is not yet considered suitable for narrow-body or wide-body aircraft, but hybrid-electric versions may eventually be on the market, which also increases the need for access to electricity. Forecasts show that major airports could have electricity consumption in 2050 several times higher than today, driven by alternative propulsion technologies, and some airports face major challenges gaining access to sufficient power capacity.

**A general overview of the electric aircraft development in mid-2025:** The first electric aircraft are expected to be used on short regional routes and in niche markets such as Norway, Sweden, Scotland and parts of the USA, where the electricity infrastructure and political support are strongest. According to EUROCONTROL's Long-Term Outlook (2024), electric aircraft with 9–19 seats are expected to enter limited regional operations by 2030, while hybrid-electric aircraft with up to 30–40 seats could be in commercial operation around the same time.

Emerging commercially viable concepts are moving from the prototype and test phase towards certification, particularly in the small and regional aircraft segment. The overall trend is a gradual evolution from short-range fully electric aircraft to hybrid-electric solutions that combine batteries and conventional energy to achieve longer operational ranges. Battery energy density and weight remain the primary limitations to range and payload, while certification and regulation are being developed continuously in close cooperation with EASA in Europe and FAA in the US. Similar developments are taking place in Asia, primarily in China.

**Technological status and leading actors:** Several European and international manufacturers are making progress. Heart Aerospace expects to introduce its electric and hybrid aircraft ES-30 regional aircraft around 2028/29, with a capacity for 30 passengers and a range of up to 200 km on pure electric power. French Aura Aero is developing the ERA, a 19-seat electric regional aircraft, scheduled for certification in 2027–2030. German Væridion is developing a 9-seat all-electric aircraft, which the company expects to be operational in 2030. Pipistrel has already produced and certified a two-seat electric aircraft (Velis Electro) for training purposes in over 30 countries. Pipistrel is developing the Miniliner, a 20-seat hybrid/electric aircraft that the company expects to be on the market by 2030. In China, the RX4E, a four-seat electric aircraft, has been certified. The American BETA Alia CX300, a five-seat aircraft, is ready for certification and has completed demonstration flights in CPH and, in the fall of 2025, daily cargo test flights in Norway. The former Swedish Heart Aerospace, now a US company, still plans to start deliveries in 2028. Norwegian Elfly Group intends to introduce the NOEMI nine-seater seaplane in 2030 (see later section).

**The airport's tasks and duties**

It is recommended that airports prepare a realistic estimate of future power requirements. The estimate should include power for new aircraft types and the electrification of airport operations, including all equipment and vehicles on airside and landside. This will involve dialogue with regional and national utilities and authorities on upgrading and, if necessary, establishing high-voltage grids in the vicinity of the airport.

Investments should be planned in the expansion of the underground power grid on airside and the purchase and installation of fast chargers on stands dedicated to future aircraft. In a start-up phase, lighter charging units can be used if the need can be met. In any case, the airport should actively contribute to safety and regulatory studies on charging operations and the fire risk posed by battery packs. There may also be a need to review/standardize charging plugs and charging stands to ensure interoperability. Key issues and implications may include:

- Key stakeholders: Operator of the primary electricity transmission and distribution network
- Supplier of electrical energy
- Airport infrastructure team
- Expected investment level: Not an easy task (exchange of experience with frontrunners)
- Timeline/maturity: Long-term, large volume projects
- Responsibilities, requirements, and preparatory measures

**Airport obligations under ReFuelEU Aviation regarding new propulsion are limited**

Airports are expected to play an active role in preparing for the arrival of hydrogen-fuelled and electric planes. ReFuelEU Aviation not only introduces blending requirements for sustainable aviation fuels (SAF), but also tasks airports with preparing for future alternative propulsion technologies that are expected to roll out over the next several decades.

Airports must develop and adapt ground infrastructure to enable the supply of both hydrogen and electricity in line with developments. This includes establishing airside hydrogen refuelling capacity that meets safety and regulatory requirements. The expansion of electrical infrastructure includes high-voltage and charging systems to support the operation of electric aircraft, in parallel with the electrification of ground support equipment.

From 2025 onwards, airports must provide reports every two years on the progress of hydrogen supply projects and electric charging infrastructure efforts, and on their overall readiness to accommodate alternative propulsion aircraft. - The aim is for airports to anticipate the operational needs of future fleets and coordinate with national authorities to deliver reliable, safe and scalable energy solutions.

**Landing on water:** A rare type of airport and aircraft type should be mentioned, not least because of its development potential. In September 2024, the Danish seaplane company Nordic Seaplanes and the Norwegian developer Elfly Group entered a Memorandum of Understanding (MoU) that includes an order for five electric amphibious Noemi aircraft, with an option for an additional ten aircraft. The total agreement is valued at around 150 million USD over ten years. Nordic Seaplanes operates several times a day between Denmark's two largest cities in the harbours of Aarhus and Copenhagen with a Twin Otter DHC-6-300. Remarkably, the only commercial seaplane route in Europe.

Elfly Group's Noemi electric aircraft are designed to operate from both water and traditional runways, with an expected capacity of 9 passengers or 1000 kg, a range of approximately 200 kilometres, and a top speed of around 200–250 km/h. The goal is to achieve commercial operation around 2030. Nordic Seaplanes will be the launch customer for the aircraft type. The agreement includes that Nordic Seaplanes will provide the manufacturer with initial operational experience.

## 6.4 Introduction to hybrid aircraft

There are several hybrid aircraft developments on the way. One technology solution is to combine conventional internal combustion engines with electric propulsion systems. This combination offers the advantage of efficiently using liquid fuels, fossil and SAF, while still benefiting from electric power for parts and aircraft movements, including takeoff, landing, and low-speed operations. This concept helps reduce emissions and fuel consumption. Hybrid technology can be beneficial for longer flights where all-electric solutions might not be feasible due to current battery limitations.

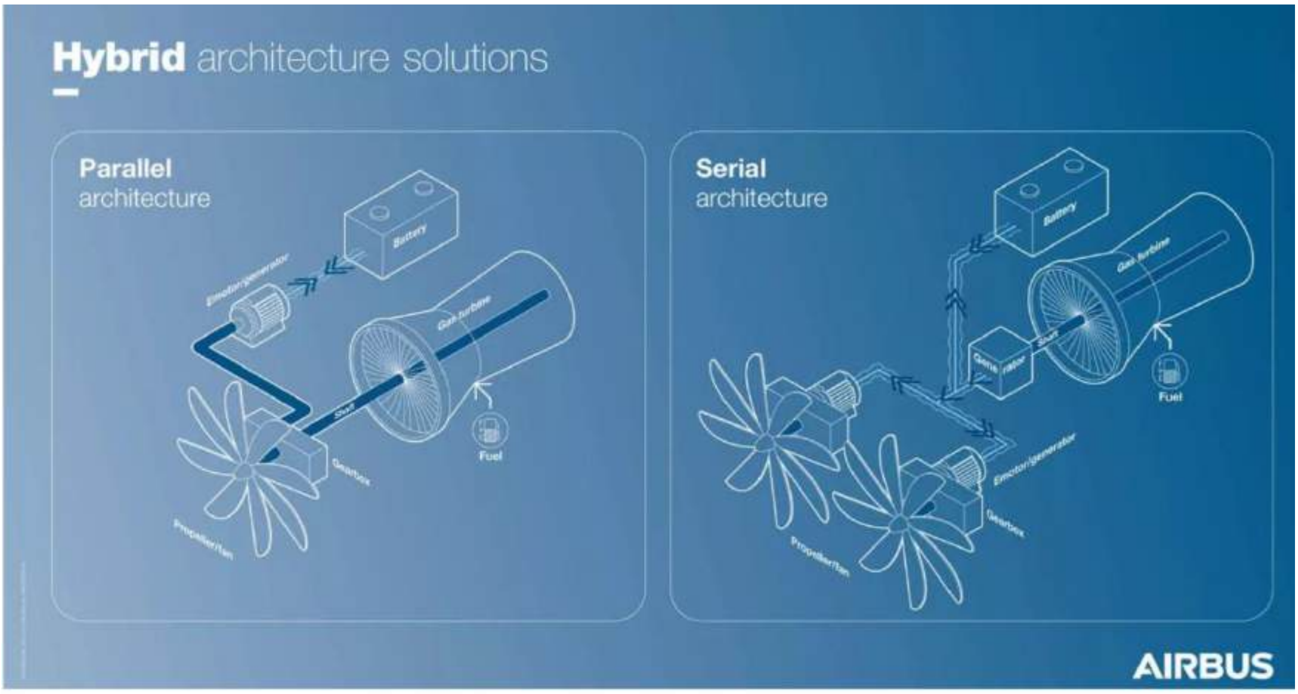



*Figure 55* Hybrid architecture solutions, Airbus[189]
(Other models and combinations can be found on *ResearchGate*)[190]

Both major engine and aircraft manufacturers are working on developing more efficient hybrid solutions. Hybrid technologies that combine hydrogen with conventional liquid fuels or with electricity are also being researched.

However, it is not just the advantages of such solutions. Even if the solutions must reduce the climate burdens and still ensure a greater range, their prerequisites are that there must be extra engine/technology capacity on board the aircraft, which in addition to increased costs and extended control technology, also entails greater weight and consequently increased fuel

[189] Airbus, Hybrid architecture solutions
[190] ResearchGate.net

consumption and emissions. But in the interim, until batteries and/or hydrogen can solve the challenges, hybrid solutions are being developed as transitional technologies.

Heart Aerospace's ES30 is being launched as an electric aircraft that can also fly on liquid fuel (SAF) if a range of approximately 200 km or more is desired. Other examples are under development. For example, Rolls-Royce is developing a turbogenerator design with integrated system to ensure smart power distribution during flight. The turbogenerator will recharge batteries after take-off or power propellers directly, enabling aircraft to switch between power sources in flight. It is an on-board power source with scalable power offerings and will complement the Rolls-Royce Electrical propulsion portfolio, enabling extended range on SAF and, later, as/if it becomes available through hydrogen combustion.

ATR and partners under the EU's Clean Aviation program are developing hybrid-electric versions of the ATR 72 series with the goal of demonstration flights by 2030. Ampaire (USA) received certification for its hybrid propulsion system in 2025 and plans to introduce a converted Cessna Grand Caravan aircraft into regional service beginning in 2026. According to the manufacturer, the system can reduce fuel consumption by up to 70%. RTX/Pratt & Whitney Canadian Collins Aerospace (USA/Canada) successfully tested a hybrid system for use in Dash 8 aircraft in June 2025. The system is expected to improve fuel efficiency by 30%. Airbus and Boeing are also researching hybrid technology solutions, for example, in collaboration with General Electric and NASA.

In the context of the future aircraft stand, hybrid solutions mean the stand should be highly flexible, as an aircraft will need to be refuelled with multiple energy products. If there are aircraft powered by a combination of electricity and liquid fuel, possibly SAF, then a stand must be able to supply the aircraft with both propellants, and vice versa for other combinations. The topic is interesting and important to clarify in the context where the first future aircraft stand is to be arranged, but even more important and crucial to decide in relation to future solutions where more such aircraft stands are in demand. Whether it is practically and legally possible to combine all available, current, and future fuels and energies on one and the same stand is discussed in "Future Aircraft Stands Conceptual Design" when it comes to Copenhagen Airport.

## 6.5 Electric aircraft checklist

Many requirements for an electric aircraft would be like those for traditional aircraft, but there are also significant differences and additional considerations due to the unique characteristics of electric aircraft. In this chapter, in the sections below, you will find key requirements and keywords to consider, further elaborate on, discuss, and prepare specifications for. The points listed can also be used as an overarching checklist for the ongoing process.

### 6.5.1 Overarching checklist for electric aircraft

**Power infrastructure:** Power infrastructure is a major topic. Electric aircraft require charging infrastructure, so the aircraft stand should be equipped with appropriate electrical connections, power distribution systems, and charging equipment to support the aircraft's charging needs. There may be two leading solutions, which can also be combined depending on the circumstances. A: Expansion of power supply so that it can meet future charging requirements in terms of capacity and distribution. B: Establish a battery warehouse that meets the future needs for charging, possibly as a mobile solution, so that more stands can be served. Checklist.

**The electrical systems must** deliver the required voltage and current capacity for the specific electric aircraft. Different types of electric aircraft might have different power requirements, so the infrastructure should be adaptable to accommodate various needs. This topic is important to coordinate between airports. Checklist.

**Battery cooling:** Electric aircraft batteries and systems generate heat during charging and operation. This may be integrated into chosen technologies, but should also be subject to separate check procedures. The aircraft stand should be designed with adequate cooling systems to dissipate heat and prevent overheating. Checkpoints and attention issues should be coordinated between the airline, suppliers, and ground service providers. Checklist.

**Electrical safety:** Electrical safety is a top priority. This not only concerns the safety and quality of the solutions, the choice of materials, etc., but also the long-term possibilities for further expansions and upgrades. The electrical systems should be designed to meet all relevant safety standards and regulations to prevent electrical hazards and ensure the safety of personnel and of the aircraft. Checklist.

**Integration issues with existing ground services:** The aircraft stand should be equipped with the necessary connections for other ground services, such as ground power units (GPU), pre-conditioned air (PCA) units, data communication links, pushback/doc-in tasks, cleaning, and staff issues. This may depend on the scope and topics of the solutions chosen, but it is essential to be aware that certain functions may be delegated to other actors and that cooperation and coordination between the parties are therefore relevant. Checklist.

**Safety protocols:** As always, a main priority in an airport is to prevent injuries and accidents to people, planes and equipment, and to ensure that potential misunderstandings or procedural errors do not occur. Develop safety protocols for personnel working with and around electric aircraft stands. This includes guidelines for handling electrical equipment, responding to emergencies, and ensuring proper training for ground crew. Checklist.

**Regulatory Compliance:** Ensure the aircraft stand's design and operation comply with all relevant aviation and electrical safety regulations and standards. Checklist.

**Charging time and turn-around: The charging infrastructure should be designed to minimize time on the** ground. This is a decisive parameter for airlines and, by extension, for the airport that must supply or secure the power. Faster charging capabilities can be a significant advantage for operators, so the aircraft stand should support rapid charging technologies when available. This is also an important topic to discuss and process in a stakeholder coordination forum that should be established among relevant actors (ref. section 6.7 Checklist).

**Sustainability considerations:** There may be variations in the sustainability capability of equipment. Ranging from qualities in cables and switches to location and distances for the selected supplies. Designing and establishing the aircraft stand with environmental and sustainability in mind should align with the sustainability tasks set up in the ALIGHT project. Consider energy-efficient equipment, renewable energy sources, and minimizing the carbon footprint o charging processes. Checklist.

**Remote monitoring and control:** The infrastructure should allow for remote monitoring and control of the charging process. This enables operators to operate the system, monitor charging status, troubleshoot issues, and ensure efficient operations. Checklist.

**Taxiing:** Aircraft location in relation to taxi-in and taxi-out; time, slots, and conditions? Checklist.

**Prevent redundancy and reliability failures:** Incorporate redundancy into electrical systems to ensure that charging can continue and that measurements and controls work even if some components fail. Reliability is essential to maintaining efficient operations. Checklist.

**Standards and compatibility:** The charging systems and connectors should be compatible with the electric aircraft's charging ports. Industry-standard or type-specific connectors should be used. Mapping options, prioritized grids, and coordination among airports, suppliers, and regulators are to be integrated into the ongoing preparations. Checklist.

**Space and layout:** Design the aircraft stand layout to accommodate different sizes and types of electric aircraft. Consider factors such as spacing between aircraft, accessibility for maintenance, and optimizing the use of available space. Checklist.

**Weather conditions:** They influence which design decisions must be made, of course, especially in areas with very low or very high temperatures. The aircraft stand with its installations and equipment should be designed to withstand various weather conditions, including storms, rain, snow, and extreme temperatures, to ensure safe and reliable charging operations. Checklist.

**Scale and future expansion:** Plan for scalability to accommodate an increasing number of electric aircraft. Future-proofing the infrastructure to adapt to evolving electric aircraft technologies and standards is essential. This can also be important for coordinating purchases in joint agreements among several airports, which could lead to better prices with suppliers and to coordinated solutions that benefit all actors. Checklist.

**Staff training:** All staff working with electric aircraft should undergo specialized training to understand and handle the additional risks associated with high-power systems, cables, and connections. Checklist.

The above requirements vary depending on aircraft type, charging technology, airport infrastructure and operating conditions. Several airports in the Nordics and globally are preparing for electric aircraft, and some are already building the necessary facilities. In the ALIGHT project, these experiences are incorporated into the preparatory work. Collaboration with aircraft manufacturers, airports, charging providers and regulators is essential to ensure compliance with standards and operational needs.

## 6.6 Hydrogen aircraft

Hydrogen as an energy carrier for aircraft has, in recent years, been considered a key solution for the green transition in aviation, especially for medium- and long-haul flights. Several players are no longer involved in the development, and Airbus has postponed the development of hydrogen as a direct propellant in the engines. There are still players investing, so when, and if hydrogen for fuel cells arrives, airports must be prepared.

Hydrogen can be used in either gaseous ($GH_2$) or liquid ($LH_2$) form, and each technology has its advantages and challenges. Gaseous hydrogen requires simpler storage and distribution but has a lower energy density, limiting its range. Liquid hydrogen has a higher energy density and can thus support longer flights but requires cryogenic storage at around –253 °C as well as advanced materials and safety procedures. The choice between $GH_2$ and $LH_2$ will depend on the aircraft's mission, energy needs, airport infrastructure, and operational and economic conditions.
Gaseous hydrogen is expected to be available in aircraft by the end of this decade for fuel cell technology, whereas liquid hydrogen is not likely to be introduced until the end of the next decade.

**Airport preparations for hydrogen aircraft**
The phasing in of hydrogen aircraft will place significant demands on the airport's infrastructure, safety procedures, and cooperation with external partners. The transition requires both technical upgrades and organizational adaptation. On a technical level, airports must establish specialised hydrogen zones with secure storage and refuelling facilities capable of handling either gaseous hydrogen ($GH_2$) at high pressure or liquid hydrogen ($LH_2$) at cryogenic temperatures. This may include advanced piping systems, ventilation solutions and fire prevention measures.

Operationally, staff must be trained in handling hydrogen, including emergency procedures and safety standards. Airports must also work closely with hydrogen producers, energy companies, authorities, and aircraft manufacturers to ensure compatibility and standardization of refuelling procedures.

Throughout history, there have been numerous attempts to develop hydrogen aircraft. In recent times, ZeroAvia's development work has been among the most advanced. Similarly, the ZEROe development project at Airbus is well known. Boeing is also investigating possible hydrogen solutions, and several aircraft engine manufacturers have begun developing hydrogen solutions. While, for example, ZeroAvia develops fuel cell technology in which hydrogen is converted into electricity to power a battery, the plan at Airbus and Rolls-Royce is to develop aircraft engines that can run directly on hydrogen injection into the combustion chamber. As mentioned, Airbus has postponed the project to use hydrogen directly for 5-10 years but continues to develop fuel cell technology.

Hydrogen for aircraft technology includes several aspects regarding its introduction in the aircraft stand context, which are still not sufficiently detailed to initiate an actual aircraft stand layout. As it appears at the outset, some of the development projects have a relatively short time horizon. For example, ZeroAvia announced that it would be on the market in 2027.

Regarding the supply of sustainable hydrogen, it relates to national, regional, and, to a certain extent, international plans for the production and rollout of hydrogen. Political plans for the use of hydrogen in aircraft and the transport sector are intended to proceed in parallel with aircraft technology development. Suppose airports can prepare for hydrogen solutions in a timeframe that aligns with the ambitions of the first movers among aircraft manufacturers. In that case, it is urgent to initiate planning for the adaptations that may lie ahead. Although hydrogen policy and hydrogen technology are still being developed, several aspects can already be considered.

Many requirements for a hydrogen aircraft would, in many ways, be like those for traditional aircraft, but there are also significant differences and additional considerations due to the unique characteristics of hydrogen handling and refuelling.

In the following, you will find the key requirements and keywords to consider, further elaborate on, discuss, and specify. The points listed can also be used as an overarching checklist for the ongoing process:

With today's knowledge, we can set up three ways hydrogen can be delivered and brought to the plane:

**A.** On-site production, which will require extensive infrastructure investments, access to space for the plant, as well as piping and distribution facilities. Furthermore, for access to enough renewable energy for splitting water, etc.

**B.** Transport of hydrogen from a major production facility outside the airport. The hydrogen is brought to storage tanks from where it must be distributed through specific pipe systems to the stand and aircraft.

**C.** Transport of hydrogen on trucks from the producer. Delivered in tanks ready to exchange with the empty tanks located in the aircraft, and thus, there will be a continuous supply that can take place without direct installation measures at the airport.

Planning should address both the short-term introduction of regional hydrogen aircraft and the long-term integration of larger models, using flexible solutions adaptable to different hydrogen types and technologies to avoid future reinvestments.

**Energy supply scenarios for hydrogen to the aerodrome were centralised GH2/LH2 supply via truck transport is expected to be the primary option for the first years of deployment - could also be executed by using exchangeable, centrally-refilled hydrogen tanks**

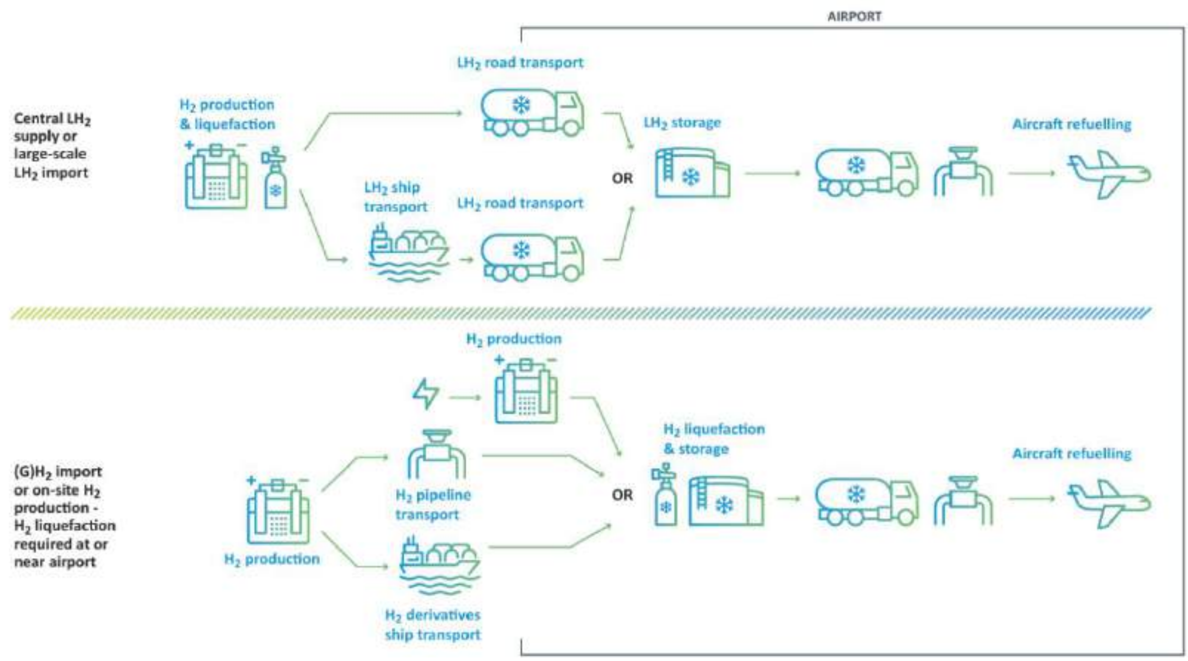



*Figure 56 Energy supply models for hydrogen to the airfield* [191]

*Central supply of liquid hydrogen via truck transport may be the primary option in the early years of implementation. Trucks can also provide replaceable, reusable, centrally refilled hydrogen tanks.*

[191] AZEA, Flying on electricity ang hydrogen in Europe. Energy supply models for hydrogen to the airfield. June 2024

### 6.6.1 Overarching checklist for hydrogen aircraft

**Compatibility between aircraft and stand designs:** Requirements for refuelling systems and the locations of filling ports must be matched and agreed upon in the specific layout to ensure optimal, efficient fuelling conditions. Checklist.

**Spacing and layout:** Design the aircraft stand layout to accommodate different sizes and types of hydrogen aircraft (eventually also hybrid/hydrogen?). Consider factors such as spacing between aircraft, accessibility for maintenance, and optimizing the use of available space. Checklist.

**Weather conditions:** Hydrogen aircraft stands must be designed to withstand rain, snow, storms, and extreme weather temperatures to ensure safe operation. Checklist.

**Filling:** The layout of the aircraft stands and all equipment used must allow refuelling to be performed safely and efficiently. All equipment must be carefully coordinated and aligned between the stand and the aircraft, the connections, pressure flows, pressure control and other measuring instruments installed and used. Checklist.

**Quality and purity:** With pump and refuelling activities installed on the aircraft stand, there must be a focus on filter and quality measurement systems to ensure hydrogen is delivered to the aircraft with the highest possible purity and quality. Checklist.

**Training of staff:** All staff working with hydrogen aircraft should undergo specialized training to handle hydrogen safely and effectively. All staff working with hydrogen aircraft should undergo specialized training to understand and handle safely the additional risks associated with hydrogen compared with conventional aircraft. Checklist.

**Safety procedures:** If hydrogen is delivered to the airport, the aircraft stand should have the necessary infrastructure for loading and offloading, whether it is directly to/from the aircraft or to/from storage tanks. Safety is extremely important given hydrogen's flammable nature. Therefore, safety measures, safety protocols, gas sensors, emergency shut-off systems, and firefighting measures are of the utmost importance. The aircraft stand should be equipped with advanced firefighting systems capable of quickly addressing hydrogen-related fires.

Ventilation and preventive measures to disperse any leaked hydrogen are essential if a spill should occur to maintain a safe environment. It must be considered that hydrogen has a low density and can accumulate in indoor locations. Checklist.

**Rules and regulations:** Ensure that the aircraft stand's design and operation meet all relevant aviation and safety regulations and standards. Dialogues and coordination with appropriate parties should be undertaken well in advance of decisions. Checklist.

**Operational conditions/Scalability and future expansion:** Plan for scalability to accommodate an increasing number of hydrogen aircraft. Future-proofing the infrastructure to adapt to evolving hydrogen aircraft technologies and standards is also essential. It can also be important for coordinating purchases in joint agreements among several airports, which could lead to better prices and coordinated solutions to the benefit of all actors. Checklist

**Turn around and filling time:** The refilling infrastructure should be designed to minimize time on ground. This is a decisive parameter for airlines and, thus, also for the airport that must store, supply, and secure hydrogen. Faster refilling capabilities can be a significant advantage for operators, so the aircraft stand should support rapid charging technologies when available. This is also an important topic to discuss and process in a Stakeholder network/coordination forum, which is proposed to be established (ref chapter 6.7). Checklist.

It's still unclear when hydrogen-powered planes will be in use, and even more uncertain which airports and operators will be involved. Airports need to prepare infrastructure that meets requirements for flexibility, turnaround times, and operational costs. The "Zero Emission Aviation Alliance WG 03 Aerodromes March 2025" catalogue offers useful fact sheets on infrastructure, operations, and safety for future planning.

Figure 55: Specifically addressing future hydrogen access and cross-national coordination opportunities:

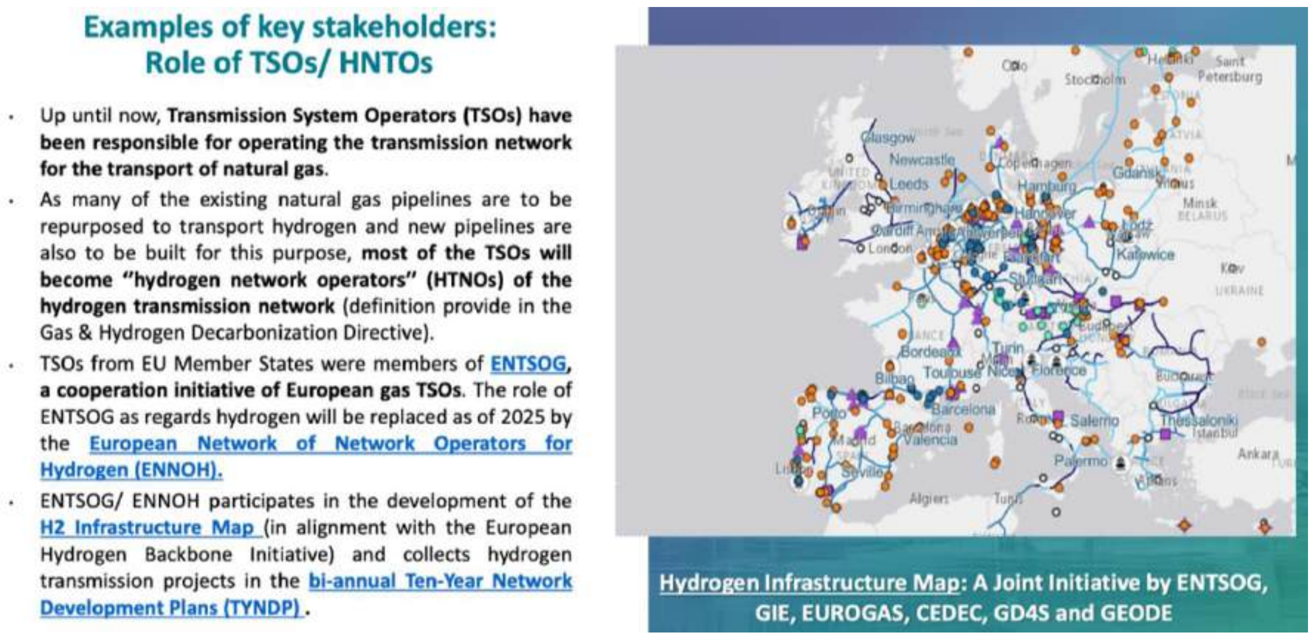



*Figure 57 Future hydrogen access and cross-national coordination opportunities [192]*

[192] AZEA, Zero Emission Aviation Alliance WG 03 Aerodromes, March 2025, page 31.

**Recommendations for engagement with TSOs/HNTOs & ENTSOG/ENNOH**

**1. For airports, early engagement with existing TSOs and future HNTOs will be essential to ensure that the required volumes of hydrogen are adequately supplied to airports:**

- As a first step, the existing links to airports in the planned national hydrogen networks, as well as the existing gaps in the planned infrastructure, should be analyzed. As an example, airports requiring a direct connection to the hydrogen network should be identified. Ongoing projects at airports should be also mapped in order to better understand which airports could be more easily integrated in the hydrogen network.
- Airports should seek early alignment with the ongoing work of TSOs/ future HNTOs and national regulatory authorities to make sure that the planning of the national hydrogen networks and of the cross-border links considers the required hydrogen supply of airports and that airports are well integrated in the hydrogen networks. Airports should regularly consult the projects in the TYNDPs.

**2. In this transition period, it will be also important for airports to engage with ENTSOG and the recently launched ENNOH.**

**3. TSOs/HNTOs should be also invited to become members of AZEA could be particularly helpful to strengthen this necessary engagement.**

| EU Member State | TSO/Potential HNTOs |
|---|---|
| Belgium | Fluxys<br>Interconnector Fluxys |
| France | GRTgas/ Terega |
| Denmark | Energinet |
| Germany | OGE, Ontras, bayernets, Fluxys TENP, Gascade, GTG Nord, Gasunie, GRTgaz Deutscheland, Thyssengas |
| Italy | Snam, SGI |
| Netherlands | Gasunie, bbl company |
| Spain | Enagas |

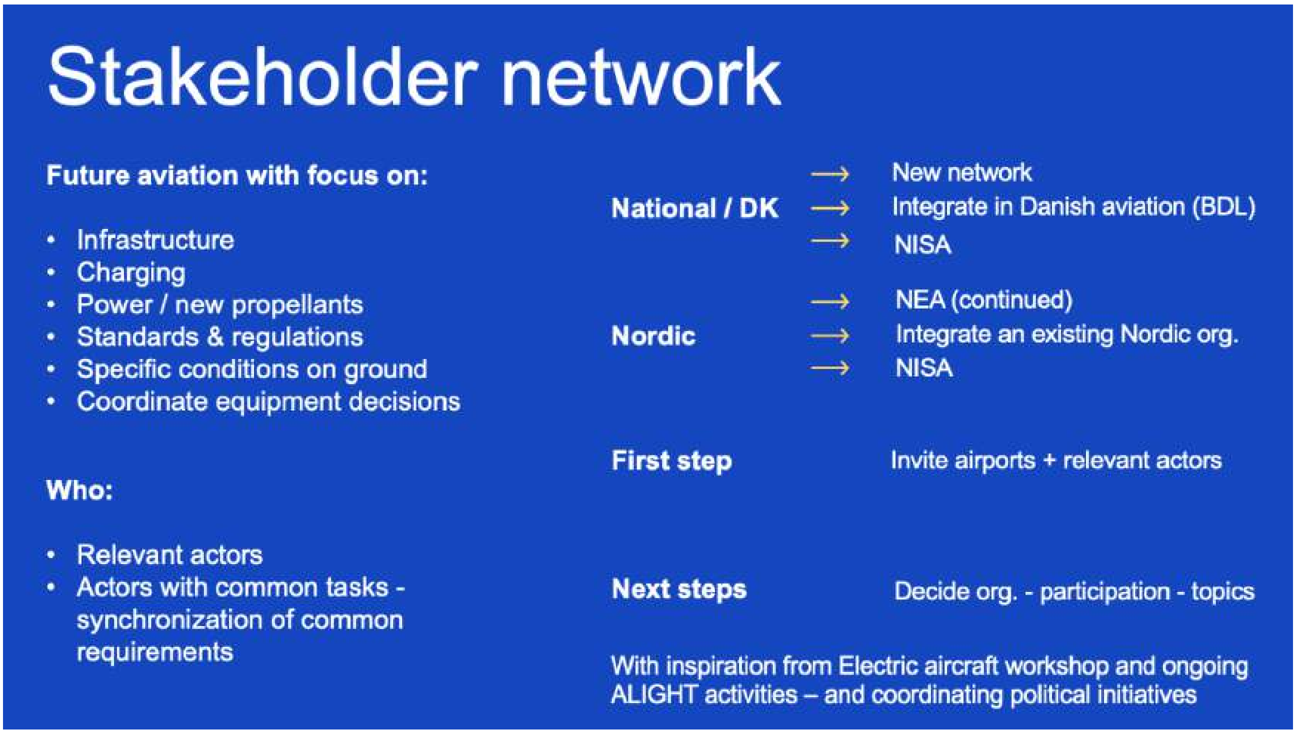
Examples of TSOs at the EU level and future potential HNTOs (see complete overview here)

*Figure 58 Examples of TSOs at the EU level and future potential HNTOs* [193]

## 6.7 Stakeholder network

To contribute to the continued development of the preparations, WP2 and NISA, on the background of ALIGHT activities, have proposed to establish a stakeholder network/forum or network, which will bring together relevant actors to prepare interested and relevant airports to handle the aircraft of the future, starting with an assessment of how the airports can adapt in terms of infrastructure. The electric aircraft and charging challenges will be given priority and, in addition to involving airports, will also include authorities responsible for climate, energy and transport. The intention is that the stakeholder forum or network will be established in cooperation with the relevant authorities and organization representatives. The initiative is prepared to be launched in Denmark and is expected to be continued in the Nordics and other international frameworks if support can be created for this.

[193] AZEA, Zero Emission Aviation Alliance WG 03 Aerodromes, March 2025, page 32




## 6.8 NEA simulation tool

NEA, Nordic network for Electric Aviation, works to promote electric aviation in the Nordic region and position the region as a global leader in sustainable aviation. The organization brings together actors from the aviation industry, technology developers, research institutions, and authorities to support development and foster an innovative ecosystem.

With support from Nordic Innovation, NEA focuses on promoting research, innovation and collaboration within electric aviation. This includes the development of new technologies, as well as initiatives to create the necessary infrastructure, charging options, relevant regulatory frameworks and standards for electric aviation. The organization supports small and medium-sized enterprises and innovation hubs that can contribute new solutions for electric aviation, such as the Norwegian El-fly Group, which develops electric seaplanes. (see section 6.2)

The goal is to create a decision-support system that enables stakeholders to optimise infrastructure, operations, and human factors in the electric aviation of the future, achieved by developing a toolkit for simulating future scenarios. The intention is also to ease the implementation of electric aviation in the Nordics through focused communication activities, aimed explicitly towards policy makers, technology providers, broader industry stakeholders, investors and new as well as existing operational stakeholders

One of the tasks in the NEA collaboration has been to explore where and how the aircraft of the future can be used, and the NEA Vision Tool is a contribution to this. The purpose of this tool setup is to capture a visual representation of airports, routes, destinations, and aviation patterns in the Nordics as they occur today, and to provide an outlook on what is possible with the introduction of electric aviation. It is built to inform and inspire. The tool itself does not give the answer to future aviation patterns, but it can visualise several options.

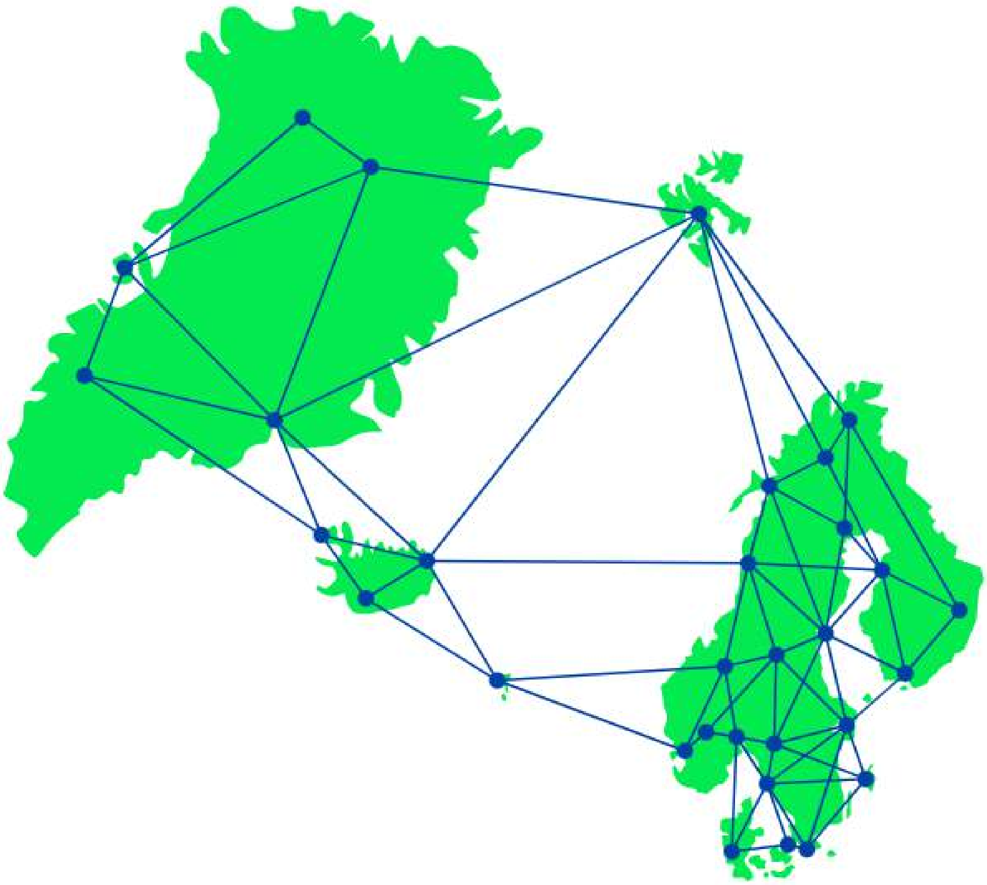


*Figure 59 The NEA Vision Tool [194]*

*The NEA Vision tool is a web-based map solution that plots existing airports and routes but also visualizes routes that are feasible given criteria and filters that you can define yourself. The results are both visualised on a map and in an analytics view, with dynamic lists and graphs.*

The NEA Vision Tool can be used to simulate future aviation scenarios. Through the tool, stakeholders can test different solutions, assess capacity needs, and identify potential challenges before major investments, such as infrastructure investments, are made. This

[194] NEA: The NEA Vision Tool

provides a valuable basis for planning and testing the integration of electric aircraft into existing and future infrastructure at selected destinations. Simulations can provide insight into logistics and operational patterns, which are crucial for flexibility and adaptability when assessing, implementing, and scaling new technologies. In addition to showing all conceivable routes, the tool can also calculate the advantages of using electric aircraft compared to, for example, current transport options.

## 6.9 eVTOL development 2025 and beyond

Electric vertical take-off and landing aircraft (eVTOL) have become a dynamic and closely watched innovation in the aviation industry. The potential of eVTOLs lies in providing sustainable, efficient and flexible solutions for urban and regional air mobility, while contributing to the decarbonization goals of global transport systems. Several airports in major cities are considering linking eVTOL operations closely to airside traffic to meet the desire for fast transport to and from the airport and the city centre, or to dedicated private business centres or public hubs.

However, there are many prerequisites that need to be analyzed before CPH, major European airports, or other new operators, make decisive decisions. eVTOLs may also be suitable for use independently of airports, for example, between metropolises or selected centres with potential benefits from this form of transport. In areas requiring efficient transportation of medical equipment, blood tests, ambulant transport, and package- or freight delivery, eVTOL is also seen as having a significant role to play. Several test flights in these areas have been conducted on selected dedicated routes, with satisfactory results. By mid-2025, eVTOL development will have reached a significant level of maturity in flight testing and regulatory engagement, but it will still be constrained by technical, economic, and infrastructural challenges. This section outlines the current global state of the eVTOL sector and highlights regional technological advances, regulatory environments, and long-term prospects.

**Industrial and technological landscape:** Europe played an early pioneering role, with Volocopter, Lilium and Vertical Aerospace among the most visible startups and developers. Many of these companies are currently struggling with funding constraints, certification delays and technical barriers. Airbus, which had advanced the CityAirbus NextGen program, paused development in 2024 in favour of a strategic reallocation of resources to hydrogen and sustainable aviation fuels. EASA has been proactive in setting specific conditions for VTOL (SC-VTOL), but cross-country harmonization and slow infrastructure development have hampered the necessary progress.

Several analyses highlight that the US has established itself as the global leader in eVTOL development. Companies such as Joby Aviation and Archer Aviation have made progress towards certification with the Federal Aviation Administration (FAA). Both companies have conducted pilot test flights in controlled airspace and are aiming to offer limited commercial services by 2025-2026. With strong financial resources and strategic partnerships with major airlines (e.g., Delta and United) and automakers (Toyota and Stellantis), these companies arguably represent the most credible short-term path to operational deployment.

In Asia, China has positioned itself as a leading centre for eVTOL innovation, with EHang achieving type certification for its autonomous passenger eVTOL in late 2023. Demonstration flights in urban environments such as Guangzhou and Beijing are underway in 2025, backed by strong government support. In Japan and South Korea, government and industry consortia are also advancing demonstration projects, often tied to broader smart-city initiatives and the anticipated growth of autonomous aviation services.

Elsewhere in the world, the Middle East has shown strategic interest in eVTOL deployment. The United Arab Emirates (especially Dubai) has positioned itself as a testbed for advanced air mobility, leveraging regulatory flexibility and investment capital. Latin America and Africa, which are currently less central to development, are monitoring eVTOL applications as potential solutions for infrastructure in regions with underdeveloped ground transportation networks.

**Regulatory and infrastructure development:** Globally, regulators are working to establish frameworks for eVTOL certification, air traffic integration, and vertiport development. The FAA and EASA are key players in this, and their standards have increasingly become international practice. Nevertheless, differences in certification timelines and operational requirements across regions could fragment the market in the short term.

**Infrastructure remains a bottleneck:** Vertiport planning in major metropolitan areas is still in its infancy, and integration into existing transport ecosystems has proven to be very complex. In regions like China and the UAE, government-driven urban planning may accelerate infrastructure deployment. In contrast, in Europe and North America, development is more fragmented and relies on private investment and/or public-private partnerships.

**Market dynamics:** According to Airways magazine, the global eVTOL industry remains highly capital-intensive. While the early years saw significant venture investment, the sector in 2024–2025 is undergoing a phase of consolidation. Companies with weak financial situations or delayed certification milestones have struggled to maintain investor confidence, leading to several bankruptcies and mergers. Conversely, companies with strong strategic partnerships and diversified revenue streams, especially in the US, are gaining market dominance.[195]

[195] Airways Magazine, Sector analysis: The state of evtol innovators, Marts 2025

**Public perception and social acceptance also play a crucial role**: Safety, disturbance, noise and environmental performance are critical factors that will determine the willingness of cities and citizens to adopt eVTOL services. Demonstration projects, such as those carried out in New York, Los Angeles, Paris, and Dubai, also serve as necessary tests of public acceptance. Also, drone tests of different sizes, e.g., for package deliveries and medical transport, can serve as a basis for future decisions. Interfaces between manned and unmanned systems may need clarification. Interfaces between eVTOL and fixed-wing aircraft will play a crucial role in the decisions to be made.

**Outlook, short term (2025-2030):** The US will likely achieve the first scaled commercial eVTOL operations, supported by strong financial ecosystems and progressive regulation. China will continue to implement autonomous models, while Europe may remain in a demonstration phase due to fragmented markets and financing challenges.

**Medium term (2030-2040):** Widespread integration of eVTOLs into urban mobility systems, delivery, and healthcare tasks is possible if technological improvements are achieved in battery density, noise reduction, and infrastructure. Public acceptance will largely depend on experience, test flight results, and documented safety and affordability.

**Long term (beyond 2040):** eVTOL aircraft could become a standard component of sustainable regional mobility systems, especially if integrated with other new propulsion systems, such as electric and hydrogen aircraft.

The long-term viability of eVTOL as a global mobility solution will depend on resolving technological bottlenecks, meeting market needs, addressing policy decisions, scaling infrastructure, building public trust, and, last but not least, developing solid, integrated use cases.

When assessing eVTOL implementation, one must think much broader than "airlines + airports" - because advanced air mobility (AAM) will involve new types of operators, landing sites and integration challenges, for example from airlines to startups and rescue services, more types of airports, for example from hubs to regional and GA fields, and entirely new categories of landing sites such as vertiports, rooftops, multimodal hubs. The development of and interaction between these actors will determine how advanced air mobility can be scaled in practice.

Major airports such as CPH must assess how and whether eVTOL could serve as a first/last mile connector for some travellers or other tasks, whether it is likely to develop dedicated vertiport areas or rooftop pads integrated into terminal design, or whether combining landside/airside models makes the most sense.

Regional airports will benefit from eVTOL feeder services connecting smaller cities to larger hubs or activity centres. All this requires planning and integration considerations, especially around charging stations and capacities (fast DC for eVTOL), passenger handling lounges, security screening where necessary, and, not least, airspace management and the integration of urban air traffic with U-Space (EU) or UTM (US). New stakeholders may come into play, such as urban planners, local municipalities, utilities (power grid upgrades), and mobility-as-a-service (MaaS) platforms.

**Overview of possible actors and tasks/functions eVTOL Deployment: Operators × Airports/Landing Sites**

| Hub Airports | Regional Airports | GA Airports | Dedicated vertiports | Heliports | Rooftops/ Hospitals | Multimodal Hubs | Industrial/ Remote Sites |
|---|---|---|---|---|---|---|---|
| Airlines, feeder to / from long-haul | Airlines (regional connectors) | Air taxi startups | Urban air taxi/package delivery, operators | Helicopter - to - eVTOL transition | Emergency/ Medical operators | Urban air taxi (commuter) | Cargo/ logistics |
| Urban air taxi, premium routes, customized solutions | Cargo/logistic operators, customized solutions | Emergency/ medical services, specific destinations | On-demand mobility platforms or agreements | Corporate shuttle services. VIP/business | Police/public service | Airline partners, customized/ ad hoc solutions | Public services, resuce, surveillance, monitoring |

# 7 Airports on the way to 2050. Fuel, energy, and mobility

## 7.1 SAF and energy supply to airports - Horizon 2026 to 2050

Airports have historically served as transport hubs where passengers, cargo and air traffic meet. In line with the increasing demand for sustainability, digitalization, and resilience, airports will have significant opportunities to undergo a transformation. In the coming decades, many airports are expected to evolve from primarily transport hubs to complex energy and innovation hubs with broader functions, thus becoming next-generation airports. Provided, of course, that airports understand how to navigate and adapt to the changes and opportunities. Development will be pushed forward by technological advances, political regulations, new passenger needs, customer demands, business opportunities and a global agenda characterized by digitalization, climate requirements and energy transition.

It is not the task of this report to analyze or go into detail about what the airport of the future will look like or how it will be designed, or to specifically point out which decisions must be made in the context of 2050. However, it may be helpful to outline some technological themes and possible frameworks, some aimed at the airport as such and others more specifically at the necessary supplies of fuels and energy.

At the Bold Vision conference held by ALIGHT in May 2024, several scenarios were outlined that are relevant to future scenarios. What we are taking a little further here are some of the overall themes that may become crucial for airports to play an important role, and according to our findings, an even more critical role, as a hub for not only transport and mobility, but also as a possible player in innovation, collaboration, and sustainable development. A development that is driven by the need to be able to handle increased traffic, the possibilities of technical and data regulation, and to be able to align with the urgent environmental and climate obligations.

While this is the final chapter of the report, it also serves as input for continuing to define interesting development paths, structures, and frameworks to be considered in future planning and decision-making processes for airports and aviation.

The following is a review of key topics in relation to a development horizon 2026-2050

**Energy and fuel hub:** The airport of the future should be able to handle a wide range of energy forms side by side. Where today's supply chain is primarily based on conventional jet fuel, future systems would include Sustainable Aviation Fuels (SAF), hydrogen (both in gas and liquid form), and electricity for electric aircraft, eVTOLs, and an increasing number of vehicles and other activities on the ground. This requires the construction of flexible storage and distribution infrastructure, the possible integration of SAF into multiple pipeline systems, and dedicated solutions for high-capacity charging and a broad range of energy supply. The airport can become an energy cluster by bringing together several technologies into integrated systems.

Perhaps, over the next 25 years, new forms of energy, technologies, and methods we may not know of today will be invented. For example, aircraft fuselage can be used as an energy storage, so-called "structural batteries" or "multifunctional energy storage systems".

Research into so-called structural batteries, or multifunctional energy storage systems, aims to enable aircraft structures, wings, fuselage, and tail to serve both as load-bearing elements and as energy storage systems. The technology combines lightweight composites with electrically conductive materials, enabling energy storage directly in the aircraft's structures and components. It could significantly reduce weight and increase the overall energy efficiency of future electric and hybrid aircraft, and to an even greater extent as batteries' energy density increases.

In the middle of this decade, however, development is still on a laboratory and prototype scale. Chalmers University of Technology, Airbus, NASA and Boeing are researching the subject and have demonstrated materials with both mechanical strength and energy density, but so far only at relatively low levels (20–30 Wh/kg, far below modern lithium-ion batteries). The biggest challenges are safety, certification, electrical insulation and maintenance and repair, as energy storage is directly part of the aircraft's supporting structure.

It is estimated that structural batteries may play a role in small electric aircraft around 2035, especially where weight optimisation is crucial. Use in larger passenger aircraft is not expected until after 2040 at the earliest. Technology represents a significant step towards a new generation of integrated energy solutions in aviation, where the boundary between structure and energy storage is gradually erased.[196]

**Sustainability and climate:** Airports will increasingly play a central role in achieving national and European climate goals, including, of course, their integration into ReFuelEU Aviation and international aviation's goal of zero emissions by 2050. This involves both reducing $CO_2$ and contributing to managing and reducing non-$CO_2$ effects that create condensation trails and unacceptable air quality in and near airports. In addition, airports must reduce their own footprint through energy-efficient operations, the use of environmentally acceptable products and methods, circular waste management, and the production of renewable energy on-site, for example, solar cells, perhaps smaller wind turbines, and possibly Power-to-X plants in or near airports. The possibility of building or participating in installations or plants that reduce carbon

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[196] References
Chalmers Uni. of Technology Unveiling the Multifunctional Carbon Fiber Structural Battery + Realisation of structural battery composites, 2023
World Economic Forum: 1. Structural battery composites - Top 10 Emerging Technologies of 2025 | World Economic Forum, 2025
MDPI: Structural Batteries for Aeronautic Applications—State of the Art, Research Gaps and Technology Development Needs, 2021
Boeing/NASA, Electric skies: Boeing joins GE and NASA's hybrid electric aircraft project, 2022
Clean Aviation, Multi Functional Fuselage Demonstrator, 2025

levels should also be considered. The airport of the future can very likely function as a partner in climate solutions to the same extent as a transport facility. The many potential changes, adaptations and, not least, expansions require capital and a willingness to invest, or be attractive to invest in. The nature of many possible common and integrative projects clearly suggests the possibility of joint ventures in key areas. Public-private partnerships (PPPs) can be crucial in funding airport infrastructure projects, ensuring sustainable growth, and fostering economic development in the aviation sector. By collaborating with private investors, financial institutions, and government agencies, airports can secure the funding for infrastructure upgrades, modernisation projects, and expansion initiatives.

**SAF and energy supply to airports - Horizon 2026 - 2050**


*Figure 60 SAF & energy supply to airports* [197]

**Digitalisation and data optimisation:** Digitalisation will be a pervasive driving force. AI and machine learning will manage traffic flow, gate utilization, and logistics, while digital twins will enable real-time simulation of operations and optimisation of decision-making processes. The passenger experience will be supported by fully automated check-in and security solutions, as well as way-finding guidance. Predictive maintenance tools and procedures will reduce aircraft downtime and associated costs. Data, digitalization, and automation are expected to become critical assets, both for efficient operations, supplies, smarter and more efficient handling of passenger and cargo flows, and for transparent reporting of all traffic types, bottlenecks, error minimization, consumption, and climate footprint. The use of IoT, AI, and autonomous systems

[197] NISA, May 2025

holds the potential to revolutionize all operations, enabling real-time data collection, improved personalized services, and meeting safety protocols.

**Passenger experience and multimodal integration:** The airport of the future will, to a greater extent than today, be able to function as a multimodal transport hub, where air travel is directly connected to train, metro, road traffic, possibly sea and new forms of transport such as eVTOL. At the same time, customers will expect transparent options to choose sustainable solutions, such as tickets and transport with the lowest possible climate impact, or additional green services. Automation and digital services are expected to make travel and transport more seamless. At the same time, the airport itself could be increasingly developed to serve as a centre for many activities and integrated solutions.

**Security and robustness:** As critical infrastructure, airports will face increasing demands for both physical security and cybersecurity. At the same time, climate adaptation will become a strategic necessity: rising sea levels, heat waves and extreme weather require robust systems, flexible infrastructure, and continuity plans. Robustness across several parameters can be expected not only to be a technical issue but also to become a competitive advantage, where the ability to ensure operations in various types of crises can be crucial.

**Innovation and collaboration platform:** The airport of the future will increasingly function as a living lab, where new forms of energy, technologies and business models can be tested at full scale. This requires strong collaboration between airlines, energy companies, technology manufacturers, authorities, and research institutions. Holistic assessments, coherent solutions, and exploitation of interaction effects will play larger and, in some areas, decisive roles. The airport can, in many ways, become a platform for innovation and development, helping ensure a future-proof position while accelerating the transition to green aviation.

**Regional development and jobs:** By serving as an energy and innovation hub, airports can contribute to regional growth, job creation, and international profile, including areas not traditionally linked to aviation. New energy supply facilities, especially power supplies, research into advanced SAF and new supply routes for propellants, as well as the integration of Power-to-X and eSAF facilities in or nearby, bring opportunities and perspectives for many activities, also with regional industries and organizations.

**Perspective towards 2050:** The topics mentioned earlier must be analyzed, further developed, and additional aspects and challenges added. Airports, authorities, and experts are tasked with establishing a process that can create the framework for the future airport. As a suggestion, the development can be set out in three phases:

• Short term (2026–2030)

• Medium term (2030–2040)

• Long term (2040–2050)

**Airport route 50 - Key capabilities**

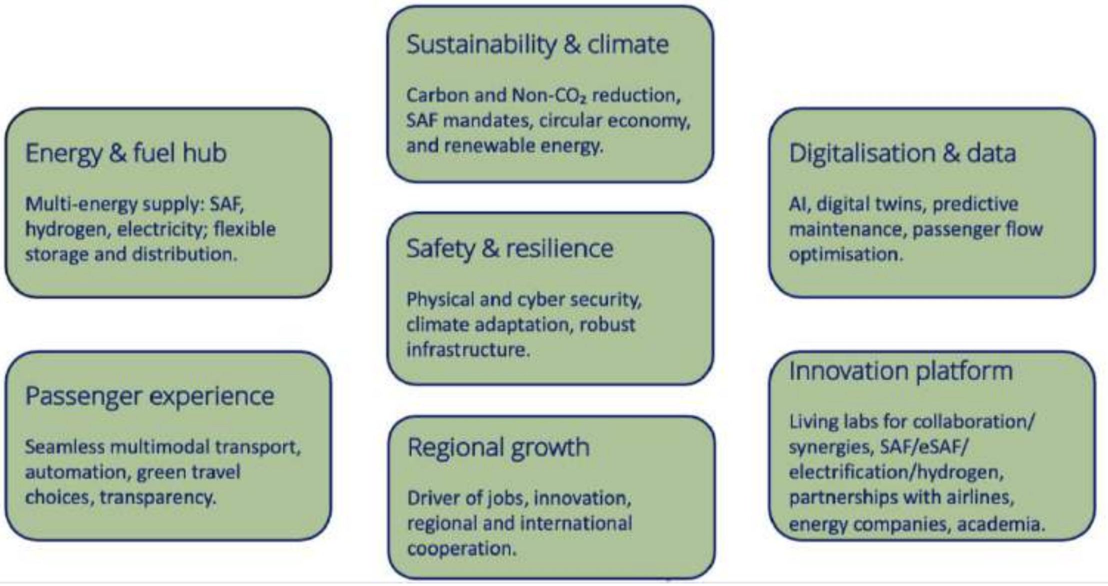



*Figure 61 Key capabilities Airport route in 2050* [198]

**Concluding note:** The major airports of the future will be much more than passenger and cargo terminals. At least the conditions and possibilities clearly point to that. Airports can become multi-energy hubs, digital and multi-modal traffic centres, innovation platforms and climate drivers. A transformation that is needed to support the role of aviation in sustainable global mobility. This can be handled in response to the development, but it should be handled proactively. The development will require investments, collaboration and innovation across sectors, technologies, advisors and experts. How the development is handled will depend on many factors, some of which are linked to internal conditions, governance, management, structures, geographical and traffic locations, and externally to political decisions, regulatory conditions, the ability of suppliers and developers, and, for example, in the fuel supply area, also on the ability of oil companies to adapt through necessary investments and to fulfil their social responsibility to reduce climate impact.[199]

[198] NISA, May 2025

[199] ACI, The Evolution of Airports: Flightpath to 2050, June 2023

# 8 Recommendations & considerations

**Policy workshop, Brussels 15. May 2025**

In May 2025, ALIGHT held a policy workshop in Brussels, which was a good opportunity to summarise experiences and perspectives, especially related to the many aspects of the SAF challenges. WP2 presented several recommendations, suggestions, and considerations, primarily of a political nature, as well as concrete, possible airport-specific topics.

The proposed topics are presented in various ways throughout previous sections of the report, along with corresponding recommendations and considerations in the form of checklists, questionnaires, and key arguments. The selected topics are reviewed in the presentations below.

**WP2 matrix**

The starting point was the WP2 General Matrix, a management tool determined based on the tasks, objectives, and delivery descriptions in the Grant Agreement, and which has served as the overall guideline for WP2 throughout the project.

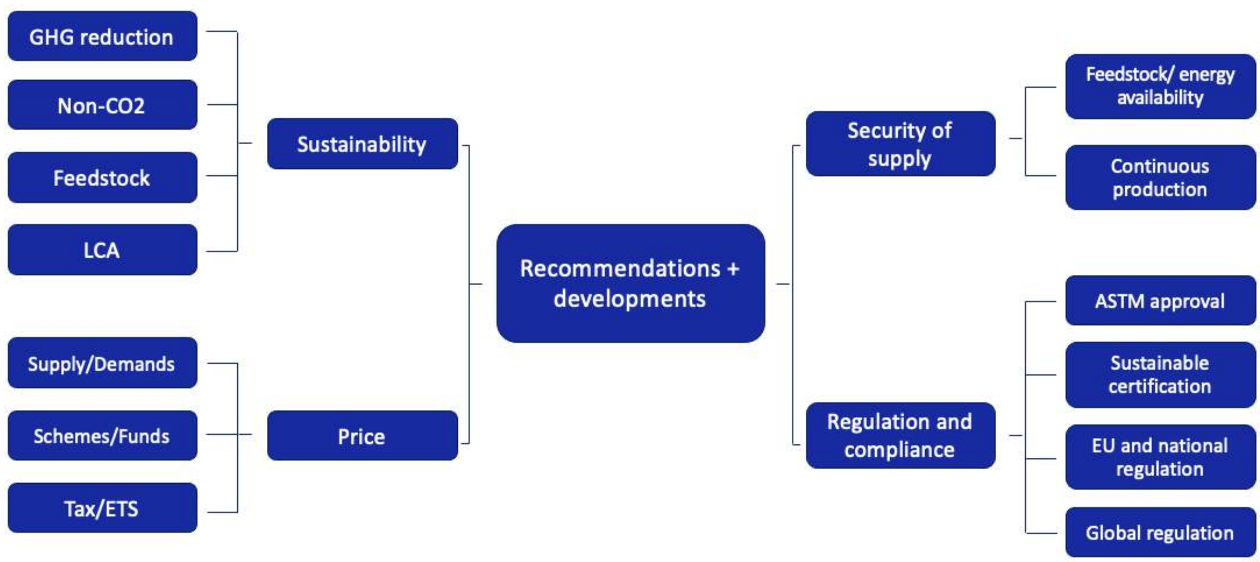
In 2019 and 2020, the total SAF volumes on the market were less than 1 per mille of the total jet fuel used. Although several airlines had used different blend-in quantities at selected destinations and for other purposes, and although some manufacturers launched promising production plans, not much SAF was available. The COVID-19 period 2020-22 and 2023 did not result in any significant increase in SAF on the market. Only from 2024, after the adoption of the RefuelEU Aviation mandate, did production increase noticeably, to the extent that the 2% target in 2025 is likely to be achieved.

For the project, the situation highlighted the need to analyse who, how, and where could contribute to bringing SAF to market. Acquiring SAF was outside the project's scope. First and foremost, the airlines were in a position to create demand as customers of the fuel suppliers. Although some individual European airlines showed great interest, there were very few SAF orders.

With WP2's main task to promote, review and document the "Sustainable Aviation Fuels supply line" and "To create the optimal conditions for the supply of SAF to CPH, including future opportunities", it was necessary to focus efforts on development activities and to consider recommendations and incorporate the central issues related to it, - which can be seen in the matrix below. A central part of this has been to establish close contacts with manufacturers, suppliers, researchers, and developers to consider product prices, delivery capacity, sustainability, and continuity, and to review methods and quality checks for delivery and quantities in an upcoming SAF flow. Although the large flow has been delayed and will continue to be a considerable challenge, it is relevant to extract the most essential recommendations and key considerations for the many actors involved in the broad, complex supply-and-offtaker chain, including political and investment-related matters, as well as new technologies, methods, and products.

Several recommendations and suggestions for consideration for political and operational decision-makers follow the matrix below.

## 8.1 WP2 general matrix




**Recommendations for political considerations and decisions**

Providing SAF and sufficient energy capacity for aviation requires thorough, long-term considerations, prioritisation, commitments, and investments. Despite significant regulatory initiatives, the aviation and transport sectors face many unresolved challenges. RefuelEU Aviation points positively to the future and provides a useful foundation for much of what is needed. Several interim goals require further decisions and transitions to meet the ambitions of contributing to national and international climate goals. The transition can hardly be driven solely by market forces or technological solutions but requires further political participation and strategic investments. A key prerequisite is that aviation, SAF, energy and new fuels are fully included in national and European energy policy. This is to counteract fragmented decision-making processes and a lack of decisions and coordination with other energy and climate policies.

Consideration should be given to rethinking existing subsidies and economic incentives. Fossil fuels continue to receive significant direct and indirect support schemes in Europe. A shift of these subsidies in favour of SAF and other sustainable energy sources should be accelerated. It should create a fairer market where the climate impact is reflected in fuel prices. This can be complemented by national or sector-specific economic models and initiatives that internalise the current external costs of fossil fuels.

Another challenge is related to the credibility and regulation of feedstocks such as biomass and used cooking oil (UCO), which constitute the primary source of today's SAF production (HEFA) and limited access to biomass. Several analyses have highlighted the risks of traceability problems and adverse effects in global feedstock flows. Further policy initiatives should support the development of control systems, certification and databases that strengthen transparency and reduce the risk of questionable feedstocks.

To enable investments in eSAF and other technologies with high capital costs, new financial models and partnerships are needed, including public-private partnerships, special contracts and passenger-based payment models ("pax payer model"), where a small transport- or ticket-fee finances the purchase of SAF. Consideration should be given to whether such cost-sharing can help secure a market for development projects and products, with the aim of scaling the technologies and gradually reducing product prices.

These issues show that a sustainable aviation of the future is not only a technological challenge for the industry, but also a political, economic, and governance task. Without strategic political action, the development of sustainable aviation SAF and eSAF risks stagnating due to high costs, insufficient demand and a lack of coherent regulation. A holistic energy policy that includes aviation is therefore crucial to support the sector's transition towards climate neutrality. Some recommendations and considerations are presented below:

## Policy / regulatory recommendations and considerations

| | | |
|---|---|---|
| **Aviation and SAF should be included in the national energy policy** | **Fossil fuel subsidies should be rearranged to SAF and sustainable energies** | **Support efforts that address the UCO topic of fraud and doubt** |
| **Include fuel producers/refinery output in RefuelEU Aviation regulation** | **Evaluating sustainability criteria: Consider using Attributional and Consequential LCA's** | **Classify the different SAF methods and productions when accounting greenhouse gas reduction** |
| **Pax payer model to finance premium price for SAF products and SAF developments** | **Financial models and collaboration to unlock development, investment and manufacturing of eSAF** | Consider domestic carbon price or cap-and-trade mechanism to price in the costs of GHGs from fossil fuels |

**Recommendation**

Aviation and SAF should be included in the national energy policy

Key Arguments:

- **Climate impact:** Long-term sustainable solutions require increasing access to electrical power
- **EU obligations**: SAF mandates under ReFuelEU Aviation and REDIII require national support and implementation
- **Energy security**: Domestic SAF production reduces reliance on fossil imports and enhances energy independence
- **Economic opportunity**: SAF development promotes innovation, job creation, and regional industry growth
- **Infrastructure synergies**: SAF developments enabling smoother integration into current fuel- and energy networks
- **Compliance & reporting**: National policy support streamlines tracking, certification, and ETS alignment via the Union Database (UDB)

**Recommendation**

Fossil fuel subsidies should be rearranged to SAF and sustainable energies

**Key Arguments:**

- **Climate:** Redirecting subsidies supports decarbonization goals and helps meet Paris Agreement targets
- **Cost-effective transition**: Can accelerate the scale-up of SAF and renewables, making them more competitive
- **Market correction:** Ending fossil fuel subsidies removes artificial cost advantages and levels the playing field for clean energy
- **Energy security**: Investment in SAF and renewables reduces dependency on volatile fossil fuel markets
- **Economic opportunity**: Shifting support to clean technologies stimulates green jobs, innovation, and new industries
- **Public health**: Reducing fossil fuel use cuts air pollution and related health costs
- **Fossil fuel subsidies:** In 2022 USD 7 trillion, equal to 7.1% of world GDP- USD 13 million per minute. Europe: Aprox 100 billion EUR

**Recommendation**

Support efforts that address the UCO topic of fraud and doubt

**Key Points:**

- **Preventing fraud**: Enhanced traceability systems are essential to combat fraudulent UCO declarations and double-counting
- **Ensuring sustainability:** Only genuinely waste-based UCO should be eligible for incentives—unsustainable practices must be filtered out
- **Protecting market integrity**: Fraud undermines investor and public trust in biofuels; robust controls protect the reputation of sustainable fuels
- **Fair competition**: Preventing market manipulation ensures a level playing field for legitimate UCO collectors and SAF producers
- **Supporting innovation**: Reliable UCO data enables effective policy design and stimulates investment in advanced waste-to-fuel technologies
- **Enhancing oversight**: Cooperation across borders, harmonized standards, and EU-level databases (e.g., UDB) aUCO origin and qualityre key to tracking

**Recommendation**

Include fuel producers in regulating fuel supplies to the market. Prioritize SAF in refinery output

**Key Arguments:**

- **Upstream influence**: Fuel producers control refinery outputs—regulating them ensures SAF gets prioritized at the source
- **Systemic impact:** Changes at the production level cascade through the supply chain, maximizing SAF market integration
- **Capacity planning**: Including producers enables strategic investments in SAF-compatible infrastructure and technology
- **Market signal alignment**: Regulation encourages fuel producers to shift away from fossil fuels and invest in low-carbon alternatives
- **Accountability & transparency**: Tracking SAF production from the refinery supports better compliance, traceability, and fraud prevention
- **Faster transition**: Engaging producers accelerates the phase-out of fossil-based fuels and drives a unified clean fuel strategy

**Recommendation**

Evaluating sustainability criteria: Consider using attributional and consequential LCA's

**Key Arguments:**

- **Holistic understanding:** Attributional LCA captures direct emissions and resource use; Consequential LCA shows broader system impacts, such as market shifts and indirect land use change
- **Policy effectiveness:** Consequential LCA helps policymakers anticipate real-world effects of biofuel deployment, enabling smarter, impact-based regulation
- **Environmental integrity:** Combining both LCAs ensures that claimed GHG savings are not offset by hidden or indirect emissions elsewhere in the economy
- **Avoids greenwashing:** A dual LCA approach prevents misleading sustainability claims by capturing rebound effects and displacement impacts
- **Supports long-term planning:** Consequential LCA is essential for assessing future scalability and sustainability of SAF and other renewable fuels in dynamic markets

**Recommendation**

Classify the different SAF methods and productions in terms of greenhouse gas reduction

**Key Arguments:**

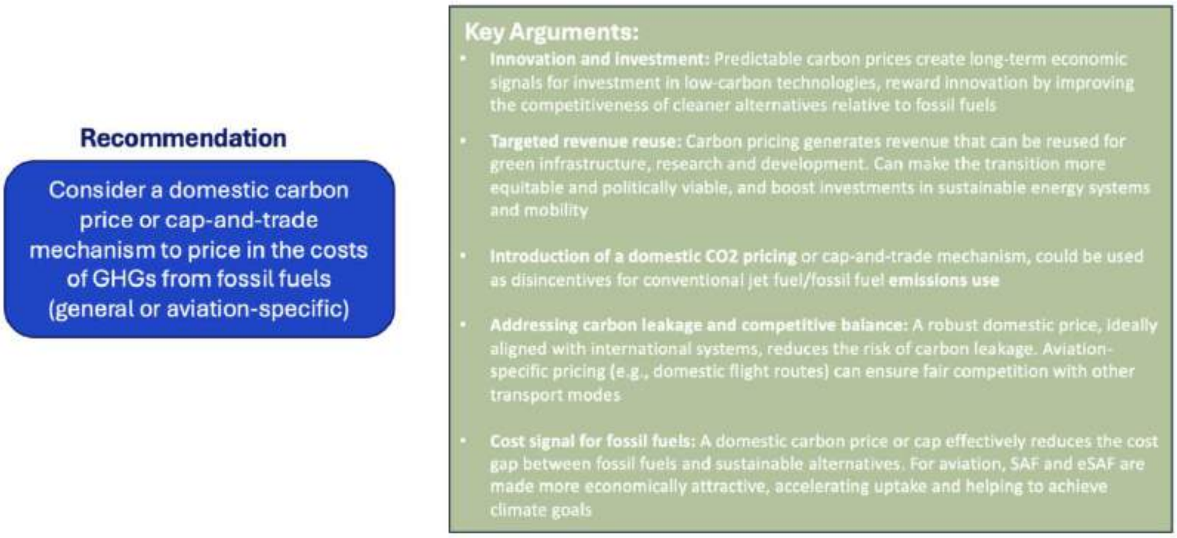
- **Ensure climate impact transparency**
  Not all SAF pathways offer the same GHG savings. Classification highlights which methods provide the highest environmental benefit
- **Optimize policy incentives**
  Accurate GHG classification enables governments to design incentive schemes that prioritize the most climate-effective fuels
- **Guide investment decisions**
  Investors and producers need clarity on which technologies align best with climate goals and market demands
- **Prevent greenwashing**
  Standardized classification avoids inflated sustainability claims by ensuring only verified reductions are credited
- **Support EU and global climate targets**
  Classifying GHG performance supports effective implementation of REDIII, RFEUA, and the Paris Agreement

**Recommendation**

Pax payer model to co-finance premium price, SAF products and SAF developments

**Key Arguments:**

- **Polluter pays principle**
  Aligns with environmental justice by ensuring those generating emissions (passengers) contribute to the solution - paid funds back for sustainable aviation purposes. Ex: Develop an EU pax payer model for eSAF production, inspired by the Danish pax payer model
- **Market stability for SAF**
  Creates a predictable revenue stream to de-risk investments in SAF infrastructure and innovation
- **Fair cost distribution**
  Spreads the cost of decarbonization broadly across many/all passengers, minimizing financial burden per company
- **Accelerates innovation and scale**
  Supports early-stage SAF technologies by bridging the price gap between conventional jet fuel and future SAF products
- **Increases public awareness**
  Embeds sustainability into travel/freight decisions, raising awareness and consumer support for a more sustainable aviation
- **Enables transparent climate action**
  Earmarked contributions provide visibility and accountability for climate finance in aviation


SAF and energy supplies to airports are facing major changes in the medium and long term. What can and should airports consider regarding changing, and what specific initiatives can come into play? Based on the tasks in the Grant Agreement and the experiences in the project, we have finally prioritized some topics for consideration and thus as inspiration for aviation players and for regulators and politicians who must help ensure an optimal infrastructure that matches needs and development as described in Chapter 7, "Airports on the way to 2050 - Fuel, energy, and mobility", and is also aligned with not least the political recommendations and considerations that are included in the presentation just above.

On the following pages there are a set of recommendations and considerations at airport and operational level.

## Operational recommendations & considerations

How airports can push SAF use

Airport supporting aviation in energy policy

Airport Route toward 2050 - Key capabilities

Airport support to carbon removal solutions
-as an infrastructural hub
-as actors with own (or shared) climate goals

Segregated delivery
-relevant? huge challenge
-100% SATF drop-in approval.
New options?

SAF data for airports

### Airport engagements

Airports' access to SAF data

**Airports access to SAF data for scope 3 reporting**

| Indicate yes/no if SAF data is accessible and if standardized | Airport | Data supplier | Authority | Data agreed yes/no |
|---|---|---|---|---|
| Agreement with fuel supplier whether CO2e/GHG data is available? | | | | |
| Agree on how the relevant data will be retrieved/delivered | | | | |
| Agreement with operating airlines on whether CO2e/GHG data is available? | | | | |
| Agree on how the relevant data will be retrieved/delivered | | | | |
| Agreement with respective national authorities on whether and how CO2e/GHG data is available? | | | | |
| Agreement with Union Database whether and how CO2e/GHG data is available? | | | | |
| Agreement with EASA on whether, and how, CO2e/GHG data is available? | | | | |
| Access to relevant data for use in scope 3 reporting has been agreed - and data access described. | | | | |

***Notice:*** *While this is being reported, it is not known whether and how airports gain access to data in a qualified manner that can contribute to effective scope 3 reporting, but it is recommended that this be clarified between relevant actors in the indicated SAF value chain.*

| What role can airports play in the development and use of SAF | | | |
|---|---|---|---|
| **Indicate yes/no if it is up to the airport to decide** | **Direct** | **Indirect** | **Airport decision: Yes/No** |
| Purchase SAF for the airport's own flights or shipments | x | | |
| Purchase SAF for the airport's users against full or partial payment | x | x | |
| Price agreement with producers/supplier or bulk purchase agreements on behalf of airlines/customers (SAF Pool) | | x | |
| Investment in own tanks to purchase and store SAF | x | | |
| Financial support for airlines and customers' purchases of SAF | | | |
| Increase in Pax or take-off fees to pay SAF premium price | x | | |
| Establish airport incentive schemes to co-finance SAF premium prices | x | | |
| Establish airport incentive schemes toco-finance SAF premium prices | | x | |
| Establish partnerships to scale up the SAF-marked | | x | |
| Can the airport, possibly through partnership, establish a SAF and energy supply chain? | x | x | |

**Considerations regarding Airport' SAF storage tank**

- SAF and/or low aromatic fuel on selected long-haul routes contributes significantly more to GHG emission reductions due to less Non$CO_2$ emissions and air quality on ground
- Supplies with trucks are a capacity challenge, and costly in terms of manpower, equipment, time, and congestion
- CO2 and NonCO2 Climate Credits may in the future become attractive to the extent that it can justify the investments in updated infrastructure with separate SAF refuelling options
- What could be the best location for a SAF tank upstream of the airport?
- Airside, landside. What's possible/not possible to achieve? If there are restrictions, could they be reassessed?
- If a concept is developed to place SAF in separate tanks in the aircraft, for use during non-CO2-critical routes, it could increase interest in the option of segregated refuelling. What options?

| SAF and aviation in national energy policy | | | | | |
|---|---|---|---|---|---|
| **The energy policy** | **Airport** | **Airline** | **Aviation organization/other** | **Energy/fuel Supplier/producer** | **Authority** |
| a. **Integrated**<br>b. **Partial**<br>c. **Not** | | | | | |
| **Need change?** | | | | | |
| **What topics are proposed to be integrated** | | | | | |
| **How can I/we take initiative?** | | | | | |
| **Energy policy coordination?** | | | | | |
| **Stimulate development /invest through policy** | | | | | |
| **Stimulate production through policy** | | | | | |

**Airport engagements**

Active role in development and implementation of carbon removal solutions, both as infrastructural hubs and as actors with own (or shared) climate goals

**Facilitator and host of technological $CO_2$ removal**

- Airports often have access to large areas and infrastructures that can be explored for the location of carbon removal technologies; PPP etc
- PtX plants in combination with DAC, where CDR is used as a feedstock for eSAF
- Heat and power integration: Airports with district heating or surplus energy, e.g. from solar cells or biogas plants) can provide the necessary energy sources for CDR

**Partner in eSAF production and CDR certification**

- Help to promote carbon capture - partnerships with producers/suppliers of SAF and carbon removal
- Document $CO_2$ reductions and obtain certified carbon removal credits

**Climate compensation and own emission reduction**

- Own use of carbon removals can be part of the airport's net zero strategy
- Possible to invest in
- Certified carbon removal projects

**Catalyst and showcase for innovation**

**Düsseldorf and Dublin airports**

**Political and regulatory bridge-builder**

### Considering DAC Facility Placement- Decision Matrix

| Criterion | Near runway | Elsewhere at airport |
|---|---|---|
| $CO_2$ concentration (efficiency) | Marginal gain (450–500 ppm) | Normal background (420 ppm) |
| Symbolic value / branding | Very high – strong visibility | Moderate – less visible |
| Logistical integration | Short chain, but complex area | Good integration with energy zones |
| Safety and regulatory conditions | Highly challenging, ATEX, safety | Restrictions, but far fewer |
| Air quality / operations | Issue: $NO_x$ and particulates (UFP) | Cleaner air, lower operating costs |
| Renewable energy availability | Topic: Sufficient renewable energy | Easier access to renewable energy |
| Space and scalability | Limited: Space, noise, regulation | Ample space, higher scalability |
| Involvements PP + local community | | |

### SAF and energy supply to airports - Horizon 2026 to 2050

**2026–2030 Short-term**

- Establish SAF blending & storage facilities
- Expand fuel farm capacity (alternative?)
- Dedicated SAF pipelines (or?)
- Engage with local/regional producers and suppliers
- National incentives or rules for SAF uptake, electrification etc.
- Carbon/UFP removal initiatives
- SAF/new energies WG's: Experts, producers, suppliers, aviation actors
- Airport enabler for supply of SAF/energy

**2030–2040 Medium-term Airport duties:**

- Strengthen regional SAF/eSAF production + invest- agreements
- Intermodal hubs (road, rail, sea, air)
- Future aircraft stands developed
- Long-term supply agreements (airlines, others, own)
- Promote auction-based supply models
- New energy incentives implemented
- Regional collaboration on harmonised supply-corridors

**2040–2050 Long-term**

- Fully integrated energy hub SAF, H2, electricity
- Multifaceted infrastructure
- Dedicated pipelines & large storage facilities
- RE supply secured
- R&D hub for advanced and combined propellants
- Long-term policy & investment frameworks
- Geospatial & scenario planning tools, digitalization, etc.

# 9 Appendix

## 9.1 Appendix 1 - Best practice framework: Guidance on Sustainability

### Criteria and Best Practice Framework for SAF Deliverables – main points

### 1. Introduction

The integration of sustainability criteria and best practices into Sustainable Aviation Fuel (SAF) deliverables ensures environmental, social, and economic benefits while minimising negative impacts. This guidance outlines the essential criteria, principles, and practices that must be incorporated to ensure SAF meets its intended sustainability objectives.

**Key sustainability criteria:**
The following overarching sustainability criteria should guide SAF deliverables:

**A. Environmental impact**
**GHG emissions reduction:** According to RefuelEU Aviation and REDII/III, SAF must demonstrate at least a 60-70% reduction in lifecycle greenhouse gas emissions compared to conventional jet fuels.

**Feedstock sustainability:** Use of feedstocks must avoid deforestation, land-use changes, and biodiversity loss. Preference should be given to waste-derived and non-food competing feedstocks.

**Water use and quality:** SAF production processes must minimise water consumption and prevent contamination of water bodies.

**Soil health:** Promote practices that preserve soil quality and prevent erosion.

**B. Social responsibility**
**Labour rights:** Uphold fair labour practices, including the prohibition of forced and child labour.

**Community well-being:** Ensure that SAF projects benefit local communities, with no displacement of indigenous peoples or adverse impacts on livelihoods.

**Food security:** SAF feedstock production must not compromise food availability or affordability.

**C. Economic viability**
**Cost-effectiveness:** SAF production should aim for cost parity with conventional fuels without sacrificing sustainability.

**Market scalability:** Ensure production pathways can scale to meet growing demand while maintaining sustainability standards.

## 2. Best practice framework

To operationalise sustainability, the following best practices should be adopted:

### A. Certification and standards compliance

Align with established certification systems such as the Roundtable on Sustainable Biomaterials (RSB) or the International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Implement rigorous third-party audits to validate compliance with sustainability standards.

### B. Lifecycle Assessment (LCA)

Conduct a comprehensive LCA to assess the environmental impact of SAF production, from feedstock cultivation to end-use combustion.

Use standardised LCA methodologies to ensure consistency and comparability.

### C. Stakeholder engagement

Engage stakeholders, including local communities, regulators, and industry partners, to foster transparency and inclusivity.

Establish grievance mechanisms to address community concerns and conflicts.

### D. Innovation and continuous improvement

Invest in research and development to improve SAF technologies and reduce environmental impacts.

Regularly review and update sustainability practices to reflect technological, environmental and economic advancements

## 3. Implementation rules and monitoring

### A. mandatory reporting

SAF producers must submit periodic sustainability reports that detail compliance with the criteria and performance metrics.

Reports should include GHG reductions, resource usage, and social impact assessments.

### B. performance benchmarks

Establish quantitative and qualitative benchmarks for environmental, social, and economic performance.

Ensure these benchmarks are ambitious yet achievable, with penalties for non-compliance.

### C. independent verification

Accredited third-party verifiers to audit SAF deliverables and ensure adherence to sustainability criteria.

### D. Conclusion

Implementing this sustainability framework can help integrate Sustainable Aviation Fuel (SAF) as a key component of the aviation sector's transition towards greater sustainability. The guidelines support objectives within climate, ecosystem protection, and equitable economic development.

## 5. Summary of GHG reduction potentials by pathway:

| SAF Pathway | Feedstocks | GHG Reduction Potential |
|---|---|---|
| HEFA | Used cooking oil, fats | 50-80% |
| ATJ | Corn, sugarcane, residues | 40-70% |
| FT | Waste, biomass | 70-90% |
| Pyrolysis | Agricultural/forestry residues | 65-85% |
| PtL | Renewable electricity, $CO_2$ | 90-100% |

*Figure 62 GHG reduction potentials by pathway*

*Results from various sources are summarised in the table, NISA 2023/24. It isn't easy to calculate a true GHG reduction from the SAF feedstock and the manufacturing chain. It is also a question of selecting the right parameters and defining the scope's boundaries. Many factors come into play, including feedstocks, technologies, energy sources, pathways, and transport, which are used along the way and affect the result. If the consequence of prioritising one use over another is also considered, and if a feedstock is in such high demand that it leads to predatory exploitation, there is a risk, according to several researchers, that it may do more harm than good. This is particularly evident regarding biomass from nature-sensitive areas: if the use, especially increased use, of biomass comes from places where food could be grown or from regions with vulnerable nature, such as rainforests. See section 3.7.1 on LCA. Most recently, the English consulting firm Cerulogy calculated that, when all impacts are included, biofuels emit 16% more $CO_2$ on average today than fossil fuels, because palm- and soy-based fuels are included to a large extent (globally, they constitute by far the largest share, according to analyses) [200]. The extent to which RefuelEU Aviation's stricter provisions on not using palm oil and food make the situation much better should be analysed, with direct and indirect effects included, using both an attributional and a consequential calculation method.*

[200] T&E International biofuels briefing, October 2025

## 9.2 Appendix 2 - Best practice SAF Status 2025 EU offtake agreements

The European aviation sector is among the global leaders in the use of Sustainable Aviation Fuel (SAF), but significant challenges remain to meet the EU's ambitious targets. In particular, the ReFuelEU Aviation Directive's requirements for sustainable raw materials are higher than those in other regions, which may result in continued reliance on imports.

Let's take a look at the development of SAF in Europe, including regulatory influence, economic drivers, supply capacity challenges, and feedstock and trade dynamics.

**Europe's aviation market and fuel consumption**

Europe is the world's second-largest aviation market after Asia-Pacific, accounting for 27% of global air traffic in 2023. This equated to approximately 65 million tonnes of jet fuel per day, a volume expected to increase as passenger traffic grows.

**Key policies and initiatives**

EU climate and energy policy plays a crucial role in the development of the SAF market. The following initiatives are particularly important:

• The Green Deal and Fit for 55: This policy framework promote sustainable solutions in the transport sector, including aviation.

• The Revised Renewable Energy Directive (RED III): Requires 42.5% of the EU's energy consumption to come from renewable sources by 2030. For the transport sector, a target of at least 14% of energy must come from renewable sources has been set.

• The ReFuelEU Aviation Directive: Imposes a minimum SAF blending requirement on airlines of 6% in 2030, increasing to 70% in 2050. The directive prohibits the use of food and feed crops as raw materials. The mandate thus includes the target of 1.2% of the SAF share in 2030 to be synthetic SAF, increasing to 35% in 2050.

The UK has set an even more ambitious target of 10% SAF in 2030.

**Rising costs of conventional fuel**

European domestic flights are subject to the EU's Emission Trading Scheme (ETS). As part of the Fit for 55 policy, free $CO_2$ allowances will be gradually phased out towards 2026, resulting in higher costs for the aviation industry.

• 2024: 75% reduction in free allowances

• 2025: 50% reduction

• 2026: Full implementation of the ETS

SAF is an attractive option for airlines as the use of this fuel reduces the need for $CO_2$ allowances

**SAF production capacity and security of supply**

According to IATA data, Europe is expected to achieve an average SAF blend rate of 0.6% in 2024, well below the 2025 requirement of 2%. Some forecasts indicate airlines may reach only 1.25% on average, which could result in fines for fuel suppliers or increased purchases of SAF certificates. The majority of forecasts indicate that it will be possible to reach the 2% in 2025

**Offtake agreements as a strategic solution**

To secure supply, several European airlines have entered into long-term offtake agreements with SAF producers:

• Air France-KLM & Neste (until 2030)

• Air France-KLM & TotalEnergies (until 2035)

• DHL & Lufthansa (ongoing)

• IAG (British Airways, Iberia, Vueling, Aer Lingus, Level and IAG Cargo), which has secured the largest synthetic SAF agreement to date (2024-2039)

Despite these agreements, there is uncertainty about the total volume, which could lead to continued dependence on the spot market, especially for products imported from Asia.

**Production capacity and import dependency**

If all planned production plants are realised, Europe's capacity will be sufficient to meet the 2030 target, according to SkyNRG. However, experience has shown that projects are often delayed, making it challenging to achieve short-term goals. Not least, we have yet to see the construction of the first eSAF plant that can produce the required synthetic fuels

Examples of recent delays:

**Rotterdam:** Construction of a large SAF plant was temporarily paused.

**BP:** Has reduced its planned SAF production in Rotterdam due to lower market prices.

**Shell:** has withdrawn from its planned SAF and renewable diesel project in Rotterdam, due to market dynamics and the cost of completion, September 2025

**Import dependence and global trade flows**

Europe will not be able to cover its SAF demand solely with domestic production and will, for several years, rely on imports from North America and primarily Asia. In recent years, the US and China have significantly expanded their SAF production, which could lead to a larger supply for the European market.

**Limited availability of raw materials**

Feedstocks and trade dynamics are challenged. The availability of agricultural and waste-based raw materials in Europe is limited compared to the expected demand. In addition, the EU's sustainability criteria are stricter than those in other parts of the world, reducing the number of approved feedstocks.

Used cooking oil (UCO) and animal fat: Well-organised supply chains, but the limited volumes may eventually shift from road transport to aviation.

Crop and forestry residues: Have potential but require the development of new supply chains.

**Trade development and market outlook**
Trade flows for SAF feedstocks have been volatile. For example, EU imports of used cooking oil fell by 30% in 2023, mainly due to concerns about the authenticity and sustainability of imports from China. However, data from the first half of 2024 show that imports are increasing again, supporting a strong business case for UCO-based SAF, particularly from China.

**Conclusion**
Europe is a global leader in implementing SAF but faces significant challenges in meeting upcoming regulatory requirements. Ensuring a sustainable supply chain requires increased investment in production, feedstock supply and governance. With increased demand for the criticised and challenged biomass-based SAF products, eSAF projects that offer significant carbon access and large amounts of renewable energy should be given serious priority. Continued reliance on imports is likely, making it necessary to strengthen cooperation with international producers and to ensure stable, controlled global trade in sustainable fuels.

## 9.3 Appendix 3 – Biomethane for eSAF production

Bio-methane and e-methane as a basis for future SAF: Biomethane can also serve as a feedstock for SAF production. As an alternative to the current eSAF production based on $CO_2$ and green hydrogen ($H_2$), a methane-based approach is used, with e-methane (synthetic methane) or bio-methane as the feedstock. Proposals for this have been prepared and can be read in more detail in the appendix.[201]

The discussion about bio-SAF requires a nuanced perspective, as it can be produced via very different technologies and raw materials with distinct climate footprints. For example, bio-SAF production from biogas can be based on agricultural straw. In contrast to today's bio-SAF from vegetable oils (e.g., rapeseed or used cooking oil), this method is based on residual products, as straw is typically ploughed into the soil in Denmark and most of Europe. When straw is used for biogas instead, methane emissions from agriculture are reduced and fossil gas is replaced, which can result in very low – and in some cases negative – $CO_2$ emissions overall.

[201] Henrik Wenzel, Professor, Department of Green Technology, SDU

Since the European gas grid is interconnected and biomethane is traded via certificates, bio-SAF production in one place in Europe can create incentives for more biogas plants and increased use of straw across national borders. This climate benefit is considered valid as long as straw is available and ploughing is not the current practice.

The methane-based approach also opens the door to electrofuels (e-SAF) produced from e-methane. As an alternative to the current eSAF production based solely on $CO_2$ and green hydrogen ($H_2$), a methane-based approach is used, with e-methane (synthetic methane) or bio-methane as the feedstock. This does not constitute bio-SAF but eSAF, as the methane is produced via Power-to-X (PtX).

1. Production and flexibility: E-methane has already been demonstrated and used on an industrial scale in Denmark (2023). Production can be run flexibly – only when electricity prices are low – and the methane is stored in the gas grid. This enables eSAF production to run continuously, while e-methane is produced discontinuously, reducing electricity costs and avoiding the need for constant hydrogen production or hydrogen infrastructure. Like biogas, e-methane is purchased through certificates, which enables geographically separated production and consumption.

2. Economy and scalability: E-methane is expected to become cheaper than bio-methane in a few years due to learning curves. An eSAF process based on bio-methane can therefore easily switch to e-methane without major technological changes – only by changing the certification basis.

The methane pathway utilises existing gas infrastructure (1,000–2,000 MW capacity) and bypasses the limitations of the electricity grid (≈ 450–500 MW). This allows eSAF plants to be up to ten times larger, significantly reducing CAPEX per ton of SAF produced.

3. Tripple feedstock: (methane + $CO_2$/$H_2$): The current Danish eSAF development (Arcadia in Vordingborg, CIP in Aalborg) is based on RWGS + Fischer-Tropsch (FT) with only $CO_2$ + $H_2$ as input. The methane pathway also produces syngas and can be combined with $CO_2$ and $H_2$.
A dual feedstock model allows using $CO_2$+$H_2$ when electricity prices are low and methane+$CO_2$ when electricity prices are high. The result should be continuous operation of FT plants at a lower cost, without the requirement for constant electrolysis or expensive PPA power. Technologies such as Topsoe eREACT make it possible to reform methane and $CO_2$ directly to syngas with high efficiency.

4. Climate perspective and strategy: In the short term, bio-methane can act as a green carbon source rather than direct $CO_2$ capture, as bio-methane is available via the European gas grid

and is not geographically limited. In the long term, the strategy can automatically switch to e-methane as production scales and prices decline. Such a strategy should be politically supported by a technical and socio-economic analysis comparing single-feedstock ($CO_2$ + $H_2$) with dual-feedstock ($CO_2$ + $H_2$ + methane).

Conclusion: The methane-based eSAF approach offers flexible electricity use, lower production costs, greater scalability, and easy integration via the gas grid, and can serve as a strategic bridge between bio-SAF and future full eSAF production.[202]

## 9.4 Appendix 4 - Best practice: SAF/RFNBO: ALIGHT Bold Vision Workshop

The final part of the second day leveraged the network established through the Sustainable Airports Platform, developed as part of ALIGHT's Task 7.5, to delve into long-term perspectives on Sustainable Aviation Fuels (SAF) and aviation's non-$CO_2$ emissions. Discussions centred on how these emissions could be mitigated and the pivotal role airports can play in this process.

Building on the earlier conclusion that SAF will be a key driver in aviation's transition towards net-zero emissions, SkyNRG presented a long-term outlook on SAF market development, focusing on required production capacities and anticipated price trends. The presentation underscored the need for diversifying pathways and for efficient, flexible use of feedstocks to meet long-term targets.

It was emphasised that the development of e-SAF production pathways will require significant policy support. To scale up production, the SAF market will need investments, innovation, and collaboration among key stakeholders.

The topic of e-SAF was further explored in a subsequent presentation, which stressed the urgency of ramping up e-fuel production, particularly for hard-to-decarbonise sectors such as aviation and maritime transport. Achieving this goal will require internationally aligned, comprehensive sustainability criteria, regulatory clarity, and financial frameworks to provide the security needed for massive investments.

Conclusion and future perspectives. The cost of electricity is the primary determinant of the price competitiveness of eSAF with fossil-based jet fuel. Storing electricity in the form of fuels requires significant reductions in electricity prices to make these pathways competitive with fossil alternatives or increases in fossil fuel prices. The analysis indicates that e-SAF produced from electricity sourced from dedicated offshore wind plants (LCOE of 30 €/MWh) can become

[202] This This section on the possibilities of biomethane is based on research by Henrik Wenzel, Professor, University of Southern Denmark, Department of Green Technology, SDU, who suggests the proposal taken up by decision makers.

cost-competitive with their fossil counterparts. The choice of $CO_2$ source greatly influences the energy efficiency and resource consumption of the e-SAF pathways, but it also highlights potential issues with $CO_2$ and future biomass availability for jet fuel production. It is worth noting that biomass consumption in the e-SAF pathways is significantly lower than in bio-SAF. The hydrogen share in the production process has a significant impact on the efficiency of the pathways and, here also on the costs. Utilising revenue streams from by-products, i.e., mostly excess heat, can benefit price reduction but is also highly dependent on the possibility of connecting to the district heating network. This influences the infrastructure planning process and the decision on which electrolysis technology is more suitable. However, when using high-temperature electrolysis, the co-location of electrolysis and fuel synthesis is necessary to harvest the improvements in efficiency that can be achieved by the use of heat integration within the process. It should be noted, however, that the high cost of SOECs affects the technology's competitiveness and its role in near-term investments in e-jet production. Due to technological developments, it is expected that the efficiencies of both the FT and methanol-jet routes will be somewhat similar. The flexibility of the methanol route appears to offer additional benefits for the overall implementation. The methanol route applies to the smaller-scale production sites (decentralisation) and could also enable the utilisation of by-products infrastructure, such as for hydrogen or $CO_2$. With methanol as a median product that can be transported but also used directly it offers a more versatile value chain. Even though e-SAF is included in the EU regulation, promoting higher blends of e-SAF could minimise biomass requirements and address sustainability issues associated with bio-SAF pathways.

## 9.5 Appendix 5 – Political SAF focus / ALIGHT perspective

**From demonstration to deployment: Bridging the gaps. 2020–25 SAF deliveries – symbolic volumes - Tomorrow: Massive ramp-up under RefuelEU Aviation. Why this matters politically:**

- Easy Integration: SAF works with existing airport fuel infrastructure, fuel supply chain, etc.
- Critical Roles Emerging: Producers, suppliers, regulators, airports, airlines
- Structural Gaps: Consider segregated storage/delivery models for SAF
- MRV Essentials: Monitoring key variables — amount, price, quality, origin, method, transparency
- Regulatory Uncertainty: ETS, CORSIA, flexibility tools still in flux
- Governance Complexity: Handlers, national authorities, Union Database, legislation
- Missing Links: Disjointed responsibilities, unclear oversight, sustainability verification
- What's at Stake: From small-scale trials to full-scale, climate-critical implementation
- Many moving parts – coordination and clarity urgently needed
- TBD/TBR: To Be Defined / To Be Resolved

**SAF needed!**

## 9.6 Appendix 7 – Overarching checklists for electric and hydrogen aircraft

Checklist over the requirements for an aircraft stand for electric aircraft

#### 9.6.1.1.1 Power infrastructure

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
| Charging | | | | | | | |
| Electrical connections | | | | | | | |
| Power distribution systems | | | | | | | |
| Charging equipment | | | | | | | |
| | | | | | | | |

#### 9.6.1.1.2 The electrical system

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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#### 9.6.1.1.3 Electrical safety

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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9.6.1.1.4 Charging time and turn around

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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9.6.1.1.5 Standards and compatibilities

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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9.6.1.1.6 Integration issues with existing ground services

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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9.6.1.1.7 Battery cooling

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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#### 9.6.1.1.8 Weather conditions

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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#### 9.6.1.1.9 Remote monitoring and control

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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#### 9.6.1.1.10 Prevent redundancy and reliability failures

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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#### 9.6.1.1.11 Taxiing

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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###### 9.6.1.1.12 Sustainability considerations

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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###### 9.6.1.1.13 Scale and future expansion

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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###### 9.6.1.1.14 Safety protocols

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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###### 9.6.1.1.15 Regulatory compliance

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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#### 9.6.1.1.16 Space and layout

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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#### 9.6.1.1.17 Staff training

| Staff training | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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### Checklist over the requirements for an aircraft stand for hydrogen aircraft

#### 9.6.1.1.18 Filling

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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#### 9.6.1.1.19 Compatibility between aircraft design and stand design

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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#### 9.6.1.1.20 Safety procedures

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
|---|---|---|---|---|---|---|---|
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#### 9.6.1.1.21 Quality and purity

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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#### 9.6.1.1.22 Weather conditions

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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#### 9.6.1.1.23 Scalability and future expansion

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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##### 9.6.1.1.24 Rules and regulations

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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##### 9.6.1.1.25 Spacing and layout

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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##### 9.6.1.1.26 Training of staff

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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##### 9.6.1.1.27 Turn around and filling time

| | Responsible | Course of action | Status | Deadline | Address | Approval | Approval criteria |
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