CENA HESSEN

CENA SAF-Outlook 2025–2030

Volumes, Technologies and Markets for Sustainable Aviation Fuels

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Executive summary

Sustainable aviation fuels (SAF) are considered a key technology for reducing the climate impact of aviation. Ensuring a reliable and sustainable supply of SAF is therefore paramount for the transition to a fossil-free aviation sector. Binding SAF quotas have been in force in the European Union (EU) since 2025 as part of the ReFuelEU Aviation regulation. Around 1 million tonnes are needed to meet the SAF quota in 2025. The latest announcements indicate the planned production capacity will be adequate for this quantity.

The CENA SAF-Outlook 2025-2030 analyzes current global SAF production and future production volumes up to 2030, examining various production processes – from biogenic to electricity-based fuels – in relevant regions of the world to show how production volumes are distributed. The report's findings also analyze the development status of the projects, enabling a realistic assessment of feasibility and, consequently, the actual production volumes to be expected.

As of December 31, 2024, there were 265 active projects and proposals for SAF production worldwide. The majority of these facilities are located in the USA (58), followed by Germany (31) and the United Kingdom (17). Compared to the previous year[1], the forecast production volume for 2030 has risen from 30 million to around 35 million tonnes of SAF, primarily due to increases in Asia (plus 3 million tonnes) as well as North and South America (plus 2 million tonnes each), while announced production in Europe has fallen by 1.5 million tonnes. Of the total volume, approximately 16 million tonnes are produced in North America, Europe and Asia each account for 8 million tonnes, with the remainder divided among other regions.

On a global scale, the announced SAF production in 2024 was approximately 2.6 million tonnes, with biogenic processes accounting for the vast majority. Current projections indicate that biogenic production methods will continue to dominate global SAF production, accounting for the majority of output by 2030. Synthetic processes, meanwhile, are projected to contribute slightly under a quarter of total production. In contrast, Germany places significantly more emphasis on synthetic processes. The total production of SAF in Germany is expected to reach approximately 420,000 tonnes by 2030, with synthetic processes accounting for more than half of this amount.

Despite the increase in announced volumes, the market ramp-up of SAF is lagging behind the demand required by 2030, according to EU quotas. This is especially true for synthetic SAF, which is being held back by high production costs and a lack of willingness to purchase among airlines, as well as regulatory uncertainties. The lack of investment security in the early market phase prevents the construction of necessary reference plants and curtails the potential for long-term cost reduction. To establish SAF as a key technology, all stakeholders must collaborate to address these challenges: Policymakers should reduce regulatory hurdles, accelerate approval procedures and create stable framework conditions through hedging instruments such as sureties and revenue guarantees. SAF producers and investors need reliable conditions for capital-intensive projects with long amortization periods, while airlines should actively contribute to the market ramp-up through long-term, binding purchase agreements. This is essential for the successful establishment of a SAF market in Europe and the achievement of the ambitious climate targets in aviation.

1 CENA Hessen (2024) | https://www.cena-hessen.de/en/projects/saf-outlook/

1. The role of SAF in aviation

1.1 Climate targets, quotas and future demand

Despite continuous efficiency improvements through better engines and operational optimizations, absolute emissions from aviation continue to rise due to the global growth of the industry. In 2023, aviation emitted 950 million tonnes of CO_2, accounting for 2.5% of global energy-related CO_2 emissions[2]. This is comparable to the annual emissions of the industrialized nation of Japan[3].

> *SAF will play a decisive role in the transformation of air traffic.*

Sustainable aviation fuels (SAF) are regarded as a decisive lever for reducing emissions, as they produce up to 80% less CO_2 emissions over their life cycle than fossil kerosene. A theoretical 100% use of synthetic aviation fuels (e-SAF) would result in a CO_2 reduction of almost 100%. The use of SAF also reduces climate-impacting non-CO_2 effects such as condensation trails. Technologies such as electric or hydrogen-powered aircraft are not yet technologically mature. Due to range and infrastructure limitations, they are not a viable alternative for commercial air transportation in the foreseeable future. They will not be a permanent solution even for long-haul flights. In the long term, liquid fuels will be necessary, underscoring the growing importance of sustainable aviation fuels (SAF).

Efforts to incentivize SAF through a quota system are underway in the EU and beyond. Table 1 provides an overview of the quotas for SAF and associated sub-quotas that have been established or are planned in various regions and countries. In addition to the EU, the UK also has specific, gradually increasing quotas and sub-quotas for e-SAF and Power-to-Liquid-SAF (PtL-SAF). Similar regulations are being considered in Switzerland and the Canadian province of British Columbia. Japan, Singapore, India and South Korea also have plans for mandatory SAF blending, although the exact implementation varies from country to country. Furthermore, Chile, Taiwan, Indonesia and Malaysia have stated targets for the coming decades. Some of these targets have not yet been enacted into law, but they have been published in official roadmaps or policy statements.

> *Considering the predicted growth in aviation, the global demand for SAF is expected to be around 360 million tonnes in 2050.*

Given these quotas, the question arises as to the production volume required to meet demand. Considering the predicted growth in aviation, the global demand for SAF is expected to be around 360 million tonnes in 2050[4]. For the EU, this results in a "mandated" SAF demand of 3.1 million tonnes in 2030, 20 million tonnes in 2040 and 48.4 million tonnes in 2050. These figures are based on a projection from 2024 onwards, assuming that EU kerosene consumption will remain at its pre-Covid 2019 level[5], with an annual growth rate of 1.5%. This report analyzes the extent to which these required SAF volumes can be achieved by 2030.

2 International Energy Agency (2025) | https://www.iea.org/energy-system/transport/aviation#tracking (last access 20.02.2025)
3 International Energy Agency (2025) | https://www.iea.org/countries/japan/emissions (last access 20.02.2025)
4 IATA (2023) | https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-policy-2023.pdf (last access 28.02.2025)
5 Eurostat (2025) | https://ec.europa.eu/eurostat/web/main/data/database (last access 28.02.2025)

Table 1: Overview SAF quotas worldwide

Region/country	2025	2026	2027	2028	2029	2030	2035	2040	2050	Annotations
EU (ReFuelEU-Aviation)	2 %	→	→	→	→	6 % (1.2 % e-SAF)	20 % (5 % e-SAF)	34 % (10 % e-SAF)	70 % (35 % e-SAF)	Binding quotas; gradual increase
United Kingdom	2 %	→	→	→ 0.2 % PtL	→ →	10 % →	→ →	22 % 2.5 % PtL	→ →	Mandatory SAF quota from 2025
Switzerland										Orientation towards ReFuelEU-Aviation delayed, expected start in 2026
British Columbia (Canada)				1 %	2 %	3 %	→	→	→	Province-specific quota
Canada (national)						10 %	→	→	→	Target stated in the Climate Action Plan 2022-2030
Japan						10 %	→	→	→	Legal implementa-tion still pending
Singapore		1 %	→	→	→	3-5 %	→	→	→	Gradual increase from 2026
India			1 %	2 %	→	5 %	→	→	→	Blending obligation for international flights
South Korea			1 %	→	→	→	→	→	→	Blending obligation for international flights
Chile									50 %	Announced in the national SAF-Road-map 2030
Taiwan						5 %	→	→	→	Recommendation of the aviation authority on the use of SAF
Indonesia			1 %	→	→	2.5 %	→	12.5 %	30 %	SAF-Roadmap 2024
Malaysia									47 %	Planned blending obligation by 2050

Source: CENA Hessen

1.2 Methodology and procedure of the analysis

The data collection for the CENA SAF-Outlook 2025-2030 is based on a systematic combination of publicly available sources with published data and data provided by the companies themselves. In addition, the publications of industry associations (including aireg, CAAFI, argus and Green Air) were continuously evaluated and compared with relevant publications[6,7,8]. Mostly German and English sources were evaluated. This can lead to inaccuracies in projects with sources in other languages only.

6 SkyNRG (2024) | https://skynrg.com/skynrg-releases-sustainable-aviation-fuel-market-outlook-2024/ (last access 11.03.2025)
7 Transport & Environment (2024) | https://www.transportenvironment.org/uploads/files/2024_01_E-kerosene_Tracker_TE_2024-04-29-155012_cevi.pdf (last access 11.03.2025)
8 International Energy Agency Bioenergy (2025) | https://task42.ieabioenergy.com/databases/ (last access 17.03.2025)

The cut-off date for data collection is December 31, 2024. The data consists of:

- **General information** (manufacturer and project partner, project name and geographical location of production)
- **Plant type** (industrial production, pilot- or research plant) and
- **Development status of the projects** (idea, in planning, under construction / in commissioning, in operation).

Taking these categories into account, an outlook is provided for the announced SAF volumes for the years 2026, 2028 and 2030, as well as a review of the production volume in 2024. The announced volumes are generally to be understood as target or indicative values, i.e. they represent maximum production capacities. There may be shifts in the country-specific distribution for companies that only provide higher level SAF production volumes. **Canceled or currently halted projects** are not included in the forecast totals. Projects that have announced their intention to produce SAF at a certain point in time, but have not specified any **quantities**, are only included in the presentation of the number of projects. If the **share of SAF in total synthetic fuel production** is not specified, it is assumed to be 40 %[9].

The CENA SAF-Outlook also differentiates between **plant types: Research plants** used to optimize technologies or produce intermediates are included in the number of projects, but not in the forecast production volumes. **Pilot plants** are defined by a maximum production volume of up to 10,000 tonnes of SAF per year. The category of **industrial production plants** (> 10,000 tonnes/year) also includes the globally increasing share of SAF produced by co-processing. **Co-processing** involves the joint processing of fossil and renewable feedstocks in a refinery. The resulting proportion of SAF is taken into account according to the manufacturer's specifications.

The production processes have been divided into two categories:

- **Synthetic Aviation Fuels (e-SAF):** Fischer-Tropsch-technology (FT)[10], Methanol-to-Jetfuel (MtJ)
- **Aviation Biofuels (Bio-SAF):** Alcohol-to-Jet (AtJ), Hydroprocessed Esters and Fatty Acids (HEFA).

Projects using production methods other than those described above but leading to e-SAF or bio-SAF are grouped under the category **"alternative technology (AT)"**.

Regarding the **development status** of the projects, the transition between the project idea and the start of project planning was defined by the existence of a specific location and/or technology definition. The specified development status also refers to the reference date of the data collection for the following years.

9 IATA (2024) | https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-handbook.pdf (last access 19.03.2025)
10 Including Sun-to-Liquid, Biogas-to-Liquid, Power-to-Liquid, hybrid technologies

2. Availability of SAF: Present and future

First, a global overview of the current market situation is given, followed by a look at developments in Europe and Germany. Both current trends and prospects for the coming years are analyzed.

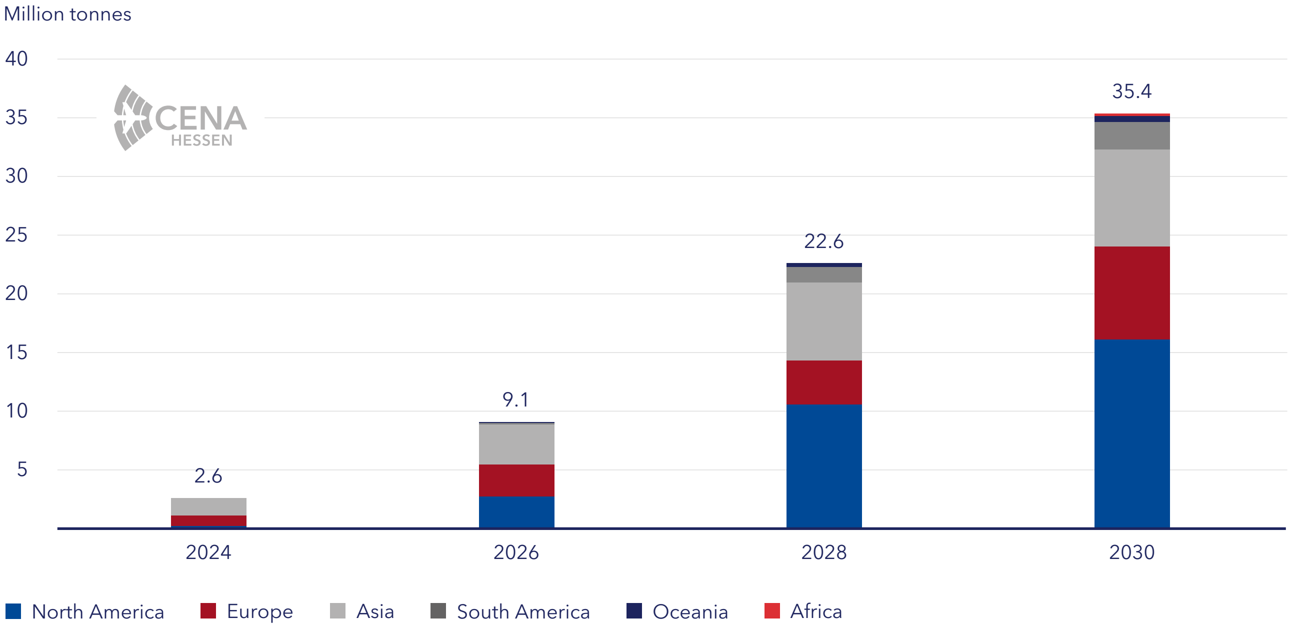
2.1 Global overview

Development of projects and production capacities
Available publications suggest that approximately 2.6 million tonnes of SAF were produced worldwide in 2024. This represents an increase of 0.5 million tonnes compared to 2023. The forecast for future SAF production capacity has also increased compared to the previous SAF-Outlook 2024. While last year a capacity of 30 million tonnes was announced for 2030, the current forecast is now around 35 million tonnes (Figure 1).

This is due to production increases of more than 3 million tonnes in Asia and 2 million tonnes each in North and South America. In Europe, SAF production announced for 2030 has decreased by 1.5 million tonnes, mainly due to changes in the announcement of major projects in Spain, the Netherlands, Austria and Germany. Despite the continued growth, the production structure remains rather decentralized, with no large local production centers, but with many medium-sized plants around the world.

> *Global SAF production is set to increase from 2.6 million tonnes in 2024 to 35 million tonnes in 2030.*

Figure 1: Announced SAF production volumes worldwide for 2024 to 2030



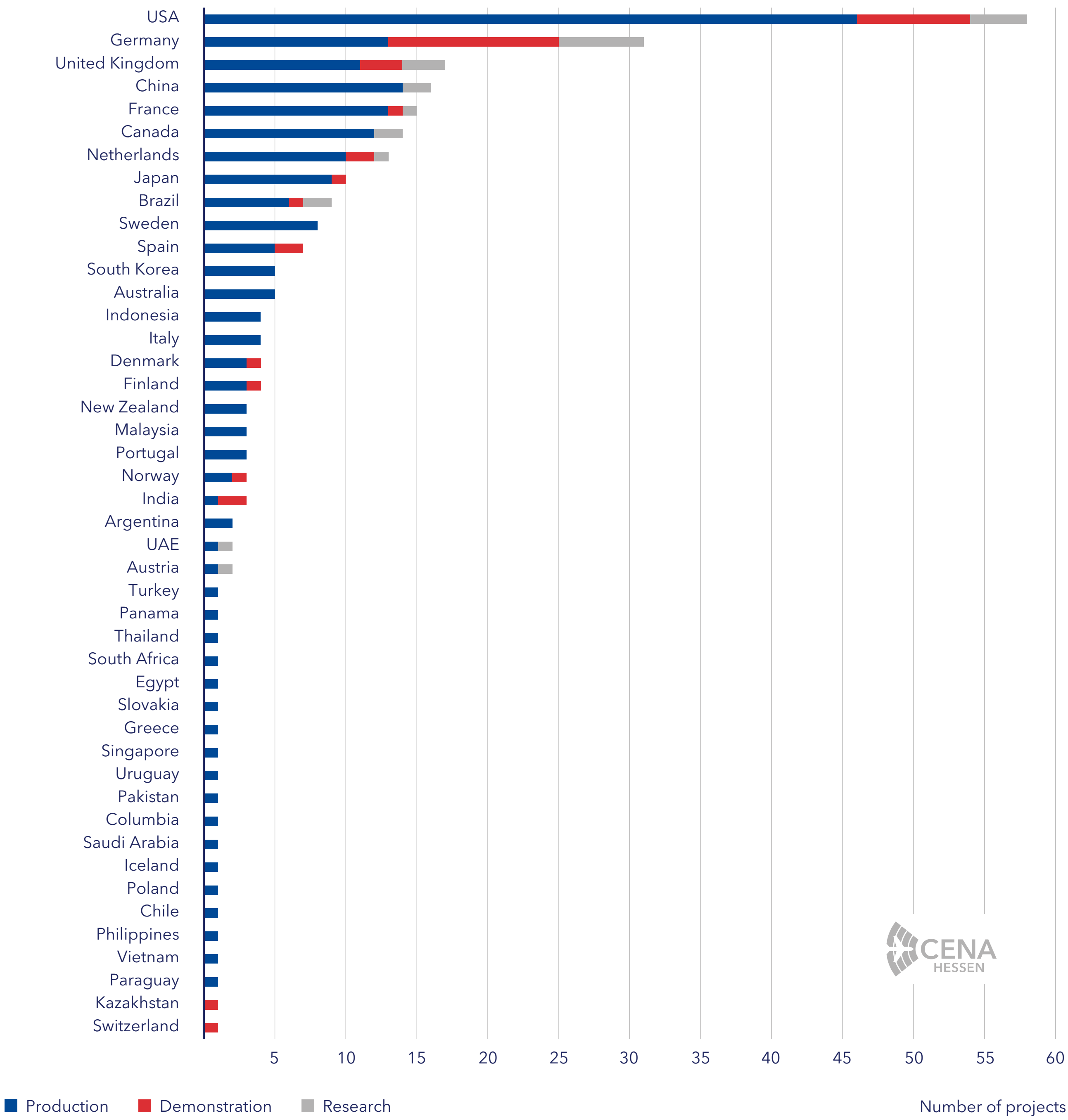
Source: CENA Hessen

However, 3 plants are already in operation and are expected to reach a production capacity of more than 1 million tonnes each by 2030: Neste in Singapore (1 million tonnes from 2024), the Satorp project in Saudi Arabia (1.5 million tonnes from 2028) and another Neste plant (MY SAF/ NEXBTL) in Rotterdam (1.2 million tonnes from 2026).

The number of planned and implemented SAF projects worldwide that are included in the SAF-Outlook has increased significantly in recent years. While in 2024 the SAF-Outlook recorded 144 projects, the current number is 265, which shows a significant increase and the continued global expansion of the SAF industry. Projects are now recorded in 45 countries (see Figure 2) – an increase from the 33 countries previously documented. It is particularly noteworthy that approximately one third of all projects are located in the USA or Germany. In addition, 8 countries have at least 10 projects each, while 20 countries have only one project.

This development is also reflected in the global distribution of production sites. There are currently 49 plants in operation worldwide, including 31 industrial production plants, 12 pilot plants and 6 research plants. Of the 31 in-

Figure 2: Number of SAF projects by location in 2024



Source: CENA Hessen

dustrial production plants, 13 are located in Europe, 10 in Asia and 8 in North America. Overall, there is a very even global distribution of production capacity, with no single dominant production location.

The largest SAF producers worldwide in 2030 are expected to be the Finnish company Neste and the U.S. company DG Fuels. Neste currently operates 3 production sites where SAF is already produced using the HEFA process and plans to reach an annual production of 2.2 million tonnes from 2026. DG Fuels plans to produce SAF at 4 sites using the FT process from 2027 and to reach a capacity of 2.3 million tonnes per year in 2030. World Energy and Satorp are each aiming to produce 1.5 million tonnes of SAF. The other five largest producers have announced plans to produce between 0.7 and 1.2 million tonnes of SAF each in 2030 (Table 2).

> *Around a third of all projects are located in the USA or Germany.*

Table 2: Largest SAF producers worldwide in 2030

	Manufacturer	Continent	Announced volumes 2030	First production start	Technology	Number of projects
1	DG Fuels	North America	2.3 MT	2027	FT	4
2	Neste	Europe, Asia	2.2 MT	2016	HEFA	3
3	Satorp	Asia	1.5 MT	2023	HEFA	1
4	World Energy	North America	1.5 MT	2016	HEFA	2
5	Fidelis New Energy	North America	1.2 MT	2027	HEFA	1
6	SGP Bioenergy	North America	1.1 MT	2027	HEFA	1
7	Summit AG	North America	0.8 MT	2027	AtJ	1
8	CVR Energy	North America	0.8 MT	2030	HEFA	1
9	Diamond Green Diesel	North America	0.7 MT	2024	HEFA	1
10	Indaba Renewable Fuels	North America	0.7 MT	2030	HEFA	3

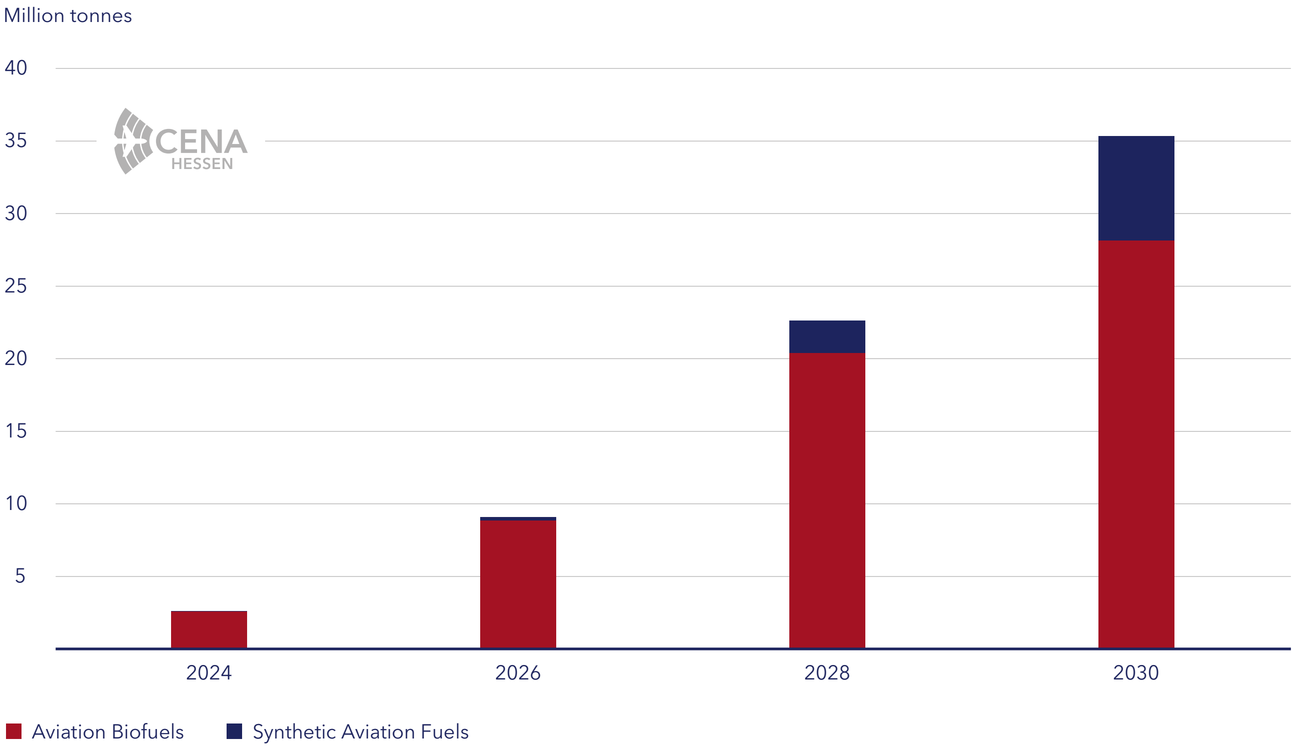
Source: CENA Hessen

Trends in SAF types and production paths

In 2024, SAF was produced almost exclusively using biogenic processes. For example, plant or animal waste materials containing oils and fats, waste wood or oil plants are used. As feedstock, waste materials can only be scaled up to a limited extent. Oil plants, on the other hand, compete with food and animal feed production. However, they may be used in Europe[11] as a source material for SAF production, provided they are not suitable for use in the food or animal feed chain. In principle, e-SAF are based on almost unlimited resources such as water, CO_2 and renewable energy from wind or sun – and their production requires much less space than growing biomass. However, the necessary infrastructure and suitable locations (sufficient renewable energy potential and water resources) to implement these technologies are limited, making their expansion even more difficult. In addition, the financial cost of providing resources from sustainable sources is very high. Biogenic processes are cheaper and technologically easier to implement than synthetic production processes, as they already operate at Technology Readiness Level (TRL) 9 (e.g. HEFA), while power-to-liquid processes with Fischer-Tropsch-technology are still at TRL 6[12].

It is anticipated that SAF production will rise to approximately 35 million tonnes by the year 2030. Of this, approximately 28 million tonnes will be bio-SAF, while about 7 million tonnes will be produced through synthetic processes (see Figure 3). On average, each plant will produce approximately 75,000 tonnes of e-SAF or 230,000 tonnes of bio-SAF in 2030.

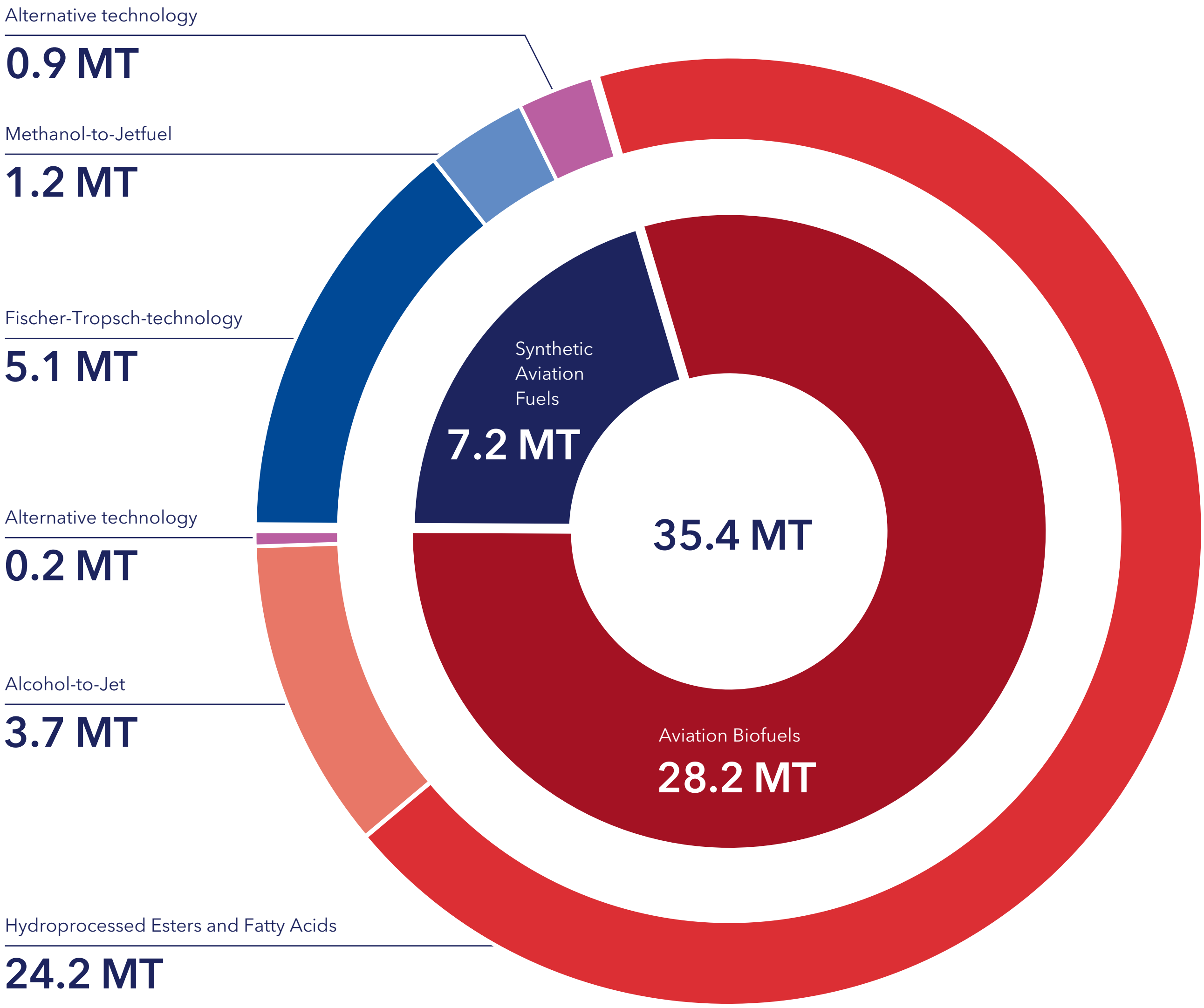
Figure 3: Announced production volumes of Aviation Biofuels and Synthetic Aviation Fuels worldwide from 2024 to 2030



Source: CENA Hessen

11 European Commission (2024) | https://eur-lex.europa.eu/legal-content/DE/ALL/?uri=CELEX:32024L1405 (last access 15.04.2025)
12 Umweltbundesamt (2022) | https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/background_paper_power-to-liquids_aviation_2022.pdf (last access 02.04.2025)

Figure 4: Announced SAF production volumes worldwide in 2030 by technology in million tonnes



Source: CENA Hessen

In the medium term, HEFA will remain the most significant production route for SAF, accounting for the largest share at approximately 24 million tonnes (Figure 4). Among the biogenic processes, the AtJ process contributes 3.7 million tonnes to the total volume, in addition to HEFA.

> *In the medium term, HEFA will remain the most significant production route for SAF.*

Alternative bio-SAF technologies account for less than 0.2 million tonnes. Among the synthetic processes, the FT process accounts for the largest share of the production volume, at almost 5.1 million tonnes, followed by the MtJ process with 1.2 million tonnes and alternative e-SAF technologies with 0.9 million tonnes. Regarding the forecast volumes from the MtJ process, it should be noted that the ASTM certification for aviation fuels, which is relevant to global aviation does not currently allow for a process to produce SAF from methanol. Work is currently underway to obtain such certification. Once this is completed, the forecast for MtJ volumes may change significantly.

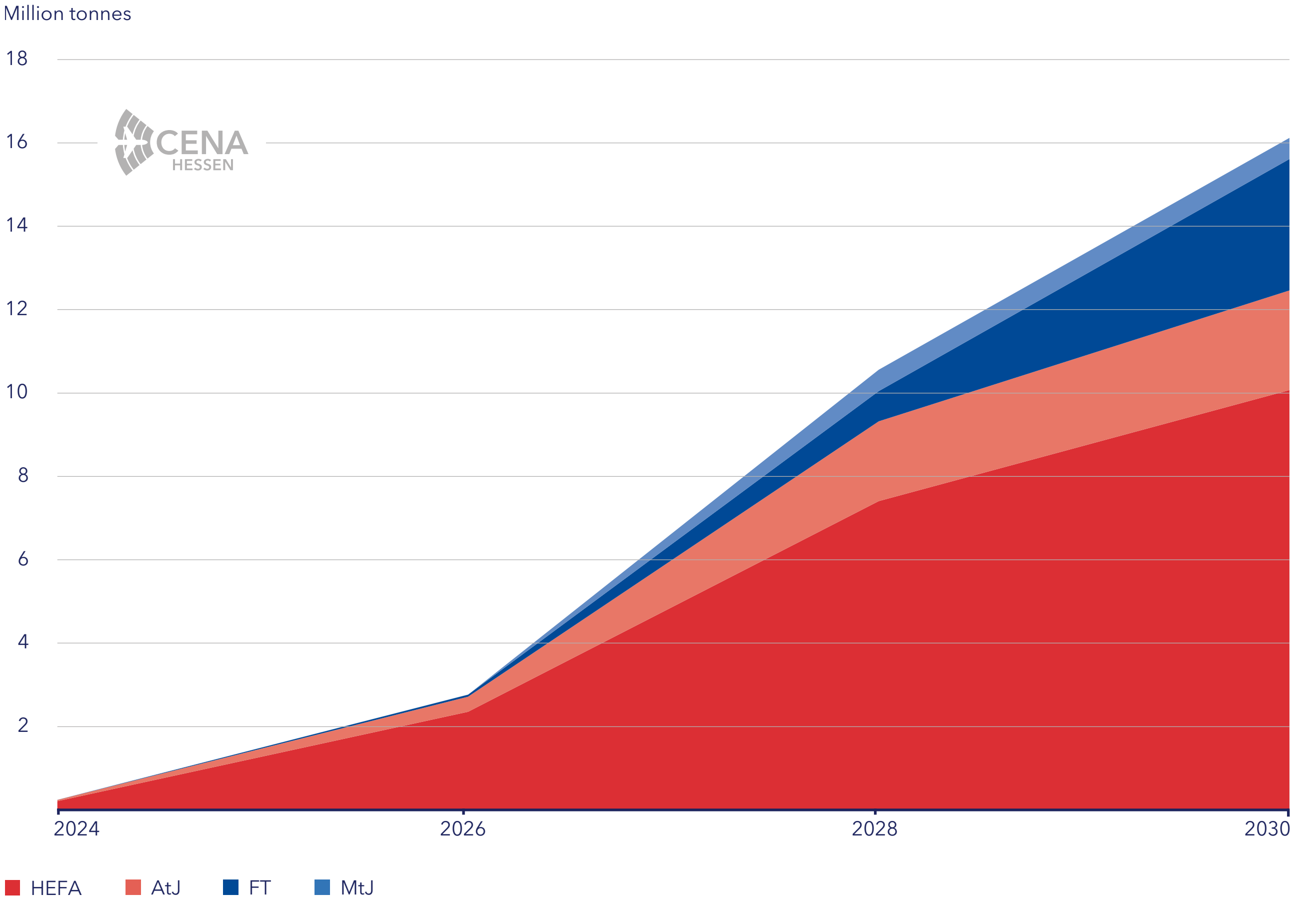
Prospect America

The development of SAF production in the Americas shows clear regional differences, particularly in terms of newly announced projects and production processes. North America has announced the largest SAF volumes worldwide for 2030, with 86 % of these volumes stemming from 58 U.S. projects. Other regions are also noteworthy for their recently announced SAF projects in 2024. While the U.S. has announced 8 new plants, expected to produce approximately 2 million tonnes by 2030, significant progress is also being made in South America, particularly in Brazil. There, 5 new projects are expected to produce nearly 1 million tonnes SAF. Due to the abundance of biomass resources in the region, 90 % of the production is projected to come from plants using HEFA in 2030. Additionally, South America's potential for long-term adoption of FT and MtJ processes is significant, driven by the region's abundant renewable energy resources. Large-scale industrial plants are not planned before 2030, as both the technical capacity and the regulatory framework need to be established.

The US regulatory landscape has been favorable for bio-SAF so far, due in part to the policies of the Biden administration, such as the Inflation Reduction Act[13]. Under the Trump administration, however, there is considerable uncertainty regarding long-term policy support, which calls into question the further expansion of SAF plants despite the progress made to date[14].

Figure 5 illustrates the evolution of production volumes in North America categorized by production process. While the production volume in North America in 2030 has increased by 2 million tonnes compared to the SAF-Outlook 2024, recent publications indicate that the announced production of the largest project to date (SGP BioEnergy,

Figure 5: Development of production processes in North America



Source: CENA Hessen

13 Climate Catalyst (2025) | https://climatecatalyst.org/wp-content/uploads/2025/03/Sustainable-aviation-fuel-policy-in-the-United-States.pdf (last access 03.04.2025)
14 Reuters (2025) | https://www.reuters.com/sustainability/trump-administration-approves-sustainable-aviation-fuel-refinery-loan-2025-02-11/ (last access 03.04.2025)

Table 3: Largest SAF projects by production volumes in 2030 in North and South America

	Manufacturer	Project name	Country	Technology	Degree of implementation	Production start	Announced volume 2030
1	Fidelis New Energy	Grön Fuels	USA	HEFA	In planning	2027	1.2 MT
2	SGP BioEnergy	Golden City Biorefinery	Panama	HEFA	In planning	2027	1.1 MT
3	Summit AG	Summit Next Gen USA	USA	AtJ	In planning	2027	0.8 MT
4	World Energy	World Energy USA I	USA	HEFA	In operation	2016	0.8 MT
5	CVR Energy	CVR Energy USA II	USA	HEFA	In planning	2030	0.8 MT
6	World Energy	World Energy USA II (Aviation Zero plant Two)	USA	HEFA	In planning	2027	0.7 MT
7	Diamond Green Diesel	Diamond Green Diesel USA	USA	HEFA	In operation	2024	0.7 MT
8	Shell	Shell USA	USA	HEFA	In planning	2028	0.7 MT
9	Petrobras	Bio Jet Fuel RPBC	Brazil	HEFA	In planning	2028	0.7 MT
10	Montana Renewables	Montana Renewables USA	USA	HEFA	In operation	2022	0.7 MT

Source: CENA Hessen

Panama) has decreased by more than 5 million tonnes. This decrease is fully compensated by the growth of new projects (Table 3). While HEFA dominated with 87 % of production in North America in 2024, the AtJ process is becoming increasingly important. The first major AtJ plant from LanzaJet Freedom Pines Fuels in Georgia, USA, has been in operation since 2024. A substantial capacity increase is projected for 2026, with AtJ expected to account for 18 % (1.9 million tonnes) of total North American production by 2028. At the same time, the first volumes from FT and MtJ are expected from 2028, with a combined share of 12 % (1.2 million tonnes). As AtJ loses momentum by 2030, FT and MtJ capacity increases to 3.7 million tonnes (23 % of the total production). However, it remains uncertain whether all FT projects will be implemented, as no final investment decisions for industrial production facilities have been made yet. The actual volumes from the MtJ process are also difficult to estimate currently. While HEFA capacities are increasing, their percentage share is projected to decline to 62 % (10 million tonnes) in North America by 2030, provided the assumptions for FT and MtJ projects are met.

Perspective on Asia

By 2030, the production of SAF in Asia is projected to increase to over 8 million tonnes, with the share of non-HEFA processes slowly but steadily rising. The development of production processes is marked by an increasing diversification, though this is significantly lower than in Europe and North America. Notably, the Fischer-Tropsch process plays a negligible role. While HEFA continues to dominate, processes such as AtJ are gaining prominence.

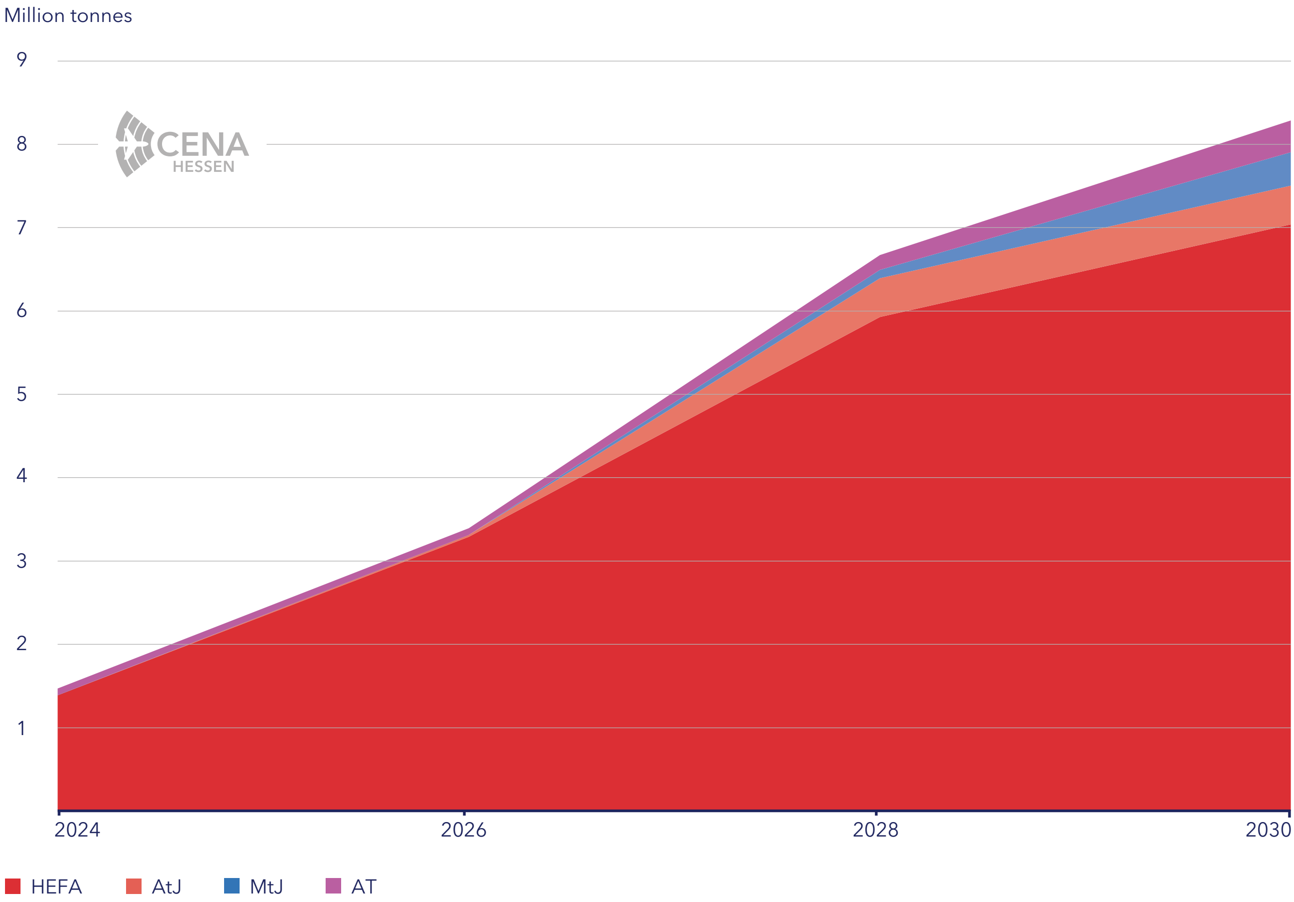
China is set to lead in terms of SAF production, with projects there expected to generate around 2.8 million tonnes annually from 2030. However, it should be noted that many of these projects are still in the planning or construction phase and only 3 are already in operation. In Saudi Arabia, the ongoing Satorp project is expected to produce up to 1.5 million tonnes starting in 2030. In Singapore, Neste aims to achieve annual production of 1 million tonnes (Table 4). In South Korea, the SAF production is expected to reach approximately 0.2 million tonnes in 2030.

Table 4: Largest SAF projects by production volumes in 2030 in Asia

	Manufacturer	Project name	Country	Technology	Degree of implementation	Production start	Announced volume 2030
1	Satorp	Satorp	Saudi Arabia	HEFA	In operation	2023	1.5 MT
2	Neste	Neste Singapore (MY SAF/NEXBTL)	Singapore	HEFA	In operation	2023	1.0 MT
3	Oriental Energy	Oriental Energy China	China	HEFA	Under construction / In commissioning	2030	0.5 MT
4	Lianyungang Jiaao Enprotech	Jiaao China	China	HEFA	Under construction / In commissioning	2026	0.5 MT
5	ENEOS	TotalEnergies Japan	Japan	HEFA	In planning	2027	0.3 MT
6	China Energy Engineering Group Co Ltd (Energy China)	China Energy Engineering Group Co Ltd (Energy China)	China	MtJ	Under construction / In commissioning	2028	0.3 MT
7	Chandra Asri/ LX International	Chandra Asri	Indonesia	HEFA	In planning	2030	0.3 MT
8	China Energy Engineering Group Co Ltd (Energy China)	China Energy Engineering Group Co Ltd (Energy China)	China	AT	Under construction / In commissioning	2027	0.3 MT
9	PT Pertamina	PT Pertamina Indonesia	Indonesia	HEFA	Under construction / In commissioning	2025	0.3 MT
10	Petronas	Petronas Malaysia	Malaysia	HEFA	In planning	2028	0.3 MT

Source: CENA Hessen

Figure 6: Development of production processes in Asia



Source: CENA Hessen

Technologically, the HEFA process is dominant in Asia and is projected to remain so, with an annual production volume of approximately 7 million tonnes in 2030 (see Figure 6).

AtJ is primarily used in Japan, where 4 of the 6 announced projects are located. Another project is in India, already in operation as a pilot plant of Praj India, and another in South Korea. To date, MtJ is only present in one project in Inner Mongolia, China. The FT process plays a minor role, with 2 projects in Japan, one of which is already in operation (Velocys project, Chiba).

In 2024, there were a total of 50 active SAF projects in Asia, marking a significant increase of 31 projects compared to the previous SAF-Outlook 2024 statistics. This growth can be attributed to the initiation of new projects and the expansion of research activities in the Asian region. However, the precise timing of some announcements, particularly from China, remains uncertain due to the challenges in accessing local sources of information. China leads the list of new projects by a significant margin, with 14 projects. Following China are South Korea with six projects and Japan with four projects. Other new projects were announced in Malaysia, Indonesia, Pakistan, India, Kazakhstan, and Vietnam, but in much smaller numbers.

2.2 SAF production in Europe

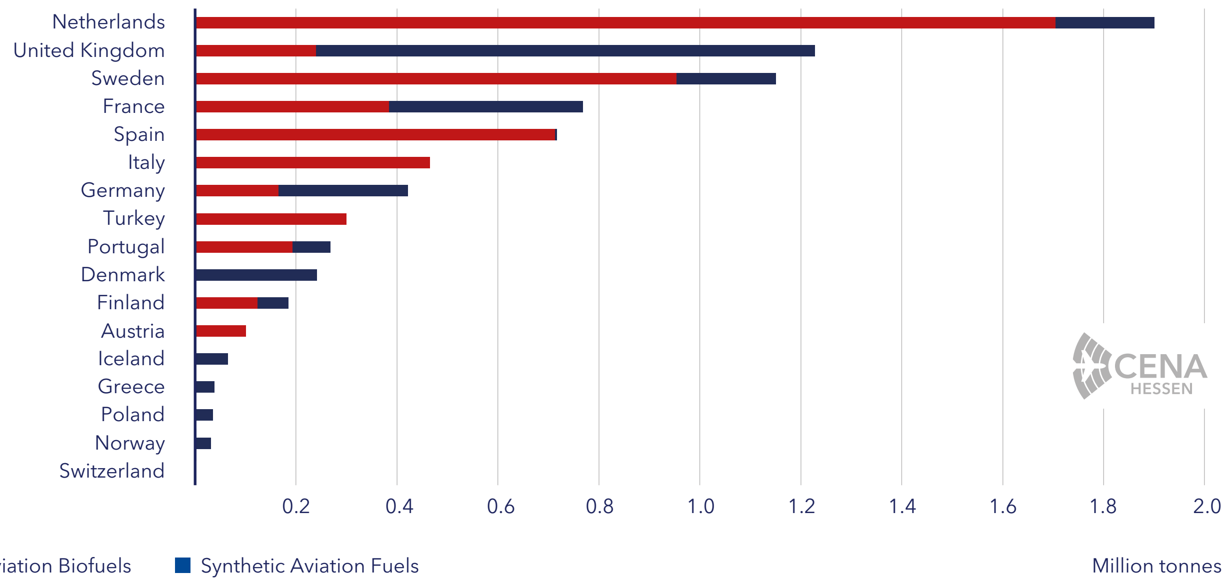
In Europe, the number of SAF projects has increased significantly in recent years. Compared to 2023, the number has risen from 72 to 117 projects in 2024. The number of plants in operation has also developed accordingly: In 2024, there were 13 industrial production plants in Europe that were already producing SAF, as well as 10 additional pilot or research plants. In 2024, the SAF production volume in Europe was approximately 0.88 million tonnes. Significant capacity expansion is expected in the coming years: By 2030, production is projected to reach approximately 8 million tonnes per year.

Germany continues to have the most SAF projects in Europe, but most of these are pilot and research plants rather than large industrial production plants. This is partly due to the large number of research centers and universities in the country. In contrast to the global trend toward an even distribution of production plants without large local centers, the situation in Europe is different. By 2030, approximately half of European SAF production will then be concentrated in the Netherlands, the United Kingdom and Sweden (see Figure 7).

Three major production sites are responsible for this: the Neste Netherlands (MY SAF / NEXTBTL) project in Rotterdam, Netherlands, the Firefly Green Fuels UK project in Cranfield, United Kingdom, and the Preem Sweden I project in Lysekil, Sweden. These sites will play a central role in the European SAF market (see Table 5).

The predominant production method for SAF in Europe is currently the HEFA process. In 2030, HEFA will still account for the largest share of European SAF production, estimated at approximately 4.6 million tonnes. However, e-SAF is expected to gain importance in the future: About a quarter of the expected SAF production in Europe in 2030 will be e-SAF, primarily composed of FT with around 1.6 million tonnes and MtJ with around 0.3 million tonnes. Alternative technology approaches could contribute an additional 0.7 million tonnes (see Figure 8).

Figure 7: Announced production volumes in 2030 in European countries



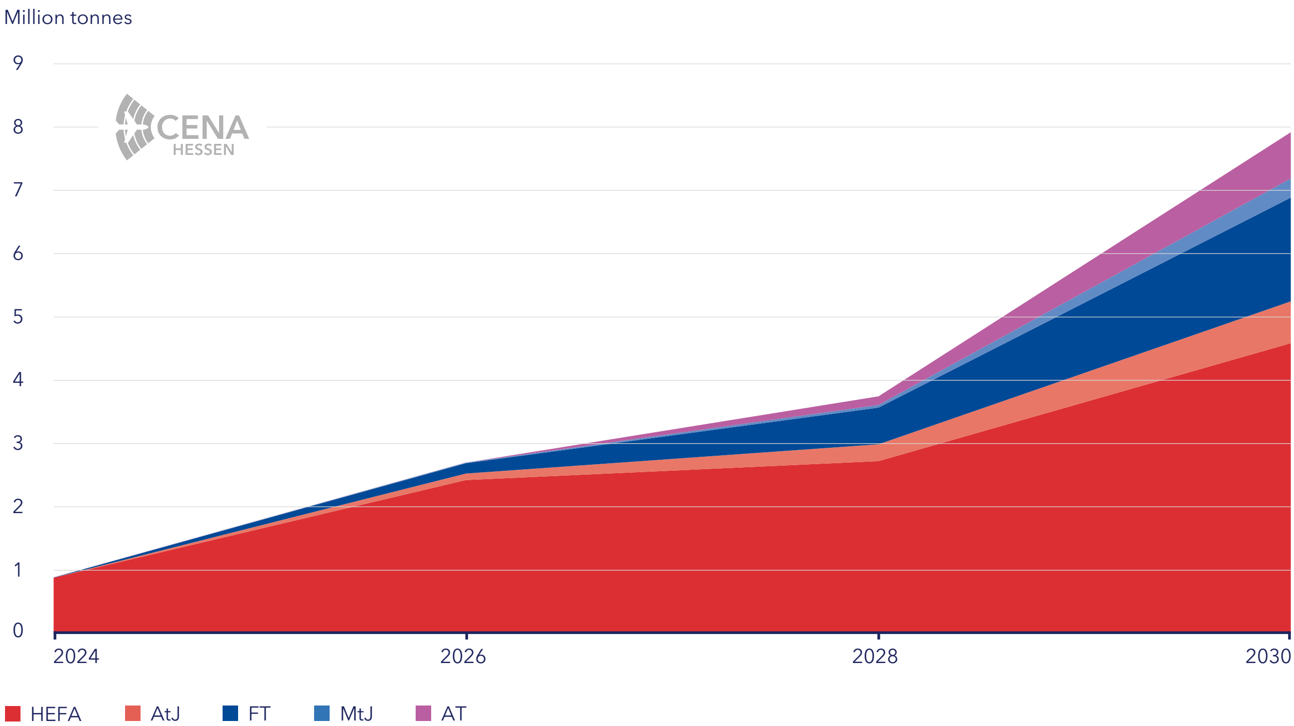
Source: CENA Hessen

Table 5: Largest SAF projects by production volumes in 2030 in Europe

	Manufacturer	Project name	Country	Technology	Degree of implementation	Production start	Announced volume 2030
1	Neste	Neste Netherlands (MY SAF/ NEXBTL)	Netherlands	HEFA	In operation	2024	1.2 MT
2	Firefly Green Fuels	Firefly Green Fuels UK	United Kingdom	AT	In planning	2027	0.5 MT
3	Sasol	Sasol Germany I (NetZeroLEJ)	Germany	FT	On hold	2029	0.5 MT
4	Preem	Preem Sweden I	Sweden	HEFA	Under construction / In commissioning	2027	0.5 MT
5	Eni	Eni Italy II (Biojet)	Italy	HEFA	Under construction / In commissioning	2025	0.5 MT
6	Swedish Biofuels AB	Swedish Biofuels AB Sweden	Sweden	AtJ	In planning	2025	0.3 MT
7	bp	bp Spain	Spain	HEFA	Under construction / In commissioning	2030	0.3 MT
8	Tupras	Tupras Turkey	Turkey	HEFA	In planning	2026	0.3 MT
9	TotalEnergies	TotalEnergies France I	France	HEFA	Under construction / In commissioning	2025	0.3 MT
10	Cepsa (Moeve)	Cepsa Spain	Spain	HEFA	in operation	2024	0.3 MT

Source: CENA Hessen

Figure 8: Development of production processes in Europe



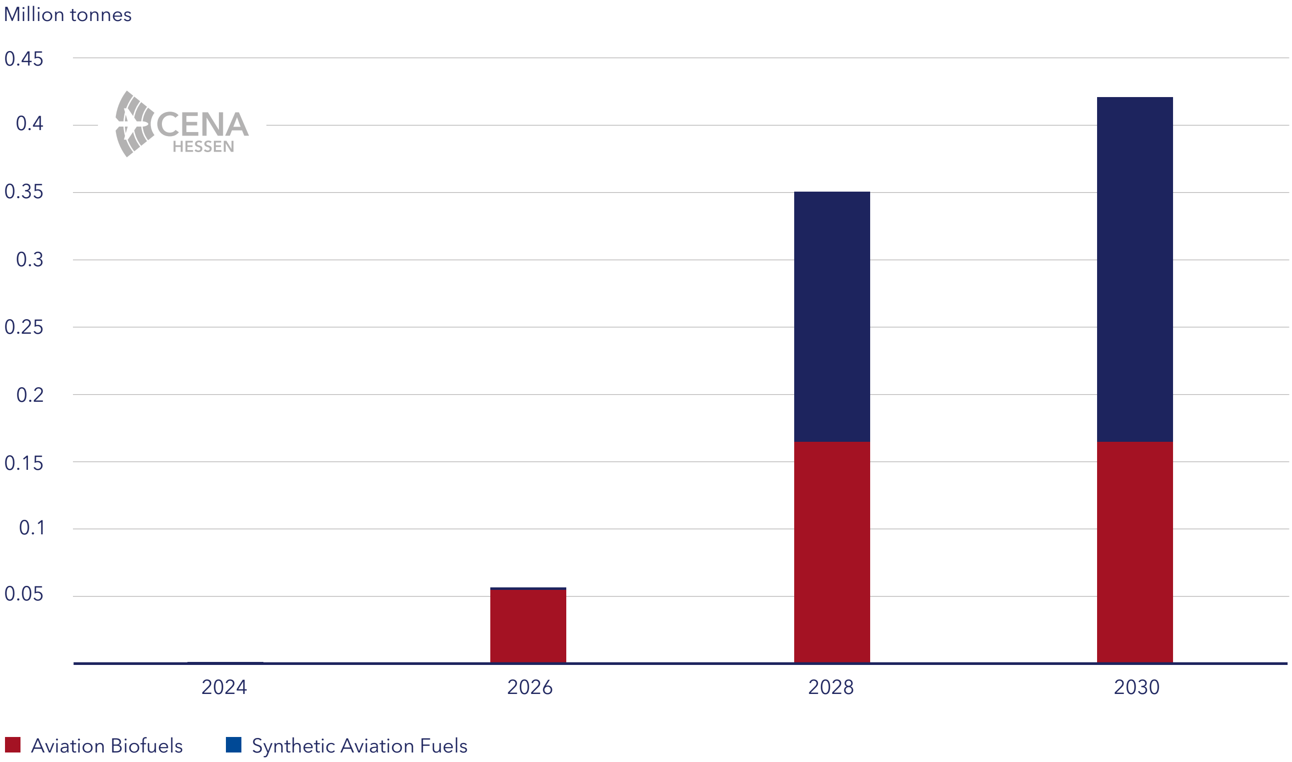
Source: CENA Hessen

2.3 SAF production in Germany

In 2024, the announced SAF production volume in Germany is approximately 50 tonnes. For 2026, the expected production volume is 56,000 tonnes, with projections of 0.35 million tonnes for 2028 and just under 0.42 million tonnes for 2030 (see Figure 9). Overall, many companies in Germany have postponed the start of their projects compared to the SAF-Outlook 2024.

In 2024, there were a total of 31 active SAF projects in Germany, ranging from project ideation to planning and construction to operation. Of these, 13 are industrial production plants, while the remaining 18 are pure research and pilot projects. Several new projects have been added since the SAF-Outlook 2024, mainly as a result of company inquiries and further web research. Newly identified projects include the only industrial-scale HEFA project to date, Holborn Europa Raffinerie, as well as other smaller projects, such as Flugplatz Straubing-Wallmühle GmbH, Fraunhofer IGB, and Leibniz Institute for Catalysis.

Figure 9: Announced production volumes of Aviation Biofuels and Synthetic Aviation Fuels in Germany



Source: CENA Hessen

Table 6: Largest SAF projects by production volumes in 2030 in Germany

	Manufacturer	Project name	City	Technology	Degree of implementation	Production start	Announced volume 2030
1	Sasol	NetZeroLEJ	Schkeuditz	FT	On hold	2029	0.50 MT
2	Holborn Europa Raffinierie GmbH	Holborn Hamburg Harburg	Hamburg Harburg	HEFA	Under construction / In commissioning	2027	0.11 MT
3	Haltermann Carless (HCS)	Amelia	Speyer	AtJ	In planning	2026	0.06 MT
4	EDL	HyKero	Böhlen	FT	In planning	2027	0.05 MT
5	SkyNRG	SkyNRG Germany/ SAF@STR	Heiden-heim-Mergel-stetten	FT	In planning	2028	0.05 MT
6	RWE AG	NRW-Revi-er-Power-to BioJetFuel	Hürth-Knap-sack	FT	Idea	2028	0.05 MT
7	Hy2gen	Jangada/Green Fuels Lausitz	Drewitz/ Jänschwalde	MtJ	In planning	2028	0.03 MT
8	Shell Park Rheinland	Relli+	Cologne	HEFA	Closed	2026	0.03 MT
9	Concrete Chemicals	Concrete Chemicals Germany	Rüdersdorf	FT	In planning	2028	0.03 MT
10	OMV	OMV Germany (M2SAF)	Duisburg	MtJ	In planning	2026	0.02 MT

Source: CENA Hessen

With a planned annual capacity of 0.11 million tonnes of SAF in 2030, the Holborn Europa refinery project is currently the largest project in Germany. The plant is already under construction and is expected to start industrial production of bio-SAF in 2027. The leading producers of e-SAF are expected to be EDL (HyKero), SkyNRG (SAF@STR) and RWE AG (NRW-Revier-Power-to-BioJetFuel), each of which is expected to supply 0.05 million tonnes per year (Table 6).

In addition to the ongoing projects, there are several that have been terminated, discontinued, or paused. Sasol's NetZeroLEJ project has been suspended for the time being due to insolvency issues with its hydrogen supplier HH2E. Sasol had originally announced production volumes of up to 0.5 million tonnes of SAF in 2030, which would have doubled Germany's currently expected total production in 2030.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3. Status and feasibility of SAF projects

3.1 Project security and development status

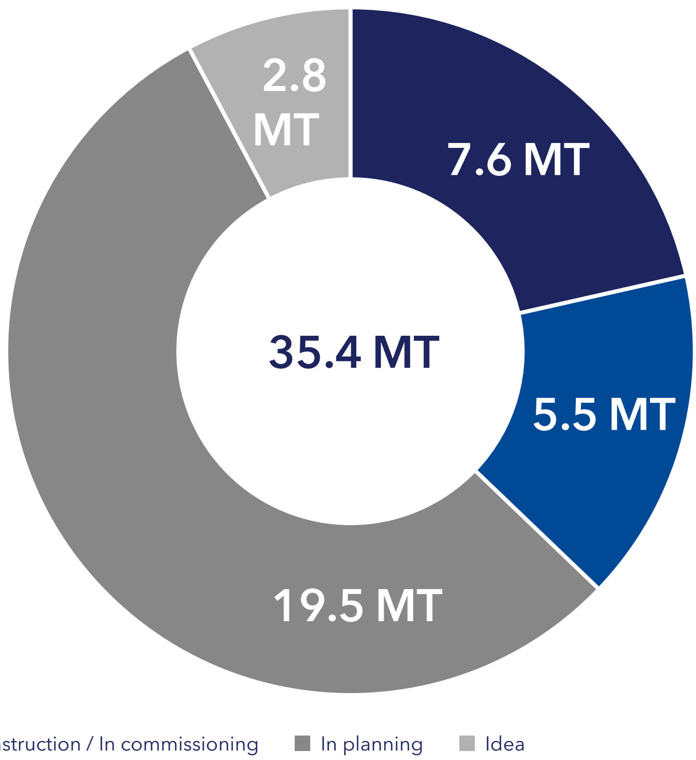
Globally, more than half of the current projects are still in the early stages of development – either in the planning or idea phase. Specifically, 42 projects out of a total of 265 are still in the idea phase, while a further 134 are in the planning phase.

> *Globally, more than half of the current projects are still in the early stages of development.*

Figure 10 provides a detailed breakdown of the expected production volumes categorized by the development stage of each project. Approximately 37 % of the production volumes announced for 2030 are derived from facilities that are already operational or under construction and, as a result, have a high development status. A further 55 % of the forecast volumes are based on planned but not yet realized projects.

A review of the regions reveals that only 23 % (3.6 million tonnes) of the announced volume in North America originates from projects at a high stage of development. In Europe, about half of the announced volume comes from projects with a high development status, corresponding to 3.9 million tonnes. A similar situation is evident in Asia, with approximately 65 % of the announced production volume – equaling about 5.4 million tonnes – deriving from projects that are already in operation or under construction. A significant proportion of these projects utilize the HEFA process.

Figure 10: Announced SAF volumes in 2030 by project status



Source: CENA Hessen

3.2 Attainability of SAF quotas in the EU

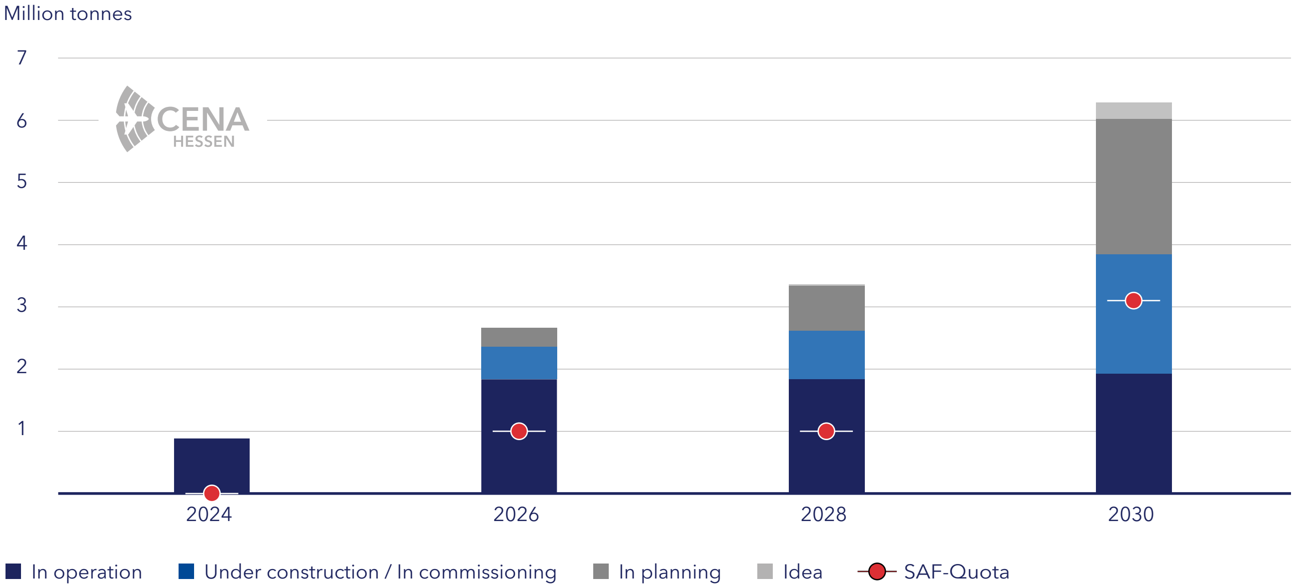
Given the projected growth in air traffic, it is anticipated that kerosene consumption in the EU will reach approximately 51 million tonnes by the year 2030. To meet the EU's mandatory 6 % SAF quota in 2030, approximately

> *Realistic fulfillment of the SAF quota – mainly from HEFA*

3.1 million tonnes of SAF will be required. Of this, around 0.62 million tonnes must be provided by e-SAF according to the e-SAF sub-quota of 1.2 %. To forecast the required SAF quantities, it was assumed that in 2024 (for which no final consumption figures were yet available) the level of the pre-Covid year 2019 would be reached. These approximately 47 million tonnes of kerosene consumption[15] were used as the base year from 2024, with an assumed future annual growth rate of 1.5 %. This results in a total fuel demand of around 51 million tonnes of kerosene in 2030.

This analysis indicates that approximately 3.8 million tonnes of SAF can be produced in the EU in 2030 from existing projects with a high probability of implementation (see Figure 11). This would make it realistic to meet the SAF quota. Furthermore, the analysis indicates that SAF production capacities in the EU could potentially increase to as much as 6.3 million tonnes per year by 2030, with the majority coming from biogenic production processes.

Figure 11: Production volumes compared to the SAF quota in the EU by project status



Source: CENA Hessen

15 Eurostat (2025) | https://ec.europa.eu/eurostat/web/main/data/database (last access 28.02.2025)

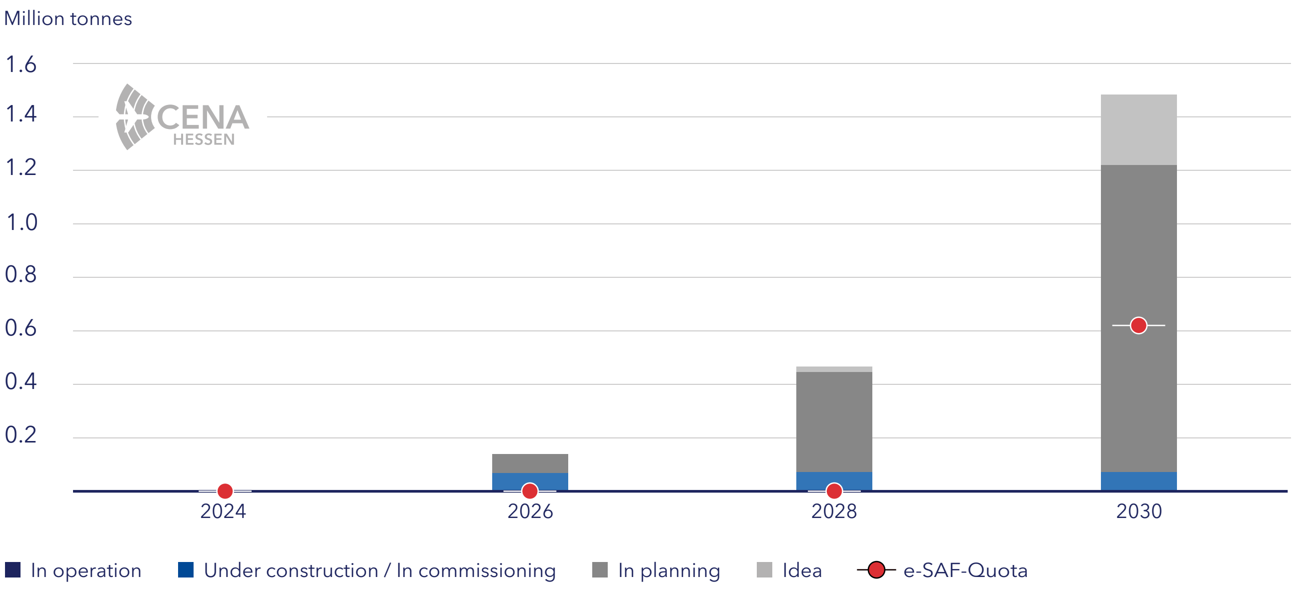
Meeting the e-SAF quota of 1.2% in 2030 will be more challenging, as it will require 0.62 million tonnes (see Figure 12). Currently, only around 0.072 million tonnes of secure production is foreseeable in the EU. While there are projects with a potential capacity of around 1.4 million tonnes under consideration, these are still in the idea or planning stage or are awaiting final investment decisions. The fulfillment of the e-SAF quota is therefore not guaranteed at this stage and depends largely on the successful implementation of several large projects.

> *The fulfillment of the e-SAF quota is not guaranteed and depends on several large projects.*

It is crucial to establish realistic timelines, as the typical 4 to 6-year lead time between the investment decision and the start of production often results in delays. The Sasol project in Schkeuditz near Leipzig/Halle airport, which is currently on hold and has a potential production capacity of 0.5 million tonnes in 2030, plays a key role in this regard. On a positive note, the German government has received EU state aid approval for a EUR 350 million subsidy for the Concrete Chemicals Germany project in Rüdersdorf (annual production volume: 0.03 million tonnes from 2028)[16]. However, at the editorial deadline, it was not known whether the approved funding will be granted by the federal government..

Quotas will continue to increase until 2035: Demand to meet the SAF quota is then estimated at 11.1 million tonnes, while around 2.8 million tonnes will be needed for the e-SAF sub-quota. This represents twice the current announced production capacity in the EU for both quotas. Although some of the projects currently in the ideation and planning phase could be implemented by 2035, they alone will not be sufficient to cover the additional demand of several million tonnes. A comparison with the projected production volumes for 2030 makes it clear that a significant increase in capacity will be required to meet the target quotas.

Figure 12: Production volumes compared to the e-SAF quota in the EU by project status



Source: CENA Hessen

16 European Commission (2024) | https://ec.europa.eu/commission/presscorner/detail/de/ip_24_6435 (last access 19.03.2025)

4. Global demand for SAF

4.1 Current SAF purchase volumes

According to surveys by the European Federation for Transport and Environment[17], the largest SAF customers in Europe in 2023 were Air France-KLM, DHL Group and IAG, each of which tanked between 0.05 and 0.09 million tonnes of SAF. U.S. airlines have caught up in recent years and reached a total volume of around 0.46 million tonnes SAF in 2023. For other airlines, the volume of SAF purchased by 2023 ranges from a few hundred tonnes to a maximum of 10,000 tonnes.

As shown in Table 7, the tanked volume was particularly high for DHL Group (due to the business customers) and at Air France-KLM, SAS Group and IAG and has increased significantly in recent years. U.S. airlines such as United Airlines and JetBlue also demonstrate a growing SAF share, although the overall figures remain relatively low.

Table 7: Percentage of SAF shares tanked by airlines worldwide with more than 0.1 %

	2021	2022	2023
DHL Group	0.74 %	1.27 %	3.27 %
Air France-KLM	0.08 %	0.59 %	1.12 %
SAS Group	0.23 %	0.41 %	0.68 %
IAG	0.07 %	0.15 %	0.65 %
Norwegian	0.26 %	0.32 %	0.28 %
Finnair	0.11 %	0.15 %	0.24 %
Qantas		0.16 %	0.21 %
Air Canada		0.04 %	0.19 %
United Airlines	0.03 %	0.09 %	0.17 %
Virgin Atlantic		0.21 %	0.16 %
Lufthansa Group	0.17 %	0.18 %	0.15 %
JetBlue	0.06 %	0.07 %	0.15 %

Source: Own calculation based on European Federation for Transport and Environment (2025)[17]

17 European Federation for Transport and Environment (2025) | https://www.transportenvironment.org/topics/planes/saf-observatory (last access 18.03.2025)

4.2 Future SAF purchase volumes

There are currently two types of SAF demand. On the one hand, there is the "mandated" market, which is defined by binding SAF quotas. These quotas oblige the distributors – that is, manufacturers, dealers and suppliers – to offer SAF quantities in accordance with the applicable quotas. On the other hand, there is the voluntary market, which is based on direct demand from airlines. This market is characterized by its volatility and price sensitivity, and its viability is contingent on airlines' ability to pass on the additional cost of SAF to their customers. This principle has already proven successful in the B2B air cargo segment, where business customers can reduce their Scope 3 emissions through SAF. This approach is also used in the passenger segment, especially by corporate customers who want to improve their Scope 3 balance. However, private travelers are less willing to pay higher costs for SAF.

The SAF purchase volumes announced to date are generally not binding commitments, but rather declarations of intent that often include a profitability clause. While these announcements indicate a basic willingness to use SAF, they do not guarantee a reliable financial basis for manufacturers and investors ("bankability").

The major European customers (Air France-KLM, IAG, DHL Group) intend to continue their existing purchase agreements, thereby ensuring the continuity of their existing SAF purchases. However, the total announced EU purchases for 2030 are less than 0.5 million tonnes, well below the expected SAF requirement of 3.1 million tonnes to meet the ReFuelEU Aviation quota. At the same time, major U.S. airlines such as United Airlines, Delta Air Lines and American Airlines have committed to large volumes through specific purchase agreements and investments in production facilities. These represent several million tonnes of SAF over periods ranging from 5 to 20 years, with half of the deliveries not scheduled to begin until the end of this decade.

> *At 0.5 million tonnes, the announced purchase volumes for 2030 are well below the SAF requirement of 3.1 million tonnes.*

Numerous other airlines have also announced increased use of SAF. Purchases range from a few 10,000 tonnes to several 100,000 tonnes per year. Major purchase agreements of at least 150,000 tonnes per year have been announced by Air France-KLM, British Airways and Qantas Airways Limited. Airlines around the world rely primarily on bio-SAF. In contrast, there have been limited observations of purchase agreements for the procurement of e-SAF.

5. Future of the SAF market: Prospects and options for action

The defossilization of the aviation sector is a challenging but attainable objective. Renewable energy and a closed carbon cycle – e.g. by using biogenic carbon or atmospheric CO_2 – provide the necessary foundation for SAF in the long term. Due to the technical limitations of hydrogen and battery electric propulsion systems, SAF will play a crucial role in the transformation of aviation towards a more climate-friendly future. The aviation industry's ambitious climate targets and increasingly stringent EU regulatory requirements underscore the need for SAF as a crucial element in reducing emissions.

> *The defossilization of the aviation sector is a challenging but attainable objective.*

Global production of SAF has seen substantial growth, particularly in the technologically advanced HEFA-SAF (Bio-SAF) category. However, it is important to note that the available usable biomass is limited and cannot be increased indefinitely. The announced quantities suggest that the SAF quotas set by the EU for 2030 can probably be achieved. In contrast, the production of e-SAF based on the PtL process faces challenges due to its current technological maturity. This development is currently in a critical phase.

Without a significant increase in SAF production, international emissions targets will be difficult to achieve. While statutory blending mandates provide some incentive, they are not sufficient, as recent years have shown. There are still major challenges and regulatory barriers to the implementation of SAF projects and the scaling up of plants, which is slowing down the market ramp-up[18]. This problem is particularly evident in the case of synthetic aviation fuels, which are much more expensive than bio-SAF and would benefit the most from the market ramp-up. According to EASA, the production cost of e-SAF alone is €7,695 per tonne, which is ten times the price of fossil kerosene at €734 per tonne[19]. The price of bio-SAF, on the other hand, is €2,085 per tonne.

While the additional cost of blending SAF is comparatively small in the initial years due to the low quotas, it can impact airline margins. However, as economies of scale and technological advancements take hold, the price of e-SAF is expected to decrease over time. This effect will be most noticeable once commercial reference plants are operational. The potential for cost reduction remains untapped without first movers to serve as a basis for further investment.

> *Without a significant increase in SAF production, international emissions targets will be difficult to achieve.*

To achieve the emission reduction targets in aviation, targeted political and economic measures and guarantees are therefore necessary – on both the supply and the demand side. On the demand side, in addition to quotas, a voluntary commitment on the part of governments, for example, to fly only CO_2-neutral and to make greater use of SAF themselves (including for the Executive Transport Wing of the German Air Force) could send a clear signal to the market.

On the supply side, targeted instruments such as guarantee programs, warranties, tax credits or accelerated depreciation are needed to secure SAF plants from planning to operation. Simplified approval procedures and rapid path qualification – e.g. via the EU SAF Clearing House – can further accelerate the market ramp-up. Given the ab-

18 InnoFuels (2024) | https://redaktion.hessen-agentur.de/publication/2024/4317_InnoFuels_Anwendungsfeld_Luftfahrt_Hemmniss_Bericht.pdf
19 European Union Aviation Safety Agency (2025) | https://www.easa.europa.eu/en/document-library/general-publications/2024-aviation-fuels-reference-prices-refueleu-aviation (last access 24.03.2025)

sence of long-term guarantees for SAF under current EU regulations, targeted measures are essential to mitigate investment risks, particularly in the initial phase of market ramp-up. Manufacturers and investors need a reliable framework to reduce potential uncertainties in securing revenues over the typical amortization periods of 10 to 15 years. In addition, effective funding and import strategies are needed to supply the European market with sufficient SAF at competitive prices in the long term – a point that is also addressed in the Hessian German Bundesrat air transport initiative[20].

International models present potential solutions to bolster investment security in the SAF market. For instance, the United Kingdom is developing a Revenue Assurance Mechanism, which would establish a private-law entity with enforceable rights to provide investors with reliable revenue prospects[21]. Singapore's Civil Aviation Authority is proactively managing the procurement of SAF to ensure compliance with national quotas and reduce market uncertainty on the demand side[22]. A similar mechanism can be found in the EU's Clean Industrial Deal for centralized procurement and stockpiling of rare earths. Such a model could also be considered for SAF.

> *The market ramp-up of SAF can be accelerated with clear investment conditions, funding and import strategies and long-term purchase agreements.*

For SAF to be successful, the market must be designed to provide long-term revenue security for producers and a level playing field and competitive protection for airlines. SAF is central to climate-friendly aviation, but the transition from pioneer to standard product will largely depend on whether these framework conditions can be reliably secured in the coming years.

20 Bundesrat (2025) | https://www.bundesrat.de/SharedDocs/beratungsvorgaenge/2025/0001-0100/0051-25.html (last access 02.04.2025)
21 Department for Transport (2025) | https://assets.publishing.service.gov.uk/media/679a0f8fa39e422368d10dce/dft-saf-revenue-certainty-mechanism-government-response.pdf (last access 01.04.2025)
22 Steer (2025) | https://www.bdl.aero/wp-content/uploads/2025/02/Fit-for-55-mitigation-measures-report-final.pdf (last access 01.04.2025)

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