Task 4.2: D4.7 Report on use of synthetic fuels in the transport sector (shipping and aviation) to demonstrate new business models

By

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ABBREVIATIONS & GLOSSARY

ANSPs	Air navigation service providers
ASTM	American Society for Testing and Materials
ATAG	Air Transport Action Group
ATM	Air Traffic Management
ATJ-SPK	Alcohol to Jet Synthetic Paraffinic Kerosene
CH4	Methane
CHJ	Catalytic Hydrothermolysis Jet
CfD	Contracts for Difference
CO2	Carbon dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
C-SAF	Canadian Council for Sustainable Aviation Fuels
ECAC	European Civil Aviation Conference
EU	European Union
EU ETS	European Union’s Emissions Trading System
FID	Final investment decision
FT	Fischer-Tropsch
FT Co	Processing - Fischer-Tropsch biocrude
FT-SPK	Fischer-Tropsch Synthetic Paraffinic Kerosene
GDSs	Global distribution systems
GHG	Greenhouse gas
HEFA	Hydroprocessed Esters and Fatty Acids
HEFA-SPK	Hydroprocessed Esters and Fatty Acids – Synthetic Paraffinic Kerosene
HFS	Hydroprocessed Fermented Sugars
HFS-SIP	Synthetic Iso-Paraffin from Fermented Hydroprocessed Sugar
HTL	Hydrothermal Liquefaction
IATA	The International Air Transport Association
IAG	International Airlines Group
ICAO	International Civil Aviation Organization
IRA	Inflation Reduction Act
IRR	Internal rate of return
LEAP	Low Emission Aviation Program
METI	Ministry of Economy, Trade, and Industry
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MoU	Memorandum of Understanding
MSW	Municipal Solid Waste
Mt	Megatons
NEDO	New Energy and Industrial Technology Development Organization
NRC	National Research Council
NZIA	Net Zero Industrial Act
OEMs	Engine original equipment manufacturers
OpEx	Operational expenditure
PtL/E-fuels	Power-to-Liquids
R&D	Research and development
RCFs	Recycled carbon fuels
RED II	Renewable Energy Directive II
RED III	Renewable Energy Directive III
RFNBO	Renewable fuels of non-biological origin
SAF	Sustainable aviation fuels
SBTi	Science-based Targets initiative
SIF	Strategic Innovation Fund
USA	United States of America

1. Introduction

Aviation accounts for 10%[1] of overall transport greenhouse gas emissions, which is approximately 25% of global CO2 emissions. However, aviation is particularly challenging to decarbonize due to its reliance on energy-dense fuels, the cost associated to the decarbonisation of the fleets particularly after Covid-19 and the extensive debt accumulated by commercial airlines. As a result, there is a pressing need to explore sustainable fuel options that can significantly reduce the carbon footprint of these modes of transport.

Synthetic fuels, also known as electrofuels or e-fuels, offer a promising solution. These fuels are produced through the chemical synthesis of hydrogen (obtained from renewable energy sources) and carbon dioxide (captured from the air or industrial processes). The resulting fuels can be used in existing engines and infrastructure, making them a practical alternative to fossil fuels.

This report delves into the good practices of using synthetic fuels in the aviation and shipping sectors. It highlights successful case studies, shares insights from existing literature and stakeholders, and provides comprehensive desk research on potential users. Additionally, the report maps out the potential use of synthetic fuels in Europe and discusses sustainable business models for their implementation, with a focus on Sustainable Aviation Fuels (SAF) and Fischer-Tropsch (FT) synthesis (as part of e-fuels)

In aviation, SAF has the potential to reduce lifecycle carbon emissions by up to 80% compared to conventional jet fuels. These fuels can be blended with existing jet fuel and used in current aircraft without additional modifications, facilitating their adoption. In line with the European Commission´s mandate related to sustainable aviation fuels and its implementation by commercial airlines, there are European key players, that are leading its introduction in their main commercial hubs have, showcasing its feasibility and benefits.

The report aims to provide a comprehensive overview of the current state and future potential of synthetic fuels and SAF in the transport sector, offering valuable insights for stakeholders looking to contribute to a sustainable and low-carbon future.

Increasing global awareness of climate change and the need to reduce carbon emissions in aviation are leading airlines to adopt SAF as a cleaner alternative to traditional jet fuels.

2. The European SAF mandate

According to the Clean Skies for Tomorrow SAF Ambassadors group, “stable policy and supportive regulations will be critical to enable the SAF scale-up required to achieve sectoral decarbonization by 2050.”[2]

At the global level, the ICAO’s Resolution A41-21, called “Consolidated statement of continuing ICAO policies and practices related to environmental protection — Climate change”, together with Resolution A41-20 and Resolution A41-22, constitute the framework of the policy commitment to decarbonise the air transport sector. Several milestones shaping policies and practices for sustainable aviation preceded these statements, such as the 1999 Report on Aviation and the Global Atmosphere published by the Intergovernmental Panel on Climate Change (IPCC), the ICAO Global Framework for Aviation Alternative Fuels established at the first Conference on Aviation and

[1] Aviation’s share of transport sector emissions= Aviation’s global emissions /Transport sector’s global emissions=2.5%/25%=10%
[2] WEF Insight Report, 2021, p. 37

Alternative Fuels (CAAF/1) in November 2009, and the 2050 ICAO Vision for Sustainable Aviation Fuels Declaration approved at CAAF/2 in October 2017.

On these bases, and aligned to the "No Country Left Behind" (NCLB) ICAO initiative launched in 2014, this Organisation has developed a substantial strategy for capacity building and other technical and financial assistance in the preparation and submission of States' action plans for SAF, in particular the ICAO Doc 9988, Guidance on the Development of States' Action Plans on CO2 Emissions Reduction Activities, an interactive web-interface, the ICAO Fuel Savings Estimation Tool (IFSET), the ICAO Environmental Benefits Tool (EBT) and a Marginal Abatement Cost (MAC) curve tool. As of July 2022, 133 Member States representing more than 98% of global international air traffic prepared and submitted action plans to ICAO.[3]

Furthermore, the ICAO's Resolution includes 16 guiding principles for the design and implementation of market-based measures (MBMs) to reduce emissions and possible evolution of Standards and Recommended Practices (SARPs), "taking into account potential implications of such measures for developing as well as developed countries."[4]

The European Union, for its part, whereas all Member States participate in the ICAO commitments, but also the voluntary nature of the States' Action Plans -which involve SAF mandates- has decided to go one step further by adopting a mandatory SAF regulation.

2.1. The ReFuelEU Aviation Regulation: boosting the use of more environmentally friendly fuels in the aviation sector

The "Fit for 55" package is a set of proposals to revise and update EU legislation to slash the EU's greenhouse gas emissions by at least 55% by 2030 in the frame of the Council and the European Parliament climate agreement (European Council, s.f.). Among these proposals, the ReFuelEU Aviation regulation aims to curb the carbon footprint of the aviation sector by promoting the adoption of a European mandate on sustainable fuels as one of the primary measures. The Council adopted ReFuelEU in October 2023 (ref). The regulation is regarded as the most advanced SAF mandate at the global level today.

SAF are indispensable to achieve the decarbonisation of aviation because electric or hydrogen fuel cell technologies are not valid for medium and long-haul flights, and also to replace traditional fossil fuel kerosene for the short- and medium-term during the short- and medium-term that it will still take to deploy these technologies.

The ReFuelEU Aviation regulation will allow for tackling the challenges of limited supply and higher costs of SAF compared to fossil fuels. Under the regulation, fuel suppliers must fulfil minimum requirements, with targets progressively escalating from 2% SAF in 2025, 5% in 2030 and an ambitious 70% by 2050.

Additionally, the regulation encompasses synthetic aviation fuels (e-fuels), delineating specific targets for their integration into the fuel supply chain and ensuring fair competition within the EU air transport market. Furthermore, to minimise fuel tankering practices, airlines are mandated to ensure that the quantity of fuel uplifted at EU airports aligns with the requisite fuel for their flights.

The regulation also imposes reporting duties on both aircraft operators and fuel suppliers, with financial penalties stipulated for non-compliance with the set obligations. These

[3] ICAO, Resolution A41-21, p. 4.
[4] Idem, p. 5

measures underscore a concerted effort to steer the aviation sector towards greater sustainability and environmental responsibility.

2.2. Deploying ReFuelEU

2.2.1. Eligible types of SAF

The ReFuelEU aviation initiative defines the three types of aviation fuels that are eligible under the SAF mandate:

- synthetic aviation fuels.
- aviation biofuels.
- recycled carbon aviation fuels.

The following table summarizes the differences between each aviation fuel:

Table 1: Eligible types of SAF under the ReFuelEU SAF mandate and the synthetic aviation fuel sub-mandate

'SAF' mandate		'Synthetic aviation fuel' sub-mandate	
Synthetic aviation fuel	*See other column.*	**Renewable fuels of non-biological origin (RFNBO)**	Hydrogen or liquid fuel complying with RED II RFNBO criteria (e-fuels), the energy content of which is derived from renewable resources.
Aviation biofuels	Advanced biofuels: biofuels made from feedstocks in RED-II Annex IX-A, such as municipal solid waste, agricultural or forestry residues.	**Synthetic low-carbon aviation fuels**	Hydrogen or fuels made from low-carbon hydrogen, the energy content of which is non-fossil and non-renewable, i.e. nuclear.
	Biofuels made from feedstocks in RED-II Annex IX-B, currently UCO and animal fats.		
	Other RED-II eligible biofuels, with exception of 'food and feed' biofuels, e.g. cat. 3 animal fats.		
Recycled carbon fuels	Fuels of which the energy content is derived from waste **fossil energy**, e.g. steel mill or refinery waste gases. Needs to comply with the RED II GHG methodology for RFNBOs and RCFs.		

Source: Skynrg

ReFuelEU Article 2 defines SAF, including synthetic aviation fuels, aviation biofuels, and recycled carbon aviation fuels, according to the Directive (EU) 2018/2001. ReFuelEU is open to the need to revise the SAF definition, the eligible fuels and the minimum shares of SAF available at Union airports, as well as the possibility to include other energy sources and other types of synthetic fuels defined in Directive (EU) 2018/2001, while taking due account of the principle of technological neutrality.

The Regulation places particular emphasis on synthetic fuels to scale up production to the levels of demand that will presumably be required, as well as for their lower environmental drawbacks than biofuels (e.g., it does not require incremental resource usage such as water or land clearing, and more broadly, do not promote environmental challenges such as deforestation, soil productivity loss or biodiversity loss). This aligns with the exclusion of biofuels from ‘food and feed crops’ (Article 4(5) of the Regulation).

Moreover, the ‘synthetic low-carbon aviation fuels’ category was added during the negotiation process to include fuels made with non-fossil, non-renewable energy (thereby indirectly referring to nuclear power) but pending specifying the GHG methodology for this category of fuels by the forthcoming Gas Directive[5].

2.2.2. Main provisions for fuel suppliers, aircraft operators and national authorities

Under ReFuelEU, aviation fuel suppliers are required to ensure that all fuel provided to aircraft operators at EU airports contains a minimum proportion of Sustainable Aviation Fuel (SAF) starting in 2025. By 2030, this obligation extends to include a minimum share of synthetic fuels as well, with both proportions steadily increasing until 2050. The targets set for suppliers entail incorporating 2% SAF by 2025, escalating to 6% by 2030 and eventually reaching 70% by 2050. Concurrently, from 2030 onwards, 1.2% of fuels must also comprise e-fuels, rising to 35% by 2050.

The table below shows the minimum volume of shares committed by year and type of eligible SAF[6]:

Table 2: Minimum shares of SAF to be delivered to EU airports by fuel suppliers

Year			Volume shares (% of aviation fuel to EU airports)	
			SAF	Synthetic aviation fuel
2025			2%	-
2030	1st Jan 2030 – 31st Dec 2031		6%	Avg 1.2% (min. 0.7%)
	1st Jan 2032 – 31st Dec 2034	1st Jan 2032 – 31st Dec 2033		Avg 2.0% (min 1.2%)
		1st Jan 2034 – 31st Dec 2034		2.0%
2035			20%	5%
2040			34%	10%
2045			42%	15%
2050			70%	35%

[5] SkyNRG. (2023). *Disentangling ReFuelEU*. Retrieved from https://skynrg.com/refueleu-how-it-will-shape-the-saf-market
[6] SkyNRG

Aircraft operators must guarantee that the volume of aviation fuel uplifted at an EU airport annually constitutes at least 90% of the total aviation fuel required, aiming to deter fuel practices which contribute additional emissions due to excess weight.

The range of eligible SAF encompasses certified biofuels, renewable fuels of non-biological origin (including renewable hydrogen), and recycled carbon aviation fuels in compliance with the Renewable Energy Directive (Ref. complete RED) sustainability and emissions-saving criteria, up to a maximum of 70%. Exceptions are made for biofuels sourced from food and feed crops. Additionally, low-carbon aviation fuels (including low-carbon hydrogen) are permissible to meet the prescribed minimum shares as outlined in the respective sections of the regulation.

Provisions are established concerning the competent authorities appointed by member states tasked with enforcing this regulation, along with rules outlining fines.

A Union labelling scheme regarding environmental performance for aircraft operators utilizing SAF is to be implemented. This scheme is intended to aid consumers in making informed decisions and to promote eco-friendly flights.

Data collection and reporting obligations are imposed on both fuel suppliers and aircraft operators, facilitating the monitoring of this regulation's impact on the competitiveness of EU operators and platforms. Any information on the properties of the SAF relevant for reporting purposes by the aircraft operator should be provided free of charge by the Aviation fuel suppliers.

Using a batch of SAF under greenhouse gas schemes such as the EU ETS or CORSIA is promoted to compensate for the price gap of SAF compared to conventional aviation fuel. Aircraft operators can claim a greenhouse gas scheme at their discretion without double claiming the emissions reduction.

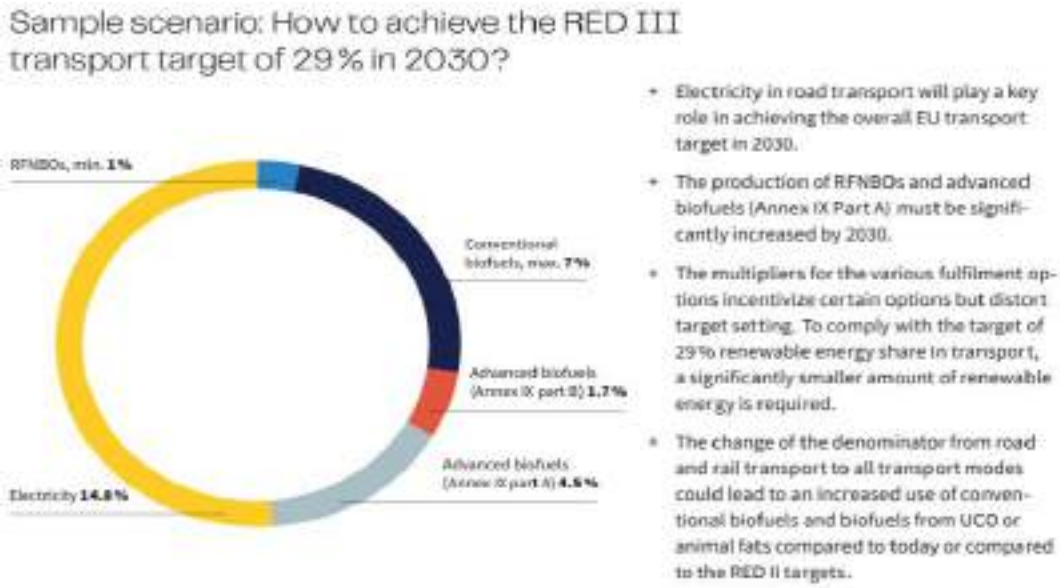
Regarding innovation, ReFuelEU is expected to accelerate SAF technologies and innovation even though the decision over when they become mature and commercially available remains to operators. In this regard, ReFuelEU will increase market certainty and predictability and act as an incentive for the necessary investments. Also, it provides that revenues generated from fines will be used to support research and innovation projects in the field of SAF, as well as the production of SAF or mechanisms allowing the price differences between SAF and conventional aviation fuels to be bridged. These financial support policies will have a value equivalent or higher to the revenues generated from fines.

2.2.3. Additional provisions of the Renewable Energy Directive (RED III)

ReFuelEU fits within the Renewable Energy Directive framework (RED III). Like RED II, RED III allows multipliers for specific fuels and use cases that meet the energy targets, encouraging these options and creating a level playing field with others. However, the RED III target for transport has been ambitiously increased. The revision raises the share of renewable energy in the EU's total energy consumption to 42.5% by 2030, with an additional indicative top-up of 2.5% to reach 45%. According to this, the EU Parliament voted in September 2023 to increase the use of SAF at EU airports, requiring fuel suppliers to incorporate at least 2% SAF starting in 2025. That percentage will increase to 6% by 2030, 20% by 2035, 34% by 2040, 42% by 2045, and 70% by 2050. Nevertheless, this target of 70% in 2050 is below the Destination 2050 roadmap's original target of 83%.

Each EU Member State must contribute to this common goal. However, they have some flexibility in national implementation and can set higher targets for fuel suppliers. The SAF flexibility agreed to by Member States is correlated to CORSIA decisions on eligible aviation fuels. The overall aim is for aviation fuel target options to contribute to reaching the RED III transport targets more easily. The figure below shows how extended eligible SAF will increase the scenario options.

Figure 1: Sample Scenario



Source: (Now-GMBH, 2024)

2.2.4. Regulation for airport infrastructures (SAF mentions)

As the fuel use requirements for sustainable aviation fuels can largely rely on the existing refuelling infrastructure, neither ReFuelEU nor Regulation (EU) 2023/1804 of 13 September 2023 on the deployment of alternative fuels infrastructure, establish specific provisions for SAF, apart from obligations of Union airport managing body to facilitate the access to SAF (ReFuelEU Article 6) and relative to information to be provided in national policy frameworks and national progress reports (R. (EU) 2023/1804 Articles 15 and 17).

2.2.4.1. European Union Aviation Safety Agency (EASA)

EASA provides comprehensive regulatory frameworks and guidelines for the use and distribution of SAF in European airports. Key aspects include:

- Certification and Standardization: EASA ensures that SAF meets strict safety and quality standards before it is used in commercial aviation. The fuel must comply with the ASTM D7566 standard, which covers the certification of synthetic aviation fuels.

- Infrastructure Requirements: Guidelines for storage, handling, and distribution infrastructure at airports to ensure compatibility with existing fuel systems and safety protocols.

- Environmental Impact: Regulations aimed at reducing the carbon footprint of aviation, with SAF as a key component. The European Green Deal and the Fit for 55 packages are part of broader efforts to promote SAF.

2.2.4.2. International Civil Aviation Organization (ICAO)

In 2012, ICAO published the Manual on Civil Aviation Jet Fuel Supply (Doc 9977, AN/489)[7], which summarizes the main recommended practices for safely handling jet fuel along the entire supply chain from the refinery to the aircraft's wing. The manual references guidelines published by other entities such as EI and JIG. This document was created in collaboration with IATA, Airports Council International (ACI), and A4A.

ICAO sets international standards and recommended practices for aviation, including SAF infrastructure:

- CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation): Encourages the use of SAF to reduce carbon emissions. Airports need infrastructure that can support the logistics of SAF production, storage, and refueling.

- SAF Guidelines: Detailed recommendations for the safe handling and integration of SAF into airport operations. This includes blending facilities, dedicated pipelines, and storage tanks.

2.2.4.2.1. IATA (International Air Transport Association)[8]

The International Air Transport Association (IATA) supports the aviation industry's fuel management through two main areas: fuel servicing and fuel efficiency.

Fuel Servicing

- Commercial and Technical Aspects: IATA helps manage the commercial and technical sides of jet fuel, ensuring airlines get a reliable supply of quality fuel at the best prices.

- Operational Needs: Aligns fuel provision agreements with airlines' operational needs and regulatory requirements, promoting member interests in commercial and technical fuel aspects.

Fuel Efficiency

Best Practices: Focuses on operational best practices for fuel management to enhance efficiency and reduce costs.

Monitoring Fuel Costs

Jet Fuel Price Monitor: IATA provides a weekly update on jet fuel prices globally, helping airlines monitor price changes and understand the geopolitical and market dynamics influencing these fluctuations. This is crucial since fuel costs are often the largest component of an airline's operating expenses.

2.3. Implementing the SAF mandate at global level

ReFuelEU provides a stable regulatory framework that ensures fair competition rules during the decarbonisation of the aviation sector process. In this respect, the Member States have some leeway to define their action plans within the ICAO climate change

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[7] Source: ICAO
[8] Developing Sustainable Aviation Fuel (SAF). IATA. https://www.iata.org/en/programs/sustainability/sustainable-aviation-fuels/

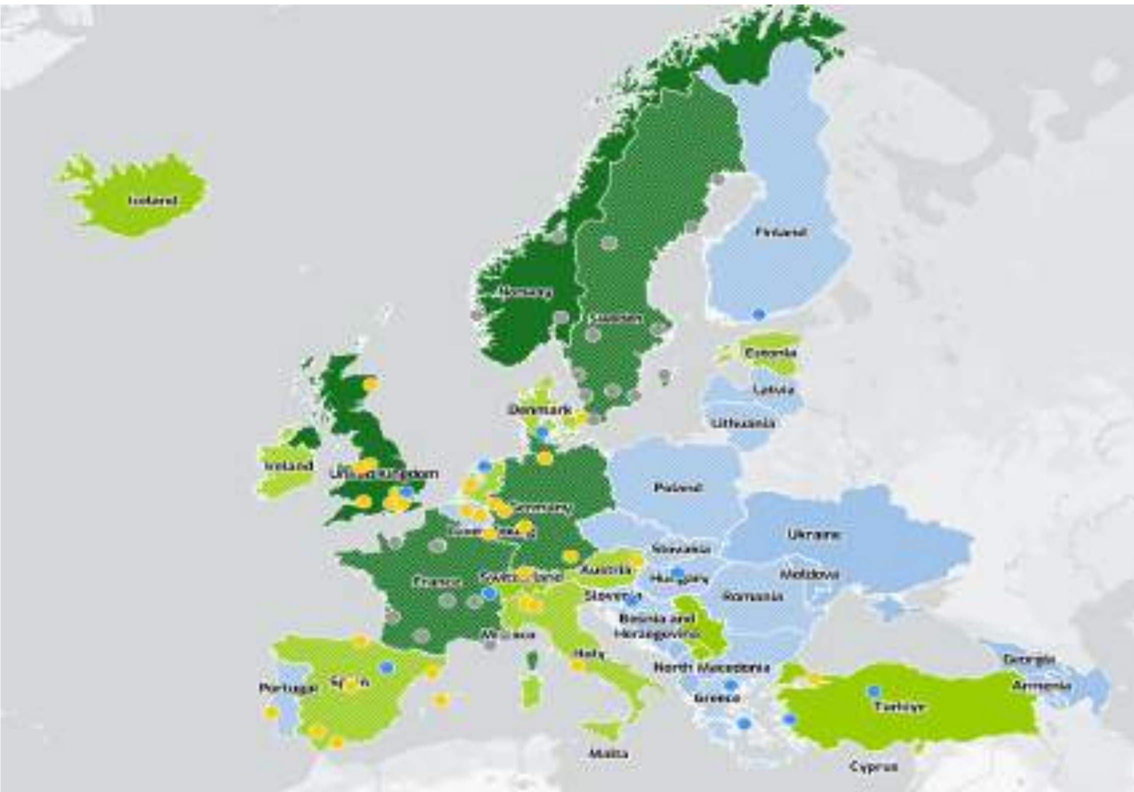
framework. Given possible market fluctuations, a certain flexibility is also allowed for fuel suppliers' obligations.

2.3.1. European Airports Offering Sustainable Aviation Fuels (SAF)

In Europe, a growing number of airports are incorporating Sustainable Aviation Fuels (SAF) into their operations as part of a broader effort to reduce carbon emissions in the aviation industry. It is important to bear in mind that at the end, it will be in most of the cases a decision taken by the commercial airline operating in a particular hub. Therefore, main hubs in Europe in terms of traffic will trigger the development of infrastructures and move forward investments. Companies providing mature technologies capable of producing SAF on time for the airlines to comply with the mandate of the European Commission will be very attractive and demanded.

The figure below showcases various pioneering initiatives related to the use of Sustainable Aviation Fuels (SAF) across Europe. It details the application of EU SAF obligations, the development of national SAF roadmaps by different countries, enacted national SAF measures, airports offering SAF, bases of aircraft operators utilizing SAF, and airports where SAF mandates are in place. This map provides a comprehensive overview of the ongoing efforts to integrate SAF within the European aviation sector.

Figure 2: Current Airport with SAF in Europe [9]



[9] EUROCONTROL. (n.d.) SAF: Safety. Retrieved from https://www.eurocontrol.int/shared/saf/

Source: Eurocontrol

2.4. More advanced SAF national policies and practices in the EU

2.4.1. France

France has been the European country to adopt a national strategy on SAF. At the end of 2019, the French government introduced its "French Roadmap for the Deployment of Sustainable Aeronautical Biofuels." In July 2021, it launched a call for projects to develop a French production sector for sustainable aviation fuel (SAF), aiming to establish a blending mandate of 2% SAF by 2025 and 5% by 2030. Additionally, France has set an annual SAF blending mandate of 1%, starting in 2022. France was also the first European country to upgrade its SAF action plan for ICAO.

In terms of attracting SAF suppliers to the country, the Government has undertaken an ambitious programme wanting to lead the SAF production in Europe. Even the Minister for European Affairs, has himself conducted several meetings with strategic SAF producers evaluating investing in France.

The French Civil Aviation Department has launched several Funding Calls in 2022 related to research and development in the field (increasing the TRL of promising technologies in France). In 2023, the government move forward ambitiously in the field, aiming to support FEED and FID phases in companies with mature technologies. Indeed, there is a clear strategy being successfully implemented at national level involving the full value chain, from SAFsuppliers, to airports, to airlines and blenders.

Air France/KLM is a strong European player with an ambitious strategy and objective which is securing SAF with the best European and international suppliers.

2.4.1.1. The legal framework

France has established the "Energy Transition for Green Growth" law, which includes measures to promote the use of biofuels in aviation.

- **Legislation related to SAF in France:**[10]

France has established the "Energy Transition for Green Growth" law, which includes measures to promote the use of biofuels in aviation.

Some of the legal measures approved by the SAF include:

- Article 266 Quindecies of the Customs code updated by the Finance Bill for 2021 n°2020-1721 dated 29 December 2020.

[10] European Business Aviation Association. (n.d.). How is SAF implemented in the legislation of EU member states.Retrieved from https://www.ebaa.org/industry-updates/how-is-saf-implemented-in-the-legislation-of-eu-member-states/

- The "Taxe Incitative Relative à l'Incorporation de Biocarburant" (TIRIB) is a French tax incentive mechanism aimed at promoting the use of biofuels, including Sustainable Aviation Fuel (SAF), within the transportation sector.

- Blending Targets: The French legislation sets progressive targets for incorporating of SAF into jet fuel. Targets are aligned with EU objectives: **1% SAF by 2022, 2% by 2025, and 5% by 2030.**

- **SAF Mandate in France**

The French government has proposed a biofuel blending mandate that aims to ensure a minimum share of SAF in aviation fuel. According to the proposal, starting from 2024, a 1.5% SAF blending requirement would be implemented, which is expected to increase gradually in the coming years. This mandate reflects France's ambitious goals to decarbonize the aviation sector and mitigate its environmental impact.

France proposes 1.5% SAF mandate from 2024, ups biofuel targets.[11]

France has made significant progress in promoting SAF with its biofuel blending mandate. This proactive approach reflects the country's dedication to reducing greenhouse gas emissions and advancing sustainability in aviation.

2.4.1.2. Programmes supporting SAF development and deployment

The French government supports Air France (AF)`s research and development through initiatives like the "Investissements d'Avenir " program, which funds innovative projects in the energy sector, including SAF.

- **The France 2030 Investment Plan[12]**

The France 2030 plan, launched in October 2021, aims to transform key sectors of the French economy (energy, automotive, aeronautics, digital and space) through sustainable innovation.

In 2023, the French Government relaunched the "Territorial Hydrogen Ecosystems" Call for Projects under the France 2030 Initiative with a significant funding boost of €175 million. This initiative looked at positioning France as a leader in the hydrogen economy. The call focused on three main areas: industrial applications, mobility applications, and extensions of previously funded ecosystems with new mobility applications.

France 2030 builds on the achievements of the Investments for the Future Programmes (Programmes d'investissements d'avenir – PIA). France 2030 mobilises €54 billion to ensure that companies, universities and research organisations fully succeed in their transitions in strategic sectors.

2.4.1.3. Availability of SAF in France

- **Geneva Airport[13]:** Provides SAF.
- **Clermont Ferrand Airport:** Offers SAF refuelling.
- **Le Bourget Airport:** Regularly offers SAF.

[11] QC Intelligence. (2023, June 14). France proposes 1.5% SAF mandate from 2024, ups biofuel targets. Retrieved from https://www.qcintel.com/biofuels/article/france-proposes-1-5-saf-mandate-from-2024-ups-biofuel-targets-8744.html
[12] ADEME. (n.d.). *Our missions: Funding.* Retrieved from https://www.ademe.fr/en/our-missions/funding/
[13] Biofuels International (2024) SAF available at Geneva Airport for business aviation convention. Available at: https://biofuels-news.com/news/saf-available-at-geneva-airport-for-business-aviation-convention/

- **Paris Charles de Gaulle Airport (Paris-CDG):** Hosted the first long-haul flight using SAF produced in France. Main Hub of Air France in the country.
- **Caen Carpiquet Airport:** Offered SAF during the European Business Aviation Convention & Exhibition in 2019.
- **Nice to Paris Air France Flight:** Utilised SAF sourced from used cooking oil.
- **Toulon Airport:** Offers SAF.

The base for aircraft operators using SAF is located in Geneva the implementation of SAF projects in France will be very much associated to where the main blenders are located in the country. SAF Ex-works produced by a SAF supplier has to be blended. There are currently in France few places where the blending is performed by main players in the traditional Oil and Gas sector, such as Total Energies or ExxonMobil.

Regions such as Normandie where Exxon Mobil is blending or Paris Region, where Total Energies has also nearby a facility will be certainly the preferred by investors for setting up their projects- Normandie is also connected to the trappil network which facilitates the transport of sustainable aviation fuel to other regions in the country, such as Paris Region where Charles de Gaulle Airport, one of the most important Hubs for Air France is located.

2.4.1.4. SAF Industrial Projects in France

In December 2017, the French government and leading firms in the aviation industry agreed to develop a new segment to produce biofuel in the aviation value chain.

- **Total Energies**

TotalEnergies is a French multinational energy company that operates in over 130 countries. Founded in 1924 as Compagnie Française des Pétroles (CFP), it has grown into one of the world's largest energy companies. In 2021, the company rebranded as TotalEnergies to reflect its commitment to transitioning towards cleaner energy sources and reducing its carbon footprint.

TotalEnergies is involved in the exploration, production, refining, and marketing of oil and natural gas, as well as in renewable energy sectors such as solar, wind, and biofuels. The company is also investing heavily in electricity and low-carbon energy, with a goal of becoming a major player in the energy transition.

Headquartered in Paris, TotalEnergies employs over 100,000 people worldwide and is listed on the Euronext Paris, New York Stock Exchange, and other major stock exchanges. The company is known for its commitment to innovation and sustainability, aiming to achieve net-zero emissions by 2050.

Total Energies´ portfolio for energy includes a diversified offer of oil, biofuels, natural gas, green gases, renewables, and electricity as an integrated multi-energy model that aims to ensure efficiency, profitability, innovation, and high quality. By covering all value chains from production to distribution, Total Energies is well positioned within the oil and gas industry to meet the challenges of the energy transition and achieve sustainability goals.[14]

[14] **TotalEnergies.** (n.d.). *Our integrated business model.* Retrieved from https://totalenergies.com/company/strength/integrated-business-model

In April 2021, Total Energies (formerly known as TOTAL) began producing SAF in France at its La Mède biorefinery in southern France and its Oudalle facility near Le Havre. Total Energies also announced that it will increase more SAF made from animal fat, used cooking oil and other waste and residue sourced from the circular economy; no vegetable oils will be used.

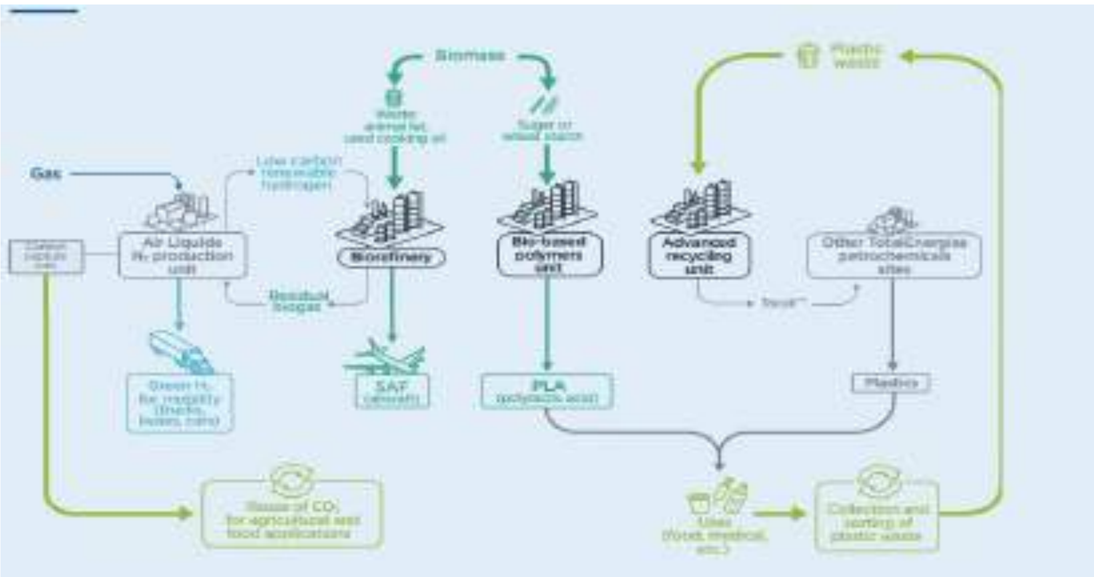
Total Energies plans to produce 1.5 million tons of SAF annually by 2030 at its production facilities in Europe, the United States, Japan, and South Korea. This output is expected to account for 10% of the global market by 2030.

Total Energies is making significant investments and has launched several SAF production projects: [15] consolidating strategic alliances with offtakers, such as Air France/KLM signed in 2023.

- **Biorefinery in Grandpuits:** Total Energies is investing €400 million to transform the site into a zero-crude platform that produces SAF from circular feedstocks like animal fat and used cooking oil. By 2025, Grandpuits is expected to produce 210,000 tons of SAF annually, with an additional 75,000 tons per year anticipated by 2027 through a new investment. The biorefinery processes more than 75% waste and residue for a second life as biofuel – SAF in particular.

  The figure below shows the technology process used in the biorefinery in Grandpuits integrating the SAF production:

  Figure 3: The technology process of the Biorefinery in Grandpuits:



  Source: Total Energies

- **Refinery in Normandy:** At the Gonfreville refinery, Total Energies has begun coprocessing SAF from used cooking oil. The company aims to increase annual production at this site to 40,000 tons by 2025. Additionally, following technical advancements with its aeronautical partners, Total Energies plans to produce another 150,000 tons of SAF per year by coprocessing HVO biodiesel produced at La Mède, pending ASTM* approval of this method.

[15] **TotalEnergies.** (2023, June 19). *Paris Air Show: TotalEnergies committed to the production of sustainable aviation fuel.* Retrieved from https://totalenergies.com/media/news/press-releases/paris-air-show-totalenergies-committed-production-sustainable-aviation

- **Biorefinery in Mède:** With an investment of €340 million, Total Energies has converted its refinery into a biorefinery. Biodiesel produced at La Mède is already used to create SAF at the Total Energies Oudalle plant near Le Havre. The company is also exploring a new investment to enable the processing of 100% waste from the circular economy (used cooking oil and animal fat) by 2024 to produce biofuels and SAF through coprocessing.

- **Other international blending projects developed in France**

Kuwait Petroleum International (KPI), through its branding Q8Aviation, has completed its first sustainable aviation fuel (SAF) blending process at a biorefinery located in Le Havre. This milestone marks a significant advancement in KPI's efforts to secure and market SAF for the aviation sector.[16]

The biorefinery in Le Havre facilitates a strategic location to supply SAF to major airports in France, including Charles de Gaulle Airport and Orly Airport, enhancing the availability of sustainable fuel in the aviation market.

The blending process adheres to the voluntary sustainability criteria set by the EU ISCC (International Sustainability and Carbon Certification) standards, with full accreditation by the European Commission.

KPI's initiative aligns with the broader goal of helping the aviation sector achieve carbon neutrality by 2050. The company aims to expand SAF blending across major aviation fuel markets worldwide. KPI supplies jet fuel to more than 70 airports globally and operates refineries in Italy, Vietnam, and Oman. This extensive network allows KPI to leverage its expertise in fuel production and distribution to promote the use of SAF on a larger scale.

- **Air France**

Together with KLM Royal Dutch Airlines, Air France operated its first flight from Toulouse to Paris in 2011 in the framework of Paris Air Show-Le Bourget.

From 2014 to 2016, Air France operated 78 flights between Paris, Orly, Toulouse, and Nice, powered by 10% sustainable aviation fuel. This long-term test phase confirmed that these sustainable aviation fuels did not impact aircraft, engines, or ground operations.

In 2017, Air France and the French Commission on Sustainable Development initiated the ECV (Engagement for Green Growth), a public-private partnership Involving Total, Safran, Suez and 3 French Ministries. Until 2021, ECV studied the conditions for the successful emergence of French and European SAF industries. Following the ECV, Air France participated in 6 French sustainable aviation fuel production programmes via a Call for Expression of Interest (CEI). Air France KLM Martinair Cargo launched the first.

After that, Air France adopted a SAF mandate and launched a SAF voluntary financing scheme for its customers in 2022.

2030, Air France aims to incorporate at least 10% SAF on all its flights.

2050, Air France aims to incorporate 63% SAF on all its flights.

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[16] **SAF Investor.** (2023, July 21). *Kuwait Petroleum completes SAF blending at biorefinery in France.* Retrieved from https://www.safinvestor.com/news/143895/kuwait-petroleum-completes-saf-blending-at-biorefinery-in-france/

The Group AF/KLM has launched an initiative called “SAF Connect” aiming to connect the full supply chain in SAF production in France, from the decision makers at the Government, to the Civil Aviation Department, the developers of the infrastructures and indeed its carefully selected SAF suppliers. This is a pioneer initiative that effectively move forward the full value chain supporting Air France´s main objective, securing SAF at competitive price with reliable technologies and suppliers.

2.4.2. Germany

Germany aims to achieve SAF targets in line with the European Commission's objectives. To support this, the government is setting SAF utilization targets and developing strategic proposals involving air transport, SAF producers, industry, research, and politics.

Germany reviews and adapts regulations for using sustainable raw materials in SAF production, integrating local SAF production into the national biomass strategy. This ensures suitable raw materials are used locally to meet SAF quotas (2% by 2025, 6% by 2030, 20% by 2035) and support climate protection goals.

Germany has mandated the use of Power-to-Liquid (PtL) SAF, also known as e-kerosene, starting at 0.5% by 2026. This target will rise to 1% in 2028 and 2% in 2030. These targets may be harmonized with the EU-wide SAF mandate.

Germany plans to introduce a blending quota for synthetic fuels in aviation — a PtL quota — starting at 0.5% in 2026, increasing to 1% in 2028 and reaching 2% by 2030. This quota aims to provide investment security and support the expansion of production.

2.4.2.1. Aviation Initiative for Renewable Energy in Germany - AIREG

AIREG' s target is to make Germany a pioneer for sustainable flying through high SAF usage.

Key initiatives include promoting PtL-SAF within the national hydrogen strategy and supporting all SAF production paths to exceed the EU's minimum SAF quotas. The regulatory framework must regularly review and adapt to promote research projects, industrial SAF pilot plants, and financial incentives to advance PtL-SAF technology and ensure its timely commercial availability.

The strategy paper highlights AIREG's role in rapidly increasing SAF use in Germany, reflecting the strong interest from aviation and related industries. It emphasizes the need for active government support to achieve ambitious sustainable aviation goals and establish Germany as a leading market for SAF.

Table 3: Blending rates from ReFuelEU compared with the aireg SAF usage targets for Germany:

Year	U SAF blending quotas	aireg SAF-Utilization targets (Germany)	EU PtL blending quotas	aireg PtL-utilization targets (Germany)
2025	2 %	2 %	0.5 % (only Germany 2026)	0,5 %
2030	6 %	10 %	1,2 %	3 %
2035	20 %	30 %	5 %	20 %
2050	70 %	100 %	35 %	50 %

Source: aireg

Aireg sees good opportunities for Germany as a high-tech location to become the global technology leader in production of SAF and in particular of PtL-SAF[17].

Objectives for 2026:

- 2% Quota: At least 2% SAF by 2026.
- Bio-SAF Plant: Operation of at least one Bio-SAF facility in Germany.
- PtL Plant: Construction and operation of a PtL Development and Demonstration Facility in Germany (10 – 15 kt per annum).

Figure 4: AIREG Roadmap for the Development and Introduction of Sustainable Aviation Fuels[18]

Source:Aireg

2.4.2.2. Measures established in Germany

Germany provides significant financial support for Power-to-Liquid Sustainable Aviation Fuel (PtL-SAF) beyond EU quotas. Despite high production costs and unproven large-scale maturity, PtL-SAF has great potential to reduce the climate impact of air traffic.

Germany promotes all sustainable SAF production methods, including HEFA, co-processing, PtL, ATJ, and BtL, to meet EU blending quotas and reduce risks during the SAF market ramp-up.

The Role of AIREG in Relation to Key Interest Groups

- **Air Traffic - Promotion of SAF Use**

Aireg is dedicated to advancing SAF use, production, innovation, and supportive policies to foster a sustainable aviation future in Germany and internationally.

[17] In the following, "Power-to-Liquid" SAF (PtL-SAF) refers to renewable fuels of non-biogenic origin (RFNBO) in accordance with EU REDIII. Sustainably produced hydrogen plays a key role here

[18] Aireg Roadmap for the Development and Introduction of Sustainable Aviation Fuels

Aireg promotes the use of Sustainable Aviation Fuels (SAF) at German airports, exceeding EU quotas. It supports long-term contracts between airlines and SAF producers to ensure stable supply and reduce greenhouse gases. Aireg also encourages airlines to invest in SAF producers to boost market ramp-up and advocates for increased public awareness of SAF's environmental benefits. Additionally, Aireg supports the development of international sustainability standards for SAF.

- **Fuel Production - Accelerate Ramp-Up**

Aireg supports the establishment of competitive SAF production in Germany, focusing on Power-to-Liquid SAF (PtL-SAF). It aims to create a PtL-SAF supply chain with a 2-million-ton capacity by 2035, with significant local production. Aireg encourages transforming existing refineries to process renewable raw materials into SAF and promotes various SAF technologies like HEFA-SAF, alcohol-to-jet (AtJ), and methanol-to-jet (MtJ).

- **Research, Development, and Consulting**

Aireg emphasizes research and development to optimize SAF production technology and processes. It supports further optimization of SAF and aircraft engines to reduce costs and environmental impact. Aireg also provides an ecosystem for SAF start-ups, supporting innovation and attracting investment.

- **Policy - Increased Promotion**

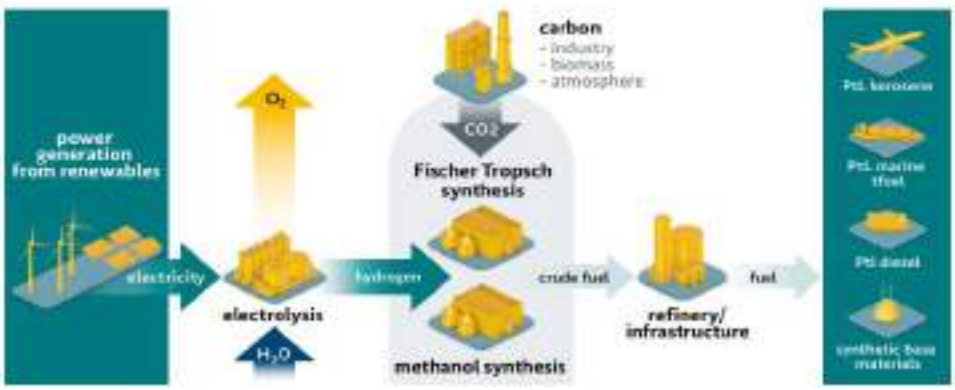
Aireg advocates for strong political support to accelerate SAF ramp-up, especially for PtL-SAF. It calls for measures to mitigate high SAF costs and ensure airline competitiveness. Aireg supports using carbon contracts for difference (CCfD) to attract private investment in SAF projects and promotes removing barriers to SAF technologies. It also seeks favorable conditions for procuring raw materials.

In summary, Aireg is committed to advancing the use, production, and innovation of SAF, along with advocating for supportive policies to ensure a sustainable future for aviation in Germany and internationally.

2.4.2.3. The production pathway in Germany

Currently, there are two methods to produce PtL kerosene: Fischer Tropsch synthesis and alcohol synthesis with the alcohol subsequently converted to kerosene. The processes for alcohol synthesis currently used in Germany are methanol-to-olefins and olefins-to-distillate conversions.

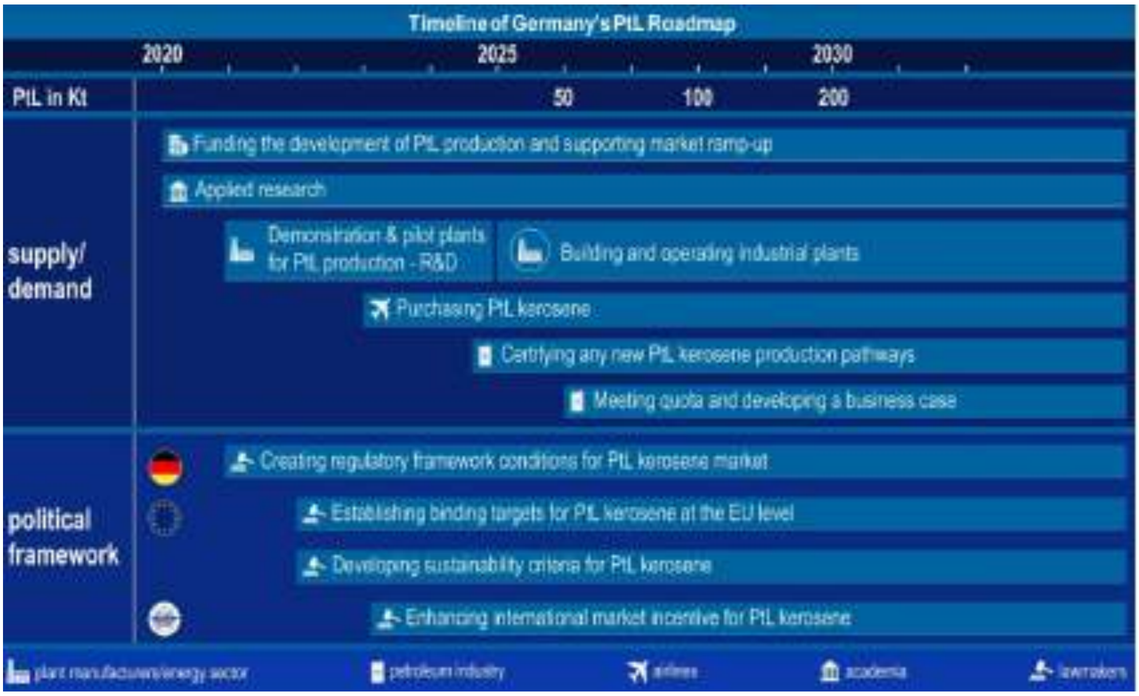
Figure 5: Simplified illustration of PtL production pathways



Source: NOW GmbH

Germany is focussing on PtL fuels as part of its National Hydrogen Strategy with an objective to ramp up production to 200 thousand tonnes by 2030 (2% of German jet fuel sales in 2019).

Figure 6: Timeline of Germany's PtL Roadmap



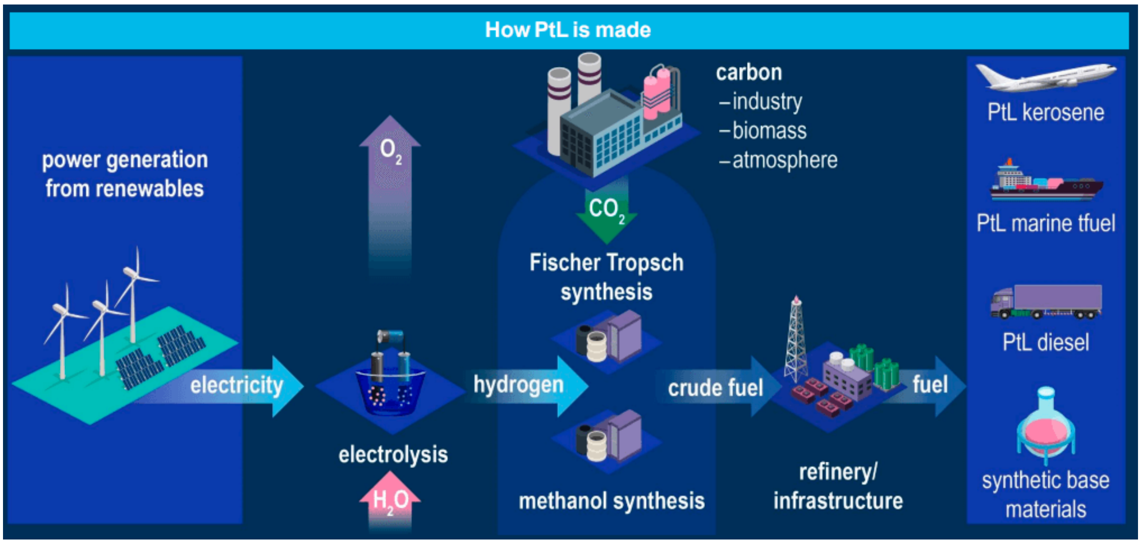
Source: Evalueserve Insights

Germany's Projected PtL Kerosene Market Ramp-Up[19]

- 200,000 tonnes (kilo tonnes, kt) of annual PtL kerosene production for use in German air traffic by 2030, preceded by 100 kt in 2028, and 50 kt in 2026
- 50% is the current feasible blend of synthetic kerosene into conventional jet fuel without any technological upgrades to aircraft
- 30% of the current fuel requirement for domestic German air traffic is equivalent to the targeted PtL production in 2030
- 2% PtL kerosene overall share of the projected kerosene sales in Germany in 2030, is what the target represents
- 14% minimum of the energy consumed in overall transport sector to come from renewable sources by 2030, according to RED II guidelines
- 42% reduction in CO2 emissions by entire transport sector by 2030, is the German Federal Government's aim
- 2 methods to produce PtL fuel considered by the German Federal government are Fischer-Tropsch and alcohol-to-jet fuel (ATJ), are under consideration
- 50% to 70% reduction in in-flight emissions of soot particles from an aircraft engine from using PtL kerosene

Figure 7: Power-to-Liquid Fuels:

[19] **Evalueserve.** (2023, March 10). *How Germany's PtL roadmap for aviation fuel outlines its larger green plans.* Retrieved from https://www.evalueserve.com/blog/how-germanys-ptl-roadmap-for-aviation-fuel-outlines-its-larger-green-plans/



Source: Evalueserve Insights

DHL, for example, plans to use 30% sustainable fuels (SAF) in its air freight business by 2030.

2.4.2.4. SAF Industrial Projects in Germany

- **Lufthansa in Germany**

Lufthansa is an airline headquartered in Germany, with its main hub at Frankfurt Airport, one of the largest and busiest airports in Europe. It serves as Germany's national airline and is part of the Lufthansa Group, which also includes other airlines such as SWISS, Austrian Airlines, and Eurowings.

The Lufthansa Group has actively engaged in various partnerships and initiatives to support the production of Sustainable Aviation Fuel (SAF). The group is involved in several projects aimed at increasing the availability of SAF, including investments in sustainable fuel production facilities.

According to the Lufthansa Group's 2023 sustainability report, the airline has joined the First Movers Coalition of the World Economic Forum. This initiative aims to utilise at least 5% SAF by 2030, with an emissions reduction of at least 85% compared to fossil fuels. These targets represent a level of ambition that exceeds statutory obligations, as the 5% pertains to the total fuel requirements of the Lufthansa Group (not just the fuel taken on board in Europe), while the emissions advantage required for SAF in the EU is 65%.

In February 2023, the Lufthansa Group became the first airline group in the world to offer a separate fare that includes compensation for flight-related carbon emissions. This initiative reduces 20% of carbon emissions by using SAF, while the remaining flight-related carbon emissions are offset through contributions to high-quality climate protection projects.

The use of SAF has enabled the Lufthansa Group to reduce its climate-impacting emissions by a total of 43,628 tonnes in 2023.

- **Lufthansa Group and the Frankfurt Airport SAF Hub**

Lufthansa is one of the five largest SAF buyers worldwide. Lufthansa has been proactive in integrating SAF into its operations. Some of their good practices include:

- **SAF Purchase Agreements**: Lufthansa Group has signed an agreement with hydrocarbons supplier HCS Group to be supplied with sustainable aviation fuel (SAF) produced within Germany. Situated near the airline's Frankfurt hub, the manufacturing site operated by HCS Group's Haltermann Carless brand in Speyer, Germany.

- **Frankfurt Airport Hub**: Lufthansa Group in collaboration with Fraport, has established a SAF hub at Frankfurt Airport. This hub facilitates the regular use of SAF in Lufthansa's flights.

- **Continuo investment in SAF:** The Lufthansa Group is investing up to USD 250 million in the procurement of SAF and actively engaging in projects to increase its market availability. In 2022, they used approximately 13,000 tons of SAF, accounting for about 0.2% of their total fuel demand and 5% of the global SAF supply, demonstrating their commitment to sustainable aviation despite current market limitations.

2.4.3. The Netherlands

In March 2020, the Dutch government announced plans to implement a Sustainable Aviation Fuels (SAF) blending obligation by 2023, pending the absence of a similar European mandate. This initiative stems from a 2019 study that assessed the potential effectiveness of a renewable energy obligation for aviation in the Netherlands20.

According to the Dutch Draft Agreement on Sustainable Aviation, the Netherlands aims for 14% of its aviation fuel to be sustainable by 2030 and 100% by 2050. These targets surpass the European Union's goals of 6% by 2030 and 70% by 2050, reflecting the country's strong commitment to sustainability.

- **Strategic Positioning**

As a major European aviation hub, the Netherlands is well-positioned to advance SAF production, distribution, and innovation[21]. The country benefits from:

- **Robust Chemical Cluster**: Expertise in biorefining enhances its SAF capabilities.

- **Extensive Logistics Infrastructure**: Numerous seaports, including the Port of Rotterdam and the Port of Amsterdam, facilitate the transport of essential feedstocks for SAF production, mitigating investment risks for manufacturers.

- **Efficient Transport**: The CEPS pipeline provides streamlined SAF transport to major European airports.

- **Opportunities for Foreign Investment**

The Netherlands offers significant opportunities for foreign investment in SAF, focusing on unlocking supply rather than demand. Current SAF capacity is fully contracted, indicating a need for companies to diversify into research and development, supply chain

[20] What Makes the Netherlands a Global Frontrunner for Sustainable Aviation Fuels - NFIA (investinholland.com)
[21] Netherlands Foreign Investment Agency (n.d.) What makes the Netherlands a global frontrunner for sustainable aviation fuels. Retrieved from: https://investinholland.com/news/what-makes-the-netherlands-a-global-frontrunner-for-sustainable-aviation-fuels/

coordination, and business growth. The country's synergistic ecosystem supports various SAF-related activities and fosters partnerships.

- **SAF Production and Storage**

Investors can leverage existing bio-refineries or construct new facilities:

- **Shell** is developing a HEFA-based SAF plant in Rotterdam, aimed at supplying Rotterdam the Hague Airport.
- **Neste** is expanding its refinery operations in Rotterdam to increase SAF and renewable diesel output.
- **Zaffra**, a joint venture between **Sasol** and **Topsoe**, is working to introduce SAF in the Netherlands.
- **Gunvor** and **VARO Energy** are collaborating on a large-scale SAF facility in Rotterdam.
- **Koole Terminals** is enhancing distillation capabilities to triple SAF production by 2025, offering toll-distillation services.
- **SkyNRG** is building Europe’s first fully dedicated SAF production facility in Delfzijl and another for synthetic kerosene (eSAF) in the Port of Amsterdam.

- **Research and Development**

The Netherlands excels in SAF research through prominent institutions:

- **Wageningen University & Research** is exploring SAF production from novel feedstocks such as algae and waste wood via its BioJet Fuel project.
- **TNO** is advancing electrification processes in the chemical industry with its VoltaChem program, focusing on eSAF production from CO2 and renewable electricity.
- The **FLITE consortium**, including **SkyNRG** and **LanzaTech**, is developing alcohol-to-jet fuel solutions derived from waste-based ethanol.

Collaboration with Airports: Airports like Schiphol are investing in SAF infrastructure, facilitating easier access for airlines.

- **KLM Royal Dutch Airlines ’s Efforts in Sustainable Aviation. The Group AF/KLM**

In 2011, KLM operated the world’s first commercial flight partially powered by SAF. Since then, KLM has continued to lead in SAF adoption, ensuring that their SAF is produced from raw materials that do not compete with food production or harm biodiversity. KLM’s

SAF meets strict sustainability criteria set by the Roundtable of Sustainable Biomaterials and the International Sustainability & Carbon Certification.[22]

At Amsterdam Airport Schiphol, KLM now adds 1% SAF to the fuel system for every departing flight, with an ambitious target of reaching 10% by 2030. This effort has already seen KLM use one-tenth of the global SAF production in 2022. By collaborating with businesses and encouraging passengers to contribute by adding SAF to their bookings, KLM not only reduces its carbon footprint but also supports the economic development of regions with marginal lands suitable for SAF crop production.

KLM's SAF initiative represents a significant step towards sustainable aviation, showcasing a viable path to reducing carbon emissions in the airline industry while promoting economic and environmental benefits globally.

- **Shell's refinery in The Netherlands**

Shell Nederland Raffinaderij operates the Pernis cracking refinery, situated in South Holland, Netherlands. According to the information reported by GlobalData, which monitors and profiles over 1,400 refineries globally, this facility is an integrated cracking refinery owned by Shell.

In the Netherlands, Shell is currently constructing Holland Hydrogen I with a capacity of 200 megawatts, one of Europe's largest renewable hydrogen plants under construction.

2.4.4. Greece

HELLENiQ ENERGY is committed to sustainability and is exploring further production of SAF as the demand for greener aviation fuel increases. The focus on SAF at the Aspropyrgos refinery aligns with global trends toward reducing carbon emissions in the aviation sector.

The company is operating three refineries located in Aspropyrgos, Elefsina and Thessaloniki.[23] They have a total refining capacity of 344 thousand barrels per day, accounting for approximately 65% of the country`s total refining capacity.

Refineries:

- **Aspropyrgos Refinery:** Established in 1958 and upgraded in 1986, this cracking/FCC-type facility has a daily refining capacity of 148,000 barrels and a storage capacity of 1.4 million m³. It is noted for its high complexity (Nelson Index 9.7) and strict environmental compliance. The Aspropyrgos refinery is currently involved in the production of SAF.

- **Elefsina Refinery:** With a daily capacity of 106,000 barrels, this refinery was upgraded in 2012 to a hydrocracking/coking facility, specializing in diesel. It has a storage capacity of 4.1 million m³ and a Nelson Index of 12, making it one of the most advanced refineries in the region.

[22] KLM Royal Dutch Airlines. (2024). Sustainable aviation fuel. KLM. Retrieved from: https://www.klm.fr/en/information/sustainability/sustainable-aviation-fuel

[23] Hellenic Petroleum (n.d.) Distribution & trading of chemicals. Retrieved from: https://www.helleniqenergy.gr/en/energeia/diylisi-efodiasmos-emporia-himika?_gl=1*15es6rz*_up*MQ..*_ga*Mjg0MDU5ODkxLjE3MjIyNTU0NjE.*_ga_BV7HGJPB33*MTcyMjI1NTQ2MC4xLjAuMTcyMjI1NTQ2MC4wLjAuMA..

- **Thessaloniki Refinery:** Utilizing hydroskimming technology, this refinery processes 90,000 barrels per day and has a storage capacity of 1.4 million m³. It is the sole refinery in Northern Greece, serving both domestic and Southeast European markets.

2.4.5. Poland

Poland follows the EU's SAF mandate, which requires a 2% SAF blend by 2025 and 6% by 2030. These targets are part of the EU's "ReFuelEU Aviation" initiative under the European Green Deal, aiming to reduce aviation's carbon footprint across Europe. Poland, as an EU member, will implement these SAF blending requirements in its aviation sector.

In 2019, the Polish government established the National Energy and Climate Plan for the years 2021-2030 and proposed 14% of renewable energy sources in transport by 2030. In 2021, the Polish Hydrogen Strategy by 2030 with a perspective until 2040 was published. The document assumes national industry initiatives in the pilot phase before 2025 and further increase of the use of hydrogen in air transport before 2030.

Government Measures:

Poland’s National Policy Framework supports the use of renewable energy sources, including SAF.

The government offers subsidies and grants for research and development in renewable energy, including SAF.

- **Principles for the update of the Energy Policy of Poland until 2040 (EPP2040)**

The specific law related with hydrogen are below:

“Article 4: Further diversification of supplies and providing alternatives for hydrocarbons.”

Efforts will be taken to gradually decrease the economic dependence from natural gas and crude oil. Nevertheless, the upcoming decades will further require securing their supplies to the customers. Thus, diversification of sources, directions and routes of supplies of these resources will be continued with a view to gaining independence from supplies from the Russian Federation and other economically sanctioned countries. For this reason, the construction of the Floating Storage Regasification Unit (FSRU) in the Gulf of Gdansk along with the extension of national grid and underground natural gas storage sites will be expedited.

Further actions will be taken to replace the demand for natural gas with decarbonised gases and other fuels of well-established efficiency, including among others by development of hydrogen-based technologies offering a valid alternative to natural gas.

Reducing demand for liquid fuel will be addressed by the intensified measures related to the use of alternative energy sources in transport i.e. biocomponents in liquid fuels, biomethane, hydrogen, low-carbon synthetic fuels or electric energy. Enhanced promotion will cover the use of “clean” public transport, changing the drivers’ behaviours to more ecological driving, or more extensive use of rail freight transport.

“Article 8: Grid and energy storage development,”

The measures boosting development of power grids, automation schemes and ensuring high level of cybersecurity remain the priority. These are of key importance for stronger integration of distributed and renewable energy sources.

Growing share of RES in the energy system requires the increase in the energy and heat storage capacity at the prosumer, RES producers, grid operators and aggregators level. This implies intensification of works associated with development of the energy storage facilities, including pumped-storage facilities and prosumer storage facilities to reduce the effects of potential disturbances in the production or transmission of energy. In future, the special role in energy storage will be attributed to hydrogen, in particular this derived from RES and ensuring management of excessive generation from RES.

GreenEvo - Green Technology Accelerator[24]

The GreenEvo – Green Technology Accelerator is an original project of the Ministry of Climate (earlier the Ministry of the Environment) created to promote Polish green technologies.[25]

So far, six editions of the Programme have been held in the years 2009–2015, in which a total of 74 technologies – GreenEvo Winners – have been selected from the following technological areas:

- waste management,
- water and waste water management,
- renewable energy sources,
- energy savings,
- air quality,
- biodiversity conservation.

The 7th edition of the Programme, commenced in 2018, was intended exclusively for the Laureates of the previous editions of GreenEvo, in order to use the existing potential of proven technologies of entrepreneurs who, together with the Ministry of the Environment, had built the GreenEvo brand.

The GreenEvo Program is one of the key tools used by the Polish Government to support the transition process towards a sustainable economy and to raise the awareness of companies as to how they can operate in a responsible manner. It is the best practice in the scope of cooperation between the central administration and business.

ETV – the EU's Environmental Technology Verification Programme[26]

Environmental Technology Verification (ETV) is a tool to help innovative environmental technologies reach the market. The concept of it is to offer a verification procedure to cutting edge environmental technologies that may otherwise find it difficult to establish their environmental added value. The verification procedure allows for an independent assessment and validation of the manufacturer's claims on the performance and environmental benefits of their technology. The information produced by the verification is public and can be used to compare performance parameters and therefore becomes

[24] Government of Poland. GreenEvo - Green Technology Accelerator. Retrieved from: https://www.gov.pl/web/climate/greenevo---green-technology-accelerator
[25] Source: https://greenevo GreenEvo. About Program. Retrieved from: https://greenevo.gov.pl/en/about-program/
n/about-program/
[26] Government of Poland. ETV - The EU's Environmental Technology Verification Programme. Retrieved from: https://www.gov.pl/web/climate/etv--the-eus-environmental-technology-verification-programme

an extremely useful tool to convince third parties of the merits of a technology, potentially enhancing its market value and acceptance.

The European Commission initiated the EU-ETV Pilot Programme as one of the initiatives under the Eco-Innovation Action Plan in December 2011. Poland was one out of seven countries participating in the Pilot Programme. Three Polish technologies has been verified so far.

2.4.6. Hungary

Hungary is actively implementing measures at both the EU and national levels to comply with climate regulations and targets. The Hungarian government places a high priority on climate protection, aligning its strategic goals with the European target of achieving climate neutrality by 2050 and the Paris Agreement's aim of limiting global warming. Hungary has committed to reducing its national greenhouse gas (GHG) emissions by at least 40% by 2030 compared to 1990 levels and aims to become climate-neutral by 2050. These goals are enshrined in Law No. XLIV of 2020 on Climate Protection.

The State Action Plan aims to present current and planned mitigation measures in Hungary. In the near future, Hungary intends to further explore and expand its capacities, particularly regarding alternative aviation fuels (SAFs). Hungary is eager to participate in international initiatives, establish long-term regional partnerships, and learn from best practices. As energy supply crises unfold, it is in the interest of both Hungary and the broader European community to expand domestic energy supply capacities. SAFs offer significant opportunities for countries that have historically relied on imported energy.

European collective Measures

- **ACI Airport Carbon Accreditation**

The Airport Carbon Accreditation programme is included in this Action Plan to promote and facilitate the adoption of best practices in carbon and energy management by airports. The primary aim of this programme is to assist airports in voluntarily reducing their impact on climate change. Additionally, a key immediate environmental benefit of the programme is the enhancement of local air quality. This is achieved through the reduction of non-CO2 emissions associated with decreased fuel burn, which airport operators can manage, guide, and influence.

- **ReFuelEU Aviation**

The large-scale use of SAF not only reduces CO2 emissions but also other pollutants, improving air quality around airports. SAF can reduce non-volatile particulate matter (nvPM) by up to 90% and sulphur (SOx) emissions by 100%, compared to fossil jet fuel. This contributes to more effective waste management and the preservation of natural resources.

- **SAF Research and Development Projects**

The AVIATOR project, funded by the EU's Horizon 2020 programme, aims to better understand the impact of aviation emissions on local air quality at airports. It measures pollutant emissions from aircraft and evaluates the impact of SAF on particulate matter and other pollutants. The project involves 17 partners from seven countries and runs until 2022.

- **EU's Single European Sky Initiative and SESAR**

The Single European Sky (SES) initiative and its SESAR programme aim to create a modern, interoperable, and high-performing air traffic management infrastructure in Europe. While SESAR's primary goal is to reduce fuel burn, it also significantly mitigates non-CO2 emissions and noise impacts. The SESAR Programme includes tools like the EUROCONTROL Integrated aircraft noise and emissions modelling platform (IMPACT), which helps assess environmental impacts.

- **Green Airports Research and Innovation Projects**

The European Commission's Green Airports projects aim to achieve benefits beyond CO2 emissions reductions, including:

- Promoting circular economy practices, such as using eco-friendly materials in construction and converting waste to sustainable fuels.
- Enhancing biodiversity and green land planning.
- Addressing air quality and noise impacts.
- Developing market mechanisms and regulatory actions to incentivise low-emission solutions.
- Fostering new governance arrangements among airport stakeholders, including authorities, operators, local communities, and planning departments.

National Actions in Hungary

- **Policy Framework**

As part of the EU, Hungary is committed to meeting European goals by supporting both regional and local initiatives. Important policy frameworks include the European Green Deal, the Fit for 55 package, the Smart and Green Mobility Strategy, and the upcoming ReFuelEU Aviation initiative. These frameworks help guide Member States' efforts in sustainable aviation, focusing on four main areas: developing aircraft technology, improving air traffic management, promoting sustainable aviation fuels, and implementing market-based measures to reduce emissions.

- **Institutional Arrangements**

Alongside European efforts, Hungary has its own national measures to reduce carbon emissions. These initiatives are led by the Ministry of Technology and Industry, which oversees aviation and sustainability policies. The key departments involved include the Energy Policy Department, the Climate Policy Department, the Transport Policy

Department, the Civil Aviation Authority, and the National Climate Protection Authority. They work together on sustainability issues in aviation.

To provide a clear picture of the efforts within Hungary's aviation sector, various stakeholders contributed to the State Action Plan, sharing their guidelines and activities. This chapter includes both public initiatives and contributions from industry actors, demonstrating a collaborative approach to making aviation more sustainable in Hungary.

2.4.7. Spain

Spain's national policy on Sustainable Aviation Fuel (SAF) is shaped by its commitment to decarbonizing the aviation sector, aligning with broader European Union goals such as the EU Green Deal and the ReFuelEU Aviation initiative.

Spain's SAF policy is closely aligned with the EU's ReFuelEU Aviation proposal, which mandates increasing SAF usage in the aviation sector to meet EU-wide targets. This regulation sets progressively increasing SAF blending mandates for all flights departing from EU airports, including those in Spain. By 2030, the minimum SAF content required in jet fuel is expected to be 5%, with a focus on advanced biofuels and e-fuels.

Spain is investing in building domestic SAF production capacity through public-private partnerships and EU funding mechanisms. Major energy companies such as Repsol[27] and Cepsa are developing SAF production facilities, using both advanced biofuels from waste and residues, and synthetic fuels derived from renewable hydrogen and CO_2.

In Spain, various funds, tax incentives, and policies are supporting the development and deployment of hydrogen. Key initiatives and financial support mechanisms include:

- **Funding Programs**

Spain is actively investing in green projects under the Strategic Project for Economic Recovery and Transformation (PERTE), particularly focused on renewable energies, hydrogen, and storage. The first provisional resolutions of the PERTE aid programs amounted to €250 million, mobilizing a total investment of €890 million across 29 projects. This initiative aims to position Spain as a leader in green hydrogen and renewable energy, indirectly benefiting SAF development.

- **Tax Incentives**

The Spanish government offers various tax incentives to promote research, development, and innovation (RDI). Companies involved in RDI activities, including those working on SAF, can benefit from up to a 42% corporate income tax credit. Additionally, a 40% bonus on Social Security contributions is available for research staff, and further tax benefits exist under the "patent box" regime, which offers up to a 60% exemption on net income derived from specific intangible assets.

- **Government Commitment**

[27] https://www.safinvestor.com/news/144716/repsol-begins-saf-rd-production-at-cartagena-plant/

The Spanish government is committed to hydrogen technology as part of its broader energy transition strategy, which includes SAF as an emerging sector. The government has committed significant funds.

Spain Allocates €794 Million to Renewable Hydrogen Projects to Accelerate Industrial Decarbonization[28]

On 9 July 2024, the Government of Spain, through the Council of Ministers, allocated €794 million in direct aid to seven major projects aimed at promoting the production and intensive use of renewable hydrogen in industrial sectors. These projects, funded by the European Commission, are designed to support the decarbonization of industry by substituting fossil fuels with renewable hydrogen. This initiative is part of Spain's broader strategy to achieve 4 gigawatts of renewable hydrogen capacity as outlined in its national roadmap.

The funded projects, which add up to a combined power capacity of 652 megawatts, will generate approximately €6 billion in total investment over their lifetime. They are strategically located in major industrial clusters in Andalusia, Asturias, Castilla-La Mancha, Murcia, and the Basque Country. Additional projects in Aragón will focus on replacing fossil fuels with green hydrogen and natural hydrogen.

These investments underscore Spain's commitment to decarbonizing industrial processes, particularly where electrification is not feasible, by creating 'renewable hydrogen valleys' that integrate production, transformation, and consumption of hydrogen close to end-users.

Aragón's Waste-to-Hydrogen Project: A New Milestone in Green Energy[29]

Aragón, Spain, is set to host a pioneering waste-to-hydrogen facility in Zaragoza, led by Raven SR. Recognised as a "Project and Investment of Regional Autonomous Interest," this €50 million initiative will be Europe's first hub converting organic waste into hydrogen using Raven SR Iberia's unique Steam/CO_2 Reforming technology, which operates without combustion, uses no fresh water, and requires significantly less electricity than comparable processes.

The facility is expected to produce 1.8 million kilograms of hydrogen annually from 2026, addressing both waste management and renewable energy needs. Additionally, the project has the potential to leverage this technology for the production of Sustainable Aviation Fuel (SAF), offering a further opportunity to reduce emissions in the aviation sector.

Backed by €2.4 million from the European Commission's Hy2Market project and €1.4 million from Spain's PERTE H2 initiative, the project positions Aragón as a leader in the sustainable hydrogen economy and sets a new standard for future projects in Europe.

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[28] Government of Spain. (2024, July 9). *Council of Ministers allocates €794 million to renewable hydrogen projects to advance the decarbonisation of industry*. Moncloa Palace, Madrid. Retrieved from https://www.lamoncloa.gob.es/lang/en/gobierno/councilministers/Paginas/2024/20240709-council-press-conference.aspx.

[29] Hy2Market, 2024. *Waste-to-hydrogen flagship project in Aragón, Spain*. Retrieved from https://hy2market.eu/waste-to-hydrogen-flagship-project-in-aragon-spain/

The project is aligned with the development of the hydrogen European supply chain and intensively cooperating with other European regions, such as, Constanta (Rumania) or Braga (Portugal) to scale up the Steam/C02 Reforming Technology.

This project is involved with the acceleration of green mobility in Europe through the production of clean hydrogen for heavy vehicles and the development of infrastructures. Hy2Market aims to unveil successful business models for green mobility. Competitive hydrogen production is very valued among logistics companies together with leasing formulas for new hydrogen trucks that could facilitate the transition and decarbonisation of heavy vehicle fleets at competitive cost.

2.5. SAF progress outside the EU

2.5.1. United Kingdom

Under the UK's new mandate, SAF will make up 2% of total UK jet fuel demand in 2025, increasing to 10% in 2030 and then to 22% in 2040. In parallel, the UK has announced final details for its national SAF mandate, aiming for a 10% SAF target by 2030. IAG is another large European player that is implementing a strategy to secure SAF supply among main European Hubs, in the United Kingdom and Spain.

The Group has invested in some technologies aiming to ramp up production and scale up to other international hubs.

IAG Signs MoU with Velocys for Sustainable Aviation Fuel Supply

International Airlines Group (IAG) has signed a Memorandum of Understanding (MoU) with Velocys, a sustainable fuels technology company, to purchase 220,000 tonnes of sustainable aviation fuel (SAF) over ten years. This represents one-third of the expected output from Velocys' Bayou Fuels project in the US, which is set to begin deliveries in 2026. The SAF will be utilised by IAG's airlines, including British Airways, Aer Lingus, and Iberia.[30]

The project will use technology that captures CO2 during the manufacturing process, permanently removing it from the atmosphere. IAG, the first European airline group to commit to using SAF for 10% of its flights by 2030, aims to reduce its annual emissions by two million tonnes, equivalent to removing one million cars from Europe's roads. IAG is investing $400 million in SAF development over the next 20 years to achieve this goal.

IAG Commits to 10% Sustainable Aviation Fuel by 2030

International Airlines Group (IAG), owner of Aer Lingus, British Airways, Iberia, and Vueling, has pledged to operate 10% of its flights with sustainable aviation fuel (SAF) by 2030. This involves purchasing one million tonnes of SAF annually, which will reduce the group's carbon emissions by two million tonnes per year—equivalent to taking one million cars off European roads.[31]

IAG is also extending its net-zero emissions commitment to its supply chain by 2050 and plans to invest $400 million in SAF development over the next 20 years, partnering with

[30] International Airlines Group (IAG). "IAG Signs MoU with Velocys for Sustainable Aviation Fuel Supply." IAG Press Release, 2021. Available at: https://www.iairgroup.com/media/riophyfd/iag13.pdf.

[31] Business Traveller. (23 April 2021) "IAG to Operate 10 Per Cent of Flights with Sustainable Aviation Fuel by 2030." Business. Retrieved from: https://www.businesstraveller.com/business-travel/2021/04/23/iag-to-operate-10-per-cent-of-flights-with-sustainable-aviation-fuel-by-2030/.

companies like LanzaJet and Velocys. CEO Luis Gallego emphasized the need for government support to achieve these goals, which will create green jobs and drive economic growth.

IAG (International Airlines Group) has reached an agreement with Repsol for the purchase of over 28,000 tonnes of Sustainable Aviation Fuel (SAF), marking the largest SAF purchase in Spain to date. This SAF will be used by IAG airlines flying from Spanish airports, including Aer Lingus, British Airways, Iberia, Iberia Express, and Vueling, and will enable an emissions reduction of more than 80% compared to traditional jet fuel over its full lifecycle from production to consumption.[32]

Key points of the agreement:

- Volume: Over 28,000 tonnes of SAF.
- Impact: An 80% reduction in CO2 emissions compared to conventional jet fuel.
- Objective: To help IAG meet its goal of having 10% of its fuel from SAF by 2030.
- Production: Repsol produces these 100% renewable fuels at its Cartagena facility, the first large-scale plant in Spain and Portugal dedicated to producing renewable fuels, with a capacity of 250,000 tonnes per year.

This agreement also highlights IAG's ongoing investment in SAF technologies and suppliers, with the group's investments reaching $1 billion by the end of 2023.

2.5.2. Norway

Norway introduced a 0.5% SAF blending mandate in 2020, which is set to progressively increase to 30% by 2030.

- **Programme Environment, Energy and Climate Change**[33]

The EEA and Norway Grants are financial mechanisms financed by Iceland, Liechtenstein and Norway. The aim of the Grants is twofold – to reduce social and economic disparities in Europe and to strengthen the bilateral relations between the three donor countries and the 15 European countries which receive the funding, with Poland being the largest beneficiary.

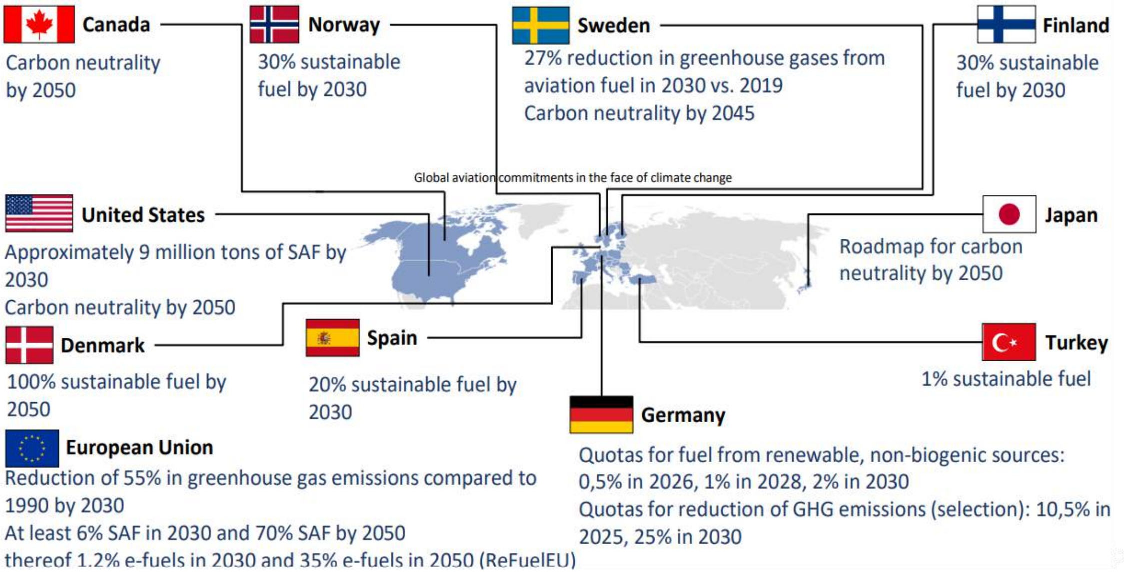
The EEA and Norway Grants fund a wide variety of topics, ranging from business development and innovation to human rights, culture and climate change.

The Programme benefits from € 140 million grant from Iceland, Liechtenstein and Norway through the EEA and Norway Grants.

The financing is complemented by the national funding: € 24 million of grants, as well as financial mechanisms in the form of low interest loans.

Figure 8: SAF blending mandate in different countries

[32] *Repsol. "IAG and Repsol Agree the Largest Purchase of SAF in Spain." Repsol Press Room, 29 July 2024. Retrieved from:* https://www.repsol.com/en/press-room/press-releases/2024/iag-and-repsol-agree-the-largest-purchase-of-saf-in-spain/index.cshtml.
[33] SAF Investor. (2023, July 21). *Kuwait Petroleum completes SAF blending at biorefinery in France.* Retrieved from https://www.safinvestor.com/news/143895/kuwait-petroleum-completes-saf-blending-at-biorefinery-in-france/



Source:aireg

2.5.3. Canada

Introduction to SAF Initiatives

According to Sustainable BIZ Canada, in July 2023, the Canadian Council for Sustainable Aviation Fuels (C-SAF) launched a comprehensive roadmap. This plan outlines the policies and steps necessary to produce one billion litres of domestic sustainable aviation fuel (SAF) annually by 2030[34]. SAF is derived from renewable feedstocks readily available in Canada, such as forest and agricultural residues, industrial fats, oils, greases, municipal solid waste, and carbon dioxide captured from industrial processes or the atmosphere. This SAF is then blended with conventional jet fuel.

The goal for 2030 is to have SAF constitute 10 per cent of jet fuel use in Canada. The roadmap projects that by 2035, Canada will be capable of producing enough SAF to meet 25 per cent of the country's total jet fuel demand, potentially reducing emissions by 15 to 20 per cent for flights departing from Canada.

Canada's Planned Actions for Sustainable Aviation Fuels (SAF)

Canada has set an aspirational target of **10% SAF use by 2030**, emphasizing the importance of significant volumes of sustainable low-carbon fuel to achieve net-zero emissions by 2050. Key planned actions include:

- **Collaboration**: The parties involved will work with the Canadian Council for SAF (C-SAF) to develop a roadmap for SAF in Canada.
- **BioEnergy Strategy**: Natural Resources Canada will explore the role of SAF within a broader BioEnergy Strategy to maximize bioenergy potential for emission reductions while supporting economic growth.

[34] SustainableBiz Canada. (2024). Canada gets roadmap to produce billion litres of SAF by 2030. Sustainable Business News.

- **Policy Environment**: The Government of Canada will investigate federal measures to facilitate SAF adoption, including:
    - Drafting regulations to provide relief from the federal fuel charge for bio-aviation fuels blended into aviation gasoline or turbo fuel.
    - Developing a consistent national approach to emissions pricing for inter-provincial aviation.
- **Support for Initiatives**: The government will support SAF initiatives through existing programs and purchase SAF for its federal fleet via the Low-carbon Fuel Procurement Program.
- **Collaboration with the U.S.**: Transport Canada will continue partnerships with the U.S. Department of Transportation, particularly under the Joint Statement on Transportation and Climate Change, and will support aviation research with U.S. partners, including the ASCENT initiative.
- **Demand Signal**: Canadian air carriers will indicate their demand for SAF through appropriate and financially sound offtake agreements.

Government Incentives and Support

To support the development of sustainable aviation, the Government of Canada has introduced several initiatives:

▪ **Strategic Innovation Fund (SIF)**

Recognizing the significant impact of the COVID-19 pandemic on the aerospace sector, Budget 2021 allocated $1.75 billion in SIF support for aerospace innovation projects. This funding aims to enhance the global competitiveness of the sector, identified as a key component in Canada's Strengthened Climate Plan. As part of this initiative, in July 2021, the Government committed up to $440 million through SIF to support new innovation projects focused on sustainable aviation, including:

- $200 million to Bell Textron Canada Ltd. for the development and commercialization of environmentally friendly aviation technology.
- $49 million to Pratt & Whitney Canada to develop all the technological components for a hybrid-electric propulsion demonstrator plane.
- $190 million to CAE for implementing a global R&D program focusing on electric aviation and digital technologies.

▪ **National Research Council (NRC) – Low Emission Aviation Program (LEAP)**

LEAP aims to transform the Canadian aviation sector towards net-zero GHG emissions by developing sustainable solutions, participating in collaborative ecosystems to stimulate the industry's green transition, and supporting other government departments in policy and regulation development. The NRC plans to work with aviation sector partners to expand LEAP activities significantly in the coming years.

- **Investment in Air Traffic Control**

On June 29, 2022, Transportation Minister Omar Alghabra announced a joint investment by the Government of Canada and NAV CANADA of up to $261 million ($105 million and $156 million, respectively) to improve air traffic control efficiency and capacity at Toronto Pearson Airport, Montréal–Trudeau International Airport, Vancouver International Airport, and Calgary International Airport.

- **Next Steps for C-SAF**

C-SAF plans to establish task forces to address various aspects of the roadmap over the next two years (June 2023 to May 2025). This includes mapping the greenhouse gas emissions of all SAF production, advancing policy frameworks, building infrastructure, and creating an active project pipeline.

Success Case: WestJet's SAF-Powered Flights

WestJet Airlines Ltd. has launched Canada's first regular flights powered by SAF. Over the next three months, the airline plans to operate 40 flights from San Francisco to Calgary using a blend of Neste MY Sustainable Aviation Fuel. WestJet estimates this initiative will reduce greenhouse gas emissions by 186 tons on this route, equivalent to more than 1,550 passengers taking a carbon-neutral flight to Calgary. Established in 1996 and headquartered in Calgary, WestJet operates over 180 aircraft, employs 14,000 people, and serves more than 110 destinations in 24 countries. WestJet and the Canadian aviation industry aim to achieve net-zero emissions by 2050[35].

2.5.4. United States of America (USA)

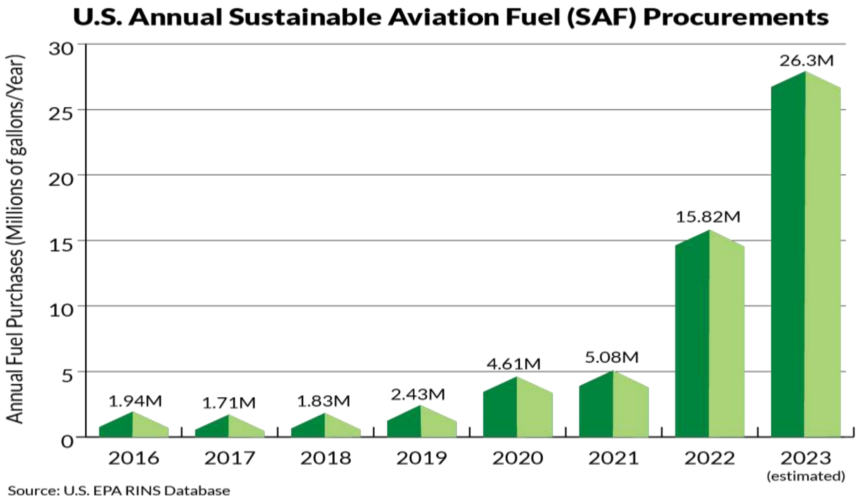
Sustainable aviation fuels (SAF) derived from renewable and waste feedstock are pivotal in reducing greenhouse gas emissions from aviation, with the potential to achieve net-zero emissions and cut emissions by up to 100%. In the U.S., key sources include used cooking oil, municipal solid waste, and recycled construction materials from waste; corn husks, wood waste, and sugar crops from soil; oils from Camelina and Jatropha seeds; seaweeds and algae from water; and carbon dioxide from air, which, when combined with renewable electricity, can be converted into SAF. These innovative sources offer diverse and impactful solutions for a sustainable aviation future.

Sustainable aviation fuels (SAF) made from renewable and waste feedstocks can reduce greenhouse gas emissions by up to 100%. These fuels, usable in current jet aircraft without modification, are produced from wastes, residues, biomass, sugar, oils, and gaseous carbon sources. The FAA has collaborated with the industry for over a decade through the Commercial Aviation Alternative Fuel Initiative (CAAFI) and is working with

[35] SustainableBiz Canada. (2024). WestJet launches Canada's first SAF-powered regular flights. Sustainable Business News.

the Departments of Energy and Agriculture on the "SAF Grand Challenge" to expand SAF use to 3 billion gallons per year by 2030 and 100% by 2050.

Figure 9: U.S Annual SAF Procurements



The goals for U.S. sustainable aviation fuel (SAF) production are to reach 3 billion gallons per year by 2030 and to meet 100% of aviation fuel demand, projected to be 35 billion gallons per year, by 2050.

U.S. Environmental Research and Innovation grants[36]

- **CLEEN Grants for Innovation**

The FAA has awarded $100 million in funding to develop the next generation of sustainable aircraft technology. The focus areas for this grant include sustainable aviation fuels, engine technology, and airframe innovations.

- **ASCENT Grants for Research**

The FAA has provided $16 million in grants to support university research aimed at achieving U.S. aviation climate goals. This research focuses on alternative jet fuels, emissions reduction, aircraft technology, climate modelling, and noise issues.

- **Sustainable Aviation Fuels Grand Challenge Roadmap**

The objective of this roadmap is to spur technological innovation in producing sustainable aviation fuels. The goals are to reduce emissions, meet U.S. domestic climate targets, and position the U.S. as a leader in the sustainable aviation fuels market.

- **VALE Grants**

[36] Federal Aviation Administration (FAA). (2022). Environmental Accomplishments 2022. Retrieved from: https://www.faa.gov/sustainability/environmental-accomplishments-2022

The purpose of VALE grants is to help U.S. airports meet the 2050 net-zero climate challenge. These grants finance low emission vehicles, refuelling and recharging stations, gate electrification, and other air quality improvements. As of September 2022, 138 projects have been funded at 59 airports.

- **Fueling Aviation's Sustainable Transition (FAST) Grant Programme**[37]

Accelerate the production and use of sustainable aviation fuels (SAF) and develop low-emission aviation technologies to support the U.S. aviation climate goal of achieving net zero greenhouse gas emissions by 2050.

Funding:

- **FAST-SAF**: $244.5 million in grants for infrastructure projects related to SAF production, transportation, blending, and storage.
- **FAST-Tech**: $46.5 million in grants to develop and demonstrate new aviation technologies to improve fuel efficiency and reduce emissions.

SAF initiatives in U.S. Airports

The Commercial Aviation Alternative Fuels Initiative (CAAFI) has worked with San Francisco International Airport and several airlines and SAF producers, to facilitate large SAF offtake agreements between airlines and SAF producers, aim to guarantee demand for SAF ahead of modifications to fuel plants to produce SAF.[38]

As part of the initiative, the U.S. Environmental Protection Agency, the Departments of Energy, Transportation and Agriculture, and the National Aeronautics and Space Administration will co-ordinate efforts to expand production and use of SAF that achieves a minimum of a 50% reduction in life cycle greenhouse gases compared to conventional fuel, by carrying out research, developing the fuels and related infrastructure and encouraging the production of raw materials. In addition, the General Services Administration plans to develop information concerning procurement decisions the U.S. government can take to reduce the sustainability impacts of federal employee travel.

- **Projects of US SAF suppliers**

Delta and Shell Aviation Partner to Supply SAF at LAX and Advance Aviation Decarbonization.

Delta Air Lines has committed to purchasing 10 million gallons of neat Sustainable Aviation Fuel (SAF) from Shell Aviation over two years for use at Los Angeles International Airport (LAX). This agreement supports Delta's goal of having 10% of its fuel usage be SAF by 2030, and 35% by 2035. SAF can reduce lifecycle carbon emissions by up to 80% compared to traditional jet fuel and can be blended with conventional fuel without modifying aircraft engines.

[37] Federal Aviation Administration (FAA). (n.d.). Fueling Aviation's Sustainable Transition - FAST Grants. Retrieved from: https://www.faa.gov/general/fueling-aviations-sustainable-transition-fast-grants
[38] Norton Rose Fulbright. (2024). New Regulatory Initiatives Supporting Sustainable Aviation Fuel. Retrieved from: https://www.nortonrosefulbright.com/en-au/knowledge/publications/f81d3390/new-regulatory-initiatives-supporting-sustainable-aviation-fuel#section5

The agreement also includes testing the Avelia platform, a blockchain-powered tool for tracking SAF delivery and usage, ensuring transparency in carbon footprint accounting. Delta’s commitment aligns with Shell's aim to achieve net-zero emissions by 2050. California’s low carbon fuel standard (LCFS) incentivizes SAF production, aiding Delta's efforts to scale up SAF usage.

Delta's Chief Sustainability Officer, Pam Fletcher, emphasized the importance of creating demand signals for SAF to drive investment and growth. Jan Toschka, President of Shell Aviation, highlighted that Delta's prioritization of SAF helps reduce lifecycle emissions and supports the scaling of SAF production, crucial for sustainable aviation's future.

Bp operates refineries in Cherry Point, Washington and Whiting, Indiana, playing a key role in powering regional transportation networks.

In October 2023, bp and the Midwest Alliance for Clean Hydrogen (MachH2 coalition) were selected by the US Department of Energy for regional clean hydrogen hub funding. bp plans to develop blue hydrogen production at or near its Whiting, Indiana refinery.

- **Overview of BP’s Cherry Point Refinery**

Located near Bellingham, Washington, BP’s Cherry Point is the largest refinery in the Pacific Northwest, capable of processing approximately 250,000 barrels of crude oil daily. It is a key supplier of jet fuel to Seattle, Portland, and Vancouver international airports and provides anode-grade calcined coke to the aluminium industry. Cherry Point was the first refinery in the region to co-process renewable diesel from biomass-based feedstocks, producing a fuel identical to petroleum diesel but with a lower carbon footprint.

Recent upgrades at the refinery include the installation of a new vacuum tower in the hydrocracker, which improves the production of gasoline and jet fuel while saving energy and reducing CO2 emissions. Additionally, a new cooling tower and related infrastructure were installed to enhance the efficiency of process water cooling.

BP’s Whiting Refinery and Clean Hydrogen Initiative

Located about 17 miles southeast of downtown Chicago **in northwest Indiana**, BP’s Whiting refinery is the largest in the Midwest and BP’s largest worldwide. It processes approximately 440,000 barrels of crude oil daily, producing a variety of transportation fuels and 7% of all asphalt in the US.

In October 2023, bp, along with the Midwest Alliance for Clean Hydrogen (MachH2 coalition), was selected by the US Department of Energy for regional clean hydrogen hub funding. BP plans to develop blue hydrogen production at or near the Whiting refinery.

2.5.5. Australia and New Zeland

Aviation, contributing 2.5% of global carbon emissions, faces significant challenges in decarbonisation. The "Sustainable Aviation Fuel Roadmap" indicates Australia is well-placed to develop a domestic SAF industry, leveraging its feedstocks but facing challenges like supply chain constraints and regulatory issues.

With limited options like electrification or green hydrogen, commercial airlines and defence forces must rely on SAF, derived from biomass, waste products, natural oils, and hydrogen, to reduce emissions. While global SAF uptake is rising, especially in Europe, the UK, and the USA, supply remains limited, raising concerns about affordability, sustainability, and feedstock competition.

Australia, already a significant feedstock producer, could expand its role in SAF production, supported by its growing hydrogen economy. The key question is identifying the most suitable SAF production options to build a robust domestic industry.

There are currently two Sustainability Certification Schemes that meet the requirements of the CORSIA sustainability criteria and are eligible to certify SAF producers.

- **Roundtable on Sustainable Biomaterials (RSB):** Certified SAF enables claims around achieving minimum 50% GHG reductions and 12 sustainability principles including environmental protection, food security and human rights.

- **International Sustainability and Carbon Certification (ISCC):** Certified feedstocks that enable claims of 10% GHG reductions over the lifecycle and 6 sustainability principles met, centred around environmentally and socially responsible practices.

- **Policy Intervention to Promote SAF**
  - **Direct Subsidies: De-risk First-of-a-Kind SAF Production Plants**

    To promote SAF, direct subsidies can play a crucial role in mitigating risks for first-of-a-kind production plants. For instance, the Australian Fuel Security Services Payment provides refiners with production payments during loss-making periods, based on the volume of fuels (petrol, diesel, jet fuel) they produce. This approach could be adapted to support SAF producers, ensuring financial stability and encouraging the development of sustainable aviation fuel infrastructure.

- **Sustainable Aviation Fuel Roadmap**

The "Sustainable Aviation Fuel Roadmap" reveals Australia is well-positioned to produce and scale SAF feedstocks, contributing significantly to the SAF industry in the Asia Pacific region. Already a major feedstock producer for biofuel, Australia can expand into a diversified portfolio of sustainable feedstock sources.

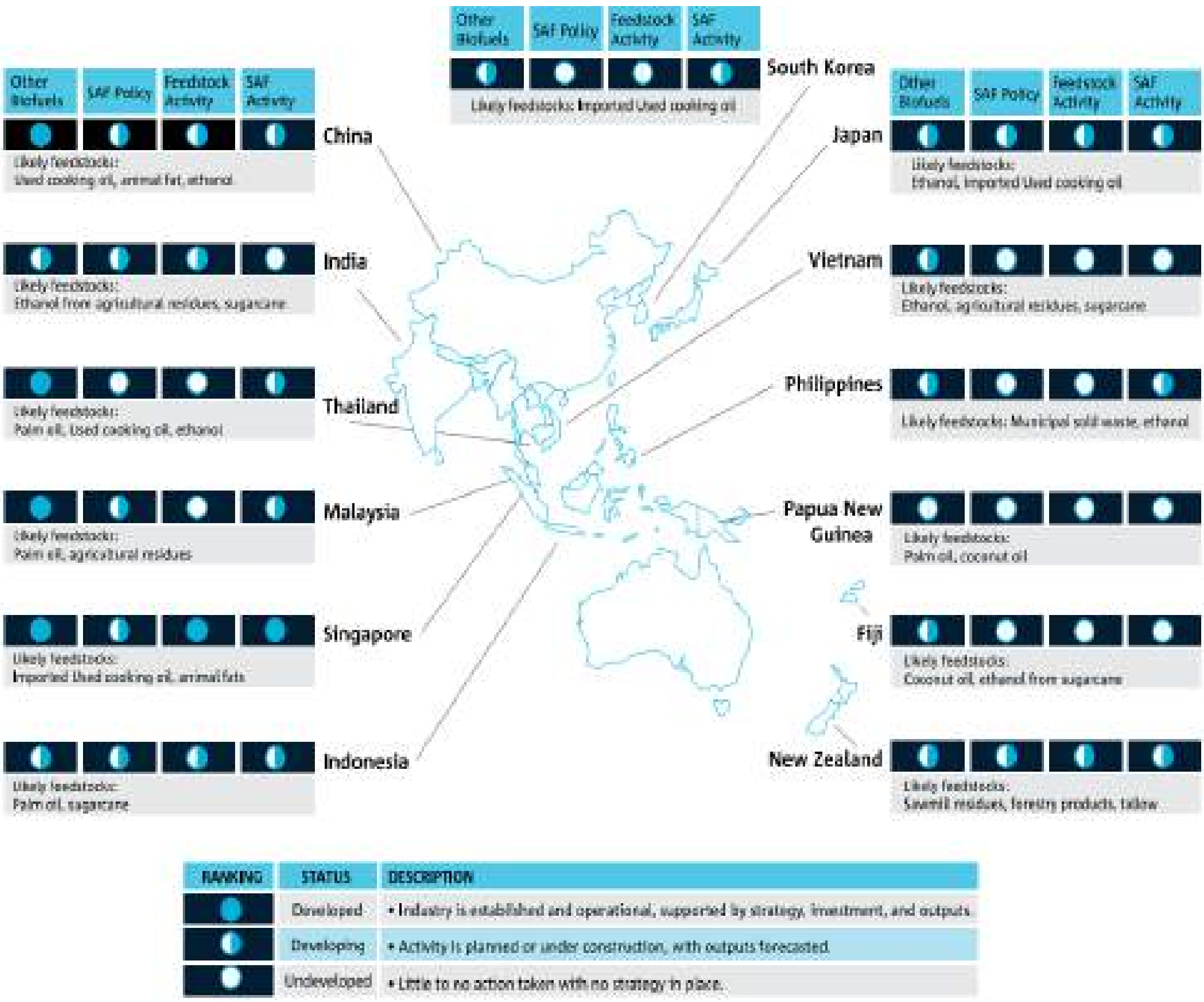
This Roadmap is part of CSIRO's efforts to help Australia’s most challenging sectors halve their emissions by 2035, aligning with the Towards Net Zero Mission.

Australia and New Zealand have agreed to collaborate on developing a sustainable aviation fuel (SAF) industry and a certification scheme for low-carbon fuels to attract investment for climate action, according to Quantum Commodity Intelligence.

New Zealand's aviation sector will join Australia's Jet Zero Council to help develop a domestic SAF industry. Both countries will work on a Guarantee of Origin scheme for low-carbon fuels.

New Zealand recently cancelled its biofuels mandate due to high costs and political issues, and Air New Zealand has abandoned its 2030 net zero emissions target. Australia, after lagging in biofuels promotion, is now developing a domestic industry, supported by a policy consultation and its AUD 1.7 billion ($1.1 billion) Future Made in Australia Innovation Fund.

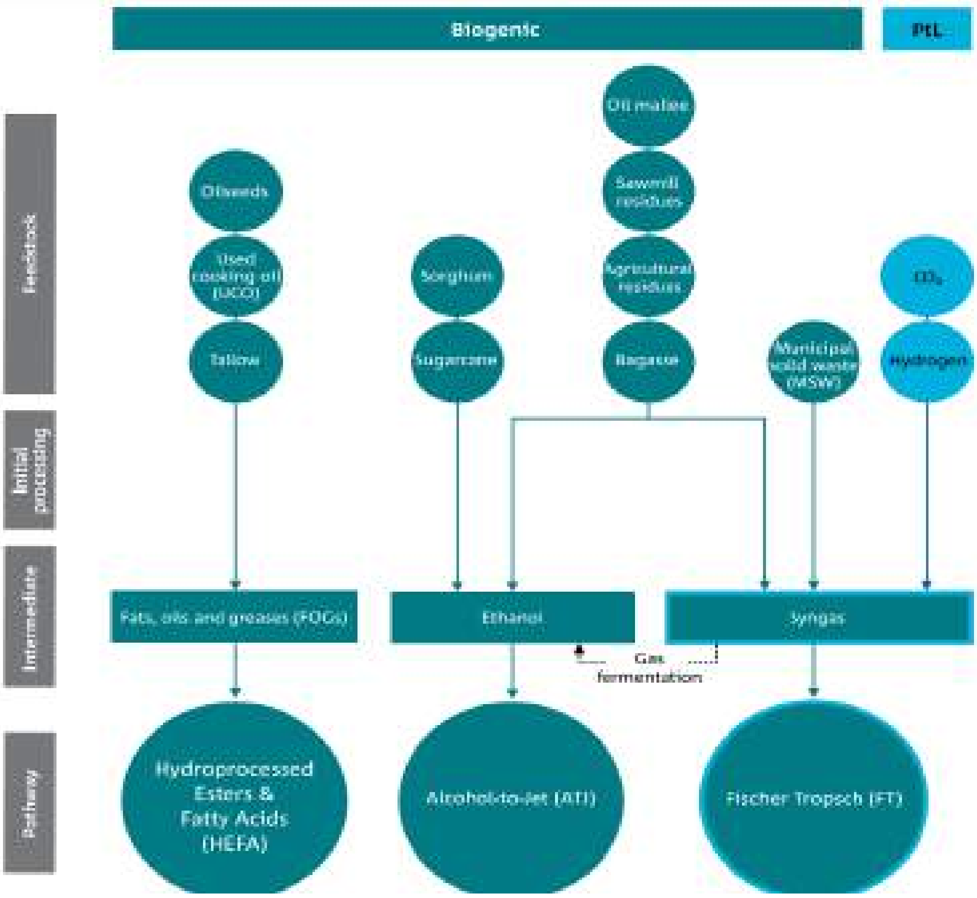
Figure 10: APAC region activity in biofuels, SAF policy, feedstock and SAF



Source: CSIRO

The Asia Pacific (APAC) region boasts numerous refiners and potential feedstock suppliers, positioning it as a promising area for SAF production. Singapore and Japan are working to become SAF refiners by importing feedstock. Meanwhile, countries with robust agricultural and biofuel industries, like China, Malaysia, and Thailand, are expected to emerge as major feedstock producers and may develop refining capabilities in the future.

Figure 11: Key SAF pathways and potential feedstocks for Australia



Source: CSIRO

Actions from government, industry and research will be necessary to overcome the challenges the SAF industry faces. The challenges and recommendations to establish a SAF industry in Australia, developed through literature reviews and stakeholder consultations with industry, government and research institutions, are below.

Table 4: Challenges and recommendations to establish a SAF industry in Australia

Immediate term (2023–2025) **Aim:** Develop supportive regulatory and social environment to build confidence for investors and empower organisations and individuals to purchase SAF and reduce their emissions.	
MAJOR CHALLENGES	**RECOMMENDATIONS**
Balancing supply and demand: To balance supply and demand over time, it is crucial to reduce the price gap. **Assuring certification and provenance:** Lack of standardised and transparent sustainability verification for SAF supply. **Carbon accounting and reporting:** Lack of standardised approaches to claim the environmental benefits of of using SAF. **Building SAF literacy:** Current knowledge of the purpose and benefits of SAF is low. **Access to capital:** Emerging industries like SAF with higher risk profiles may struggle to compete for capital.	1. Consider policy frameworks and tools that support domestic distribution and the use of certified SAF with a clear long-term support strategy for the industry. 2. Encourage the signaling of local demand for SAF across government, commercial and defence users, giving investors certainty to establish new plants. 3. Educate consumers on the role and benefits of SAF, building social license for investment and demand for fuels. 4. Invest in research and development (R&D) to support emerging technologies and improve feedstock availability and sustainability understanding. 5. Scale-up of biogenic SAF production in appropriate locations, increasing market supply and reducing costs.

Medium term (2025–2035) Aim: Unlock biogenic feedstocks for processing and begin small-scale PtL pilot projects.	
MAJOR CHALLENGES	**RECOMMENDATIONS**
Overcoming green premium: High premiums over CJF negatively affect fuel demand. **Competing feedstock uses**: Almost all feedstocks have existing uses, and feedstock producers will aim to sell their products where they can get the highest returns. **Economic collection and processing of feedstocks:** Many feedstocks are low density, making them costly to transport. **Securing feedstock supply:** Biogenic feedstock supply can fluctuate in quantity, quality, and price annually, creating supply risk.	6. Scale-up second-generation biogenic feedstock collection and processing. 7. Invest in R&D to reduce the costs and logistical hurdles for biogenic supply chains and continue scaling up PtL pilots.
Long term (2035+) **Aim**: Continue to support large-scale biogenic projects and scale up PtL.	
MAJOR CHALLENGES	**RECOMMENDATIONS**
Lowering cost and increasing availability of hydrogen: The hydrogen economy is in the early stages, so hydrogen costs are high, and availability is low. **Guaranteeing supply of CO_2:** CO_2 sources and quantities will fluctuate over time. **Competition for green electrons:** Green hydrogen and direct air capture will require significant amounts of renewable energy and will need to compete with other industries.	8. Develop large-scale production of PtL at several hydrogen and CO_2 hub locations across Australia.

Souce: CSIRO

- **Power-to-Liquids – CO2 and H2**

Power-to-liquids (PtL) is an innovative process for producing jet fuel using non-biogenic feedstocks, such as hydrogen (H2) and carbon dioxide (CO2), in combination with renewable energy sources. The term "power-to-liquids" highlights the critical role that renewable energy plays in this production method. Currently, the Fischer-Tropsch (FT) process is the only approved PtL pathway, but other pathways, like the production of eMethanol from water and CO2 for conversion into jet fuel (known as Methanol-to-Jet), may be adopted in the future.

The success of PtL technology is heavily dependent on the availability of green hydrogen. The scale and expansion of PtL will thus be closely linked to the development of a robust local hydrogen industry. Despite Australia's ambitions to become a major hydrogen producer, as outlined in its National Hydrogen Strategy, current green hydrogen production is minimal, limited to small-scale demonstration projects. Substantial increases in green hydrogen production will be necessary for PtL to become viable.

PtL also requires substantial quantities of CO2, which can be sourced in three ways: from industrial waste streams (such as ammonia and ethanol production), by combusting biomass to produce biogenic CO2, or directly from the air using Direct Air Capture (DAC) technologies. Initially, point-source CO2 from industrial processes should be targeted for cost-effective PtL fuel production due to its concentration and availability. Ammonia and ethanol plants are particularly suitable for this purpose. After leveraging point sources, more sustainable biogenic CO2 should be explored. Finally, investments in DAC should be scaled up gradually to eventually replace point-source CO2.

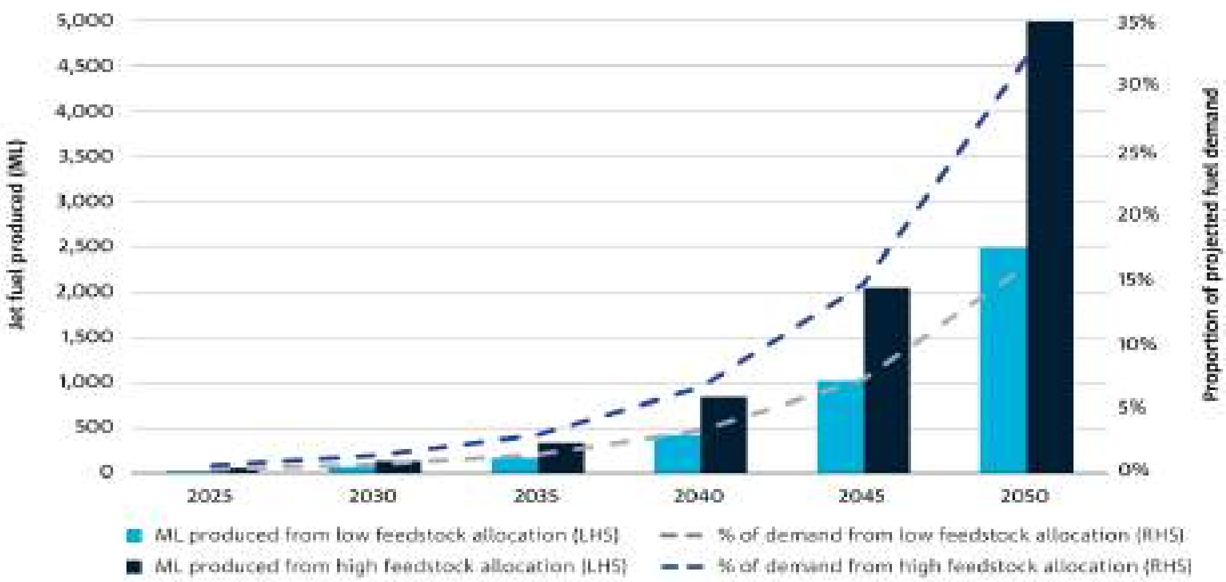
Currently, there is no PtL production activity in Australia. To put the requirements into perspective, assuming a maximised SAF yield, a small-scale FT plant capable of producing 50 million litres (ML) of SAF per year would necessitate 6% of Australia's projected green hydrogen production by 2035 under a high-growth scenario. A larger-scale plant producing 300 ML per year would require 38% of the projected hydrogen production by 2035.

This indicates that significant advancements in green hydrogen production and CO2 sourcing technologies are essential for the widespread adoption and scaling of PtL technologies.

Figure 12: Green hydrogen project announcements and government-designated "hydrogen hubs"

Source: CSIRO

Figure 13: Potential SAF production from Australian green hydrogen and contribution toward domestic fuel demand



Source: CSIRO

The primary pathways for producing sustainable aviation fuel (SAF) utilise different methods to process feedstocks, each offering distinct advantages and disadvantages. These variations can include differences in by-products, logistical arrangements, capital and operating costs, pricing structures, and the maturity of the technology involved. To provide a clear overview of these fuel processing pathways, an assessment was carried out to highlight the pros and cons across various criteria, as illustrated in the table below.

Figure 14: Fuel processing pathways:

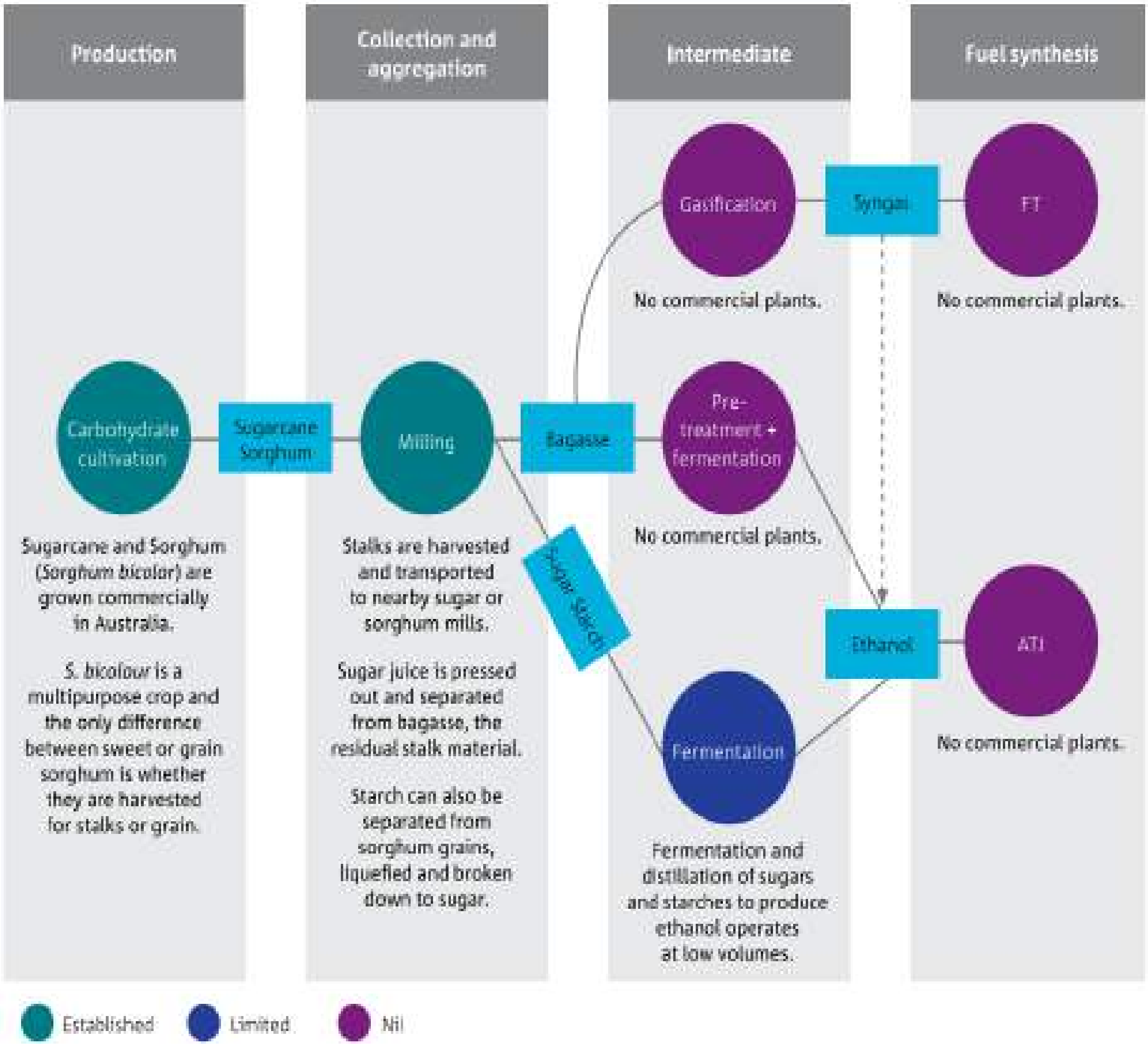
CRITERIA	IMPORTANCE	LOW	MEDIUM	HIGH
Fuel readiness level (FRL)	Maturity of supporting technologies and process, coupled with the readiness to be used as an ASTM approved drop-in fuel.	FRL 1-3	FRL 4-6	FRL 7-9
Energy dense intermediate	The ability to increase the density of the feedstock is favourable as it reduces logistical burden and makes for more economical fuel.	Density is poor and cannot be economically improved.	Limited options to increase density.	Density is high by default or can be achieved through proven processes.
Feedstock flexibility	The ability to accept a range of feedstocks is favourable as it can reduce supply certainty risks.	Cannot accept different feedstocks.	Can process a limited number of feedstocks.	Can accept a wide range of feedstocks.
Potential for R&D improvements	Emerging processes have more scope to improve through the application of R&D, overcoming the challenges of other criteria.	Mature process with only minor continuous improvements possible.	Maturing process with improvements in efficiencies and logistics possible.	Step-change can be achieved through the application of R&D.
Waste management	Onsite waste and by-products can be hazardous to processes and personnel and needs to be minimised. These requirements are seen as unfavourable.	Significant or hazardous waste produced presenting range of difficulties in management.	Some waste or hazardous by-products but can be overcome with strict protocols.	Little waste and by-products produced, or safe protocols developed to manage.
Social acceptance	Projects that produce waste, odour or are not perceived to be sustainable may meet social opposition. Social impact concerns are unfavourable.	Project likely to be opposed by public.	Project likely to be accepted by public.	Project likely to be welcomed by public.

Source: CSIRO

Today there is sufficient feedstock to supply approximately 5 billion litres of SAF production, but Australia is currently constrained by refining potential. Even with planned SAF production coming online from 2026 onwards, a large opportunity remains to produce SAF from Australian feedstocks. By utilising the feedstock and technoeconomic modelling from the report’s analysis, this opportunity equates to $10 billion worth of fuel in 2025 and $19 billion by 2050. Without acting to liberate and refine these resources, Australia risks losing them to offshore processors.

Australia has two ethanol plants producing ethanol from waste starch and molasses, with a combined annual capacity of 360 ML, but they operated at only 57% capacity in 2022. Reopening a decommissioned ethanol plant in Dalby could add another 80 ML to the total capacity. Expanding the capacity of existing plants and reopening Dalby presents a promising opportunity to enhance local ethanol production for Alcohol-to-Jet (ATJ) facilities.

Figure 15: Current state of Australia’s carbohydrate to SAF supply chain



Source: CSIRO

2.5.6. China

China, the world's second-largest aviation market, faces a growing challenge in managing carbon emissions from its aviation sector. Although aviation currently accounts for only 1% of China's total carbon emissions, these emissions are expected to rise as those from traditional heavy industries plateau. Despite the crucial role of reducing aviation emissions in achieving China's carbon neutrality goals, the Sustainable Aviation Fuel (SAF) market in China remains underdeveloped.[39]

To date, Chinese airlines have conducted only four SAF test flights, and only two companies are capable of producing SAF, both still at the trial production stage. Globally, the SAF industry is heavily influenced by government policies, with Western nations leading in setting mandates for SAF blending, which has driven consumption from 6,000 tons in 2016 to 80,000 tons in 2021.

[39] Peking University. (2022). *Sustainable Aviation Fuel: Challenges and Opportunities in China.* Retrieved from https://energy.pku.edu.cn/docs/2022-10/bc31f41c450d46e4bbea5a33c8aeab40.pdf

China’s 14th Five-Year Plan signals an intent to increase SAF consumption to 50,000 tons by 2025. However, this target is non-binding and lacks a clearly defined pathway. Market demand for SAF in China could rise with stronger government incentives, potentially increasing production capacity to 2.05 million tons by 2025, which would account for 4.5% of the country’s total aviation fuel consumption. Despite the widespread availability of feedstocks for SAF production in China, challenges remain in developing technical pathways, improving supply chain collaboration, and making SAF more affordable.

Overall, the SAF industry in China presents both challenges and opportunities. With favourable internal and external conditions, SAF could play a significant role in reducing aviation emissions, achieving carbon neutrality, and enhancing energy security.

According to Oils & Fats International in June 2024, biofuel producers in China plan to invest over $1 billion in constructing plants to convert waste cooking oil into SAF, targeting both export markets and domestic demand following the introduction of government mandates. China, accounting for about 11% of global jet fuel consumption, is the second-largest aviation market worldwide. The forthcoming SAF policy for 2030 is expected to drive substantial investments in the sector.

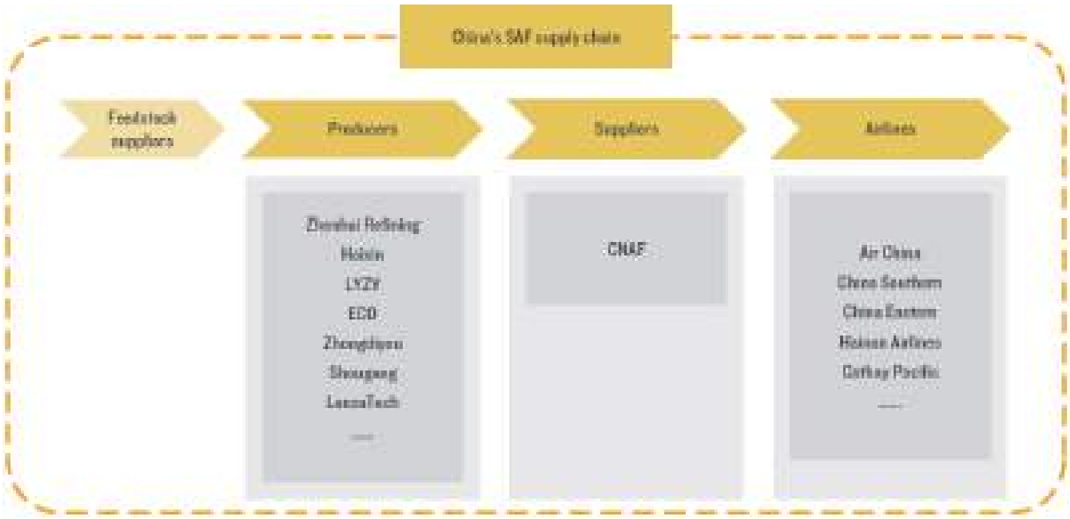
Over the next 18 months, Chinese biofuel companies aim to establish facilities capable of producing more than 1 million tonnes of SAF annually. This output would represent approximately 2.5% of China’s current annual aviation fuel demand. These projects will utilise used cooking oil (UCO), which is currently being exported, with companies such as Junheng Industry Group Biotech, Zhejiang Jiaao Enprotech, and Tianzhou New Energy leading the efforts.

In 2023, China exported a record 2.05 million tonnes of UCO, mainly to the USA and Singapore. For instance, Tianzhou New Energy is constructing a 200,000 tonnes-per-year SAF plant in Sichuan and has been in discussions with airlines and major oil companies for initial exports.

Currently, China produces less than 100,000 tonnes of SAF, primarily from a facility operated by EcoCeres. Companies anticipate a government mandate for a 2% to 5% blend of SAF in aviation fuel by 2030, potentially increasing SAF consumption to around 2.5 million tonnes, a significant rise from the 50,000 tonnes target set for 2025. Although this target is modest compared to the EU and Japan’s goals of 6% and 10%, respectively, it represents substantial progress for China.

Figure 16: China’s SAF supply chain [40]

[40] Peking University. (2022). *Sustainable Aviation Fuel: Challenges and Opportunities in China.* Retrieved from https://energy.pku.edu.cn/docs/2022-10/bc31f41c450d46e4bbea5a33c8aeab40.pdf



Source: Peking University

Chinese SAF production cost

As of July 9 in 2023, Platts, part of Commodity Insights, assessed SAF production costs in Southeast Asia at $1,585.51/mt, down $16.45/mt from the previous assessment.

SAF Actions in China from 2025-2050

- Fuel suppliers provide cost-competitive SAF on a large scale.
- Certify and approve more technical pathways for producing SAF to accelerate SAF development and uptake.
- Airport operators provide the necessary infrastructure to supply SAF in a more affordable and efficient manner.

Chinese policies related to the promotion and use of SAF

- **14th Five-Year Plan (FYP) for Green Civil Aviation Development:** Achieve breakthroughs in promoting the commercial use of SAF, with an aim to raise SAF consumption to over 20,000 tons in 2025 and cumulatively to 50,000 tons during the 14th FYP period; establish an expected goal for reducing fuel use and reducing carbon emissions—reducing fuel consumption per ton kilometer for air transport fleet to 0.293 kg and CO2 emissions per ton kilometer for air transport to 0.886 kg.
- **14th FYP for Bioeconomy Development:** The Plan points out that areas with good conditions are encouraged to promote and pilot the use of biodiesel and advance the demonstrative use of aviation biofuels.
- **14th FYP for Renewable Energy Development**: Scale up efforts to develop non-food liquid biofuels and support the R&D and promotion of advanced technology and equipment for biodiesel and aviation biofuel production.

2.5.7. Japan

Japan has committed to achieving net-zero emissions by 2050 and has set an ambitious target for Sustainable Aviation Fuel (SAF) to constitute 10% of its jet fuel by 2030, in support of decarbonising its aviation industry. Significant progress has been made in the development of SAF within the country[41]. Notably, in September 2018, the JAL Group made the first Japanese investment in a SAF production business by investing in Fulcrum BioEnergy. This marked a key milestone in Japan's SAF journey[42].

Japan's first SAF-powered flight took place on 4 February 2021, using fuel derived from cotton clothing, demonstrating the country's domestic capabilities in SAF production. In line with its ambitions, Japan has proposed to replace 10% of its jet fuel demand with SAF by 2030, amounting to 1.71 million kilolitres (451 million gallons), with plans to introduce relevant regulations by mid-2024.

Although continuous commercial-scale production of SAF is yet to be established, Japan's advancements in this area are noteworthy. The aforementioned SAF-powered flight on 4 February 2021, which powered a Boeing 787-8 aircraft, highlighted Japan's potential to develop a robust SAF ecosystem using domestic technology. Establishing such an ecosystem could significantly reduce emissions, enhance energy security, and promote economic growth, while ensuring sustained connectivity and social benefits.

Japan's commitment to the production and adoption of SAF not only contributes to the global goal of decarbonising aviation but also holds substantial economic value and potential for bolstering energy security.

Existing Policy and Regulatory Framework

In October 2020, Japan committed to carbon neutrality by 2050, with an interim goal of reducing greenhouse gas emissions by 46% by 2030 compared to 2013 levels. To support these goals, the Ministry of Economy, Trade, and Industry (METI) developed the "Green Growth Strategy Through Achieving Carbon Neutrality in 2050." A key focus of this strategy is reducing emissions from Japan’s aviation sector through the adoption of SAF.

In April 2022, METI and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) launched a public-private partnership to promote reliable domestic SAF production. By October 2022, MLIT published the Basic Policy for Promoting Decarbonisation of Aviation, which sets three key targets:

1. Stabilizing CO2 emissions from international flights.
2. Reducing CO2 emissions per unit transport from domestic flights by 16% by 2030.
3. Achieving carbon neutrality for all flights by 2050.

In alignment with these goals, METI plans to have SAF replace 10% of jet fuel by 2030.

Government Support for SAF Development

[41] ICF. (2024). SAF Ecosystem in Japan. Retrieved from: https://www.icf.com/insights/aviation/saf-ecosystem-in-japan
[42] Japan Airlines (JAL). (n.d.). Sustainable Aviation Fuel (SAF). Retrieved from: https://www.jal.com/en/sustainability/environment/climate-action/saf/

The Japanese government has actively promoted carbon-reducing innovations through funding mechanisms like the Green Innovation Fund with a budget of 2 trillion yen (approximately USD 14.4 billion). Managed by the New Energy and Industrial Technology Development Organization (NEDO), this fund supports the research, development, and commercialization of innovative projects, with SAF being a key focus.

Under this fund, NEDO awarded 114.5 billion yen (approximately USD 830 million) in grants for pilot projects to develop SAF and other sustainable fuels. Additionally, METI allocated 5.18 billion yen (approximately USD 37.4 million) to NEDO for biofuel technology and development projects. Achieving the 10% SAF target by 2030 will depend on these funding mechanisms to advance and de-risk the SAF industry.

Table 5: Policy options targeted at stimulating the growth of SAF supply[43]

Policy Option	Description
Capital Grants	A government grant is given to an entity to build or buy SAFspecific infrastructure. Capital grants reduce the financial needs and financial risks of the targeted investment. (e.g., US Department of Energy (DOE) Loan Program Office)
Loan Guarantee Programs	A loan backed by a government institution helps the project's financial case and also reduces overall project risk, making acquiring additional equity of debt easier and lowering the cost of capital.
Business Investment Tax Credits (ITC)	An ITC allows the deduction of construction and/or commissioning costs of a qualifying asset which can reduce income tax payable and flow through the investors.
Blending Tax Credit (BTC)	An incentive targeted at the providers or blenders of fuel that provides a credit against taxes. This mitigates the blender’s cost of production or purchase difference between SAF and fossil jet. (e.g., US State-level BTC in Illinois and Washington)
Production Tax Credit (PTC)	An incentive targeted at the producers of fuels that provides a credit against taxes. This mitigates the cost of production difference between SAF and fossil jet. (e.g., US Inflation Reduction Act (IRA) Clean Fuel Production Tax Credit (CFPC))
Recognizing SAF benefits under carbon taxation and cap-and-trade systems	Where a jurisdiction has introduced a carbon tax, carbon price, or carbon levy, SAF could be rated as either zero or in proportion to the life-cycle greenhouse gas emissions benefit of the particular fuel, thereby subject to reduced tax. This differs from a cap-and-trade system by not stipulating an overall emission reduction target.

[43] ICAO Commmittee

Estimated SAF Production Potential

ICF assessed Japan's SAF production potential based on domestic feedstock availability, with three scenarios:

- **Low Scenario:** 0.3 million kiloliters (95 million gallons) of SAF by 2030, increasing to 3.3 million kiloliters (883 million gallons) by 2050.

- **Mid Scenario:** 0.7 million kiloliters (193 million gallons) by 2030, increasing to 7.5 million kiloliters (1975 million gallons) by 2050.

- **High Scenario:** 1.67 million kiloliters (441 million gallons) by 2030, increasing to 11 million kiloliters (2911 million gallons) by 2050.

In the short term, only the high scenario approaches the 10% SAF target by 2030. However, by 2050, over 80% of Japan's jet fuel demand could be met with domestic feedstocks, such as municipal solid waste (MSW) and renewable electricity. While these feedstocks offer low carbon intensity and significant emissions reduction potential, the required conversion technologies are not yet commercially developed, posing a challenge for short-term SAF production.

3. Valuation of the Emerging SAF Market from a Strategic Approach

This section aims to analyse the competitive conditions of the air transport market underlying the investment decisions related to SAF or, in other words, the competitive framework for investment planning on SAF development and deployment.

The aviation market is highly competitive and globalised. At the European level, it is considered one of the best integrated in the Single Market. In this context, ReFuelEU aims to stimulate the deployment of SAF without lowering either the level of competitiveness or the market integration.

Moreover, jet fuels are a niche market in producing transport fuels. Their price is a critical factor in the competitiveness of the aviation value chain. At the same time, they must meet stringent safety and energy efficiency requirements. On these competitive premises, it is assumed that Investment in research and development to improve SAF production efficiency and advancements in feedstock technologies will significantly contribute to sector growth.

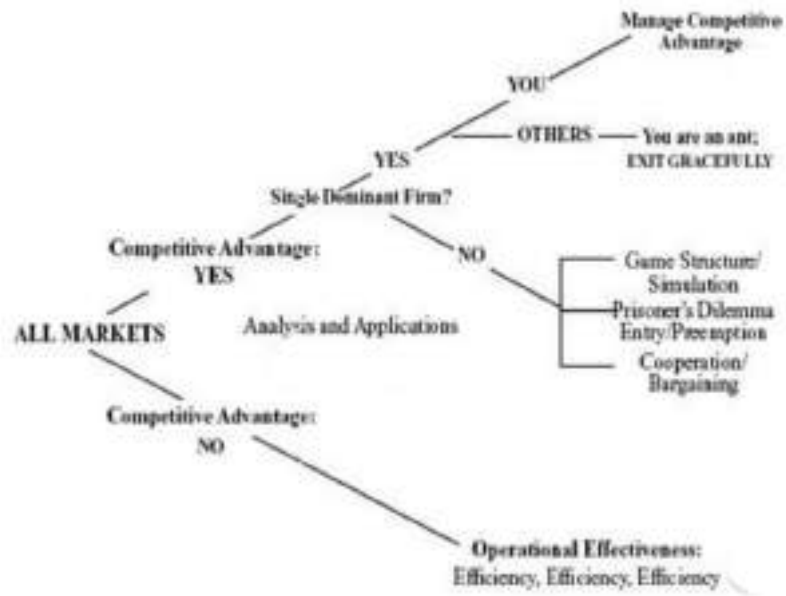
Nevertheless, investment has its own competitive rules. Investors decide what and whom to invest in according to profit expectations, return period, and risk. For this reason, the lens through which capital investors analyse the market value of SAF innovation differs from that of public policy. **The normative approach logically prioritises the preservation of the conditions for free competition market rules, while the investment seeks to assess if the market conditions will enable sustained economic profitability over a long-run period.**

There are different models for analysing the competitive environment of an industry or an entire value chain. The most renowned is Michael Porter's Five Forces[44] framework). IATA has used this to analyse the value creation across the aviation value chain (IATA Economics Report, 2022)[45]. This report will also draw on the results of the baseline quantitative analysis conducted by McKinsey & Company included in this IATA analysis.

However, Michael Porter's model is too complex for analysis at the 'micro' level of investment. For this level, the model provided by Greenwald and Kahn (Greenwald and Kahn (2005): "Competition Demystified: A Radically Simplified Approach to Business Strategy", English Edition) is a more practical tool.

Greenwald and Kahn address their model toward assessing and formulating strategic planning that sustains profitability over a long-run period, as required by capital investment. To resume Porter's five forces, they suggest focusing on barriers to entry (see fig. 22) and their three primary sources: supply, demand, and economies of scale. Depending on such competitive advantages, investors can assess a company's or project's value and proficiency more accurately than based on uncertain cash-flow projections exclusively.

Figure 17:



"Strategic planning" can be crucial in successfully transferring any SAF technological development to the market because SAF shall gradually replace conventional jet fuels. The phasing-in envisaged by the SAF mandates means that SAF will co-exist with fossil fuels for a long time, and blending will be standard practice. Assessing the competitive conditions will allow us to detect barriers to entry in the aviation value chain and their impact on the deployment of clean fuels.

On the other hand, operational effectiveness and quality management remain the most significant market rule, to the extent that "the relatively high-cost supplier with no captive customers should see that it cannot expect to gain any advantage through strategic

[44] The five forces are: "Competitive Rivalry", "Threat of New Entrants", "Bargaining Power of Suppliers", "Bargaining Power of Buyers", "Threat of Substitutes".

alliances, competitive threats, or other means. That's because, if the market is configured efficiently, such a supplier has really no role to play." (G&K, p.16)

According to Greenwald and Kahn, barriers to entry are characteristics of the structural economics of a particular market. In this market, the incumbent companies benefit from competitive conditions that new entrants cannot. The authors distinguish between incumbent (barriers) and entrant conditions (competitive advantages). The latter are situations in which the latest firm to arrive in the market enjoys an edge. In such a case, the benefit of the latest generation of technology, the hottest product design, no costs for maintaining legacy products or retired workers. Nevertheless, the authors conclude that entrant competitive advantages are limited and transitory. (G&K, pp. 26 y 27).

The model consists of analysing three sources of barriers to entry or competitive advantages:

- Supply (cost advantages) and demand (product differentiation and branding).
- Economies of scale and customer captivity.
- External: government protection and superior access to information in financial markets.

Except for government protection, sources of competitive advantages are rooted in fundamental economic conditions.

Underlying these concepts, the differential aspect of this approach is this one: in terms of profitability and operational effectiveness, "the powerful driving force is the dynamics of entry and exit, not the distinction between commodities and differentiated products." (G&K, p. 25)

Another significant assertion from this approach is that growth favours the incumbent barriers to entry.

Therefore, identifying barriers to entry and understanding how they operate, can be created, and are defended is critical to assessing the chances of SAF investment and formulating a strategic plan more accurately. This section introduces the features of the aviation value chain to check whether incumbent barriers to entry exist and the current situation of SAF in aviation. It concludes with final insights on the competitive conditions for SAF.

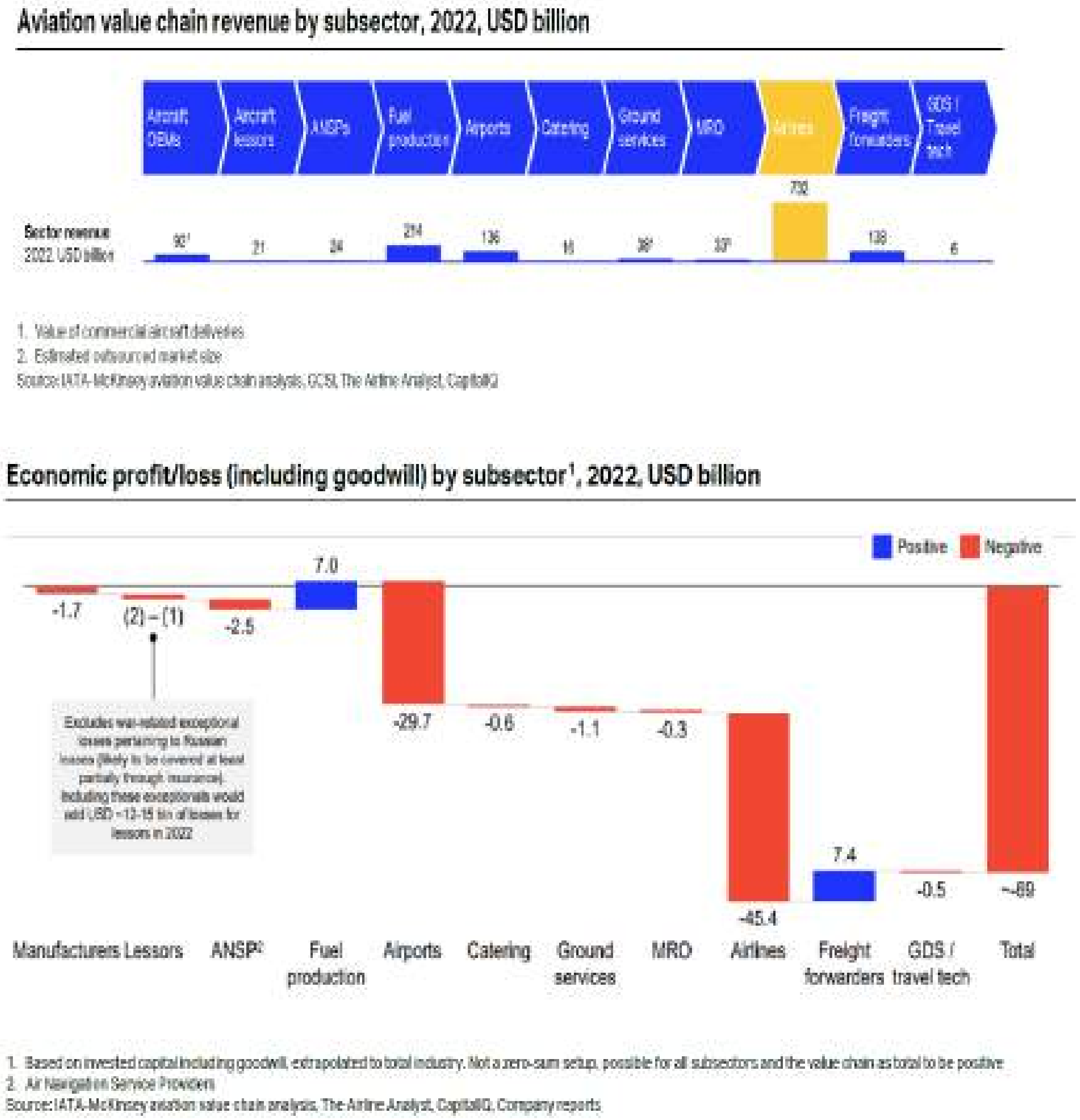
3.1. A quick overview of the Aviation Value Chain

According to the IATA economic report for 2022, the network of actors involved in the aviation value chain enables 4.5 billion passengers to travel safely and efficiently worldwide. In terms of revenue, the airline industry was the most significant subsector, with USD 732 billion in 2022, continued by fuel production companies at USD 214 billion, freight forwarders at USD 138 billion, and airports at USD 136 billion. With the addition of the other subsectors, the total revenue amounted to USD 1.450 billion in 2022. The sector was still recovering from the COVID-19 pandemic, and the value chain remained loss-making, generating a total economic loss of USD 69 billion. Fuel production and freight forwarders were the only two subsegments with economic benefits estimated at USD 7.4 billion and USD 7 billion, respectively. (REF IATA, 2022)

According to the same source, the entire Aviation Value Chain covers aircraft and engine original equipment manufacturers (OEMs); lessors; airports; air navigation service providers (ANSPs); ground handlers; maintenance, repair and maintenance repair, and overhaul (MRO) providers; catering companies; airlines (carriers; global distribution systems (GDSs); freight forwarders and, downstream fuel producers.

The two charts below show the revenue and the economic profit/loss distribution by subsector in detail:

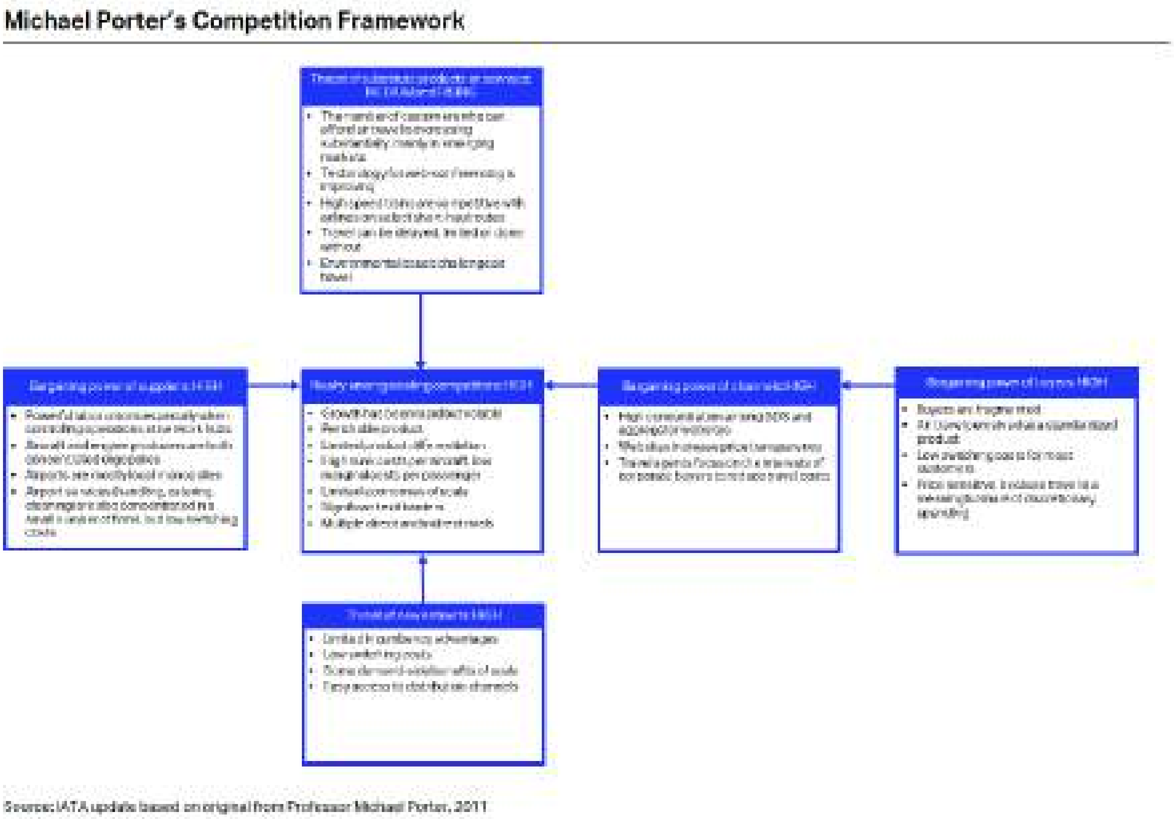
Figure 18: The revenue and the economic profit/loss distribution by subsector in detail



Source: IATA

As the report's authors point out, the inequality of returns between airlines and other actors in the value chain is a system-wide issue, affecting either the supply chain or the industry structure, if not both. IATA uses Michael Porter's framework to analyze the competitive aviation environment to find an explanation. (IATA, 2022, p. 8)

Figure 19: Michael Porter's Competition Framework:



Source:IATA

The conclusions are that risk is unevenly distributed along the value chain, with the airlines bearing much of it and struggling to deliver returns to their investors that would be commensurate with that risk. Unfortunately, this weakens the entire value chain. The airline market is fragmented and unconsolidated cross-regional compared to many other industries. Many countries have ownership limits that restrict foreign ownership of local airlines. Consequently, the movement of capital is stifled, adding a barrier to cross-border consolidation. Consolidation could, in theory, lead to better network management, cost savings, and improved load factors. A further issue without an apparent solution is the monopolistic and oligopolistic pricing power in the upstream supply chain. At the other end of the supply chain, airlines should find ways to compete on factors other than price. (IATA, 2022, p.9)

In a way, Europe has a good opportunity to allow new players and new technologies get into the European SAF supply chain. European Airlines are building its own pipelines of SAF suppliers aiming to diversify risk, secure the offtake and also access more competitive SAF. This wider pipeline of suppliers, commercial airlines have higher negotiation power and at the end of the day, more choices that could give them a competitive advantage versus other commercial airlines with limited or few SAF suppliers and therefore lower power of negotiation.

At European level, it is crucial to continue attracting foreign technologies that could accelerate the production of SAF in Europe and support the newcomers facing strong entry barriers to deploy and produce SAF (i.e. high CAPEX, pilot projects being implemented, complexity of the current economic content, challenges to close the financing rounds, etc). This SAF Age in Europe, could certainly be an opportunity to rejuvenise and reinforce the European traditional industrial fuel ecosystem.

At the same time, newcomers in the SAF supply in Europe have to be supported at every level of the project and particularly, in the investment phase. In average, the cost of implementing a SAF facility could involve hundreds of millions. Reinforcing direct support for the implementation of the investment phase is critical and urgently needed.

Funding schemes that support the purchase of assets/equipment for the development of SAF sites in Europe could contribute to derisk projects and increase the appetite for other investors to join the project.

3.2. An assessment of the competitive issues at stake

In the market context described in the previous point, mandates on SAF involve a gradual but total (or almost) shift in the air transport market. The aviation industry competes intensively on price but also with significant negative environmental externalities. Air transport contributes to global warming through CO2 emissions and "non-CO2 effects," including NOx, sulfur, water vapour, and the formation of contrails. Mandates are a way to compel the aviation market players to reduce such externalities. Therefore, the air transport market needs to urgently adapt its levels of efficiency to address these environmental concerns.

According to the World Economic Forum recommendations, blending mandates are “policies aimed at creating long-term, predictable demand to de-risk investments in supply chains, which are key levers for widespread SAF deployment”. (ref WEF, 2021).

Furthermore, as part of this global policy, it is clearly stated in the recitals of the ReFuelEU that the EU’s primary concern is “restoring and preserving a level playing field on the Union air transport market as regards the use of aviation fuels” and “in a second instance” (…) to ensure that SAF is introduced at Union airports “without detrimental effects on the competitiveness of the Union air transport market.”(ref. ReFuelEU). These measures are addressed to avoid divergent requirements across the Union that could exacerbate refuelling practices, distorting competition between aircraft operators or putting some Union airports at a competitive disadvantage with others.

Therefore, it is relevant to analyse, through a Strategic approach, how the actual competitive conditions (if barriers to entry exist) in the segments of the aviation value chain influence decisions to invest in SAF and how mandates such as ReFuelEU will impact them. The analysis will concentrate on those the SAF production directly impacts: Aviation fuel suppliers, the airline industry, Airports, and Aircraft Manufacturers. Coincidentally, these segments are where the sector's returns are concentrated.

3.2.1. Key players in the Aviation Fuel Suppliers segment

3.2.1.1. Who's who

The Aviation Fuel Suppliers sector consists of a small number of downstream oil and gas companies competing at the global level. Jet fuels are just one part of its product portfolio, but it is considered one of the most remunerative.[46]

The Ten Top World Companies in the jet fuel market

- **Exxon Mobil Corporation.**

ExxonMobil is a prominent global supplier of aviation fuels, with over 120 years of experience in delivering high-quality fuel to the aviation industry. The company is actively investing in the development and supply of Sustainable Aviation Fuel (SAF) and has already begun distributing SAF to customers in key markets such as France, Singapore, and the UK. ExxonMobil currently supplies major airport hubs across 13 countries and produces aviation fuel at more than 10 refineries worldwide.[47] The company's efforts in SAF development are part of a broader strategy to support the aviation industry's sustainability goals and reduce its carbon footprint.

- **BP plc.**

Air BP, the aviation division of BP, is one of the largest global suppliers of aviation fuel, providing over seven billion gallons of jet fuel and aviation gasoline annually to customers worldwide. BP is a proactive participant in the SAF market, partnering with Fulcrum BioEnergy to produce SAF from municipal waste. This collaboration aims to scale up SAF production as part of BP's broader commitment to sustainability and reducing carbon emissions in aviation. BP's extensive global network allows it to distribute SAF efficiently, supporting the aviation industry's shift towards more sustainable fuel options.

Each year, Air BP supplies over seven billion gallons of jet fuel and aviation gasoline to customers worldwide.[48]

- **Chevron Corporation.**

Chevron is one of the world's leading integrated energy companies, with a strong commitment to advancing the production and use of Sustainable Aviation Fuel (SAF). The company has made significant investments in SAF production through partnerships with companies like Gevo[49], a key player in renewable fuel technology. In 2021, Chevron's El Segundo Refinery became the first in the United States, and among the first globally, to consistently co-process biofeedstock to produce gasoline, jet fuel, and diesel with renewable content and reduced carbon intensity. This moves underscores

[46] "Refining a barrel of crude oil results in a variety of products. Jet fuel is one of them, and on average it represents 8% of refined output. Jet fuel was the most expensive refined product in 2022." (IATA Economic Report, 2022, p. 6)
[47] ExxonMobil. (n.d.). *Sustainable aviation fuel: White paper.* Retrieved from https://corporate.exxonmobil.com/-/media/global/files/energy-and-innovation/sustainable-aviation-fuel-white-paper.pdf
[48] BP. (n.d.). BP announces investment of $30 million in biojet producer Fulcrum. Retrieved from https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-announces-investment-of-30-million-in-biojet-producer-fulcrum.html
[49] Chevron. (2021). Chevron and Gevo announce intent to pursue sustainable aviation fuel investment. Retrieved from https://www.chevron.com/newsroom/2021/q3/chevron-gevo-announce-intent-to-pursue-sustainable-aviation-fuel-investment

Chevron's broader strategy to lower the carbon footprint of its products and contribute to the decarbonisation of the aviation sector. [50]

- **Shell plc.**

Shell is a major global supplier of aviation fuel and is deeply involved in the development and distribution of Sustainable Aviation Fuel (SAF). Shell has invested in SAF production through partnerships with innovative companies such as LanzaTech[51] and Chemicals Park Rotterdam[52]. These partnerships are central to Shell's strategy of enhancing the availability of SAF and supporting the decarbonisation goals of the aviation industry. By leveraging its global infrastructure and expertise, Shell is actively working with airlines and airports to integrate SAF into the fuel supply chain, thereby promoting wider adoption of sustainable fuels.

- **TotalEnergies SE**

TotalEnergies is a major player in the global energy sector, with a strong commitment to expanding its portfolio to include Sustainable Aviation Fuel (SAF) production. The company is proactively addressing the growing demand for SAF from its aviation clients and aims to produce 500,000 tonnes of SAF annually by 2028. This production capacity will be crucial in meeting the European SAF blending requirement, targeted at 6% by 2030, and supporting the aviation industry's transition to more sustainable fuel options[53].

- **Gazprom Neft PJSC.**

Gazprom Neft PJSC is a major Russian oil company and a subsidiary of Gazprom. While traditionally focused on oil production and refining, Gazprom Neft is exploring the production of Sustainable Aviation Fuel (SAF). The company is conducting research to integrate SAF into its existing operations, aligning with global efforts to reduce carbon emissions. Although still in the early stages, Gazprom Neft aims to play a role in the Russian and regional SAF markets as it develops its capabilities in this area.

- **Indian Oil Corporation.**

Indian Oil Corporation is India's largest oil company and a significant player in the energy sector. The company is actively exploring the production of SAF as part of its broader sustainability initiatives. Indian Oil is investing in research and development to produce SAF from indigenous feedstocks, aiming to support India's commitment to reducing aviation emissions.

- **Bharat Petroleum Corp. Ltd.**

Bharat Petroleum Corporation Ltd. (BPCL), another major Indian oil company, is also involved in the exploration of SAF production. BPCL is focusing on leveraging its refining and distribution capabilities to develop and supply SAF, contributing to the aviation sector's transition to greener fuels in India.

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[50] Chevron. (2022). Sustainable aviation fuel prepares for takeoff. Retrieved from https://www.chevron.com/newsroom/2022/q2/sustainable-aviation-fuel-prepares-for-takeoff#:~:text=We%20also%20announced%20a%20letter,inedible%20corn%20to%20produce%20SAF

[51] Biofuels News. (2024). Shell invests in LanzaJet in drive to produce more SAF. Retrieved from https://biofuels-news.com/news/shell-invests-in-lanzajet-in-drive-to-produce-more-saf/

[52] Shell. (2024). Shell to temporarily pause on-site construction of European biofuels facility. Retrieved from https://www.shell.com/news-and-insights/newsroom/news-and-media-releases/2024/shell-to-temporarily-pause-on-site-construction-of-european-biofuels-facility.html

[53] TotalEnergies. (2023). Paris Air Show: TotalEnergies committed to the production of sustainable aviation fuel. Retrieved from https://totalenergies.com/media/news/press-releases/paris-air-show-totalenergies-committed-production-sustainable-aviation

- **Qatar Jet Fuel Company.**

Qatar Jet Fuel Company (Q-Jet) is a key supplier of aviation fuel in the Middle East. While its current focus is on traditional jet fuel, there is growing interest in SAF as part of Qatar's broader sustainability and energy transition goals. Q-Jet is positioned to play a crucial role in supplying SAF to airlines in the region as demand increases.

- **Allied Aviation Services Inc.**[54]

Allied Aviation Services Inc. is a leading provider of aviation fuel services in North America. The company is exploring the integration of SAF into its operations as part of its commitment to sustainability. Allied Aviation is well-positioned to support the distribution and adoption of SAF across the airports it serves, contributing to the reduction of carbon emissions in the aviation sector.

The Ten Top European Companies in the jet fuel market

- **Shell plc.**

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- **BP plc.**

Air BP, the aviation division of BP, is one of the largest global suppliers of aviation fuel, providing over seven billion gallons of jet fuel and aviation gasoline annually to customers worldwide. BP is a proactive participant in the SAF market, partnering with Fulcrum BioEnergy to produce SAF from municipal waste. This collaboration aims to scale up SAF production as part of BP's broader commitment to sustainability and reducing carbon emissions in aviation. BP's extensive global network allows it to distribute SAF efficiently, supporting the aviation industry's shift towards more sustainable fuel options.

Each year, Air BP supplies over seven billion gallons of jet fuel and aviation gasoline to customers worldwide.[57]

- **TotalEnergies SE.**

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[54] Jet Fuel Companies - Top Company List - Mordor Intelligence. Jet Fuel Market - Size, Trend & Forecast Industry - Mordor Intelligence. Jet Fuel Global Market Report 2024 - Research and Markets

[55] Biofuels News. (n.d.). Shell invests in LanzaJet in drive to produce more SAF. Retrieved from https://biofuels-news.com/news/shell-invests-in-lanzajet-in-drive-to-produce-more-saf/

[56] Shell. (2024). Shell to temporarily pause on-site construction of European biofuels facility. Retrieved from https://www.shell.com/news-and-insights/newsroom/news-and-media-releases/2024/shell-to-temporarily-pause-on-site-construction-of-european-biofuels-facility.html

[57] BP. (n.d.). *BP announces investment of $30 million in biojet producer Fulcrum*. Retrieved from https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-announces-investment-of-30-million-in-biojet-producer-fulcrum.html

and aims to produce 500,000 tonnes of SAF annually by 2028. This production capacity will be crucial in meeting the European SAF blending requirement, targeted at 6% by 2030, and supporting the aviation industry's transition to more sustainable fuel options[58].

- **Gazprom Neft PJSC.**

Bharat Petroleum Corporation Ltd. (BPCL), another major Indian oil company, is also involved in the exploration of SAF production. BPCL is focusing on leveraging its refining and distribution capabilities to develop and supply SAF, contributing to the aviation sector's transition to greener fuels in India.

- **Neste Oyj.**

Neste is a leading producer of renewable diesel and Sustainable Aviation Fuel (SAF) and is investing in expanding its SAF production capacity. The company is committed to increasing the availability of SAF to meet the growing demand from airlines and other aviation stakeholders. Neste's focus on sustainability and innovation positions it as a major player in the global SAF market, driving forward the transition to lower-carbon aviation.

- **Rosneft Deutschland GmbH.**

Rosneft Deutschland GmbH is a subsidiary of the Russian energy giant Rosneft, focusing primarily on the refining and distribution of petroleum products in Germany. While Rosneft's core business has traditionally been in fossil fuels, the company has shown interest in the production of alternative fuels, including SAF. Through its operations in Europe, Rosneft is exploring the integration of renewable energy sources into its portfolio, aligning with broader industry trends toward decarbonization. However, the company's SAF initiatives are still in the early stages, with a focus on research and potential partnerships.

- **OMV Group.**

OMV Group, based in Austria, is a leading integrated oil and gas company with a strong commitment to sustainability and energy transition. OMV has been actively involved in the development and production of SAF as part of its broader strategy to reduce carbon emissions. The company has partnered with airlines and other stakeholders to produce SAF using advanced biofuel technologies, particularly through the hydroprocessing of esters and fatty acids (HEFA). OMV's Schwechat refinery plays a central role in these efforts, where the company is scaling up SAF production to meet growing demand in the aviation sector.

- **Repsol S.A.**

Repsol S.A., headquartered in Spain, is an integrated global energy company with a significant focus on renewable energy and low-carbon initiatives. Repsol has committed to producing SAF as part of its ambition to achieve net-zero emissions by 2050. The company is investing in advanced biofuels and exploring innovative technologies, such as waste-to-fuel and hydrogen-based processes, to produce SAF. Repsol is working

[58] TotalEnergies. (2023). *Paris Air Show: TotalEnergies committed to the production of sustainable aviation fuel*. Retrieved from https://totalenergies.com/media/news/press-releases/paris-air-show-totalenergies-committed-production-sustainable-aviation

closely with airlines and regulatory bodies in Spain and across Europe to support the adoption of SAF and reduce the aviation industry's carbon footprint.

- **Lukoil.**

Lukoil, one of Russia's largest oil companies, has been traditionally focused on the production and refining of fossil fuels. However, in response to global trends towards sustainability, Lukoil has started exploring opportunities in the production of renewable fuels, including SAF. The company is looking into leveraging its extensive refining capabilities to produce SAF from various feedstocks, including biomass and waste materials. While still in the developmental phase, Lukoil's involvement in SAF represents a step towards diversifying its energy portfolio and contributing to the global effort to reduce aviation emissions.

- **Eni S.p.A**.[59]

Eni S.p.A, an Italian multinational oil and gas company, has made significant strides in the field of sustainable energy, particularly in the production of SAF. Eni is at the forefront of the transition to renewable energy in Italy, with a focus on biofuels and advanced refining processes. The company has converted several of its traditional refineries into biorefineries, capable of producing SAF from waste and residual feedstocks. Eni's biorefinery in Gela, Sicily, is one of the largest in Europe and plays a crucial role in its SAF production strategy. Eni collaborates with various airlines and industry partners to promote the use of SAF and achieve the aviation sector's decarbonization goals.

Notwithstanding this product differentiation, corresponding to their position in the value chain, jet fuels should be considered a commodity (cost-efficiency matters above all) rather than a differentiated product (efficiency is a matter of both production cost control and marketing strategy effectiveness). However, this industry segment traditionally manages putting downward pressure on airlines' financial and economic profitability.[60]

Long-run stability in the average returns and concentration in few companies with global dimensions call for assuming robust barriers to entry in the fuel suppliers segment play a significant role in the Aviation Value Chain. Nevertheless, there is not a single dominant company.

Therefore, SAF deployment requires reaching equal competitive effectiveness in costs to conventional jet fuel. However, it is also paramount to consider how these barriers to entry react to mandates like ReFuel EU.

Of course, SAF mandates open the door to new companies as SAF providers. SAF production involves the application of advanced technological know-how and industrial practices other than refining from the renewable energy and waste treatment sectors. The correct management and operational effectiveness of SAF technological innovation can give entrant companies a competitive advantage. However, the co-existent period with conventional jet fuels also means the need for blending facilities.

Given that the SAF production subsegment is still in its take-off stage, it is challenging to say what the final reconfiguration of the value chain will be in terms of profitability and

[59] Idem supra.
[60] Even since the outbreak of the war in Ukraine, when the price of crude oil increased by 44%, the jet fuel crack spread (the difference between the refined product and the crude oil price) spiked in 2022 due to refining capacity closures in 2020 and 2021. (Id., p. 6).

effectiveness. Here the Strategic Analysis provides a better understanding of the interactions at play and what technological solutions can be expected to prevail.

Because none of the incumbent aviation fuel suppliers dominates the market, the strategic options for them to plan investments are divided between single acting through “game structure/simulation” or “Prisioner’s Dilemma Entry Preception”, and collective acting as “cooperation/bargaining”.[61]

A quick review of the strategic partnerships behind innovative firms in SAF reveals the extent to which incumbent fuel suppliers engage in cooperative strategies with each other and/or new entrant firms.

On the other hand, whatever the evolution of the competitive conditions related to the incumbent barriers to entry and the competitive advantage from SAF innovation, operational cost-effectiveness of production will continue to play an essential role in blending practices and the price that can be imposed on the downstream value chain.

3.2.1.2. Competitive conditions in Prices & Quality Standards

- **Jet Fuel Prices in Europe**

According to the information of IATA, the average price of jet fuel stood at 2.47 USD/gallon on 19 July 2024, a 4% decrease compared to the level of two weeks ago.

Figure 20: Jet fuel price in Europe:

Source: European Union Aviation Safety Agency (EASA)

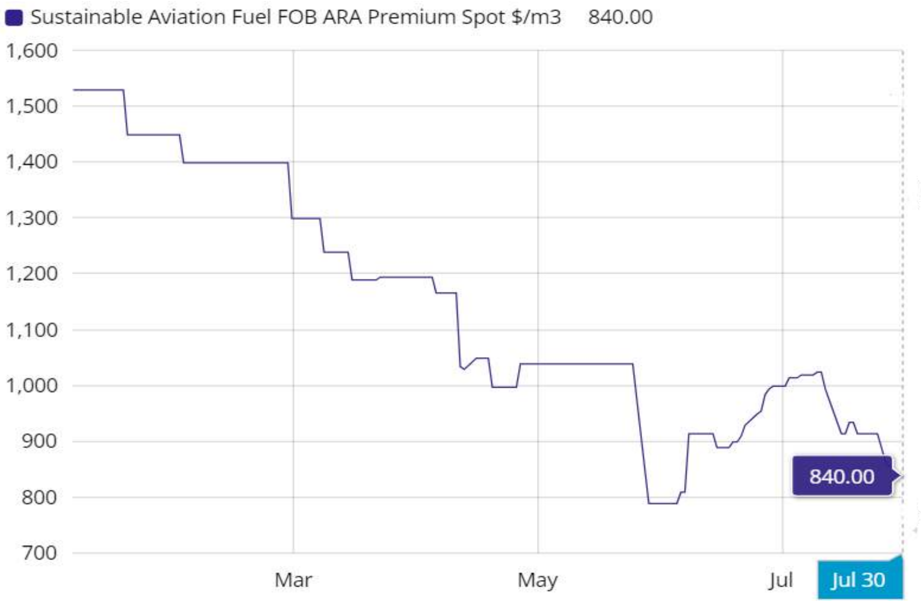
- **SAF Price evolution in Europe**

According to Quantum Commodity Intelligence, the SAF FOB ARA premium price experienced a significant decline from 25 July to 30 July, dropping by $50/m³ and

[61] For further explanation of these strategic choices, see G&K book, pp.

stabilising at \$840/m³. This trend indicates a decreasing cost for Sustainable Aviation Fuel (SAF) in the ARA region during this period.

Figure 21: Sustainable Aviation Fuel FOB ARA[62] Premium Spot[63] \$/m3 (2024):



Source: Quantum Commodity intelligence

Price Trend:

- On 25 July, the SAF FOB ARA premium price was \$890/m³.
- It fell by \$25/m³ to \$865/m³ on 26 July.
- The price decreased again by \$25/m³ to \$840/m³ on 29 July and remained stable at this level on 30 July.

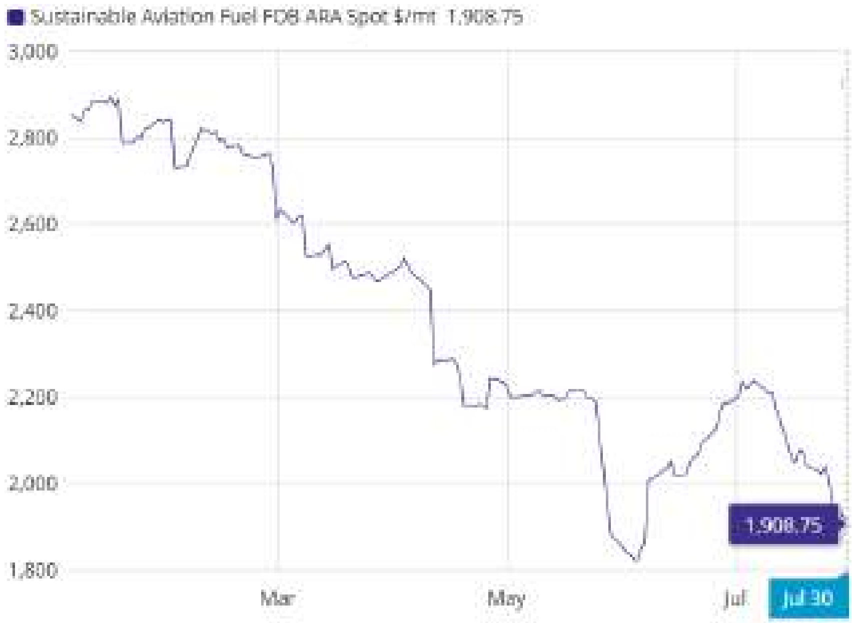
Additionally, this SAF meets ASTM D7566 specifications and achieves a minimum of 80% greenhouse gas savings compared to a baseline of 94 g CO_2e/MJ for fossil fuels.

Currently there are two standards of SAF in the market, they are bellow:

- The ASTM D7566 Standard[64]
- The ASTM D4054 Standard

Figure 22: Sustainable Aviation Fuel FOB ARA Spot \$/mt (2024):

[62]ARA Refers to the Amsterdam-Rotterdam-Antwerp region, a major hub for oil trading and storage in Europe.
[63] The spot price is the current market price for a commodity, reflecting real-time supply and demand conditions.
[64] ASTM International. (2022). ASTM D7566-22a: Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. Retrieved from: https://www.astm.org/d7566-22a.html



Source: Quantum Commodity intelligence

The spot price of Sustainable Aviation Fuel (SAF) has demonstrated a consistent downward trend over the last week of July. Beginning at $2,007.75 per metric tonne on 25 July, the price gradually declined to $1,958.25 per metric tonne on 26 July, followed by further decreases of $36.25 to $1,922.00 on 29 July and $13.25 to $1,908.75 on 30 July. As of 31 July, the price data is not yet available, indicating that it may still be pending. This overall reduction of $99.00 per metric tonne highlights the changing market dynamics for sustainable aviation fuels during this period.

3.2.2. Airlines and Airports segments

3.2.2.1. Who's who for investment

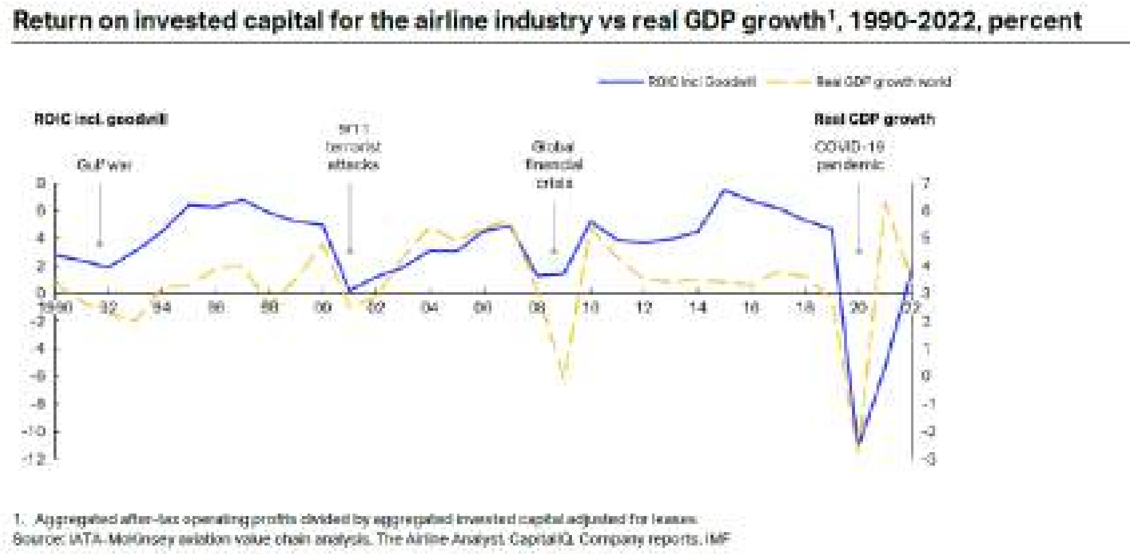
- **Airlines**

In Graham's book "The Intelligent Investor", the airline industry was already presented "a vale of tears." Things have not changed 75 years later. Although the airline industry is the largest building block of the aviation value chain, it is also the worst performer, and its risk profile for investment remains highly challenging.

In the opposite direction to the aviation fuel suppliers, airlines' historic expansion in line with global economic growth has never translated into sustained profitability. Airlines have barely managed to avoid substantial losses occasionally. They are highly exposed to external macro-economic factors (including fuel prices, geopolitical considerations, and natural disasters) on both the revenue and cost sides. This situation is similar to all types of flight services to transport passengers: "full service", "low-cost", and "regional" carriers. Cargo carriers (freight forwarders) are an exception to this high vulnerability; they have a stable average return.

According to IATA's latest statistics, over the past 30 years, the return on invested capital (ROIC) for the airline industry and the real GDP growth rate have shown a positive correlation. Nonetheless, all major global shocks harmed this ROIC, showing that the airline industry is truly global.[65]

Figure 23: Return on invested capital for the airline industry vs real GDP growth, 1990-2022:



Source: IATA

Therefore, IATA concludes that persistent airlines' return weakness is due to several factors: a high share of fixed costs, high sensitivity to external demand shocks, a fragmented industry, and a more concentrated supplier landscape, and **low entry and high exit barriers**.

- **Airports**

At first glance, Airports' role in deploying SAF may seem insignificant, considering that SAF is delivered to an airport's fuel farm after being blended with fossil fuels. This practice does not require a major transformation of airport infrastructure. However, there is some uncertainty about the role airports could and should play within the SAF value chain and in promoting and incentivising SAF offtakes.[66] Airports are the intersection nodes of several fuel producers, traders, airlines, governments, and society. Consequently, they will undoubtedly be involved in the strategic planning for both perspectives, barriers to entry and competitive advantages, of aviation fuel suppliers and airlines.

Most importantly, SAF will be part of airports' sustainability strategies for the same reasons. According to a survey conducted on behalf of the Sustainable Airports Platform in the framework of the European project ALIGHT, there are several challenges and opportunities around SAF from the point of view of airports.[67]

This survey has identified three main categories of challenges and opportunities: the costs and availability of SAF, uncertainty around airports' roles, and the required infrastructure for introducing SAF in airports. Among the examples given, most of them

[65] International Air Transport Association (IATA). (2022). IATA Economic Report 2022 p.8.
[66] ALIGHT Sustainable Aviation report, "SAF Sustainability Guidance for Airports", p.3
[67] Idem, pp. 9-10

are directly related to competitive conditions derived from the closer airport links to their closer links to local economic development, as the table below shows:

Table 6: Challenges and Opportunitie of SAF

CHALLENGES	OPPORTUNITIES
• Limited supply volumes of SAF make it more challenging to distribute across airports globally. • Airports located in incentivised markets (e.g., California) benefit from greater access. • Distribution at airports depends primarily on airlines' demand. • Limited supply volumes of SAF make it more challenging to distribute across airports globally. • Airports located in incentivised markets (e.g., California) benefit from greater access. • Distribution at airports depends primarily on airlines' demand. • Limited supply volumes of SAF make it more challenging to distribute across airports globally. • Airports located in incentivised markets (e.g., California) benefit from greater access. • Distribution at airports depends primarily on airlines' demand.	• Airports can help bridge the price premium of SAF by: — Subsidising SAF (i.e., airport's SAF incentive schemes). — lobbying policymakers for incentives or other enabling regulations (e.g., mandatory quotas, cap-and-trade mechanisms). • Airports can support regional SAF development by: — Providing loans or direct financial support to SAF production facilities. — Supporting relevant studies for SAF market development (via participation in research consortia or using own funds), such as feedstock availability assessments, new production technologies, etc. • Raise awareness with regulators around new economic development pathways, incentives and programmes that could accelerate SAF development and access to capital. • Help aggregate SAF demand from airlines. • Organise and/or support awareness campaigns targeted at passengers. • Use SAF for airports' own GHG reporting. • Support permitting of an environmental review for onsite fuel consortium / fuelling farms.

The last but not least negligible factor is the airports' geographic location. As the IATA economic report points out, significant differences exist between the Asian, North American, and European airport business models and regulatory regimes that influence the ROIC volatility and average return.[68] Combined with the potential SAF strategies

[68] International Air Transport Association (IATA). (2022). IATA Economic Report 2022 p.7.

listed above, some practices during the SAF deployment could lead to market distortions and harm air connectivity between Europe and third countries.

3.2.2.2. Competitive conditions competitive downstream in the aviation value chain

Airlines have developed ways to achieve competitive advantages in the quest for returns stability without fully consolidating them.

After the market deregulation initiated by the USA at the end of ’70s, Airlines developed a hub-and-spoke route system funneling traffic through hub cities, where long-distance and short-haul flights. This system aimed to create substantial regional economies of scale for the airline that dominated a hub airport and benefited from needing to fly fewer planes to service its routes. Although the hub-and-spoke system is still in force today, all the cost and revenue advantages fell down due to intense competition from weaker carriers, dropping prices below what it cost to fly the passengers. The hub-and-spoke route system keeps prices stable and profitable only when one or two well-established airlines serve a single hub city. The entry of a third carrier generally causes serious turmoil in the incumbents’ returns, especially if the newcomer is trying to break into a new market with low labour, other fixed costs, and aggressive management. Then, the hub-and-spoke system reacts through a complex fare structure, aiming to keep efficiency by improving yield enhancement.[69] The same experience can also apply to low-cost and other business models that have been developed further.

Regarding the influence of these competitive conditions on SAF deployment, one feature to retain is the cooperative link that airlines established with airports and the local authorities. As the primary mission of these authorities is the economic development of their region, they are always interested in promoting air traffic at their airports. Therefore, they will be well disposed to incentivise SAF innovation if they perceive it as an advantage for local promotion. However, due to the need to establish economies of scale to reduce SAF costs quickly, it is logical that international aviation hubs will be preferred as partners for an investment project on SAF.

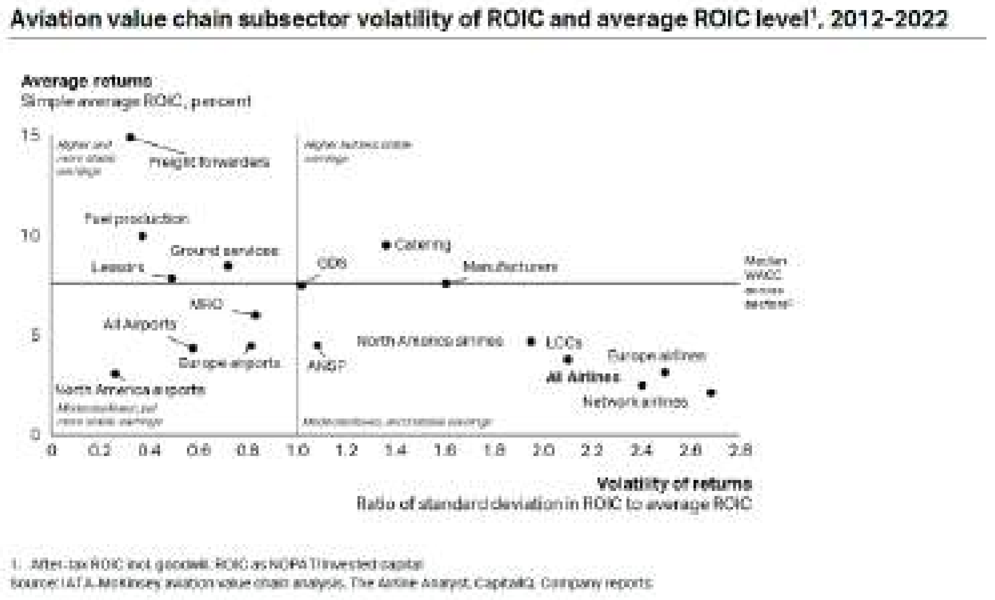
3.3. Final insights about competitive conditions in the aviation value chain for developing and deploying SAF in Europe

3.3.1. Linkages between barriers to entry in the jet fuel production and return vulnerability of the airline industry

Comparing the vulnerability of the airline industry to that of the aviation fuel suppliers reveals how vital operational efficiency is to the former and the resilience that barriers to entry provide for the latter (see figure 24 below).

Figure 24: Aviation value chain subsector volatility of ROIC and average ROIC level,2012-2022

[69] Case study included in G&K, 242-243



Source: IATA

Fuel is the most significant operating cost for the airline industry and fluctuating crude oil prices make long-term planning and budgeting challenging. This situation is at the core of the airline industry's volatility. In parallel, the barriers to entry that benefit aviation fuel supply companies are mainly based on their resilience to oil fluctuations. In such a context, SAF can address this issue by reducing airlines' exposure to fuel cost volatility, but this can also erode the robustness of the fuel supply companies' barriers to entry.

Consequently, from an investment perspective, it is reasonable to assume that incumbent fuel supply companies are very cautious about investing in SAF innovations. They will look for SAF technologies to ensure their current ROIC level refining fossil fuels. SAF isn't confined to fossil fuel drilling locations, allowing for a diverse geographic supply that could be more complicated to manage. Depending on local conditions and aviation needs, various SAF feedstocks can be grown or collected globally. Consequently, SAF economies of scale are an issue of reducing production costs and reproducing the supply chain conditions that allow return average stability in the long run.

On the other hand, the most vulnerable aviation value chain segments, the airline industry and airports, can look at SAF as an opportunity to reduce their traditional vulnerability. In this case, the SAF innovations that can be the most interesting for them are those capable of consolidating the competitive advantages they are trying to build, combining customer captivity strategies and economies of scale based on collaboration with local economies.

3.3.2. Blending facilities for SAF will be the battlefront for better balancing the negotiation power of suppliers in the upstream value chain through SAF

Growth expectations on SAF demand through mandates like ReFuelEU are often presented as a sure incentive to venture capital investing in SAF innovations. In investment planning, such expectations can be fulfilled if venture capital investments occur in new or underdeveloped markets without entrenched, dominant competitors.[70] The case for the aviation value chain is not the same. The airline industry operates without competitive advantages, while the fuel supply companies benefit from robust barriers to entry. For this reason, the performance of companies will also be linked to the scale-up of blending operations managed by incumbent companies in combination with technological properties.

3.3.3. Europe faces other competitive challenges besides the higher costs of SAF compared to conventional jet fuel

Economies of scale are one strategy SAF mandates consider necessary to reduce the price gap relative to fossil-based jet fuels. Again, from an investment perspective, economies of scale can be profitable, depending on the market share obtained through cost reduction. If all competitors operate effectively and achieve comparable scale, they will also have comparable average costs. However, as barriers to entry exist in the aviation fuel supply segment, cost efficiency is not enough. The entrants should match the incumbent's scale of operations to avoid their average costs remaining higher.[71]

Additional economic incentives from carbon market-based measures (e.g., EU ETS, CORSIA), and potential tax credits can also have a different impact on market share due to these barriers to entry and new competitive advantages built on SAF innovations.

In this context, the higher diversity of local frameworks to produce SAF,[72] the dispersion in the production incentives between and within Member States, and the fragmentation of financial markets, coupled with structural market differences between geographic continents, may result in cost barriers persisting for European SAF investment despite the EU's regulatory efforts to promote SAF through mandates and incentives.

Another obstacle is the technology of the SAF pathway in the EU. SAF technologies are at various stages of commercial development and face different challenges, with timelines for large-scale deployment ranging from short to medium-term. Crop-based biofuels are unlikely to reduce overall CO2 emissions from aviation significantly. Advanced biofuels and Renewable Fuels of Non-Biological Origins (RFNBOs) hold significant potential for increasing aviation sustainability but currently exist only at the demonstration level and face industrial challenges. Their commercial-scale emergence depends on specific incentives. Economies of scale may be complex to achieve in the context of EU Member States with different strategies for deploying EFPs, or none at all.

4. The emerging market on SAF

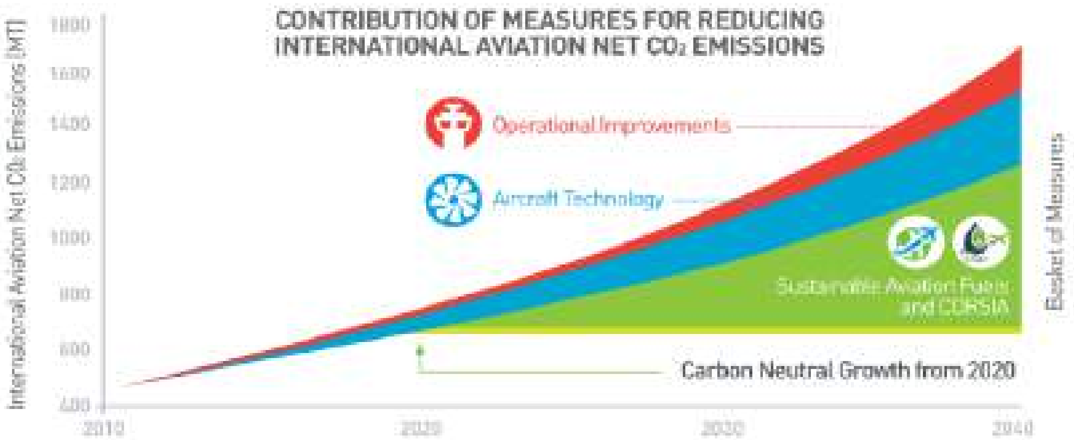
4.1. Main global market figures for SAF

The commercial global aviation industry accounts for approximately 2 percent of global greenhouse gas emissions with 781 million metric tons (Mt) of CO2 emitted in 2015. Aviation's share of total global emissions is forecast to grow to 5 percent by 2050, due to increasing demand for air transport services globally. The sector has committed to several emissions goals, including reducing net aviation emissions to 50% below 2005 levels by 2050 via technological, operational, and economic measures. Sustainable

[70] G&K, op.cit. p. 354
[71] Idem, p. 38
[72] There are technical hurdles to sourcing sufficient quantities of sustainable feedstocks, like used cooking oils, animal fats, and other biomass. Plastics? Ensuring a consistent and sustainable supply of these materials is crucial for scaling SAF production.

Aviation Fuels (SAF) are expected to be the largest contributor to such decarbonisation (see Figure 25).[73]

Figure 25: Contribution of measures for reducing international aviation emissions[74]



Source: ICAO

Only in EU, the requirement of providing a 2% blend of SAF by 2025 to aviation fuel providers will create a market for nearly 1 million tonnes of SAF, which is double the global market volume in 2023.

The global Sustainable Aviation Fuel (SAF) market is projected to grow from USD 1.1 billion in 2023 to USD 16.8 billion by 2030, with a compound annual growth rate (CAGR) of 47.7% from 2023 to 2030.[75] According to IATA, approximately 65% of the efforts to achieve net-zero carbon emissions by 2050 will rely on SAF. In 2023, SAF production exceeded 600 million litres (0.5 million tonnes), double the 300 million litres (0.25 million tonnes) produced in 2022. This volume represents 0.2% of the global jet fuel consumption. However, SAF constituted only 3% of the total renewable fuels produced, with the remaining 97% being utilised in other sectors.[76]

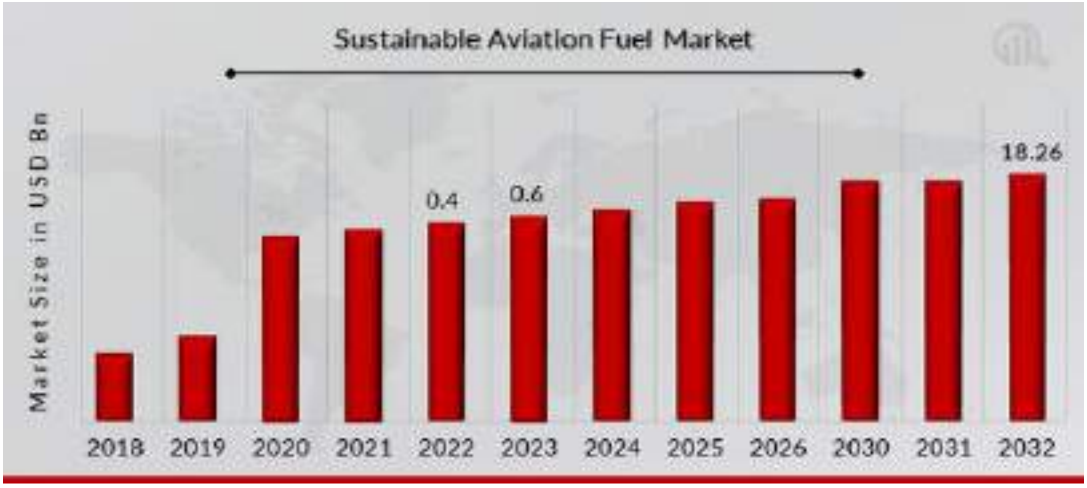
The limited production of SAF, which only accounts for 3% of global renewable fuel output, poses a challenge as it restricts supply and keeps prices elevated. To achieve the necessary trajectory for net-zero carbon emissions by 2050, the aviation sector requires 25% to 30% of renewable fuel production capacity to be dedicated to SAF. The current lower-than-needed SAF production hinders progress towards decarbonization. Therefore, substantial government support is essential. Governments must implement policies to encourage the expansion of SAF production and diversify the feedstocks used, leveraging those available locally.[77]

Current trends include increased airline adoption of SAF to reduce carbon emissions, enhanced collaboration among industry stakeholders, and advances in feedstock technologies, mainly using algae and waste materials. Supportive policies and ongoing

[73] ALIGHT. SAF Sustainability Guidance for Airports.
[74] International Civil Aviation Organization (ICAO). (n.d.). CORSIA Brochure. Retrieved from: https://www.icao.int/environmental-protection/Documents/CorsiaBrochure_8Panels-ENG-Web.pdf
[75] Statistics MRC source
[76] International Air Transport Association (IATA).
[77] International Air Transport Association (IATA).

R&D investments make SAF production more cost-effective, with a growing focus on integrating hydrogen fuel cells as a viable alternative.

Figure 26 : Sustainable Aviation Fuel Market

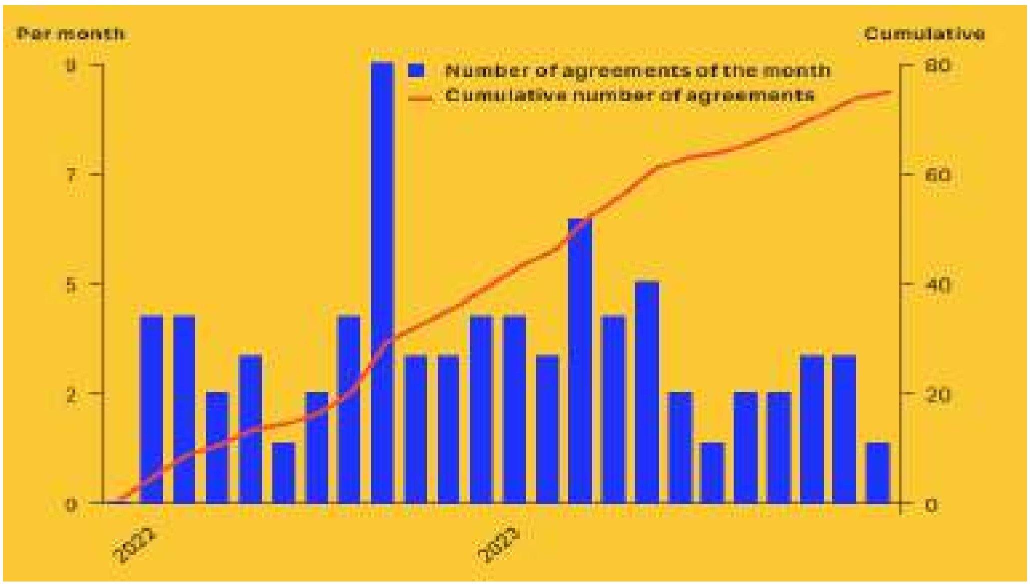


Source: Secondary Research, Primary Research, MRFR Database and Analyst Review

According to IATA estimates, the aviation industry used between 450,000 and 500,000 tonnes of Sustainable Aviation Fuel (SAF) in 2023, costing $2,500 per tonne. This price is 2.8 times higher than regular aviation fuel, adding $756 million to the industry's fuel costs for the year. The industry plans to use more SAF to reduce its carbon footprint. IATA estimates that SAF could make up 0.53% of airlines' total fuel use in 2024, adding $ 2.4 billion to the fuel bill.

Airlines have been making deals with SAF producers to secure future supplies. In the past two years, the industry has made significant progress, signing 75 agreements—53 binding and 22 non-binding. The most developed and commercially viable technologies for SAF are Hydrotreated Esters and Fatty Acids (HEFA) and HEFA co-processing, which make up most of these agreements.

Figure 27: Number of SAF offtake agreements, as of December 2023 (IATA)



Source: IATA

4.2. Competitive conditions in EU SAF supply and demand

As section 2 of this report explains, ReFuelEU aims to increase SAF production and usage in Europe. Starting in 2025, aviation fuel suppliers must blend 2% SAF, rising to 70% by 2050. SAF production costs range from €1,000/tonne to over €4,500/tonne, currently making it two to six times more expensive than kerosene. By 2030, the extra cost of a 5% SAF blend is estimated at €10 billion, with significant additional fees from the EU Emissions Trading System and kerosene taxation. Operational improvements and fleet upgrades could mitigate these costs, reducing fuel consumption by up to 15.4% by 2030.

4.2.1. SAF Cost and SAF Supply Chain Capacities

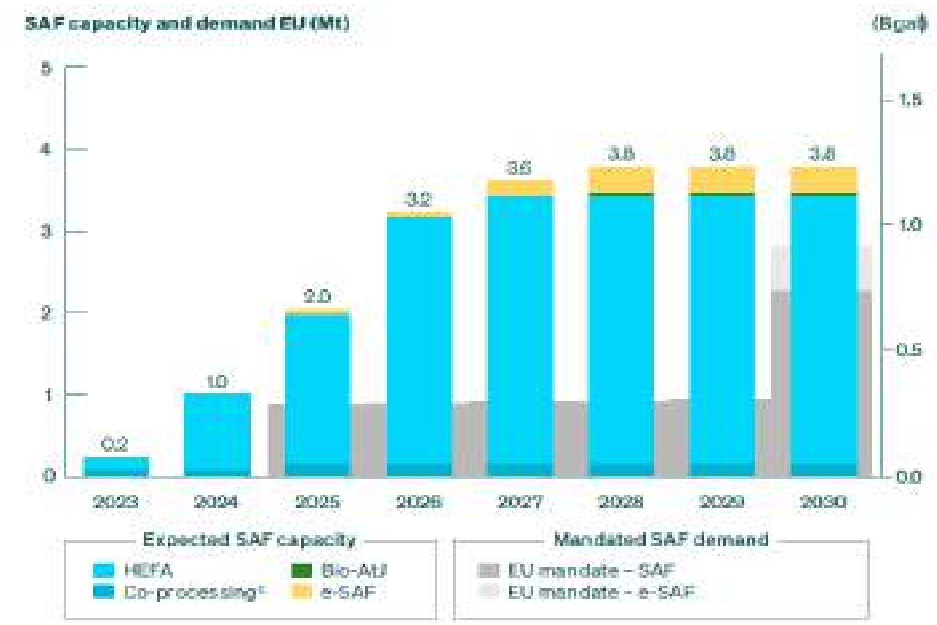
Current SAF supply chain capacity announcements project the delivery of 3.8 Mt (1.3 Bgal) SAF by 2030, with a total potential of 5.5 Mt (1.8 Bgal) in development. Meeting EU demand will require a minimum success rate of 50%. Currently, only about 1.8 Mt (0.6 Bgal) of this capacity is either operational or under construction. In addition to EU-based production, SAF imports are anticipated to help meet ReFuelEU compliance. Initially, this import strategy should balance supply as EU capacity increases. However, if imports continue alongside high success rates for EU SAF production, these projects might shift focus to producing HVO instead of SAF. Alternatively, EU projects could cater to the voluntary market.[78]

There is limited public information on petroleum refiners planning to use the co-processing of renewable feedstock to produce SAF despite its current significant contribution. Co-processing, which requires lower capital investment than other SAF pathways, offers a cost-effective compliance method under ReFuelEU. If EU refiners fully utilize their co-processing capacity to the ASTM limit of 5%, it could yield approximately 1.7 Mt (0.6 Bgal) SAF annually. The recent amendments to the Renewable Energy Directive have expanded eligible feedstocks, providing refiners with more flexibility, including biomass-based oils from intermediate or cover crops.

Announced e-SAF projects are expected to produce 0.3 Mt (0.1 Bgal) by 2030, with most projects still in the feasibility stage. The total potential for e-SAF projects is 1.2 Mt (0.4 Bgal). Achieving just 20% of the announced e-SAF pipeline could bring EU e-SAF capacity to the 0.6 Mt (0.2 Bgal) required to meet the sub-mandate.

Figure 28: Expected SAF capacity in the EU27 and UK by 2030, based on 2024 announcements.

[78] Fastmarkets. (2023). *SkyNRG forecasts major SAF capacity growth by 2030*. Retrieved from: https://www.fastmarkets.com/insights/skynrg-forecasts-major-saf-capacity-growth-by-2030/



Source: ING Research

4.2.2. European Market for SAF

Europe holds the second-largest share in the Sustainable Aviation Fuel market. The region is a global leader in environmental regulations and sustainability initiatives. EU's Renewable Energy Directive (RED III) and ReFuelEU regulations are expected to accelerate the development and adoption of SAF. Notably, Germany has the largest market share for SAF in Europe, while the UK market is the fastest growing outside the EU.

Until significant demand-side policies are established outside Europe, the EU is likely to import SAF to meet its needs. Initially, these imports are expected to balance supply and demand. If this situation continues and the EU achieves a high success rate in developing SAF capacity, more EU-produced SAF could be available for the voluntary market, or some projects might shift to optimise for HVO (Hydrotreated Vegetable Oil) output.

The EU's e-SAF sub-mandate will require 0.6 million tonnes (0.2 billion gallons) of e-SAF by the 2030-2032 compliance period. Currently announced e-SAF projects are expected to deliver 0.3 million tonnes (0.1 billion gallons) by 2030, with the majority of projects—totalling approximately 1.1 million tonnes (0.4 billion gallons)—still in the feasibility stage. Advancing just 20% of these announced e-SAF projects to a Final Investment Decision (FID) could meet the 0.6 million tonnes (0.2 billion gallons) requirement for the sub-mandate.

Mandated SAF demand in the EU is projected to reach 2.8 million tonnes (0.9 billion gallons) by 2030. Current renewable fuel capacity announcements are expected to produce 3.8 million tonnes (1.3 billion gallons) of SAF by 2030, with a total of 5.5 million tonnes (1.8 billion gallons) in development. This indicates that at least a 50% success rate is needed to meet EU demand without considering imports. However, ongoing trends in 2024 indicate delays in the sector, suggesting that actual SAF capacity by 2030 may be lower than announced.

With the formal adoption of ReFuelEU on 9th October 2023, EU fuel suppliers are mandated to supply a 2% blend of SAF to EU airports, which will increase to 6% by 2030.

This regulation drives the mandated SAF demand in the EU to 2.8 million tonnes (0.9 billion gallons) by 2030, based on current demand projections supporting the regulation. A sub-mandate requires 0.6 million tonnes of the total volume to be e-SAF by the 2030-2032 compliance period.

4.3. Cooperation projects for SAF in the aviation value chain

- **ECLIF3 Study on Sustainable Aviation Fuel (SAF)**

The ECLIF3 study underscores the critical role of 100% sustainable aviation fuel in reducing the aviation sector's environmental footprint, marking a significant step towards climate-compatible aviation.

The ECLIF3 study, a collaboration between Airbus, Rolls-Royce, the German Aerospace Center (DLR), and Neste, marked the world's first in-flight assessment of 100% sustainable aviation fuel (SAF) in a commercial aircraft. The study revealed that using 100% SAF in an Airbus A350, powered by Rolls-Royce Trent XWB engines, significantly reduced soot particle emissions and the formation of contrail ice crystals compared to conventional Jet A-1 fuel. Specifically, the number of ice crystals per mass of fuel was reduced by 56%, which could substantially decrease the climate-warming effects of contrails.

Additionally, global climate models estimated a 26% reduction in the climate impact of contrails when using 100% SAF. These findings were confirmed through detailed scientific analysis and published in the journal "Atmospheric Chemistry & Physics," providing strong evidence of SAF's potential to reduce climate impact.

Experts from the participating organizations emphasized the importance of these results. Alexander Kueper from Neste highlighted that the study confirmed SAF's lower climate impact and its potential for higher concentration use. Markus Fischer from DLR pointed out the significant reduction in the warming effect of contrails. Mark Bentall from Airbus and Alan Newby from Rolls-Royce also noted the dual benefits of SAF in reducing both carbon emissions and other climate effects.

Shell's refinery in Germany

Shell is focusing on producing Sustainable Aviation Fuels (SAF) at the Rhineland Refinery in Germany. This initiative is part of the broader plan to transform the Rhineland site into the Shell Energy and Chemicals Park Rhineland. The production of SAF is a key component of Shell's strategy to transition towards more sustainable and regenerative fuel solutions

- **Rhineland Refinery**

The Rhineland Refinery is Shell's largest refinery in Germany and one of the largest in Europe. It comprises two sites: Wesseling and Godorf.

Transformation and Sustainable Fuel Production:

- Shell is transforming the Rhineland Refinery into the Shell Energy and Chemicals Park Rhineland.
- The refinery will produce Sustainable Aviation Fuels (SAF) and establish the first commercial Bio-PTL (power-to-liquid) plant.

- The refinery is also focusing on producing green hydrogen and other regenerative solutions.

Shell Deutschland GmbH[79] in Germany

Shell has announced the closure of its oil refinery in Wesseling will be in 2025. The site will be converted into a facility for producing lubricant feedstock, aligning with Shell's strategy to reduce carbon emissions and transition towards a net-zero emissions energy business by 2050. The Wesseling site's hydrocracker unit will be repurposed to produce Group III base oils, primarily used in engines. Crude oil processing at Wesseling, part of Shell's Energy and Chemicals Park Rheinland near Cologne, will cease in 2025. The new lubricant feedstock facility is expected to commence operations in the second half of this decade, with an annual capacity of approximately 300,000 tonnes, meeting around 9% of current EU demand and 40% of Germany's demand for base oils.[80]

Shell Deutschland GmbH has approved the construction of REFHYNE II, a 100-megawatt renewable hydrogen electrolyser at its Energy and Chemicals Park Rheinland in Germany. Scheduled to begin operation in 2027, this facility will use renewable electricity to produce up to 44,000 kilograms of hydrogen per day to help decarbonize the site's operations. The project benefits from supportive EU and German policies and funding from the EU's Horizon 2020 program.

Shell's investment in REFHYNE II underscores its commitment to reducing emissions and advancing the hydrogen economy. The renewable hydrogen produced will be used to create lower carbon intensity transport fuels and reduce emissions at the Rheinland facility. Additionally, it may eventually support wider industrial emission reductions as demand grows. The project builds on the success and experience of REFHYNE I, a 10-megawatt electrolyser that started in 2021.

Shell's Strategic Investment in Low-Carbon Energy Solutions

Shell plans to invest $10-$15 billion across 2023-2025 to support the development of low-carbon energy solutions including e-mobility, low-carbon fuels, renewable power generation, hydrogen, and carbon capture and storage. In total, Shell invested $5.6 billion in low-carbon solutions in 2023, which was 23% of its capital spending.

The capital investment related to REFHYNE II will be absorbed within Shell's cash capital expenditure guidance, and this project exceeds the internal rate of return (IRR) hurdle rate for Shell's Renewables & Energy Solutions business as outlined during Capital Markets Day 2023.

Key project partners for REFHYNE II are ITM Power (Trading) Ltd, ITM Power Germany GmbH, Linde GmbH, TECNALIA, ETM, SINTEF AS, and CONCAWE.

Shell expects that, once operational, hydrogen produced from REFHYNE II will meet the requirements for renewable fuels of non-biological origin (RFNBO) in accordance with current EU legislation.

This investment delivers on Shell's strategy to repurpose its Energy and Chemicals Parks to provide lower carbon molecules to customers.

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[79] Shell. (2023). ***Shell to build 100-megawatt renewable hydrogen electrolyser in Germany***. Retrieved from: https://www.shell.com/what-we-do/hydrogen/latest-news-from-shell-hydrogen/shell-to-build-100-megawatt-renewable-hydrogen-electrolyser-in-germany.html

[80] Offshore Technology. (2023). ***Shell Wesseling Germany***. Retrieved from: https://www.offshore-technology.com/news/shell-wesseling-germany/

Shell and Lufthansa Group Sign MoU for Sustainable Aviation Fuel Supply

On August 1, 2022, Shell International Petroleum Co Ltd. and Deutsche Lufthansa AG (Lufthansa Group) signed a non-binding Memorandum of Understanding (MoU) to explore the supply of up to 594 million gallons (1.8 million metric tonnes) of Sustainable Aviation Fuel (SAF) from 2024 to 2030. The SAF would be produced using up to four different approved technology pathways and various sustainable feedstocks.

Delta and Shell Aviation Partner to Supply SAF at LAX and Advance Aviation Decarbonization

Delta's Chief Sustainability Officer, Pam Fletcher, emphasized the importance of creating demand signals for SAF to drive investment and growth. Jan Toschka, President of Shell Aviation, highlighted that Delta's prioritization of SAF helps reduce lifecycle emissions and supports the scaling of SAF production, crucial for sustainable aviation's future.

Shell and Lufthansa Group Sign MoU for Sustainable Aviation Fuel Supply

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BP refinery in Lingen in German[81]

As the aviation division of BP, Air BP is a leading supplier of aviation fuel products and services, with over 90 years of industry experience. In 2019, Air bp supplied more than 6.7 billion gallons of aviation fuel, servicing over 7,000 flights daily across 700 locations in more than 55 countries.

Air bp caters to a diverse customer base, including commercial airlines, the military, private aircraft owners, and airport operators. Their services encompass the design, construction, and operation of fueling facilities, technical consultancy, training, low carbon solutions, the Sterling Card for efficient refueling, and innovative digital platforms to enhance efficiency and reduce risks.

In a notable advancement, BP has established Germany's first industrial production facility at the Lingen refinery to produce sustainable aviation fuel (SAF) using co-processing technology. **This process combines used cooking oil with crude oil in existing facilities to produce SAF, allowing the refinery to maintain operations with minimal modifications while contributing to the decarbonisation of aviation**.

SAF produced at Lingen can be used in existing infrastructure and aircraft, offering substantial lifecycle carbon reductions compared to traditional jet fuel. This initiative aligns with BP's goal to achieve a 20% global market share for SAF, leveraging co-processing technology for both air and road transport sectors.

KLM Royal Dutch Airlines (KLM) and Air France

KLM Royal Dutch Airlines (Koninklijke Luchtvaart Maatschappij N.V.) is the flagship carrier of the Netherlands and one of the world's oldest airlines still operating under its

[81] **BP**. (2023). *Refineries*. Retrieved from: https://www.bp.com/en_us/united-states/home/what-we-do/production-and-operations/refineries.html

original name. Established on October 7, 1919, KLM is renowned for its long history, extensive route network, and commitment to innovation and sustainability in aviation.

KLM is a leader in sustainable aviation initiatives, focusing on reducing carbon emissions through the use of Sustainable Aviation Fuel (SAF), fleet modernization, and operational efficiencies. The airline is actively involved in developing innovative solutions to reduce its environmental footprint, such as investing in SAF and supporting research in electric and hybrid aircraft technology.

KLM has integrated SAF into its operations, sourcing it from suppliers like SkyNRG. This practice has demonstrated a significant reduction in CO_2 emissions.

In 2011, KLM conducted the world's first commercial flight partly powered by SAF made from used cooking oil. KLM ensures that its SAF is produced from raw materials that do not compete with food production or harm biodiversity.

Implementation at Amsterdam Airport Schiphol

KLM adds 1% SAF to the fuel system at Amsterdam Airport Schiphol for every departing flight, with a goal to reach 10% by 2030.

Collaboration and Contributions

KLM collaborates with businesses and encourages passengers to contribute by adding extra SAF to their bookings. These efforts led KLM to use one-tenth of the global SAF production in 2022. Due to increased SAF usage, ticket prices are adjusted based on travel class and flight distance.

4.4. Economies of scale and global SAF corridors

SAF is primarily utilized in markets where it provides the highest value, influenced by market price, available incentives, and costs associated with transportation and blending. Additionally, value can be determined by considering avoided costs. Systems like the EU's non-compliance penalties or the UK's proposed buy-out prices are mechanisms to achieve SAF blending targets. These tools can direct eligible SAF from global sources to compliance markets at risk of undersupply.

When comparing SAF demand driven by existing and announced policies with SAF capacity projections, both surpluses and deficits become apparent. By evaluating sustainability criteria and supply costs, we can predict how these surpluses and deficits will likely be balanced.

Figure 29: Overview of expected global SAF dynamics by 2030 based on SAF demand, SAF announcements and SAF policies implemented and announced.

Souce: IATA

4.5. The leading companies in the sustainable aviation fuel industry

Neste

Neste is the world's leading producer of Sustainable Aviation Fuel (SAF) [82], has been producing SAF since 2011 and distributes it globally. Neste MY SAF is available at major airports such as San Francisco (SFO), Los Angeles (LAX), Frankfurt (FRA), Amsterdam Schiphol (AMS), Changi (SIN), and Narita (NRT). The company is scaling up its production capacity to 1.5 million tons annually by early 2024. Neste MY SAF is a proven and reliable solution for reducing aviation-related emissions, used by leading airlines like Air France-KLM, Lufthansa, Delta, and American Airlines, as well as cargo carriers like DHL, Amazon Prime Air, and UPS. Neste is continually expanding its distribution network to support its partners' sustainability efforts.

Neste's SAF is available in 12 airports in the US and three in Europe. To define themselves as a leader in this space, Neste are focusing on different partnerships to draw attention to their product.

Major shareholders of Neste[83]:

- Government of Finland with 44.22% of equities.
- Keskinäinen Työeläkevakuutusyhtiö Varma with 1.701% of equities.
- Keskinäinen Eläkevakuutusyhtiö Ilmarinen with 1.216 % of equities.
- The Social Insurance Institution of Finland (Invt Port) with 0.7931 % of equiti
- City of Kurikka with 0.6049 % of equities.
- Keskinäinen Työeläkevakuutusyhtiö Elo with 0.5942 % of equities.
- Valtion Eläkerahasto - The State Pension Fund with 0.4680 % of equities.

[82] Neste. (2023). *Sustainable Aviation Fuel*. Retrieved from: https://www.neste.com/products-and-innovation/sustainable-aviation/sustainable-aviation-fuel

[83] MarketScreener. (2023). *Neste Oyj Shareholders*. Retrieved from: https://www.marketscreener.com/quote/stock/NESTE-OYJ-1412495/company-shareholders/

- Nordea Investment Management AB (Finland) with 0.3544 % of equities.
- Nordea Investment Management AB with 0.3439 % of equities.
- OP Asset Management Ltd.with 0.3376 %.

Gevo inc.

Founded in 2005, Gevo Inc. is a company specializing in renewable chemicals and advanced biofuels, including Sustainable Aviation Fuel (SAF) and renewable isooctane. Gevo is committed to producing liquid hydrocarbons that can be converted into SAF and other renewable fuels. The company aims to produce and sell one billion gallons of hydrocarbons by 2030, with a specific focus on using carbohydrates as feedstock for SAF production. Gevo is working towards increasing its SAF output to 55 million gallons annually.

Major shareholders of Gevo[84]:

- Vanguard Global Advisers LLC with 7.329 % of equities.
- Millennium Management LLC with 2.194 % of equities.
- BlackRock Institutional Trust Co. NA with 1.999 % of equities.
- Patrick Gruber with 1.671 % of equities.
- BG Fund Management Luxembourg SA with 1.502 % of equities.
- Jane Street Group LLC with 1.469 % of equities.
- Grantham, Mayo, Van Otterloo & Co. LLC with 1.388 % of equities.
- Geode Capital Management LLC with 1.067 % of equities.
- Christopher Ryan with 0.7132 % of equities.
- Northern Trust Investments,Inc.(Investment Management) with 0.6815 % of equities.

World energy

World Energy is one of North America's largest biofuel suppliers, producing SAF that is already in commercial use. The company's Paramount facility in California is the world's first commercial SAF production site. World Energy plans to convert its Houston biodiesel facility to SAF production, adding 250 million gallons by 2025. Additionally, the company aims to produce another 250 million gallons of SAF from its Paramount facility, contributing to its goal of producing one billion gallons of SAF by 2030. World Energy also operates a SAF facility in Los Angeles, which is being expanded to produce 375 million gallons of renewable fuel. Current users of World Energy's SAF include Amazon Air, United, JetBlue, Rolls-Royce, and Boeing.

Major shareholders of World Energy[85]:

- Exxon Mobil Corp
- Chevron Corp
- Shell
- TotalEnergies
- ConocoPhillips

[84] Marketscreener. (n.d.). *Gevo Inc - Company Shareholders*. Retrieved from: https://www.marketscreener.com/quote/stock/GEVO-INC-44136865/company-shareholders/

[85] MSCI. (2024). *MSCI ESG Research - Global Industry Classification Standard (GICS) Overview*. Retrieved from: https://www.msci.com/documents/10199/de6dfd90-3fcd-42f0-aaf9-4b3565462b5a

- BP
- Enbridge
- Canadian Nat Resources
- EOG Resources
- Schlumberger

Aemetis:

Aemetis is a renewable fuels company focused on producing sustainable aviation fuel (SAF) from agricultural and forest waste. Their key project, the Aemetis Riverbank Advanced Biofuels Plant, converts renewable feedstocks into SAF, helping to reduce the aviation industry's carbon footprint. Aemetis is recognized for its commitment to low-carbon fuel initiatives and partnerships with airlines to promote sustainable energy solutions.

Major shareholders of Aemetis[86]:

- Eric McAfee with 7.471 % of equities.
- BlackRock Advisors LLC with 4.876 % of equities.
- Grantham, Mayo, Van Otterloo & Co. LLC with 4.260 % of equities.
- Vanguard Fiduciary Trust Co. with 4.201 % of equities.
- Geode Capital Management LLC with 1.933 % of equities.
- Stifel, Nicolaus & Co., Inc. with 1.620 % of equities.
- State Street Corp. with 1.157 % of equities.
- Susquehanna Securities LLC with 1.059 % of equities.
- CIBC Private Wealth Group LLC with 0.5849 % of equities.
- Fran Barton with 0.4435 % of equities.

SkyNRG:

SkyNRG is a pioneer in the Sustainable Aviation Fuel (SAF) market, involved in various projects aimed at increasing the availability and adoption of SAF. The company works closely with airlines, airports, and governments to promote the use of SAF and drive the aviation industry towards a more sustainable future.

Major shareholders of SkyNRG[87]:

- Macquarie Asset Management
- KLM
- Spring Associates
- Finestra S.A.
- E.M.E, and management

Fulcrum Bioenergy

Fulcrum BioEnergy is a company focused on producing sustainable aviation fuel (SAF) by converting household waste into renewable transportation fuels. Founded in 2007 and based in California, Fulcrum's approach involves using a proprietary process to convert

[86] MarketScreener. "Aemetis Inc. - Company Shareholders." Retrieved from https://www.marketscreener.com/quote/stock/AEMETIS-INC-16646148/company-shareholders/.
[87] SkyNRG. "Macquarie Invests in SkyNRG." Available at: https://skynrg.com/macquarie-invests-in-skynrg/.

municipal solid waste (MSW) into low-carbon synthetic crude oil, which is then refined into SAF.

Fulcrum's flagship project, the Sierra BioFuels Plant in Nevada, is one of the first commercial-scale facilities to use this technology. The plant is designed to process approximately 175,000 tons of waste per year, producing around 11 million gallons of SAF. Fulcrum's SAF has a significantly lower carbon footprint compared to traditional jet fuel, helping to reduce greenhouse gas emissions in the aviation industry.

The company's innovative approach has attracted partnerships with major airlines and energy companies, which are keen to invest in SAF as part of their efforts to meet carbon reduction targets. Fulcrum BioEnergy's work is seen as a crucial step towards the broader adoption of sustainable fuels in aviation.

Major shareholders of Fulcrum Bioenergy[88]:

- Cathay Pacific
- United Airlines
- Rustic Canyon Partners
- Government of UK
- SK Innovation
- Marubeni
- Japan Airlines

Alder Fuels

Alder Fuels is a key player in the Sustainable Aviation Fuel (SAF) market, focusing on producing low-carbon fuels derived from biomass. Their approach centers on converting abundant and renewable biomass into SAF, which can significantly reduce carbon emissions compared to traditional fossil-based jet fuels. Alder Fuels collaborates with various industry stakeholders, including airlines, energy companies, and governmental bodies, to scale the production and adoption of SAF.[89]

One of their notable partnerships is with United Airlines and Honeywell, aimed at advancing the commercialization of SAF. Alder Fuels has been recognized for its innovative technology and contribution to the aviation industry's sustainability goals, helping to meet the growing demand for cleaner aviation fuels.[90]

Major shareholders of Alder Fuels[91]:

- Directional Aviation Capital
- Avfuel Corporation
- Honeywell Ventures
- United Airlines Holdings
- Adequita Capital

[88] Tracxn. (n.d.). *Fulcrum BioEnergy - Funding and Investors*.Retrieved from: https://tracxn.com/d/companies/fulcrum-bioenergy/__5ip_XPAXRlvAB4kqqu-IvuZS1K-L7Ca_72JtLh1buX0/funding-and-investors
[89] Alder Renewables. (n.d.). *Home*. **Alder Renewables**. Retrieved from: https://www.alderrenewables.com/
[90] Munro, T. (2021). *Sustainable jet fuel company Alder Fuels seals investments from United, Honeywell*. Retrieved from: https://techcrunch.com/2021/09/09/sustainable-jet-fuel-company-alder-fuels-seals-investments-from-united-honeywell/
[91] PitchBook. (n.d.). *Fulcrum BioEnergy - Company Profile*. Retrieved from: https://pitchbook.com/profiles/company/481233-88#faqs

5. SAF Technologies and SAF innovations

5.1. Technology Insights on SAF

The market for SAF is segmented by manufacturing technologies, highlighting the demand for SAF produced through various processes such as FT-SPK, HEFA-SPK, HFS-SIP, ATJ-SPK, CHJ, FT-SPK/A, and HC-HEFA-SPK. In 2023, FT-SPK technology dominated the market in terms of revenue and exhi bited the highest CAGR during the forecast period. This emphasises the importance of synthetic paraffinic kerosene produced through Fischer-Tropsch (FT) processes in driving market growth. Ongoing advancements in manufacturing technologies, including hybrid methods like FT-SPK/A, are diversifying SAF sources to meet the diverse needs of the aviation industry.

Currently, the commercially viable technologies for producing SAF include:

- **HEFA-SPK (Hydroprocessed Esters and Fatty Acids – Synthetic Paraffinic Kerosene):** This is the most established and widely used SAF production technology. It involves processing vegetable oils, animal fats, and used cooking oils to produce SAF. HEFA-SPK is already being used by several airlines globally.

- **FT-SPK (Fischer-Tropsch Synthetic Paraffinic Kerosene):** This technology converts biomass, municipal solid waste, or other carbonaceous materials into synthetic hydrocarbons through the Fischer-Tropsch process. FT-SPK is also commercially available, though it is less common than HEFA-SPK.

- **ATJ-SPK (Alcohol to Jet Synthetic Paraffinic Kerosene):** This process converts alcohols such as ethanol or butanol into jet fuel. While still emerging, ATJ-SPK has received certification and is starting to be used commercially.

- **PtL (Power-to-Liquid) / eFuels:** Power-to-Liquid (PtL) technology produces SAF by synthesizing hydrocarbons from green hydrogen and carbon dioxide captured from the atmosphere or industrial sources. Hydrogen is produced via electrolysis using renewable energy, and it is then combined with CO2 through Fischer-Tropsch synthesis or methanol synthesis to create synthetic hydrocarbons. PtL is seen as a promising carbon-neutral SAF option, though it is still in the early stages of commercialization due to high energy requirements.

- **HFS-SIP (Hydroprocessed Fermented Sugars to Synthetic Iso-Paraffins):** HFS-SIP involves converting fermented sugars into hydrocarbons via a microbial fermentation process, which produces an isoparaffin called farnesene. Farnesene is then hydroprocessed and refined into synthetic paraffinic kerosene suitable for jet fuel blending. HFS-SIP is approved for blending with conventional jet fuel up to 10% and represents an alternative SAF pathway with limited feedstock competition.

- **CHJ (Catalytic Hydrothermolysis Jet):** CHJ technology, also known as ARA's CHJ, uses catalytic hydrothermolysis to convert lipids directly into hydrocarbons similar to traditional jet fuel. This process mimics conventional petroleum refining and is compatible with a wide range of lipid feedstocks, including fats, oils, and greases. CHJ is certified for blending up to 50% with conventional jet fuel, offering another lipid-based SAF pathway with enhanced fuel characteristics.

- **FT-SKA (Fischer-Tropsch Synthetic Kerosene with Aromatics):** FT-SKA is an advanced version of FT-SPK, incorporating aromatics into the fuel blend to improve energy density and fuel performance. This technology follows the same gasification and Fischer-Tropsch synthesis steps as FT-SPK but includes additional processing to integrate aromatics, which are necessary for certain aircraft engine specifications. FT-SKA is approved for blending with conventional jet fuel, providing enhanced compatibility with existing fuel infrastructure.

- **DSHC (Direct Sugar to Hydrocarbons) / Synthesized Kerosene with Aromatics (SKA):** DSHC, also known as SKA, involves converting sugars directly into hydrocarbons through a combination of biological and chemical processes. This method produces aromatic-rich SAF, which helps meet specific aviation fuel requirements. Although still in the developmental phase, DSHC is viewed as a future pathway with potential due to its ability to produce fully compatible drop-in fuels.

These technologies are currently leading the market and are certified for blending with conventional jet fuels, helping to reduce the carbon footprint of aviation.

5.2. SAF Production Pathways and Development

There are currently seven ASTM International-approved production pathways for Sustainable Aviation Fuel (SAF), each utilizing different feedstocks and processes. Additional pathways are undergoing rigorous assessments for aviation viability. Each pathway offers unique benefits, such as feedstock availability, cost, total carbon reduction, and processing complexity. The suitability of each pathway varies globally based on local feedstock availability and processing capabilities. All pathways, however, have the potential to significantly reduce the aviation sector’s carbon footprint, provided sustainability criteria are met.

While current blend limits exist for technical and safety reasons, they are not expected to hinder SAF development long-term. Major airframe and engine manufacturers aim for all aircraft to safely operate on 100% SAF by 2030. Ongoing testing and development of new processes and feedstocks are expected to support specification revisions, enhancing supply chain flexibility and potentially stabilizing fuel prices and availability.

Co-processing is another method to accelerate SAF production. This involves incorporating sustainable feedstock as a small percentage in the refining of conventional fossil-based jet fuel. This method allows major fuel producers to integrate sustainable feedstocks into existing production processes and facilities, offering a significant opportunity to scale up SAF production using current infrastructure while dedicated facilities are developed. Currently, ASTM limits co-processed SAF to 5% by volume of conventional fossil-based jet fuel in two specific pathways, with plans to reassess these limits in 2023.

It Is crucial to note that the sustainability of fuels depends on both the feedstock production methods and the fuel creation process. Therefore, the commercial aviation industry adheres to strict, independently verified sustainability standards, including those developed by governments, industry, and environmental groups at the United Nations.

Table 7: SAF Production Routes and Feedstocks

Pathway	Feedstock	Certification name	Blend limit
Fischer-Tropsch	Energy crops, lignocellulosic biomass, solid waste	FT-SPK	Up to 50%

Hydroprocessed Esters and Fatty Acids (HEFA)	Waste fats, oils, greases (FOGs) from vegetable and animal sources	HEFA-SPK	Up to 50%
Direct Sugars to Hydrocarbons (DSHC)	Conventional sugars, lignocellulosic sugars	HFS-SIP	Up to 10%
Fischer-Tropsch with Aromatics	Energy crops, lignocellulosic biomass,solid waste	FT-SPK+A	Up to 50%
Alcohol-to-Jet (AtJ)	Sugar, starch crops, lignocellulosic biomass	ATJ-SPK	Up to 50%
Catalytic Hydrothermolysis Jet (CHJ)	Waste fats, oils, greases (FOGs)from vegetable and animal sources	CHJ or CH-SK	Up to 50%
HEFA from Algae	Micro-algae oils	HC-HEFA-SPK	Up to 10%
FOG Co-Processing	Waste fats, oils, greases (FOGs) from vegetable and animal sources	FOG-CP	Up to 5%
FT Co-Processing	Fischer-Tropsch biocrude	FT-CP	Up to 5%

Depending on the SAF production technology pathways, the range of SAF production costs is from €1,000/tonne to more than €4,500/tonne. SAF is today typically two to six times more expensive than kerosene.

SAF produced from municipal waste offers significant environmental benefits by avoiding the use of petroleum and by turning waste that would otherwise decompose in landfill sites, producing harmful greenhouse gases like methane with no additional benefits. Instead, this waste is used to power commercial flights, which would otherwise rely on unsustainable fossil-based fuels.

Carbon Lifecycle Diagram -SAF

Figure 30: SAF’s carbon lifecycle

5.3. Success Cases of SAF Development

- **Neste Expands SAF Availability at US Terminal[92]**

According to Biofuels International on August 1, 2024, Neste has commissioned new terminal capacity at ONEOK's Houston terminal for blending and storing Neste MY Sustainable Aviation Fuel™. This move expands SAF availability to airlines from the Rocky Mountains to the East Coast. The terminal can store up to 100,000 tons (33.5 million gallons) and connects to the eastern US energy pipeline network.

In 2022, Neste supplied SAF to New York's LaGuardia Airport and, in 2023, expanded its West Coast supply by commissioning capacity in Los Angeles.

Alexander Kueper, Neste's VP of renewable aviation, emphasized the commitment to decarbonizing US aviation. Greg Lusardi from ONEOK highlighted their role in supporting sustainable fuels through their infrastructure.

- **Air New Zealand Drops Emission Target Goals Blaming High Price of SAF[93]**

Air New Zealand has abandoned its 2030 emissions reduction target, citing delays in fuel-efficient aircraft delivery and high sustainable aviation fuel (SAF) prices. Despite this, the airline remains committed to the industry-wide goal of net-zero emissions by 2050.

Aviation, responsible for about 2% of global emissions, is one of the hardest sectors to decarbonize. The airline noted that many factors essential to meeting targets, such as new aircraft availability, affordable alternative jet fuels, and regulatory support, are beyond its control.

Airlines rely on SAF and more efficient aircraft to reduce emissions, but SAF production is expensive and difficult to scale. Environmental advocates argue that the aviation industry's growth is incompatible with sustainability.

In 2022, Air New Zealand aimed to reduce carbon intensity by 28.9% by 2030 compared to 2019 levels, a goal validated by the Science-based Targets initiative (SBTi). This target was more ambitious than the global aviation industry's 2023 agreement to lower carbon emissions by 5% by 2030.

5.4. Pros and cons of the current strategies for implementing SAF in the aviation sector

Pros[94] :

- **Reduces carbon emissions**

[92] Biofuels News. (2024). *Neste expands availability of SAF at US terminal*. Retrieved from: https://biofuels-news.com/news/neste-expands-availability-of-saf-at-us-terminal/
[93] Biofuels News. (2024). *Air New Zealand drops emission target goals, blaming high price of SAF*. Retrieved from: https://biofuels-news.com/news/air-new-zealand-drops-emission-target-goals-blaming-high-price-of-saf/
[94] Vision Factory. (2024). *Pros and cons of sustainable aviation fuel*. Retrieved from: https://www.visionfactory.org/post/pros-and-cons-of-sustainable-aviation-fuel

SAF can significantly lower lifecycle greenhouse gas emissions compared to conventional jet fuel, often by up to 80%. This is dependent on the industrial process, supply chain to the airport, and sustainable feedstock.

SAF represents a promising solution for reducing the environmental impact of aviation and achieving ambitious emission reduction goals.

- **Compatibility with existing aircraft and infrastructure**

  SAF can be blended with traditional jet fuel and used in existing aircraft without the need for any modifications. This makes it a relatively easy and cost-effective way for airlines to reduce their carbon footprint and transition to more sustainable practices.

- **Increases energy security**

  SAF can be produced from various feedstocks (e.g., agricultural residues, waste oils, and even municipal waste), reducing dependency on fossil fuels and enhancing energy security.

Cons:

- **High Costs**

  SAF is currently more expensive to produce and purchase than conventional jet fuel, largely due to limited production scale and high feedstock costs.

  The higher costs can impact the economic viability for airlines, especially in a highly competitive and cost-sensitive industry.

- **Limited Availability**

  The current production capacity of SAF is insufficient to meet the entire aviation sector's demand, leading to limited availability.

- **Technological Challenges**

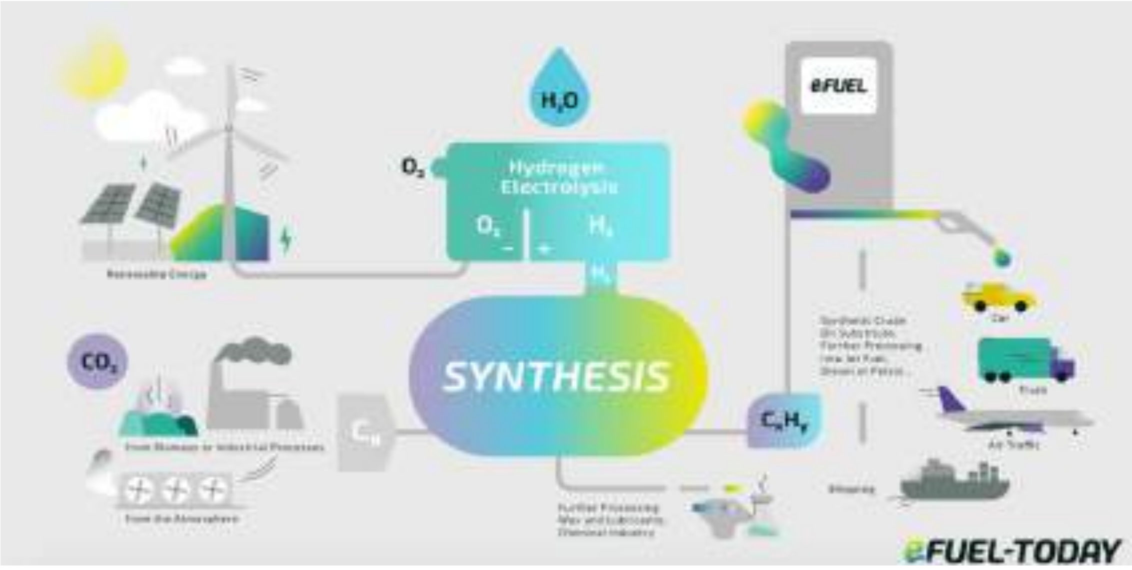
  Some SAF production technologies are still in development or early commercial stages, requiring further technological advancements and securing investments to scale up.

5.5. E-fuels (Electrofuels)

E-fuels are synthetic fuels produced using renewable electricity. They are part of the power-to-liquid or power-to-gas technologies.

E-fuels, also known as synthetic methanol, are produced through a sophisticated process involving water, hydrogen, and carbon dioxide. Unlike biofuels, E-fuels are generated from renewable or decarbonized electricity. The production process begins with extracting hydrogen from water via electrolysis. This hydrogen is then combined with carbon dioxide to create the fuel. A common method used in this process is the Fischer-Tropsch synthesis, a polymerization reaction of CO that results in hydrocarbons, olefins, paraffins, and oxygenates. This reaction takes place in the presence of metal catalysts at temperatures ranging from 150 to 300 °C (302 to 572 °F) and pressures from one to several tens of atmospheres. E-fuels deliver similar performance to conventional petrol and diesel but have a lower environmental impact due to their sustainable production methods.[95]

Figure 31: eFUEL production process:



Source: E-fuel today

Industry Status on E-Fuels Production

Industry mass production of e-fuels is still in its early stages. Notably, Porsche has committed over $100 million to the development and production of e-fuels, including a $75 million investment in HIF Global LLC in April 202296. In Germany, H&R Refining GmbH and Mabanaft GmbH & Co. KG have formed a joint venture called P2X Europe. This venture will purchase carbon-neutral products like e-fuels and petrochemical specialties from various projects and market them through Mabanaft and H&R's distribution channels. Jonathan Perkins, CEO of Mabanaft, emphasizes the significance of this partnership, noting that it enables them to offer CO2-neutral e-fuels to their customers. The project is slated to begin producing and marketing synthesis-based e-fuels and waxes from renewable raw materials at the H&R production site in Hamburg starting in September 2022[97].

Price Predictions for E-Fuels[98]

As the integration of eFuels into conventional fuels increases and production costs decline due to economies of scale, eFuels are anticipated to become affordable for consumers throughout the market's development. By 2025, the production costs for one litre of eFuel, with a 4% blending rate with conventional fuels, are expected to be between €1.61 and €1.99. By 2050, these costs could drop to between € 0.70 and € 1.33 per litre with a 100% blending rate.

This suggests that in 2025, the price of diesel for consumers at filling stations will be € 1.22. By 2050, the cost of eDiesel is projected to be between €1.38 and € 2.17, based

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[95] eFuel Today. (2022). *Production process of e-fuels*. Retrieved from: https://efuel-today.com/en/production-process-of-e-fuels/#:~=The%20production%20process%20involves%20extracting,the%20Fischer%2DTropsch%2DSynthesis
[96] Porsche. (2022).
[97] Mabanaft. (2022).
[98] eFuel Alliance. (n.d.). *Costs outlook*. Retrieved from: https://www.efuel-alliance.eu/efuels/costs-outlook

on current taxes and duties. For petrol with an eFuels admixture, the price in 2025 is expected to be between €1.34 and €1.36, while by 2050, ePetrol prices are forecasted to range from € 1.45 to € 2.24, also considering current taxes and duties.

The Future of E-Fuels: Scaling Up Production and Sustainability

Currently, there are no industrial scale e-Fuel plants due to the absence of supportive political frameworks. However, the necessary technologies and components are well understood and researched. The first large-scale plants, capable of producing over 500 million litres annually, are expected to be operational by 2026. Globally, 214 GW of hydrogen project capacity has been announced.

To quickly address climate change and support the market introduction of eFuels, our political proposals include all synthetic fuels meeting the sustainability criteria of the "Renewable Energy Directive (RED)." Immediate scaling of all sustainable energy sources is essential. Alongside electricity-based fuels, this includes sustainable biofuels derived from an expanding and innovative range of raw materials defined in the RED III.

5.5.1. E-Kerosene

E-kerosene, also known as synthetic kerosene, is a type of e-fuel designed to offer a sustainable alternative to traditional aviation fuel. It is made using renewable electricity to produce hydrogen through electrolysis. This hydrogen is then combined with carbon dioxide, which is captured from the air or industrial processes, to create liquid hydrocarbons that are very similar to conventional kerosene.

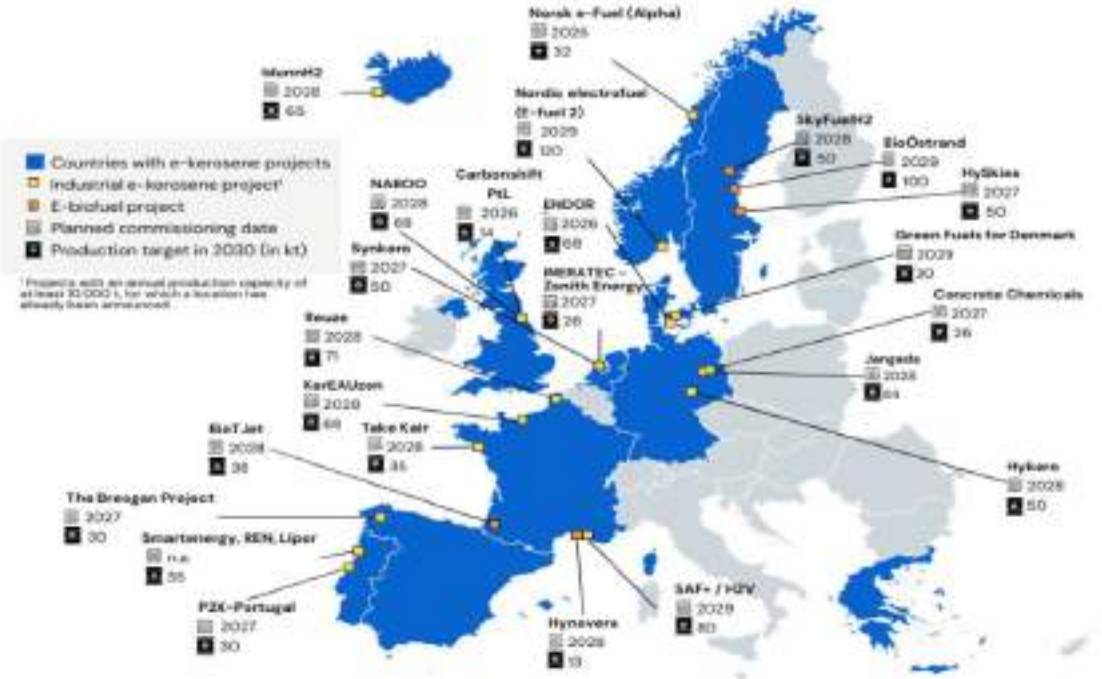
The Fischer-Tropsch process is one of the main methods used to create these synthetic hydrocarbons. In this process, carbon monoxide and hydrogen are combined to produce various fuels, including kerosene. This makes e-kerosene a cleaner and more environmentally friendly option for powering aircraft.

European Leaders in E-Fuel Production: Norway, Germany, and France

Norway, Germany, and France are leading the charge in producing e-fuels for aviation, according to a new study by the green group Transport & Environment. The study highlights a total of 45 e-kerosene projects across the European Economic Area (EEA), which could provide enough green fuel to meet the EU's sustainable aviation fuel (SAF) targets. However, these projects face uncertainty without final investment decisions, putting both the projects and the targets at risk. Transport & Environment's study identifies 25 large-scale industrial projects, and 20 smaller pilot projects committed to producing synthetic fuels for aviation.

The total production capacity of the 45 projects analysed adds up to 1.7 Mt in 2030, with the first drops of e-kerosene expected to arrive on the market in 2026.

Figure 32: Norway, France and Germany stand out as future leaders of e-kerosene production in Europe[99]



Source: Green Group Transport & Environment

The map illustrates 25 industrial e-kerosene projects across ten European countries.

Norway is leading the way, planning to produce 420,000 tonnes of e-kerosene by 2030, which is about a quarter of the total projected amount. Nordic Electrofuel and Norsk e-Fuel have ambitious plans to capture a significant share of the European market. Despite having adopted a SAF mandate (prior to ReFuelEU) that does not specifically incentivise e-kerosene, Norway benefits from stable access to renewable energy from hydropower at a relatively low cost. This can explain why it is currently leading the e-kerosene race, as electricity is a significant cost factor in the production of e-fuels.

Germany and France also have ambitious plans to increase domestic production of e-kerosene. Germany has its own target for the use of e-kerosene at airports (0.5% in 2026 and 2% in 2030), while France has pledged €200 million to support innovative SAF projects and has now caught up with Germany in terms of production capacity. Both countries could produce around 300,000 tonnes of e-kerosene in 2030.

France and Germany are accompanied by Sweden, where all four projects are actually e-biofuels projects utilizing local forestry biomass. The rest of the projects are distributed across Denmark (97 kt), the Netherlands (76 kt), Portugal (65 kt), Iceland (65 kt), Greece (44 kt), and Spain (30 kt). Despite Spain's significant share of the EU's green hydrogen production—accounting for 20% of the world's green energy projects in 2021—only 2%

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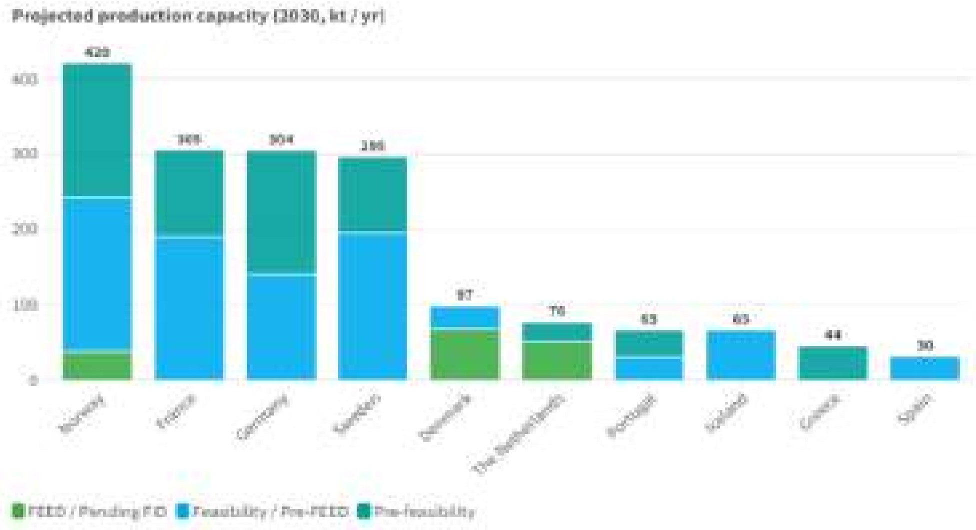
[99] Transport & Environment. (2024). *E-fuels for planes: With 45 projects, is the EU on track to meet its targets?*. Retrieved from: https://www.transportenvironment.org/articles/e-fuels-for-planes-with-45-projects-is-the-eu-on-track-to-meet-its-targets

of e-kerosene production is expected to take place there. Instead, Spain appears to be focusing on other hydrogen products, such as pure hydrogen or e-methanol. Notably absent from the map are Belgium and Italy, as well as all Eastern European countries.

Figure 33: Projected Production capacity of e-fuel in main European countries:



Source: Green Group Transport & Environment

According to the information of the green group Transport & Environment report, France has made significant progress over the past year with new projects like Take Kair, BioTJet (e-biofuel), the SAF+ Consortium, and the H2V partnership, in addition to two earlier projects by Engie (KerEAUzen and ReUze). Together, these six full-scale industrial projects aim to produce around 300,000 tons of e-kerosene by 2030. Supported by the 4th Investment for the Future Programme (PIA4) and the national roadmap for SAF deployment, France has allocated €200 million to innovative SAF projects. Notably, the first call for projects by Civil Aviation Department saw five winners, all focused on e-kerosene, despite the tender not prioritising synthetic fuels. The inclusion of low-carbon (nuclear) synthetic aviation fuels in the ReFuelEU mandate benefits France's electricity mix in the short term. However, in the long run, nuclear hydrogen is likely to be less competitive compared to hydrogen produced from renewable electricity.

Obstacles Persist for E-Kerosene Projects Despite EU Legislation

Despite EU legislation aimed at promoting sustainable aviation fuels, no major e-kerosene project has yet reached the final investment decision (FID). The e-kerosene market faces several challenges:

- Some regulatory loopholes, including a lack of incentives to supply e-kerosene before 2030, looming regulatory incentives to use e-fuels in the road sector, and the possible non-inclusion of e-fuels for aviation and shipping as a strategic technology in the Net Zero Industrial Act (NZIA).

- The limited availability of renewable hydrogen and sustainable carbon sources risks creating a bottleneck on the market.

- High production costs remain a significant barrier to secure offtake agreements with airlines, although ReFuelEU financial penalties, the SAF allowances and Contracts for Difference (CfD) schemes should contribute to solving that issue.

- EU-funding is insufficiently targeted towards hydrogen use in hard-to-electrify sectors like aviation and shipping, and too few Member States are proactively seeking to develop local e-kerosene production.

- The control oil majors retain over the downstream jet fuel supply chain could turn them into gatekeepers, making it harder for new players to enter the market.

- Social acceptability is emerging as a new topic for e-fuels projects launching public consultations to secure environmental permits.

5.6. SAF financing model of Raven SR

Raven SR is a leading innovator in the production of renewable fuels, with a particular focus on green hydrogen and its use in creating sustainable aviation fuel (SAF). The company is at the cutting edge of waste-to-fuel technologies, transforming waste materials into clean, renewable energy. Raven SR's pioneering approach enables the production of SAF and other renewable fuels with significantly lower carbon footprints, aligning with global initiatives to decarbonize the aviation industry

Raven SR has initiated a significant SAF project in France, the company has signed an MoU with a main airline to supply SAF and leveraging in the country its proprietary technology to convert waste into sustainable aviation fuel. This project is part of Raven SR's broader strategy to expand its operations and scale up in Europe and contribute to the European Union's ambitious climate goals and interregional investment.

Table 8: SAF Monetization:

SAF Monetization

SAF Monetization/Gallon	
Molecule	2,00
LCFS	0,91
RIN	3,09
IRA (45V or Q or ITC)	1,75
BTC	1,06
Environmental Attributes	2,40
Total	11,21

Table 9: Waste to SAF" financials:

Sources	
Debt	$113.750.000
Raven Common Equity Fun	$30.625.000
Investor 1 Common Equity	$15.312.500
Investor 2 Common Equity	$15.312.500
Total	$175.000.000
Uses	
Project Capex	$175.000.000
Total	$175.000.000
Check	VERDADERO

COGS	
Cost / Unit of Input	$0,00
O&M ($ / Month)	$50.000
Repairs & Maintenance (%	0,07%
Labor ($ / month)	$170.000
Benefits (% of Labor)	28,0%
Cost / KWh	$0,19
Cost / Self Gen MCF Gas	$0,00

Financing	
Total Financing	$175.000.000
Debt % Funding	65%
Debt Grace Period (Months	12
Interest	7,0%
Amortization (Months)	120,0
% of Total Investment - Pre	0%
% Common Consolidated C	100%
% Pref Equity Return	0%
Equity Return Period (Yrs)	20,0
Years to Debt Replacement	5,0
Preferred Equity Debt Repla	–

Ownership and Dividend %	
Ownershp Transfer Toggle	0
Ownershp %	50,0%

CapEx Contribution		Returns
Raven	50,0%	53,7%
Investor 1	25,0%	53,7%
Investor 2	25,0%	53,7%

Operating	
Input Type	MSW
Tons of Solids Input Capacity / Day	300
Output Type	SAF
Volume Output / Day	23.500
CO2 Output / Day	21
Construction Start Date	46.113
Months of Construction	15
Operations Start Date	46.569
Operations Start Month	41
Operating Life (months)	240
Technology	S Series SAF

G&A	
Monthly Management Fee	$50.000
Monthly Oversight if Circular Energy	$5.000
% Circular Energy	100,0%

Tax Assumptions	
NOL Limitation	80,0%
Tax Rate	26,0%
kg CO2e / kg H2	–
US Based	Yes
SAF Credit	1,8
PTC Credit	Yes
Direct Pay (ITC)	No

Investment Tax Credit (ITC)	
2023	30,0%
2034	22,5%
2035	15,0%
2036	0,0%
ITC Credits Applied	
2023	30,0%
2034	0,0%
2035	0,0%
2036	0,0%

Income	
Contracted Rate	
2024	$6,50
2025	$6,50
2026	$6,50
2027	$6,50
2028	$6,50
% Contracted	100,0%
CO2 Price / Ton	$20,00
Tipping Fee / Ton of Raw Materials	$30,00

Capex	
Facility CapEx	$175.000.000
Date of Prepayment	4/1/26
Number of Payments	4
Mo Between Payments	4
Payments	$43.750.000
Equipment Useful Life (Mo)	240
Facility MW	31,2
Self Generated MW	31,2

Carbon Intensity Tax Credit / kg C02e / kg H2	
0,45	$0,60
1,50	$0,20
2,50	$0,15
4,00	$0,12
Labor Multiplier	5,0
Carbon Tax Credit Applied	
0,45	$1,75
1,50	$0,00
2,50	$0,00
4,00	$0,00

Common Equity Funding %	
Raven	50%
Investor 1	25%
Investor 2	25%

Table 10: SAF Project financing sources:

Sources	
Debt	$113.750.000
Pref Shareholder Project Equity Funding	-
Raven Common Equity Funding	$30.625.000
Investor 1 Common Equity Funding	$15.312.500
Investor 2 Common Equity Funding	$15.312.500
Total	$175.000.000
Uses	
Project Capex	$175.000.000
Total	$175.000.000

Table 11: SAF project information:

Operating	
Input Type	MSW
Tons of Solids Input Capacity / Day	300
MCF of Gas Input Capacity / Day	0
Output Type	SAF
Volume Output / Day	23.500
CO2 Output / Day	21
Construction Start Date	4/1/26
Months of Construction	15
Operations Start Date	7/1/27
Operations Start Month	41
Operating Life (months)	240
Technology	S Series SAF

Income	
Contracted Rate	
2024	$6,50
2025	$6,50
2026	$6,50
2027	$6,50
2028	$6,50
% Contracted	100,0%
CO2 Price / Ton	$20,00
Tipping Fee / Ton of Raw Materials	$30,00
IRR	53,7%

COGS	
Cost / Unit of Input	$0,00
O&M ($ / Month)	$50.000
Repairs & Maintenance (% of Capex)	0,07%
Labor ($ / month)	$170.000
Benefits (% of Labor)	28,00%
Daily Electricity Required (KWh / Day)	0
Cost / KWh	$0,19
Additional Gas Input Required (MMBTU	0,0
Cost / Self Gen MCF Gas	$0,00

G&A	
Monthly Management Fee	$50.000
Monthly Oversight if Circular Energy	$5.000
% Circular Energy	100%

Capex	
Facility CapEx	$175.000.000
Date of Prepayment	01/04/2026
Number of Payments	4
Mo Between Payments	4
Payments	$43.750.000
Equipment Useful Life (Mo)	240
Facility MW	31,2
Self Generated MW	31,2
Purchased Power MW	0,0

Financing	
Total Financing	$175.000.000
Debt % Funding	65,0%
Debt Grace Period (Months)	12
Interest	7,0%
Amortization (Months)	120
% of Total Investment - Preferred	0,0%
% Common Consolidated Ownership	100,0%
% Pref Equity Return	0%
Equity Return Period (Yrs)	20
Years to Debt Replacement	5
Preferred Equity Debt Replacement	No

Tax Assumptions	
NOL Limitation	80,0%
Tax Rate	26,0%
kg CO2e / kg H2	0
US Based	Yes
SAF Credit	$1,75
PTC Credit	Yes
Direct Pay (ITC)	No

Carbon Intensity Tax Credit / kg C02e / kg H2	
0,45	$0,60
1,50	$0,20
2,50	$0,15
4,00	$0,12
Labor Multiplier	5,0
Carbon Tax Credit Applied	
0,45	$1,75
1,50	$0,00
2,50	$0,00
4,00	$0,00

Ownership and Dividend %	
Ownershp Transfer Toggle	0
Ownershp %	50,0%

CapEx Contribution		IRR
Raven	50%	53,7%
Investor 1	25%	53,7%
Investor 2	25%	53,7%

Investment Tax Credit (ITC)	
2023	30,0%
2034	22,5%
2035	15,0%
2036	0,0%
ITC Credits Applied	
2023	30,0%
2034	0,0%
2035	0,0%
2036	0,0%

Common Equity Funding %	
Raven	50%
Investor 1	25%
Investor 2	25%

Producing SAF involves high value investments in place and in most of the cases a pool of investors that support the project and usually investing in equity in the company. In the case of RAVEN SR, the company has already at Head Co. level a pool of investors, such as Chevron, Itochu Corporation, Ascent Fund or Samsung Ventures.

Scaling up projects and being attractive for investors to follow the way, entitles considerable breakthrough for SAF producers. In the case of the Steam/C02 Reforming technology, the cost of developing a “Waste to SAF” Series SAF single facility involves an estimated investment of €175.000.000.

Due to the current geopolitical and economic global complex context, investors are overcautious when analysing projects. Mature technologies have to been particularly attractive to gain investors and able to replicate at scale. One single project alone is not attractive but a mature technology able to provide a pipeline of projects and scale up is.

The competitive advantage of using waste as feedstock is that the cost of the raw material is controlled and the resource abundant. When launching a mature technology at industrial scale it is paramount to secure a very high IRR to investors to overcome and/or limit the impact of the risk aversion common barrier.

The business models of the Steam/C02 Reforming technology involving the production of SAF, FTs and e-fuels are highly profitable. This is a robust incentive to generate awareness among the investors 'community.

6. The Steam/CO2 Reforming Technology: an innovative solution

The steam and CO2 reforming technology is an innovative solution for producing Sustainable Aviation Fuel (SAF) from various feedstocks such as plastics, natural gas, and organic waste. Through this process, synthesis gas is generated, which is then converted into SAF.

The amount of SAF (and naphtha) obtained, as well as the CO2 emissions avoided or the biochar produced (as a by-product), will depend on the type of feedstock (see the table on the following page).

6.1. Overview of STEAM/CO2 REFORMING Business Model for SAF Production

There is an innovative business model for the production of Sustainable Aviation Fuel (SAF) that leverages the flexible and efficient use of various feedstocks. This business model is characterized by several key features:

Feedstock Agnostic: it can process a variety of feedstocks, including biogenics, plastics, and gases, consistently producing a hydrogen-rich syngas. While the quality of the syngas remains constant, the quantity of fuel produced varies depending on the feedstock, with plastics and gases producing more fuel than green waste.

Capital[100] and Operational Investment:

- **Energy Autonomy:** It includes the capability to generate at least 80% of the required electricity, thereby reducing operational expenditure (OpEx) and dependence on the public grid. This energy autonomy [101] implies a higher initial investment but significantly lowers long-term operating costs.

- **Renewable Energy Consideration:** If inexpensive renewable energy is available, its integration is also considered to optimize efficiency and sustainability.

Production and Commercialization:

- **System Sizing:** Systems are sized to meet designated SAF production targets and also generate light FT liquids that can be sold on the market, thereby strengthening the overall business plan.

- **Environmental Benefits**: Raven SR's process not only produces cleaner fuels but also offers additional green benefits such as avoided emissions, organic waste

[100] Capital expenditure (CapEx) is based on current design, engineering, and vendor quotes for Raven projects in California.
[101] We must promote technologies that are self-sufficient and do not depend on the grid. They are safer, more stable, and not affected by price fluctuations, geopolitical context, production issues, security, internal control, or, in current times, cyberattacks, etc. These technologies guarantee production and should be enhanced for the future, safeguarding against hacking and other threats.

diversion, and sequestered biochar. This biochar can be used as a soil amendment or, in worst-case scenarios, as road base material or buried.

1. **Carbon Credits:** Operators of Raven units can earn carbon credits.

2. **Carbon-Negative Fuels:** Depending on the feedstock, the produced fuels can be carbon-negative, helping to offset the CO_2 impact of Wizz's jet kerosene.

Operations and Maintenance:

- **Production and Maintenance**: Production is based on 345 days per year with an expected lifespan of 15 years, which can extend to 20 years with a good maintenance schedule.

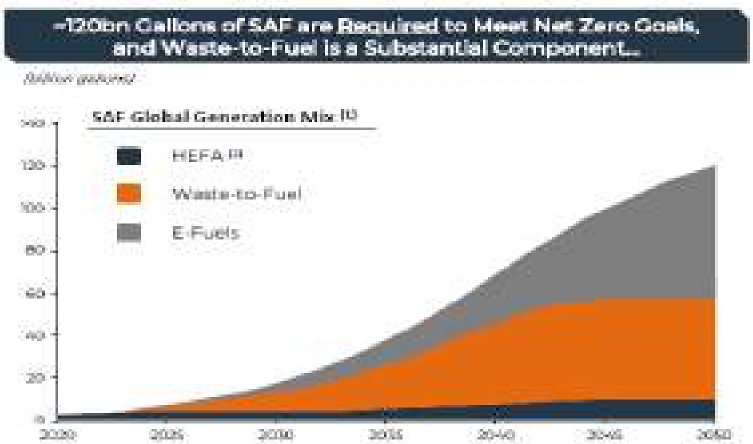
- **Revenue and Expenses:** Operations generate revenue from feedstock tipping fees, biochar sales, and sales of both heavy and light FT liquids. Major expenses include electricity, labor, maintenance, and repairs.

In summary, STEAM/CO2 REFORMING business model for SAF production is characterized by its flexibility in feedstock use, strategic investment in energy autonomy, significant environmental benefits, and a solid focus on operational efficiency and long-term sustainability.

The European Commission has proposed a SAF blending mandate for fuel supplied to EU airports, with minimum shares of SAF gradually increasing from 2% in 2025 to 63% in 2050 (EASA, s.f.)**.**
To achieve this mandate:
2.3 million tonnes of SAF would be required by 2030.
14.8 million tonnes of SAF would be required by 2040.
28.6 million tonnes by 2050.

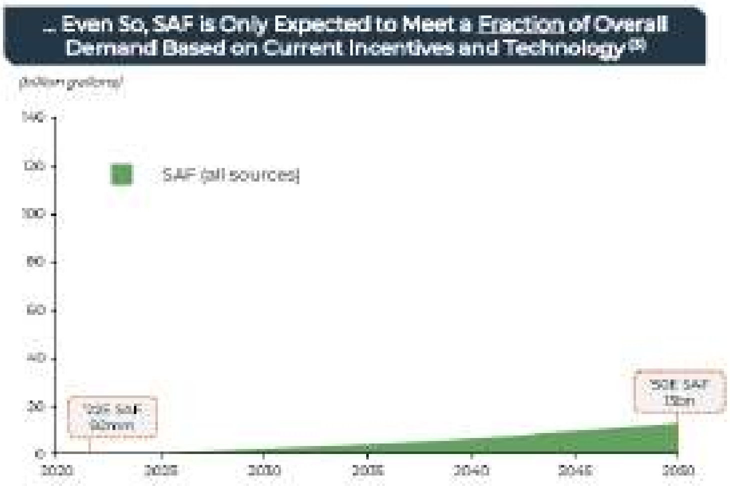
As can be seen in the charts below, without waste-to-SAF technology, it will be impossible to achieve the goal of 120 billion gallons set by the US government for 2050.

Figure 34: Waste-to-SAF technology



Source: Raven Sr

Figure 35: SAF production from 2020 to 2050 (billion gallons):[102]



6.2. The problem with the Municipal Solid Waste

Municipal Solid Waste (MSW)—more commonly known as trash or garbage—consists of everyday items we use and then throw away, such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. This waste originates from our homes, schools, hospitals, and businesses.

The problem with MSW is multifaceted and challenging to manage. Firstly, the sheer volume of waste generated poses a significant challenge for disposal and recycling facilities, which are often overwhelmed by the amount of garbage they receive daily. This results in overflowing landfills, which can lead to environmental contamination, including soil and water pollution from hazardous substances like paint and batteries.

Secondly, the diverse nature of MSW makes it difficult to sort and process efficiently. Items such as food scraps and newspapers can be composted or recycled, but they are frequently mixed with non-recyclable materials like plastic packaging and electronics, complicating the recycling process. This contamination often renders entire batches of potentially recyclable material unusable, leading to increased waste and lost resources.

Furthermore, the disposal of MSW has significant environmental and health implications. Landfills produce methane, a potent greenhouse gas that contributes to climate change. Incineration, another common disposal method, can release toxic pollutants into the air, posing health risks to nearby communities.

Addressing the MSW problem requires comprehensive waste management strategies that include reducing waste generation, improving recycling rates, and developing innovative solutions for waste-to-energy conversion. Without effective measures, the increasing amount of MSW will continue to strain our waste management systems and harm the environment.

[102] Source: Raven Sr

Figure 36: Summary of Global Municipal Solid Waste Volume Estimates (Tons of MSW Generated Annually in Billions):

Source: The World Bank data catalog

6.3. Waste Framework Directive

The Waste Framework Directive sets the basic concepts and definitions related to waste management, including definitions of waste, recycling and recovery.

The Waste Framework Directive mandates that waste management must ensure:

1. Protection of human health and the environment from harm.
2. Prevention of risks to water, air, soil, plants, and animals.
3. Prevention of nuisances such as noise or odors.
4. Preservation of countryside and special interest areas from adverse impact

Figure 37: Waste hierarchy:

Source : (European Comission, s.f.)

To meet the goals set out in this Directive, EU member states must implement the following targets:

1. By 2020, ensure that at least 50% by weight of waste materials (such as paper, metal, plastic, and glass) from households are prepared for re-use or recycled.
2. By 2020, ensure that at least 70% by weight of non-hazardous construction and demolition waste is prepared for re-use, recycled, or otherwise recovered, including backfilling operations using waste as substitute materials.
3. By 2025, increase the preparing for re-use and recycling of municipal waste to a minimum of 55% by weight.
4. By 2030, this target increases to 60%.

5. By 2035, achieve a minimum of 65% by weight of municipal waste prepared for re-use and recycling.

Waste-to-SAF (Sustainable Aviation Fuel) technology is **particularly relevant** given the immense challenges associated with managing Municipal Solid Waste (MSW) and the critical issues surrounding landfills:

1. Volume and Overflow: The sheer volume of waste generated daily from homes, schools, hospitals, and businesses overwhelms disposal and recycling facilities. Landfills are reaching capacity at alarming rates, leading to overflow issues. Overflowing landfills not only take up valuable land but also pose significant environmental hazards.

2. Environmental Contamination: Landfills are a major source of soil and water contamination. Hazardous substances like paint, batteries, and electronic waste can leach into the ground, contaminating local water supplies and ecosystems. This poses a significant risk to human health and wildlife.

3. Greenhouse Gas Emissions: Decomposing waste in landfills produces methane, a potent greenhouse gas that is far more effective at trapping heat in the atmosphere than carbon dioxide. This contributes significantly to climate change and global warming.

4. Complexity of Waste Streams: MSW consists of a wide variety of materials, including food scraps, plastics, paper, and hazardous waste. This diversity makes sorting and processing waste extremely complex and costly. Contaminated and mixed waste streams often render large quantities of potentially recyclable materials unusable, exacerbating the waste problem.

5. Limited Landfill Lifespan: Landfills have a limited lifespan, and as they reach capacity, new sites must be found, often in increasingly remote or unsuitable locations. This leads to higher transportation costs and greater environmental disruption.

6. Public Opposition and Regulation: New landfill sites often face strong public opposition and strict regulatory hurdles due to their associated environmental and health risks. This makes it increasingly difficult to establish new landfills, putting further strain on existing ones.

Hazardous materials (European Comission, s.f.):

According to the European Commission, hazardous wastes pose a greater risk to the environment and human health compared to non-hazardous waste, necessitating a stricter control regime.

Regulatory Aspects	Waste to SAF as an Optimal Option
The Waste Framework Directive imposes additional obligations for labeling, record-keeping, monitoring, and control "from cradle to grave".	Offers a viable solution by disposing of hazardous waste and converting it into Sustainable Aviation Fuel (SAF), albeit non-renewable.

Regulatory Aspects	Waste to SAF as an Optimal Option
It prohibits the mixing of hazardous waste with other categories of hazardous waste.	Contributes to effective waste management by preventing the mixing of hazardous waste with other waste types, thereby promoting safety and regulatory compliance.
Classification is based on a system for the classification and labeling of dangerous substances and preparations.	Leverages rigorous classification and labeling principles to ensure proper management of hazardous materials throughout their lifecycle.

Table 12: Different Steam/Co2 reforming pathways

Green + Food waste (50:50) [1]		Feedstock	FUELS ESTIMATE [5]						Avoided Emissions [6]	Bio-Carbon [7]	Projected CI [8]	CO_2 Reductions from CJF [9]
			SAF			Lite FTs (naphtha, etc)						
	Target [4]	WTPD	bpd	tpd	TPY	bpd	tpd	TPY	(MT CO2e/year)	(MT/year)	(gCO_2e/MJ)	%
	Standard	300.0	533.2	71.2191	24,570.6	115.2	15.4	5,308.2	20,424.04	11,902.50	(10.0)	111.20%
	Airline 2030	2,441.9	4,340.4	579.7	200,000.0	937.7	125.2	43,207.5	166,247.9	96,884.1	(10.0)	111.20%

Greenwaste w/ plastics [2]		Feedstock	FUELS ESTIMATE [5]						Avoided Emissions [6]	Bio-Carbon [7]	Projected CI [8]	CO_2 Reductions from CJF [9]
			SAF			Lite FTs (naphtha, etc)						
	Target [4]	WTPD	bpd	tpd	TPY	bpd	tpd	TPY	(MT CO2e/year)	(MT/year)	(gCO_2e/MJ)	%
	Standard	300.0	760.4	101.6	35,036.2	164.3	21.9	7,569.1	26,446.0	11,902.5	20.0	77.62%
	Airline 2030	1,712.5	4,340.4	579.7	200,000.0	937.7	125.2	43,207.5	150,963.9	67,944.1	20.0	77.62%

Gas (natural or RNG) [3] [10]		Feedstock	FUELS ESTIMATE [5]						Avoided Emissions [6]	Bio-Carbon [7]	Projected CI [8]	CO_2 Reductions from CJF [9]
			SAF			Lite FTs (naphtha, etc)						
	Target [4]	scfd	bpd	tpd	TPY	bpd	tpd	TPY	(MT CO2e/year)	(MT/year)	(gCO_2e/MJ)	%
	Standard	117,936.0	505.1	67.5	23,275.5	109.1	14.6	5,028.4	n.a.	n.a.	tbd	tbd
	IAG 2030	1,013,393.6	4,340.4	579.7	200,000.0	937.7	125.2	43,207.5	n.a.	n.a.	tbd	tbd

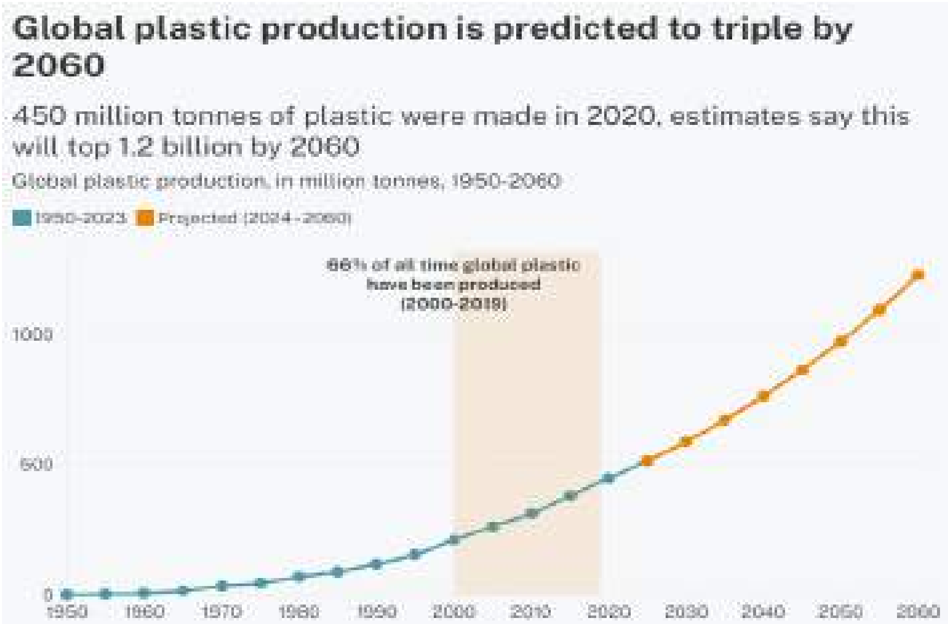
Source: Raven SR

6.4. Business Model: Plastics to SAF (Steam/CO2 Reforming)

6.4.1. Plastic demand and supply in EU

The production of plastic has increased dramatically over the past few decades, rising from 1.5 million tonnes in 1950 to 359 million tonnes globally in 2018. This growth has also led to a significant increase in plastic waste. Although production saw a significant decline in the first half of 2020 due to the Covid-19 pandemic, it rebounded in the second half of the year. (European Parlament, s.f.)

Figure 38: Global plastic production 1950-2060:



Source: OCDE

The EU is already implementing measures to reduce plastic waste, but what happens to the waste that continues to be generated despite these efforts? Additionally, how can the rates of plastic recycling be increased?

Plastic Waste Treatment in Europe

In Europe, the primary method for disposing of plastic waste is energy recovery, followed by recycling. Approximately 25% of all generated plastic waste ends up in landfills.

Half of the plastic collected for recycling is exported to be processed in countries outside the EU. This is due to a lack of capacity, technology, or financial resources for local treatment. In 2020, EU exports of waste to non-EU countries totaled 32.7 million tonnes. The majority of this waste, which includes ferrous and nonferrous metal scrap, as well as paper, plastic, textile, and glass wastes, is exported to Turkey, India, and Egypt.

Previously, a significant share of the exported plastic waste was shipped to China, but recent restrictions on imports of plastic waste in China is likely to further decrease EU exports. This poses the risk of increased incineration and landfilling of plastic waste in Europe. Meanwhile, the EU is trying to find circular and climate-friendly ways of managing its plastic waste.

The low rate of plastic recycling in the EU results in significant economic and environmental losses. It is estimated that 95% of the value of plastic packaging material is lost to the economy after just one short-use cycle.

Environmental Impact of Plastic

Globally, researchers estimate that in 2019, the production and incineration of plastic emitted more than 850 million tonnes of greenhouse gases into the atmosphere. By 2050, these emissions could increase to 2.8 billion tonnes, a portion of which could be prevented through improved recycling efforts.

6.4.2. Problems with plastic recycling

The main issues complicating plastic recycling are the quality and price of the recycled product, compared with their unrecycled counterpart. Plastic processors require large quantities of recycled plastic, manufactured to strictly controlled specifications and at a competitive price.

However, since plastics are easily customised to the needs - functional or esthetic - of each manufacturer, the diversity of the raw material complicates the recycling process, making it costly and affecting the quality of the end product. As a consequence, the demand for recycled plastics is growing rapidly, though in 2018 it accounted for only 6% of plastics demand in Europe.

EU solutions to increase plastic recycling rates

In June 2019, the EU introduced new regulations aimed at addressing the problem of plastic marine litter. These regulations include targets such as achieving 25% recycled content in plastic bottles by 2025 and increasing this to 30% by 2030.

In November 2022, the European Commission proposed additional EU-wide rules on packaging. These proposals focus on enhancing packaging design through clearer labeling to encourage reuse and recycling. There is also a push towards transitioning to bio-based, biodegradable, and compostable plastics.

Part of the EU's Green Deal initiative aims to recycle 55% of plastic packaging waste by 2030. Achieving this goal will require improved design for recyclability. However, Members of the European Parliament (MEPs) emphasize the need for measures that stimulate the market for recycled plastic to complement these regulatory efforts.**These measures could include:**

- Creating quality standards for secondary plastics
- Encouraging certification in order to increase the trust of both industry and consumers
- Introducing mandatory rules on minimum recycled content in certain products
- Encouraging EU countries to consider reducing VAT on recycled products

The European Parliament also backed the restriction of light-weight plastic bags in the EU in 2015.

In addition, MEPs called on the Commission to take action against micro plastics.

In January 2023, Parliament voted on its position regarding waste shipment rules which aim to promote reuse and recycling and reduce pollution. MEPs insist that exports of plastic waste to non-OECD countries should be banned and shipments to OECD countries should be phased out within four years.

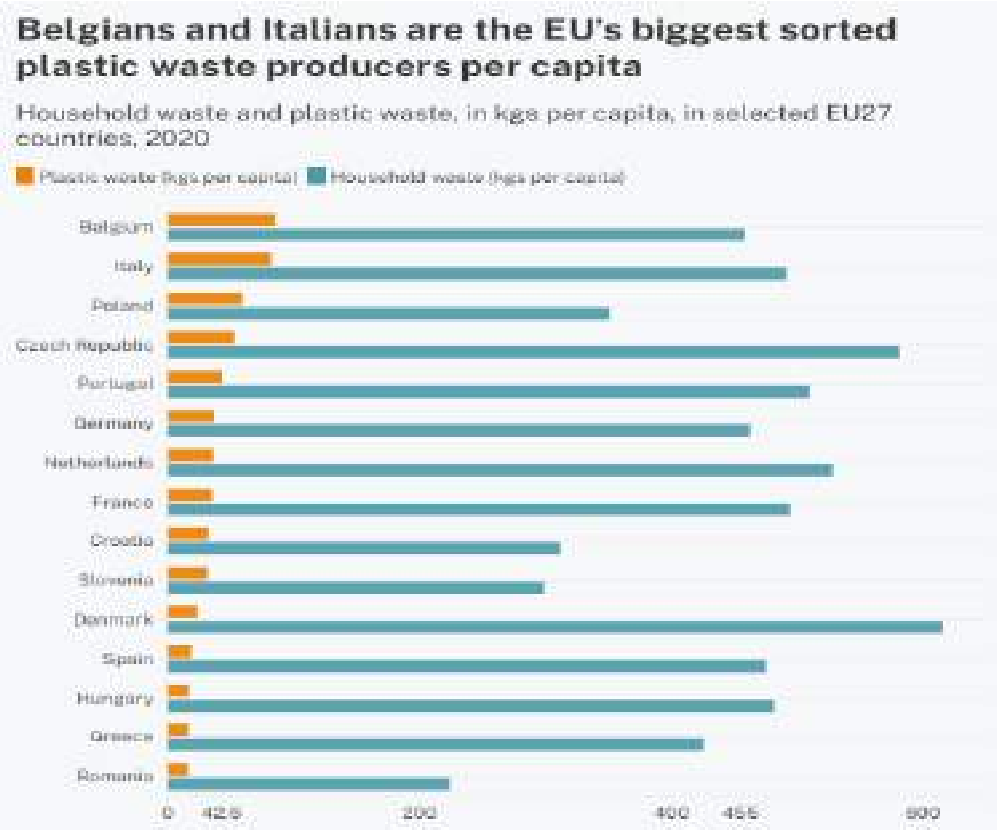
Almost 26 million tonnes of plastic waste is generated in Europe every year

Around 80% of marine litter is plastic

87% of Europeans are worried about the impact of plastic products on the environment

Source : (EU Comission, s.f.)

Figure 39: Households recycling overview in EU:



Source: (Eurostat, 2020)

On average, each EU citizen produces 42.6kg of sorted plastic waste annually, with Belgians and Italians producing significantly more despite their commendable sorting efforts. However, this figure only reflects the plastic waste collected separately. Household waste, which includes a substantial amount of plastic packaging, has grown from 180 million tonnes in 2004 to 203 million tonnes in 2020. Laboratory tests conducted in Budapest suggest that approximately 15% of mixed household waste is plastic, a portion that often avoids recycling.

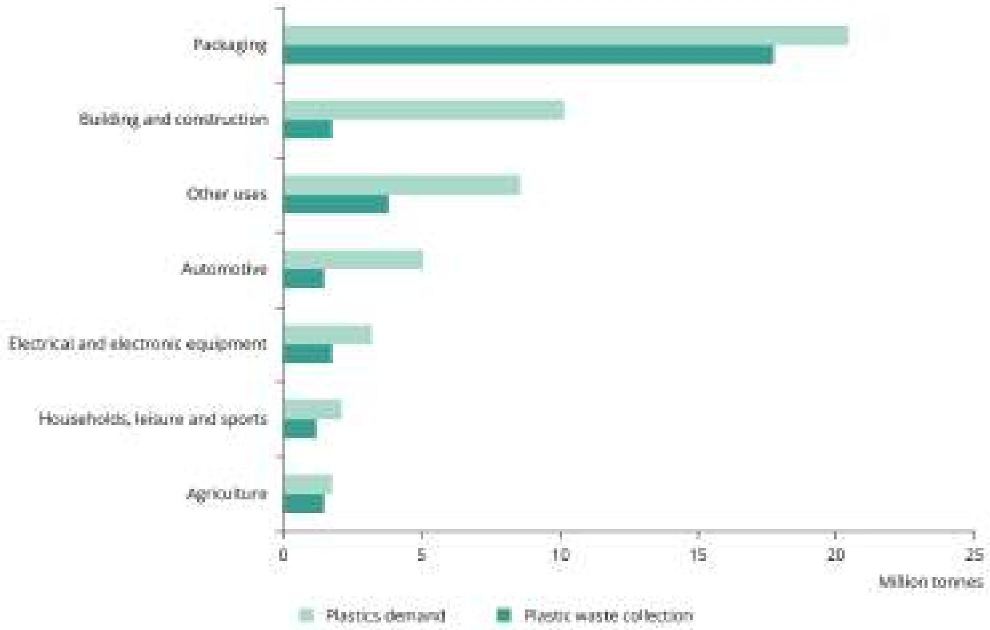
Europe's recycling efforts show that only a maximum of 32.5% of plastic is recycled, with significant amounts intended for recycling often ending up in landfills or incineration facilities. The best-case scenario estimates that 39% of discarded plastic packaging is recycled, another 39% is incinerated, and the remainder is landfilled. Around 30 million tonnes of plastic waste are generated annually in the EU, with approximately 3% of this being exported. This export figure was more than double in the 2010s, highlighting a historical trend of shipping Europe's plastic waste abroad (Kálmán, 2023).

Despite efforts to increase recycling rates, challenges persist, and the effectiveness of current recycling practices remains questionable. Various NGOs and studies have shown discrepancies in reported recycling rates, suggesting that much of the plastic labeled as "recycled" may not actually be reused in manufacturing processes. As such, the sustainability of Europe's plastic waste management strategies continues to be a subject of scrutiny and debate.

The problem with managing non-packaging plastics in European waste streams

Plastic is used in many ways and in large quantities across Europe. Environmental concerns make this a key focus for policy. Currently, most policy actions focus on plastic packaging, even though a large proportion of plastics are used for non-packaging applications, such as construction, furniture and consumer electronics. Improved reporting on the flows of non-packaging plastics is needed to inform the development of effective policies and measures that target this significant waste stream and increase resource efficiency, in line with the aims of the circular economy action plan.

Figure 40: Demand for plastic versus plastic waste collected by sector in 2018



Source: (Plastics Europe, 2019)

As evident from the figure above, collection rates for plastic waste from most non-packaging sources are lower than collection rates for waste from the packaging sector. This is likely to be the result of the longer lifetime of non-packaging items, which leads to a build-up in homes and businesses of non-packaging plastic stocks — including both products in use and those no longer in use but kept in storage. In addition, many non-packaging items contain complex mixtures of polymer types, often in combination with other materials. This complicates their segregation when discarded and means that they are often included in mixed waste sent to landfill or for energy recovery.

Non-packaging plastics usually have a longer shelf life than their packaging plastics counterparts. The service life of packaging plastics might be weeks or months, but the plastic parts made for cars and construction are made to last much longer. This means that, while non-packaging plastic materials are thrown away at a much lower rate, comprising about 40% of plastic waste every year in Europe, the overall stock of these parts and materials is always increasing as more of these products are being made (European Environment Agency, 2022).

There are several challenges that are currently being tackled by European experts in waste management. One is that data on non-packaging plastics waste flows is scarce due to incomplete monitoring of imported non-packaging plastics. Another challenge is recycling because of mixed materials in complex products, as well as hazardous additives in the products.

European leaders and sustainability experts are calling for better transparency in non-packaging plastics data, which would foster more robust policies and help manage waste flows.

6.4.3. Waste to SAF as a possible solution

Despite the measures implemented, plastic waste management in Europe continues to face significant challenges. The proportion of recycled plastics is low, at 32.5%, and a large part of plastic waste is exported, incinerated, or landfilled. Greater efforts and new solutions are needed to improve the recyclability of plastics, increase the demand for recycled products, and sustainably manage non-packaging plastic waste.

Advantages of Plastic-to-SAF Technology:

The technology for converting plastics into Sustainable Aviation Fuel (SAF) presents an innovative and effective solution to address these challenges in plastic waste management in Europe. This technology offers multiple advantages and benefits:

1. **Reduction of Landfill Waste:** Converting plastics into SAF helps decrease the amount of plastic waste ending up in landfills. This not only reduces soil and water contamination but also alleviates the pressure on waste management systems.

2. **Reuse of Non-Recyclable Plastics:** Plastic-to-SAF technology can utilize plastics that are difficult to recycle through conventional methods. This includes mixed and contaminated plastics that would otherwise be incinerated or discarded. Thus, it maximizes the reuse of plastic materials and minimizes waste.

3. **Reduction of Greenhouse Gas Emissions:** By producing SAF from plastics, the need for traditional fossil fuels is reduced, which in turn lowers the greenhouse gas emissions associated with the production and use of aviation fuels. This contributes to combating climate change and promotes a more sustainable economy.

4. **Economic Value of Plastic Waste:** Converting plastics into SAF gives economic value to plastic waste, incentivizing its collection and proper treatment. This process can foster the creation of a new industry dedicated to collecting and processing plastics, generating employment and wealth in various areas:

- **Collection and Transportation:** As the value of plastic waste increases, companies dedicated to the collection and transportation of these materials will be incentivized, creating numerous jobs.

- **Sorting and Processing**: Processing plants will be needed to sort, clean, and prepare plastics for conversion into SAF, creating technical and operational job opportunities.

- **Operation of Conversion Plants:** Facilities converting plastics into SAF will require specialized technicians and operators, increasing the demand for skilled labor.

- **Research and Development**: Continuous innovation is crucial for optimizing the plastic-to-SAF conversion process, creating opportunities for scientists and engineers focused on improving efficiency and sustainability.

Promotion of Investments in Sustainable Technologies: The added economic value to plastic waste will attract significant investments in sustainable technologies. Companies and investors will see plastic-to-SAF conversion as an opportunity to invest in profitable and sustainable technological innovations, fostering the development of new waste management solutions.

Impact on Local and Regional Economies: Establishing plastic-to-SAF conversion plants can revitalize local and regional economies. Operations will generate direct and indirect employment, boosting economic activity in surrounding areas and improving the quality of life for communities.

Contribution to a Circular Economy: The conversion of plastics into SAF is a tangible example of a circular economy. By reusing plastic waste and converting it into a valuable resource, sustainability is promoted and dependency on non-renewable resources is reduced. This closes the life cycle of plastic products, supporting more efficient and sustainable resource management.

Conclusion:

The technology for converting plastics into Sustainable Aviation Fuel (SAF) not only offers an innovative solution for plastic waste management but also provides multiple economic, environmental, and social benefits. By reducing the amount of plastic waste in landfills, decreasing greenhouse gas emissions, and adding value to plastic waste, this technology is essential for advancing towards a circular and sustainable economy in Europe.

6.4.4. Business Model: Organic waste to SAF (Steam/CO2 Reforming)

Organic feedstock plays a crucial role in the circular economy and sustainability initiatives, acting as a cornerstone for the development of eco-friendly energy and materials. Derived from renewable biological resources such as agricultural residues, food waste, and forestry by-products, organic feedstock represents a sustainable alternative to fossil fuels. Its utilization in producing biofuels, biogas, and bio-based chemicals and materials, such as bioplastics, exemplifies how waste can be transformed into valuable resources, thereby closing the loop in the production-consumption cycle. This approach not only mitigates the depletion of finite natural resources but also significantly reduces greenhouse gas emissions, contributing to climate change mitigation. By promoting the efficient use of organic waste and reducing landfill dependency, organic feedstock fosters a sustainable ecosystem where economic growth is decoupled from environmental degradation, paving the way for a resilient and low-carbon future. Its integration into various industrial processes underscores its potential to drive innovation and create green jobs, reinforcing the economic viability of sustainable practices.

Biodegradable waste

According to the European Commission, biowaste is defined as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers, and retail premises, as well as comparable waste from food processing plants. However, this definition excludes forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper, or processed wood. It also excludes by-products of food production that never become waste.

It's important to note the distinction between the types of feedstocks that can be used to produce biofuels and the organic waste defined by the European

Commission. While biowaste specifically refers to organic waste intended for waste management, feedstocks for biofuels may include a broader range of materials. For instance, **feedstocks for biofuels could include agricultural residues**, such as straw and grape marc, as well as industrial waste not fit for use in the food or feed chain, like tall oil pitch and crude glycerine or waste such as animal manure and sewage sludge (RED II). These are examples of materials allowed for biofuel production but not considered biowaste according to the European Commission's definition.

BIO-WASTE Management

Achieving the European Union's goal of recycling or preparing for reuse 65% of municipal waste by 2035 represents a significant challenge, requiring a technical and serious approach to the management of biological waste. Specifically, it is projected that this goal can only be achieved through a substantial increase in the recycling of biological waste, through composting and anaerobic digestion. This strategy entails a substantial increase in the current recycling rate, from 17% to 35%, resulting in a significant increase in the quantity of biological waste treated.

According to estimates provided by the European Compost Network, addressing this growing demand for biological waste treatment would require the installation of 3,900 new anaerobic digestion and composting facilities, with a primary focus on the EU27. This expansion in infrastructure would translate into the generation of between 17,000 and 31,000 full-time jobs and contribute between 1 and 2 billion euros to the European economy annually.

However, the implementation of these additional facilities carries significant economic and logistical implications. To mitigate these challenges, it is crucial to explore advanced technological alternatives, such as the production of biofuels and hydrogen from biological waste using Waste-to-Hydrogen/SAF technologies. These solutions offer positive synergies, alleviating pressure on biological waste treatment infrastructure, playing an important part in waste management, improving overall resource efficiency, while simultaneously supporting the EU's decarbonization goals, SAF production, and promoting sustainable mobility in the region.

Sewage sludge

Sewage sludge is a mud-like residue resulting from wastewater treatment. It can contain contaminants such as heavy metals or other chemicals, or pathogens. It also contains valuable organic matter and nutrients such as nitrogen and phosphorus and can therefore be very useful as a fertiliser or soil improver.

6.4.4.1. Overview of the organic feedstock in Europe:

In 2022, the ECN (European Compost Network, 2022) released a report confirming that less than 40 million tonnes of municipal bio-waste are collected separately and processed into high-quality compost and digestate across Europe. This represents only 17% of the total municipal solid waste that undergoes organic recycling through composting or anaerobic digestion. Achieving the EU's goal of recycling 65% of municipal waste by 2035 will require additional incentives to enhance separate collection and biological management of bio-waste at a European scale.

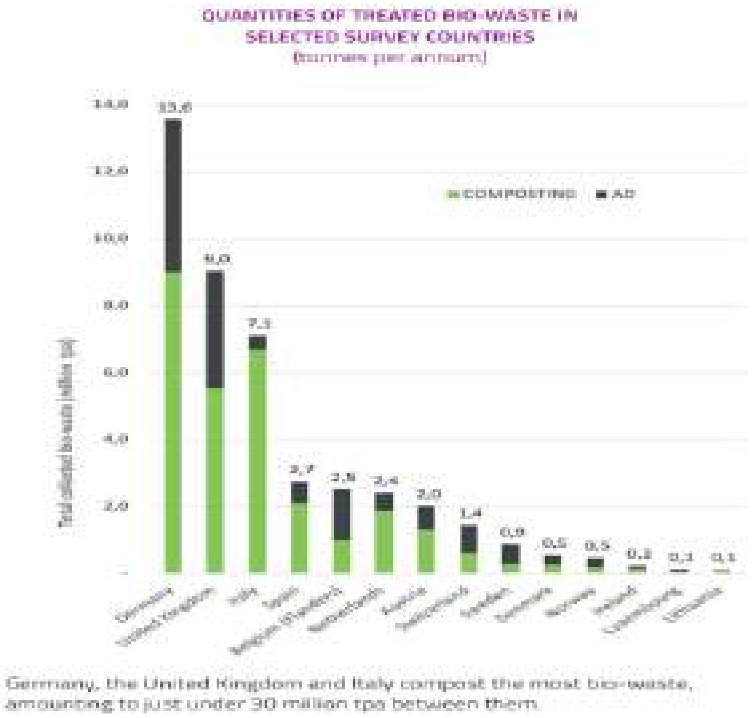
Bio-Waste Treatment

During the period of 2019/2020, approximately 71 million tonnes per annum (tpa) of bio-waste collected separately underwent treatment through composting and anaerobic digestion. This included 60 million tpa within the EU27 and an additional 11 million tpa in Switzerland, Norway, and the United Kingdom. Composting accounted for 42 million tpa (59%), while anaerobic digestion (AD) processed 29 million tpa (41%). The definition of bio-waste adhered to the European Union Waste Framework Directive (EU 2018/851), excluding mechanical biological treatment, agricultural waste/products, and sewage sludges.

The amount of separately collected biowaste treated varied significantly among countries on a per capita basis, ranging from 28 kg/capita/annum to 328 kg/capita/annum. On average, composting treated 72 kg/capita/annum, while AD treated 48 kg/capita/annum. The primary feedstocks at composting facilities were green waste, garden waste, and food waste, while food waste and unspecified "other" wastes predominated at AD facilities.

European policymakers have placed significant emphasis on municipal waste streams, setting minimum recycling and reuse targets, particularly for bio-waste. Across the EU27, Switzerland, Norway, and the UK, a total of 47 million tonnes of municipal bio-waste underwent composting and anaerobic digestion. Within the EU27 alone, 38 million tpa were processed, with 70% directed to composting and 30% to anaerobic digestion, representing approximately 17% of the total municipal solid waste fraction (European Compost Network, 2022).

Figure 41: Quantities of treated bio waste in selected countries:



Source: (European Compost Network, 2022)[103]

[103] "Bio-waste: It does not include forestry or agricultural residues, manure, sewage sludge or other biodegradable waste such as natural textiles, paper or processed wood"

7. Other applications of new synthetic fuels: the use for Shipping

7.1. The Fuel EU maritime regulation

In July 2023, as a component of the Commission's Fit for 55 legislative packages geared towards slashing EU greenhouse gas emissions by at least 55% by 2030, the Fuel EU Maritime Regulation (Regulation (EU) 2023/1805) was embraced. Its core objective is to advance the adoption of renewable, low-carbon fuels, and clean energy technologies within the maritime sector, crucial for facilitating its decarbonization.

Fuel EU Maritime sets forth maximum thresholds for the annual average greenhouse gas (GHG) intensity of energy employed by ships weighing over 5,000 gross tons docking at European ports, irrespective of their flag. These benchmarks are crafted to progressively lower the GHG intensity of fuels used, commencing with a 2% reduction by 2025 and escalating to an 80% decrease by 2050. These targets will evolve over time to spur and accommodate advancements in technology and the ramp-up of production of renewable and low-carbon fuels. Notably, the targets encompass not only CO2 emissions but also methane and nitrous oxide emissions across the entire lifecycle of onboard fuels, adhering to the Well-to-Wake (WtW) principle.

Additionally, the Regulation introduces supplementary mandates for zero-emission practices for ships while berthed, necessitating the adoption of onshore power supply (OPS) or alternative zero-emission technologies in ports, particularly by passenger and container vessels. This measure aims to mitigate air pollution in ports, often located in close proximity to densely populated areas.

FuelEU Maritime adopts a life cycle, goal-oriented, and technology-neutral approach, fostering innovation and the emergence of sustainable fuels and energy conversion technologies. It grants operators the autonomy to select fuels based on ship-specific or operation-specific requirements. Moreover, the Regulation incorporates various flexibility mechanisms to assist existing fleets in devising compliant strategies and incentivizes early adopters through rewards for investing in the energy transition.

FuelEU Maritime is slated to come into effect from January 1, 2025, with the exception of Articles 8 and 9 concerning monitoring plans, which will be enforceable from August 31, 2024 (European Comission, s.f.).

7.2. Main provisions (European Comission, 2023)

1. Measures will be taken to ensure that the greenhouse gas intensity of fuels used by the shipping sector will gradually decrease over time, with a reduction of 2% by 2025 and up to 80% by 2050.

2. A special incentive regime will be implemented to support the uptake of so-called renewable fuels of non-biological origin (RFNBO) with a high decarbonization potential.

3. Fossil fuels will be excluded from the regulation’s certification process.

4. From 2030, passenger ships and container ships will be required to use on-shore power supply for all their electricity needs while moored at major EU ports, aiming to mitigate air pollution in ports, which are often close to densely populated areas.

5. A voluntary pooling mechanism will be introduced, allowing ships to pool their compliance balance with one or more other ships, with the pool as a whole having to meet the greenhouse gas intensity limits on average.

6. There will be time-limited exceptions for the specific treatment of outermost regions, small islands, and areas economically highly dependent on their connectivity.

7. Revenues generated from the regulation's implementation ('FuelEU penalties') will be used for projects supporting the maritime sector's decarbonization, with an enhanced transparency mechanism.

8. The implementation of the regulation will be monitored through the Commission's reporting and review process.

7.3. Synthetic Marine Fuels

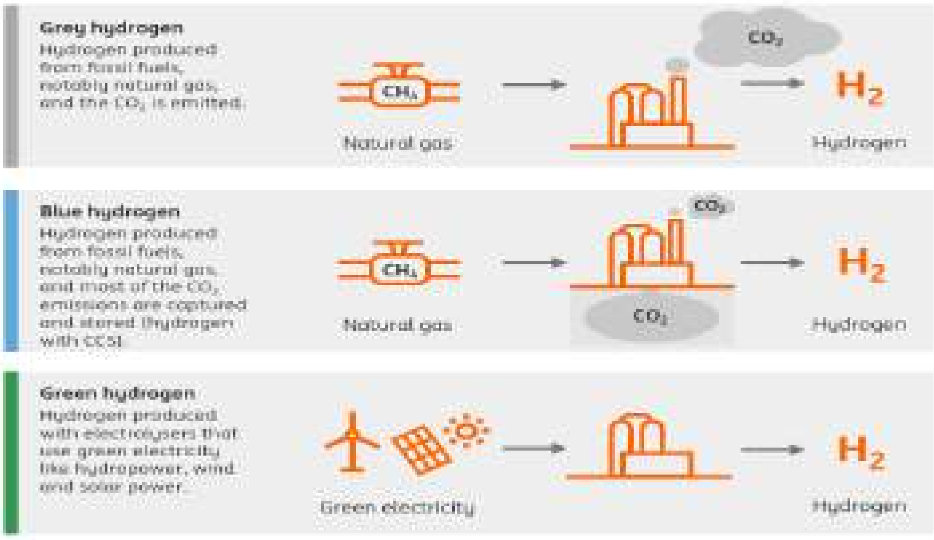
Synthetic fuels present a potential solution for the maritime industry as it seeks to transition from diesel to more sustainable alternatives. With upcoming emissions regulations from the IMO, the industry is actively exploring various options to achieve a carbon-neutral future

There is increasing interest in the role of synthetic e-fuels produced with green hydrogen as a potential pathway to decarbonize marine transport. E-methanol stands out as the most market-ready marine e-fuel and could become increasingly competitive by the mid-2030s, utilizing biomass-derived CO2. However, significant barriers remain for the adoption of e-ammonia as a shipping fuel. In our base case outlook, e-fuels are projected to account for 14% of global marine fuel demand by 2050, displacing nearly 0.8 million barrels per day of marine fuel sales. To meet the IMO 2050 decarbonization target, the marine market share of e-fuels would need to rise to just over 40%, boosting shipping's share of global low-carbon hydrogen supply from 7% to 20% by 2050. Nonetheless, increasing green hydrogen production further would be challenging due to the need for additional renewable energy capacity.

Different methods of hydrogen production

Hydrogen for synthetic fuels in shipping must be blue or green to reduce or eliminate carbon emissions.

Figure 42: Different methods of hydrogen production



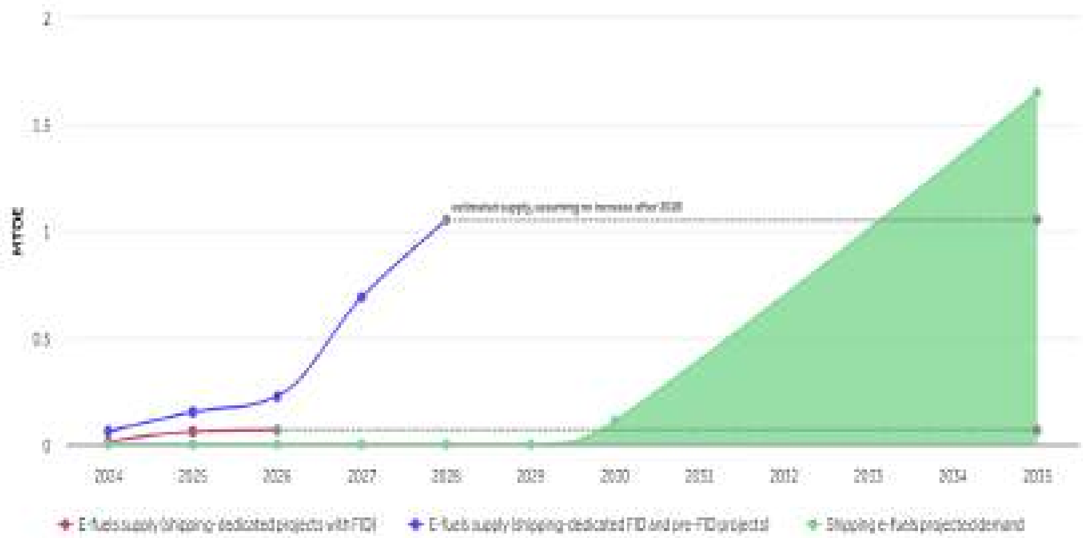
Shipping e-fuels observatory

According to Transport & Environment, 4% of European shipping could be powered by e-fuels by 2030. Currently, there are at least 17 projects across Europe dedicated to producing hydrogen-based e-fuels for the maritime industry. This shift towards e-fuels represents a significant step in reducing carbon emissions and promoting sustainable shipping practices in Europe.

Figure 43: Production sites of e-fuels (Green hydrogen, Biofuels, e-Ammonia and e-Methanol:

Source: ING Research

Figure 44: Shipping e-fuels- Projected demand and supply:



Source: ING Research

E-fuels projected demand is based on emissions intensity targets, RFNBO subquota and multiplier as per final FEUM agreement.

E-fuels projected supply assumes the realisation of all shipping-dedicated projects according to their official timelines, or by 2030.

7.4. Exploring Promising Synthetic Fuels for Sustainable Energy

Three promising types of synthetic fuels (synfuels) are being explored for their potential in reducing greenhouse gas emissions and transitioning to more sustainable energy sources:

- **Hydrogen Fuel**: Hydrogen can be produced through the process of electrolysis, where water is split into hydrogen and oxygen using electricity. This hydrogen can then be used directly as a clean fuel in various applications, including transportation and energy production.
- **Hydrogen and Carbon Dioxide Combination**: Hydrogen can be combined with carbon dioxide (CO_2) to produce syngas (synthesis gas). Syngas, a mixture of carbon monoxide (CO) and hydrogen (H_2), serves as a precursor for creating various other fuels and chemicals. This process not only utilizes hydrogen but also helps in capturing and reusing CO_2, thereby reducing overall emissions.
- **Biomass and Waste Processing**: Biomass (organic materials from plants and animals) or waste can be converted into syngas through gasification. This involves heating the biomass or waste in a controlled environment with limited oxygen to produce syngas. Syngas can then be further processed into conventional fuels such as methanol, ethanol, or diesel, providing a renewable alternative to fossil fuels.

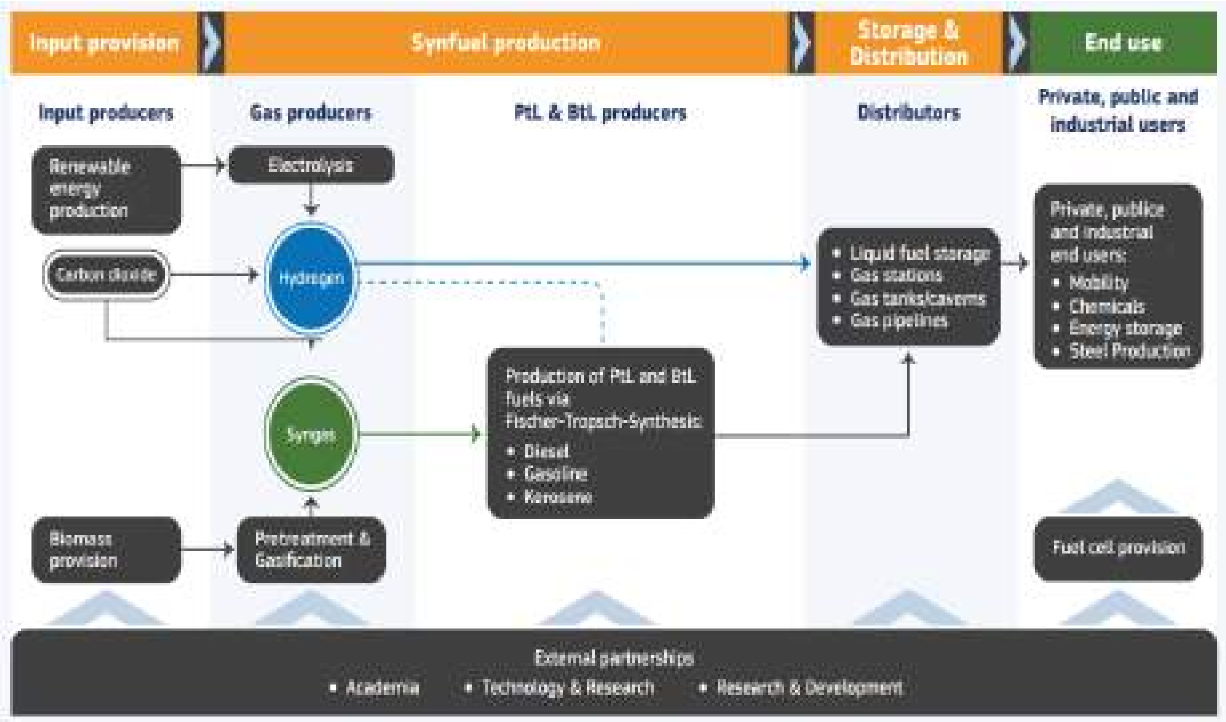
Syngas can be transformed into a range of traditional fuels through established chemical processes, contributing to a more sustainable and circular economy. These advancements in synthetic fuel technologies are crucial for reducing reliance on fossil fuels and mitigating environmental impacts.

The EU hydrogen value chain[104]

The EU hydrogen value chain is highly fragmented, primarily composed of smaller organisations that specialise in either component manufacturing or the assembly of final applications. Despite this fragmentation, Europe maintains a strong foothold in the industry, with nearly 300 companies actively involved. The value chain for synthetic fuels can be broken down into four key segments:

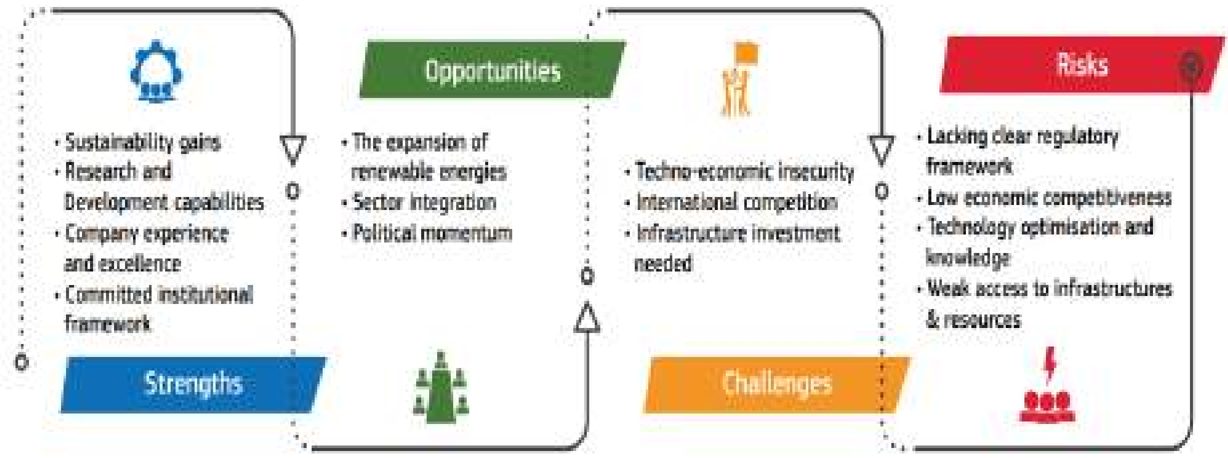
Figure 45: The synthetic fuels value chain consists of four main parts:

[104] European Commission. *Leaflet Product Watch: Synthetic Fuels*. Monitor Industrial Ecosystems, July 2021. Available at: https://monitor-industrial-ecosystems.ec.europa.eu/sites/default/files/2021-07/Leaflet%20Product%20Watch%20Synthetic%20Fuels.pdf



Source:European Commission

Figure 46: EU's competitive positioning for synthetic fuels



Source:European Commission

Success Port Initiative: The Port of Rotterdam's Initiative in Using Synthetic Fuels:

In the Netherlands, the Port of Rotterdam Authority has demonstrated a successful initiative in adopting clean fuel and energy for its vessels and emergency power facilities, including radar stations. As part of this effort, the Authority recently signed a new agreement with VARO Energy Group, a leader in the field of sustainable energy solutions.

During the Port Authority's tender process to identify the cleanest usable energy carrier, VARO's products emerged as the best option. Since 2018, the Port of Rotterdam has been utilizing VARO's HVO100 for its fleet. HVO100, a biofuel composed entirely of

Hydrotreated Vegetable Oil from sustainable materials, significantly reduces carbon dioxide (CO_2) emissions by up to 89% compared to conventional diesel fuel.

One of the key advantages of HVO100 is its versatility. It can be blended with conventional diesel in any ratio and used in all current diesel engines without any modifications. This makes HVO100 a highly accessible and cost-efficient solution for reducing CO_2 emissions.

Looking forward, the Port of Rotterdam Authority has committed to transitioning to emission-free vessels by 2025. In line with this goal, the supplier was tasked with exploring various forms of alternative fuels and oils to meet the Port's air quality objectives. This exploration includes potential energy carriers such as hydrogen, methanol, biofuels, and other synthetic fuels.

The Port of Rotterdam's initiative serves as a successful example of how synthetic fuels can be integrated into existing infrastructure to achieve significant environmental benefits and support a transition to more sustainable energy sources.

Success case of the use of synthetic fuels in the transport sector:

Maersk is one of the largest shipping companies, has ordered 19 dual-fuel vessels capable of running on methanol, a synthetic fuel produced from renewable sources. These vessels are designed to be retrofitted to run on green methanol, allowing Maersk to transition away from traditional marine fuels. This approach represents a new business model where vessels are future proofed to switch fuels as greener options become more viable. The adoption of synthetic methanol allows shipping companies to meet emission targets while maintaining operational flexibility, as these ships can still use conventional fuels during the transition phase.

Maersk's Methanol-Enabled Vessels Initiative[105]

Maersk will launch its first large methanol-enabled vessel on 9 February 2024, operating on the Asia-Europe AE7 route. Built by Hyundai Heavy Industries, the ship can carry 16,000 containers and runs on methanol, biodiesel, and conventional fuel. This launch is part of Maersk's strategy to achieve net-zero emissions by 2040, with near-term targets for 2030.

Maersk aims for Net-Zero greenhouse gas emissions by 2040 and has set near-term targets for 2030. For the maiden voyage, the company has secured sufficient green methanol and is actively working on sourcing solutions for the fleet's operations in 2024-2025. The deployment of this vessel marks a significant step in Maersk's decarbonization strategy, with additional methanol-enabled vessels expected to be introduced in 2024.

The vessel will be the second container ship worldwide capable of sailing on green methanol, following the feeder vessel Laura Maersk, which entered service earlier. By the end of 2024, Maersk expects to have multiple methanol-enabled vessels in service, reflecting its commitment to only order new ships that can operate on green fuels since 2021.

Maersk's AE7 service string is a major trade route linking Asia and Europe via the Suez Canal, with several key port calls across China, Malaysia, Sri Lanka, Morocco, the UK, Germany, Belgium, France, Saudi Arabia, and the UAE.

[105] Maersk. (7 December 2023) Maersk to Deploy First Large Methanol-Enabled Vessel on Asia-Europe Trade Lane. Maersk. Available at: https://www.maersk.com/news/articles/2023/12/07/maersk-to-deploy-first-large-methanol-enabled-vessel-on-asia-europe-trade-lane

This initiative underlines Maersk's broader sustainability efforts, positioning the company as a leader in integrating low-emission technologies into the global shipping industry.

MOL, HIF, and Idemitsu Collaborate on eFuels Supply Chain and CO_2 Marine Transport

On 19 March 2024, Mitsui O.S.K. Lines (MOL) signed a Memorandum of Understanding with Idemitsu Kosan, HIF USA, and HIF Asia Pacific to jointly develop a synthetic fuel (eFuel) and synthetic methanol (e-methanol) supply chain, including CO_2 marine transport. The synthetic fuels, produced by combining green hydrogen and CO_2, are expected to significantly reduce carbon emissions throughout their lifecycle and are positioned for rapid commercialisation.

The project aims to develop an efficient supply chain for synthetic fuels and methanol, including CO_2 transport from Japan to HIF's production plants overseas and the shipment of eFuels back to Japan. MOL will focus on CO_2 and eFuels transport, Idemitsu will explore CO_2 capture in Japan, and HIF will assess CO_2 demand for its global eFuels production.

This collaboration seeks to advance decarbonisation in the energy and transportation sectors, contributing to the transition towards net-zero emissions by creating a sustainable and cost-effective value chain. The partnership will also explore potential business opportunities and evaluate the environmental benefits of synthetic fuels.

In a related effort, HIF Global, ITOCHU, JFE Steel, and MOL are assessing potential locations for carbon-neutral eFuels facilities in Australia and establishing a CO_2 supply chain between Australia and Japan.

8. Conclusion

The comprehensive analysis presented in this report highlights the critical role of Sustainable Aviation Fuels (SAF) in the future of aviation, both within Europe and globally. The European SAF mandate, underpinned by the ReFuelEU Aviation Regulation, has set a robust framework aimed at accelerating the adoption of environmentally friendly fuels. The deployment of SAF, as outlined in this report, is supported by detailed provisions for fuel suppliers and national authorities, with additional support from the Renewable Energy Directive (RED III) and infrastructure regulations.

The report showcases the advanced SAF policies and practices of key European nations, such as France, Germany, the Netherlands, and others, which are leading the charge in SAF development and implementation. These national initiatives are complemented by significant efforts outside the EU, including in the United States, China, and Japan, where the push for SAF is also gaining momentum.

Strategic analysis of the emerging SAF market reveals a competitive landscape that is evolving rapidly, with key players in the aviation fuel supply chain working to overcome important barriers such as the high total costs of projects and how to fund them at scale, limited/few blending facilities controlled by the traditional oil and gas large players that might restrict newcomers access or impose conditions for the use of their facilities when blending SAF to third parties and complex logistics could slow down the development in the European Union. The insights provided into the competitive conditions, economies of scale, and cooperative projects highlight the challenges and opportunities that lie ahead for SAF market growth. The European Union should work closely with the Aviation sector and new emerging SAF technologies facilitating investment schemes to accelerate the implementation of projects and scale up.

The SAF market presents a promising opportunity for creating added value within the hydrogen value chain, particularly when hydrogen is used as a feedstock. Technologies such as waste-to-hydrogen, exemplified by Hy2market initiative’s approach to producing green hydrogen from organic waste, offer pathways to integrate SAF into the broader hydrogen economy. This integration not only supports decarbonisation but also opens new avenues for technological innovation and market expansion.

European Regions taking a leading approach towards the attraction of technologies producing SAF to their territories could gain a competitive advantage strengthening innovative and sustainable infrastructures and ecosystems for the aviation industry. The regions with blending infrastructures will have a competitive edge.

The technological advancements and innovations in SAF production, particularly the novel Steam/CO2 Reforming Technology, offer promising solutions to the industry's challenges. The exploration of waste to SAF business models, including the conversion of plastics and organic waste, presents innovative approaches that could significantly reduce the environmental footprint of aviation fuel production.

The report’s strategic analysis of the emerging SAF market reveals a rapidly evolving competitive landscape. Key players in the aviation fuel supply chain are addressing major challenges, such as high project costs, limited blending facilities controlled by traditional oil and gas companies, and complex logistics that could slow SAF development in the EU. To overcome these barriers, further technological advancements such as Steam/CO_2 Reforming and waste to SAF models, including plastic and organic waste conversion are essential.

Investment in infrastructure and innovative technologies will be critical to scale up production, reduce costs, and ensure the smooth blending of SAF, thus enhancing market growth. Moreover, collaboration with new SAF technologies can provide solutions that facilitate SAF’s integration into existing systems.

While the current regulatory framework, including the SAF mandate, provides a strong foundation, there may be a need for further refinement to meet the evolving needs of the market. The regulatory framework should promote supply, demand, and supporting measures in a coordinated way to prevent cumulative effects from combined stimuli or mismatches between supply and demand, which could disrupt market equilibrium. Enhanced policies will be crucial to support investment, streamline logistics, and ensure balanced market growth.

To further advance the SAF market, there is a need to address the skills gap through targeted education and training programs. Developing expertise in SAF technologies, including hydrogen integration, will be vital. Additionally, standardising production and blending processes will help ensure consistent quality and support broader market adoption.

Finally, the discussion on the broader application of synthetic fuels, such as in maritime shipping, emphasizes the potential for these technologies to transform other sectors beyond aviation.

In conclusion, the SAF mandate and related innovations represent a pivotal shift towards more sustainable aviation. However, realising this potential will require continued collaboration across the value chain, substantial investment in technology and infrastructure, and supportive regulatory environments. The path forward, though challenging, offers a transformative opportunity to achieve significant environmental benefits and to position Europe as a global leader in the transition to sustainable aviation.

Continue attracting mature SAF technologies and investments in the field to the European Union and positioning the EU as a leading world location for the SAF industry will be essential.

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