Green Finance Institute

Sustainable Aviation Fuel
Market Analysis Report

September 2024

greenfinanceinstitute.co.uk

Supported by: Breakthrough Energy

Acknowledgment

The Green Finance Institute (GFI) would like to thank KPMG LLP (KPMG) for its assistance in compiling this report. KPMG accepts no responsibility or liability to any person other than GFI in respect of its work. KPMG's role in relation to this report involved supporting GFI with:

- Conducting secondary (desk-based) research to inform production of this report
- High-level consideration of international examples on the implementation and operation of Contract for Differences models and other incentivisation mechanisms, and their applicability to SAF production
- Organising and facilitating a roundtable of key stakeholders and potential investors in the SAF sector to discuss and gather feedback on international leading practices on financing incentives

The Green Finance Institute would also like to acknowledge Breakthrough Energy for the support in funding its work on Sustainable Aviation Fuel (SAF).

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The Green Finance Institute's Objectives

The Green Finance Institute (GFI) leads global experts in unlocking investment barriers within the UK to create impactful and real economy outcomes to benefit our environment, society, and business. The transition to a decarbonised aviation sector is a priority focus area, however there are several substantial barriers to investment in the requisite technologies and infrastructure.

UK government has proposed a new mandate requiring 10% (around 1-1.2mn tonnes) of jet fuel supplied to UK departing flights to be from sustainable sources (so-called Sustainability Aviation Fuels, or 'SAF') in 2030. This will require significant investment in SAF production infrastructure to cater for this future demand.

To assist the market in this transition, the GFI is looking into ways to stimulate investment into UK SAF production by identifying the right mechanisms to incentivise and stabilise the demand for SAF.

The GFI is engaging key market and financier participants to understand pain points and their perspectives on the enablers required to establish and grow this nascent industry. The GFI's key objectives are to:

1. **Analyse the current SAF market**
2. **Identify SAF sector bankability challenges**
3. **Identify mechanisms to facilitate SAF investment**
4. **Encourage commercial investment in SAF**

Source(s): https://www.gov.uk/government/speeches/aviation-fuel-plan

Structure of the Report

This report provides an overview of the current global SAF landscape and the challenges the UK faces in stimulating investment into this growing market.

Part I

Technologies underpinning SAF production pathways:

- Hydrotreated Esters and Fatty Acids (HEFA)
- Alcohol to Jet (ATJ)
- Gasification Fischer-Tropsch (GFT)
- Power to Liquids (PtL)

Part II

Global SAF production and offtake:

- Global SAF facilities
- SAF demand and supply volumes based on announced contracts
- Market size and growth rates from 2022-2032
- Largest SAF producers and purchasers based on offtake volume

Part III

Regional market landscape of SAF for the UK, Rest of Europe (ROE), Asia Pacific (APAC), and Middle East and North Africa (MENA):

- Production and offtake volumes
- Market size, drivers, and key insights

Part IV

SAF market barriers in the UK, including a RAG rating comparison of each market against the following criteria:

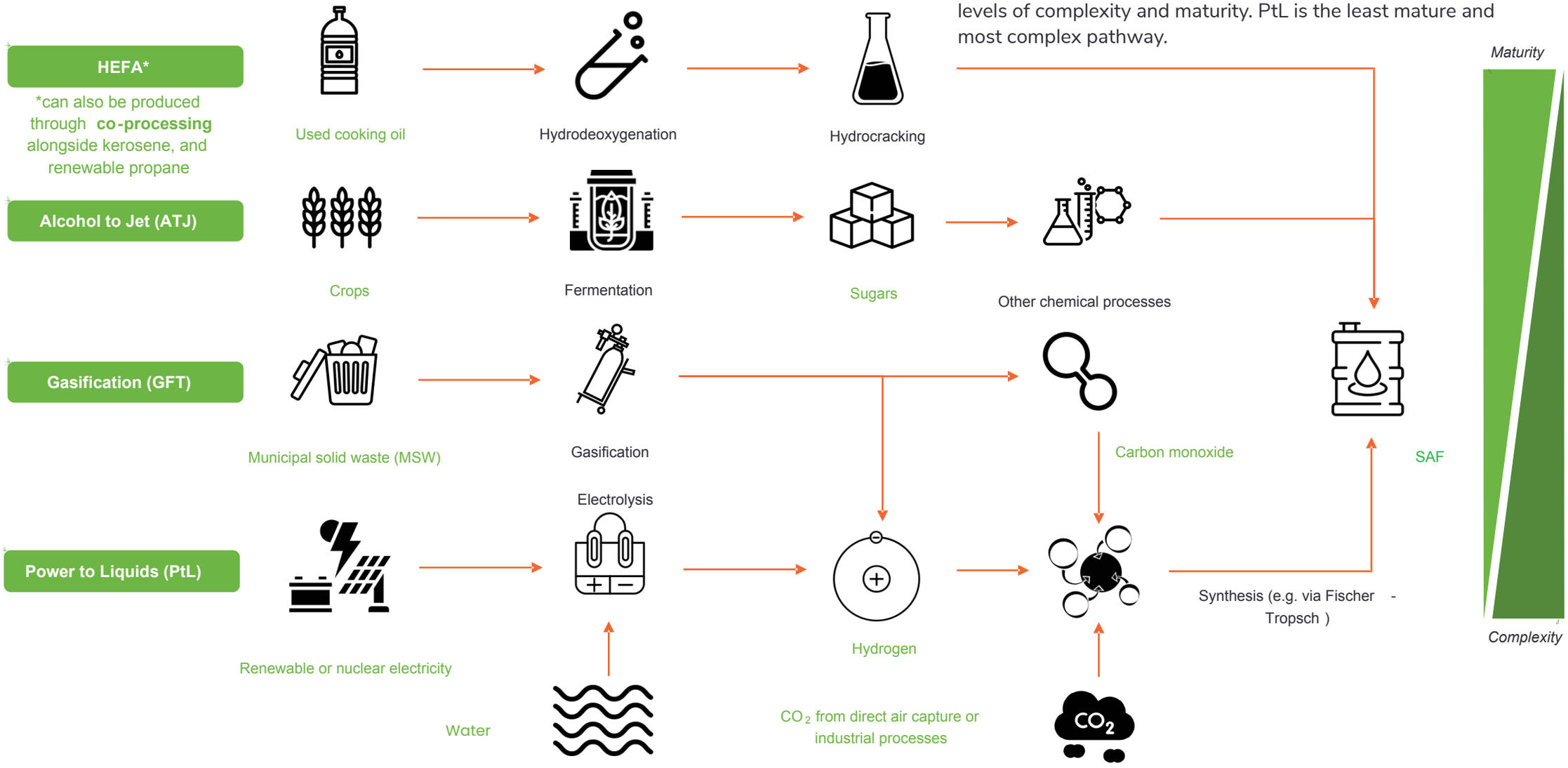
- Government policies / mandates
- Funding / investments
- Production capacity
- Purchasing capacity
- Fuel types

Part I:

SAF Technology Overview

SAF Technology Overview

There are four principal SAF production pathways with varying levels of complexity and maturity. PtL is the least mature and most complex pathway.



Part II:

Global Overview of SAF Production and Offtake

Methodology and Data Sources

Announced SAF production vs purchase offtake contracts

- Data was extracted from the Ishka database, by sorting and filtering announced offtake and production contracts by year of announcement. The Ishka database captures announcements of contracted offtake, using the nomenclature provided in the announcement or press release. This may include a range of agreement types such as 'Offtake Agreement', 'MoU', 'Certificates', 'Partnerships', 'Take or Pay Agreements', among others. For announcements for which a type of agreement is not specified, Ishka defaults to 'Purchase Agreement'.
- The database captures and records offtake and purchase contract announcements, either communicated directly to Ishka by market participants or sourced through open data. This includes contract start and end years and total volumes.
- The illustrations in this report show production and offtake per region where an aggregate view is provided for tonnes per year of production split by ultimate destination, and tonnes per year offtake split by where the SAF originated.
- The offtake regions represented in this report are based on the registered home country of the airlines, not necessarily where the fuel is bunkered and drawn from.
- The volumes depicted in the charts are calculated based on annual estimates of production/purchase for announced contracts, based on the contract durations. It is assumed that volumes are consistent per annum throughout the lifetime of the offtake contract, so that any given facility will produce a fixed amount of SAF per year. Contracts are depicted within the total volumes only during their duration.
- 2024 values shown in this document are indicative of only the contracts announced in the first third of the year.
- Historical values have been amended based on updates to the Ishka database since the original production of this research.

Top Companies, market sizes and CAGR

- The market size for the SAF market in this report is determined by the total value of sales in a particular market. The forecasts for the market size have been sourced from Apollo Reports, which followed a multi-phase methodology. This involved collecting data from prospective end-users from over 40 countries, gathering revenue figures of manufacturers and service providers through secondary research, interviews, and databases. This revenue was then narrowed down to focus on target products/services. Additionally, interviews and secondary research were utilised to gather pricing details of the various target products. The collected pricing information was used to calculate the average selling price. The market volume was derived using country-level data and then multiplied by the average selling price to arrive at the market value. The company utilised in-house statistical models and expert inputs to triangulate market values.
- No new updated reports have been identified for updating the market values.
- The compound annual growth rate (CAGR) has been calculated from 2022-2032.

Methodology and Data Sources

SAF production volumes to date by technology

- SAF technologies are identified at the beginning of this slide pack and are included in the Ishka database, from which this data has been extracted.
- Separation of production by technology encompasses all known pathways, including co-processing.
- Co-processing is not a standalone SAF production technology, as it takes place alongside fossil-based refinery operations, concurrently processing biobased material, such as fats, oils and other feedstocks.
- Where 'multiple pathways' is shown, the SAF production facility utilises two or more of the established pathways identified on slide 7.

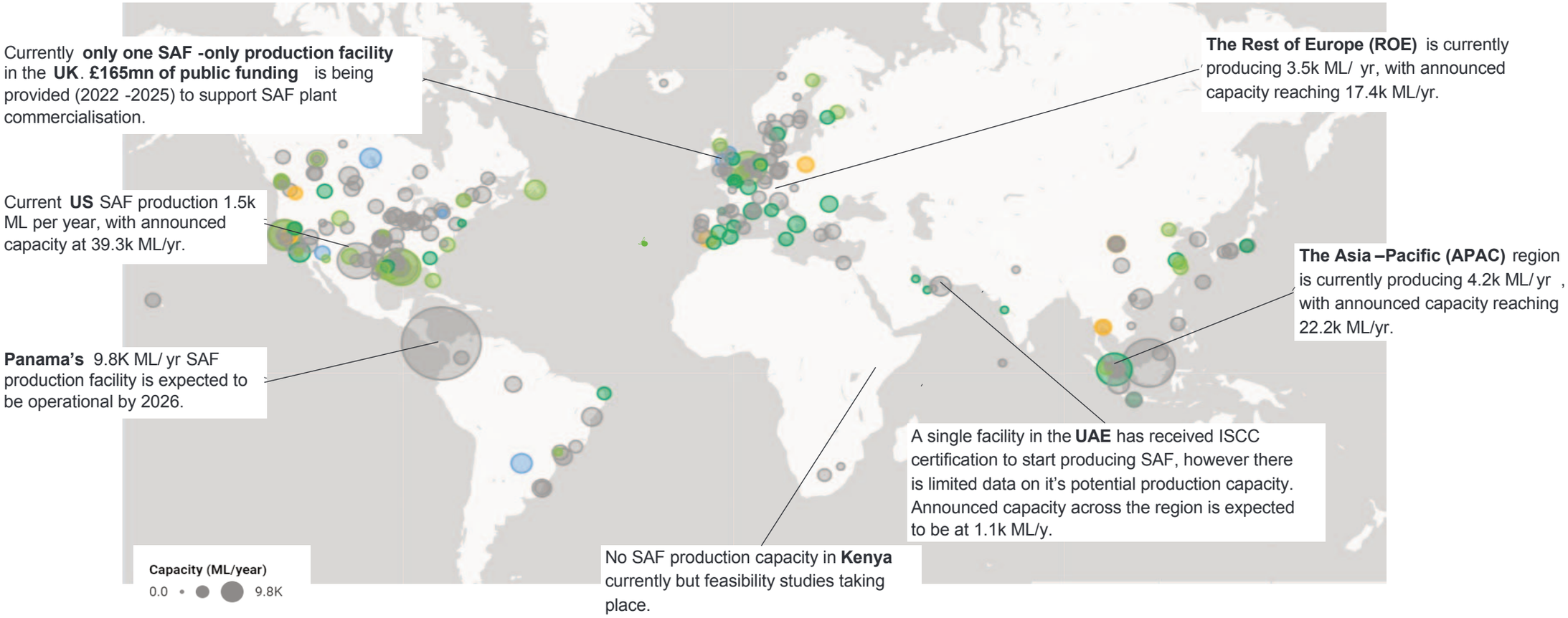
VC investments in SAF

- Venture capital data was pulled from the Pitchbook database and supplemented from external sources where needed.
- Data was sorted and filtered based on deal volumes and sizes per year in respective territories analysed in this report.
- Data has been updated from prior versions of this document based on new information in the Pitchbook database and any retrospective changes therein.
- Key deals per territory were also extracted from the database, with secondary sources complementing and expanding the information provided.

Global SAF and Other Renewable Fuels Plants

There are a number of facilities (existing and announced) able to produce Sustainable Aviation Fuels globally. These are shown on the ICAO map of SAF and other renewable fuel production facilities (link below).

Please note: The data on this map reflects capacity that could be used to produce SAF, including both SAF-specific and broader renewable fuel production. As a result, the quantities represented here may differ from those shown elsewhere in the presentation.



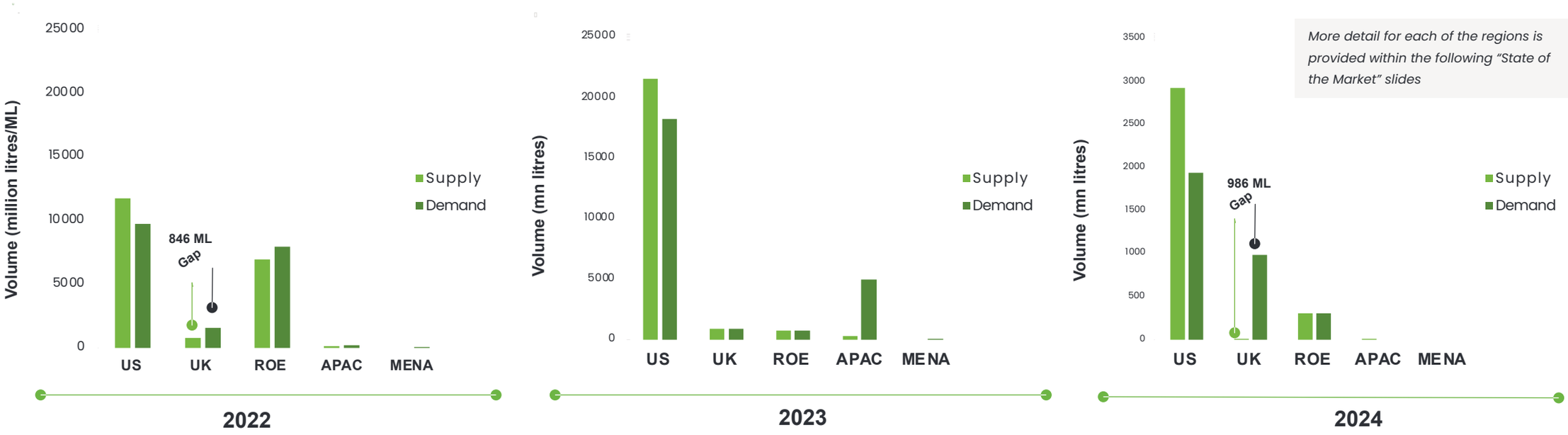
Note(s): Production capacity per year has been derived from the ICAO map, reflecting only those facilities that are in service and currently producing SAF or other renewable fuels. The announced capacity encompasses facilities in service producing renewable fuels, as well as those just announced, being designed or under construction. **Source(s):** ICAO Map of SAF production facilities

SAF Demand-supply Gap Based on Announced Contract Volumes

This report utilises data from the Ishka database to analyse the demand and supply of SAF through offtake agreements. The graphs illustrate the announced SAF volumes in millions of litres from 2022 to 2024, with contracts extending until 2046.

Key Insights:

- The **US** is the only region **over-supplying SAF in comparison to its levels of demand** in currently announced offtake agreements between 2022-2046. US continues to over-supply in 2024.
- **In 2022 and 2024, the UK has the largest proportionate deficit in SAF production and purchase offtake agreements which span 2022-2046** in comparison to other regions. A supply gap remains as production does not keep up with anticipated demand for 2030 through domestically produced fuel. This means the UK could be importing the majority of SAF over the coming years unless new production facilities can be constructed, and new offtake agreements negotiated.
- The **ROE saw a large jump in offtake agreements in 2022 due to the RefuelEU initiative being announced in 2021**, whilst the US has seen steady levels of agreements due to its continued commitment to SAF initiatives. Europe faces significant regulatory targets under the European Union's Fit for 55 program, necessitating increased SAF uptake.
- The **APAC region saw a surge in activity in 2023**, owing to two major contracts between Japanese airlines, All Nippon Airways & Japan Airways, to import SAF from the US producer Raven SR.

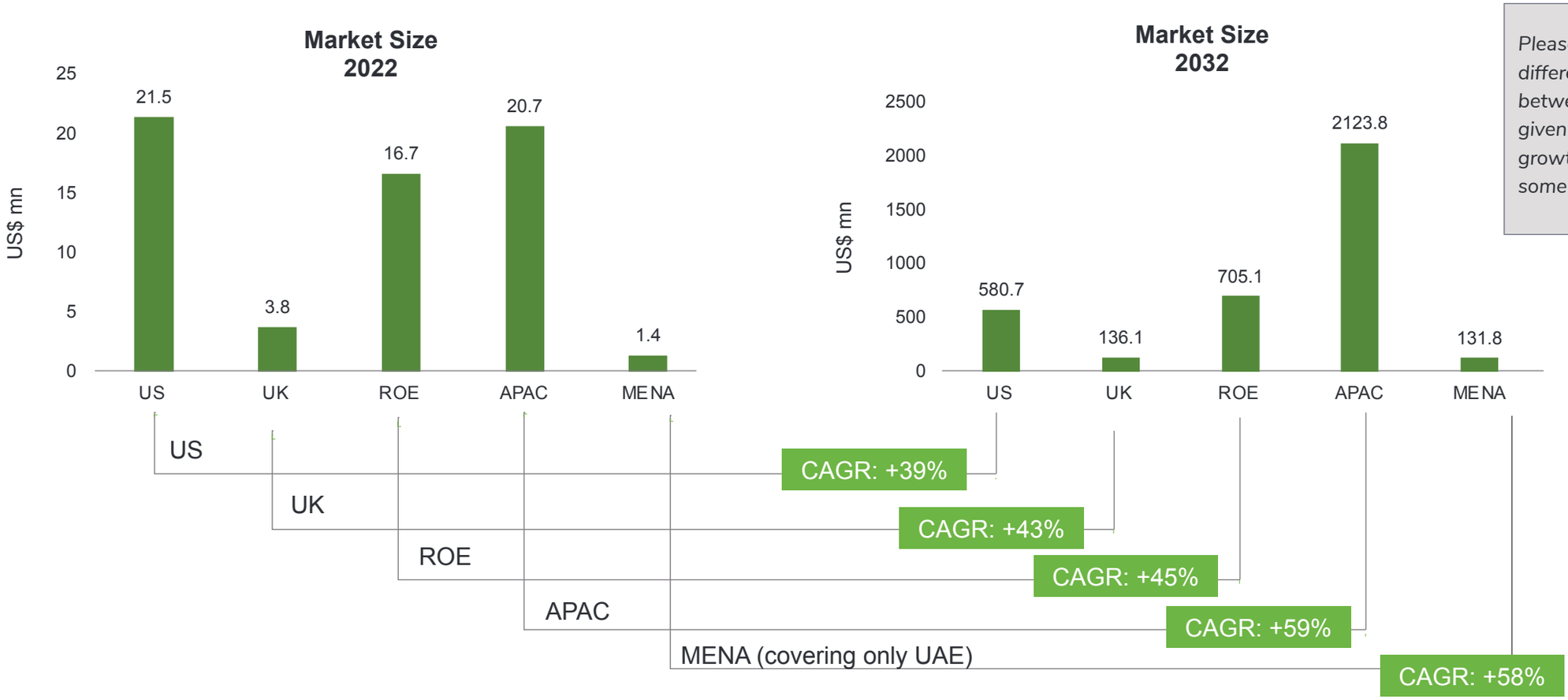


Note(s): These figures represent the total contract values at the time of announcement, not spread out over the contract duration. The specific distribution of supply and demand within individual contracts remains undisclosed. Consequently, the annual demand might not precisely align with the announced supply. The graphs prioritise the volumes announced each year, acknowledging that projects may span multiple years but are only counted once in the data.

Sources: Ishka database, Global SAF production set to double in 2024, with future growth policy-dependent | S&P Global Commodity Insights (spglobal.com)

Global SAF Market Size (US$ mn), FY22–32

According to a research report published in 2021, the US is expected to have the lowest market growth rate between 2022 and 2032 compared to other regions due to the SAF market being comparatively mature. The UK has the second lowest expected market growth rate amongst the regions being compared. APAC is projected to grow significantly to become the largest SAF market valued over $2bn by 2032. It is forecasted to be 4x the size of the current largest market, which is the US, and 16x the projected market size of UK in 2032.

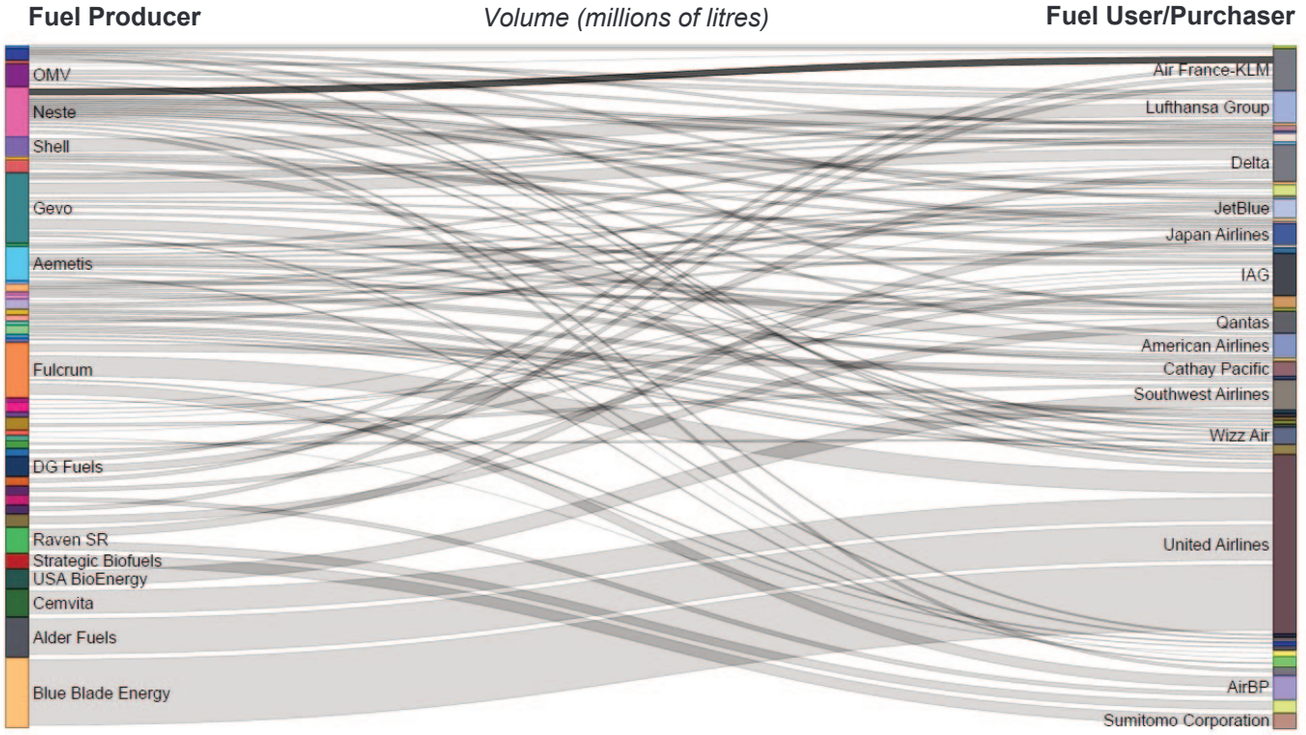


Please note the different scales used between the graphs given the exponential growth rate of SAF in some regions

Note(s): The market size forecasts for the Sustainable Aviation Fuel Market in this report have been sourced from Apollo Reports. Apollo followed a multi-phase methodology that involved collecting data and insights from prospective end-users from over 40 countries around the world, gathering revenue figures from manufacturers and service providers, and utilising in-house statistical models and expert inputs to triangulate market values.
Source(s): Apollo reports: SAF Market Estimates and Forecasts

Fuel Producers and Purchasers

- The majority of top SAF producers are based in the US, with a few large producers such as Neste located in Finland. Top purchasers are located in several countries including the US, UK, Japan, France, and Australia.
- Blue Blade Energy is the largest producer, while Fulcrum, Alder fuels, Gevo and Cemvita are among the highest producer for offtake volume with a handful of large contracts.
- In contrast, Neste, Gevo and Fulcrum have a higher number of offtake agreements each but with smaller volumes per contract.
- United Airlines is the largest purchaser of SAF, whilst IAG and Air France- KLM group as well as United Airlines have agreed a larger number of offtake agreements of smaller volumes to diversify their SAF supply geographically. Delta and Lufthansa Group also have a relatively large number of offtake agreements.

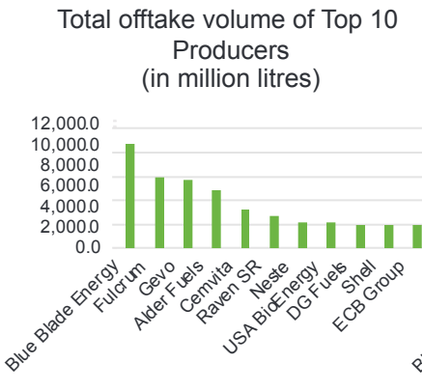


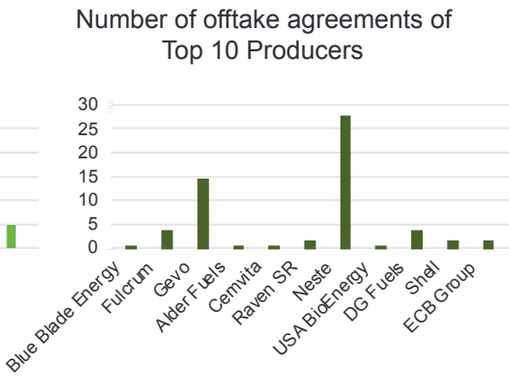
Note: The Sankey diagram shown above showcases the flow of announced SAF volumes between fuel producers and fuel users/purchasers in millions of litres from 2022 to 2024, with contracts extending until 2046.

Exclusion: Supplier volumes (between producers and purchasers) has not been included in this diagram for simplicity. Furthermore, this diagram does not visually represent the volume of contracts where Shell and World Energy acted as fuel users/purchasers. Additionally, any contracts where the producer or purchaser names were not available have not been included or considered in this diagram.

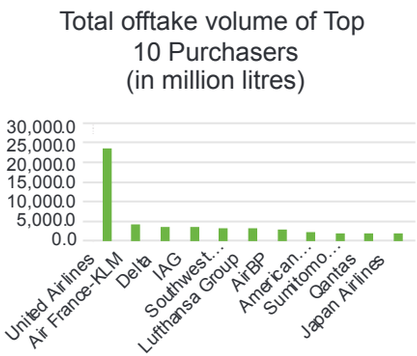
Source(s): Ishka database

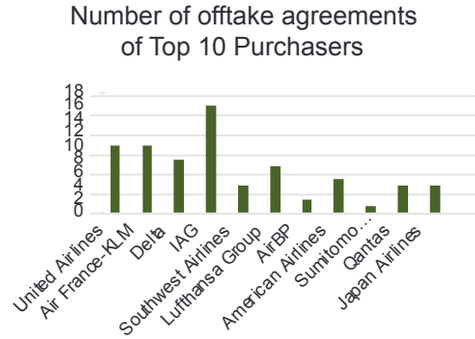
Top 10 Producers





Top 10 Purchasers

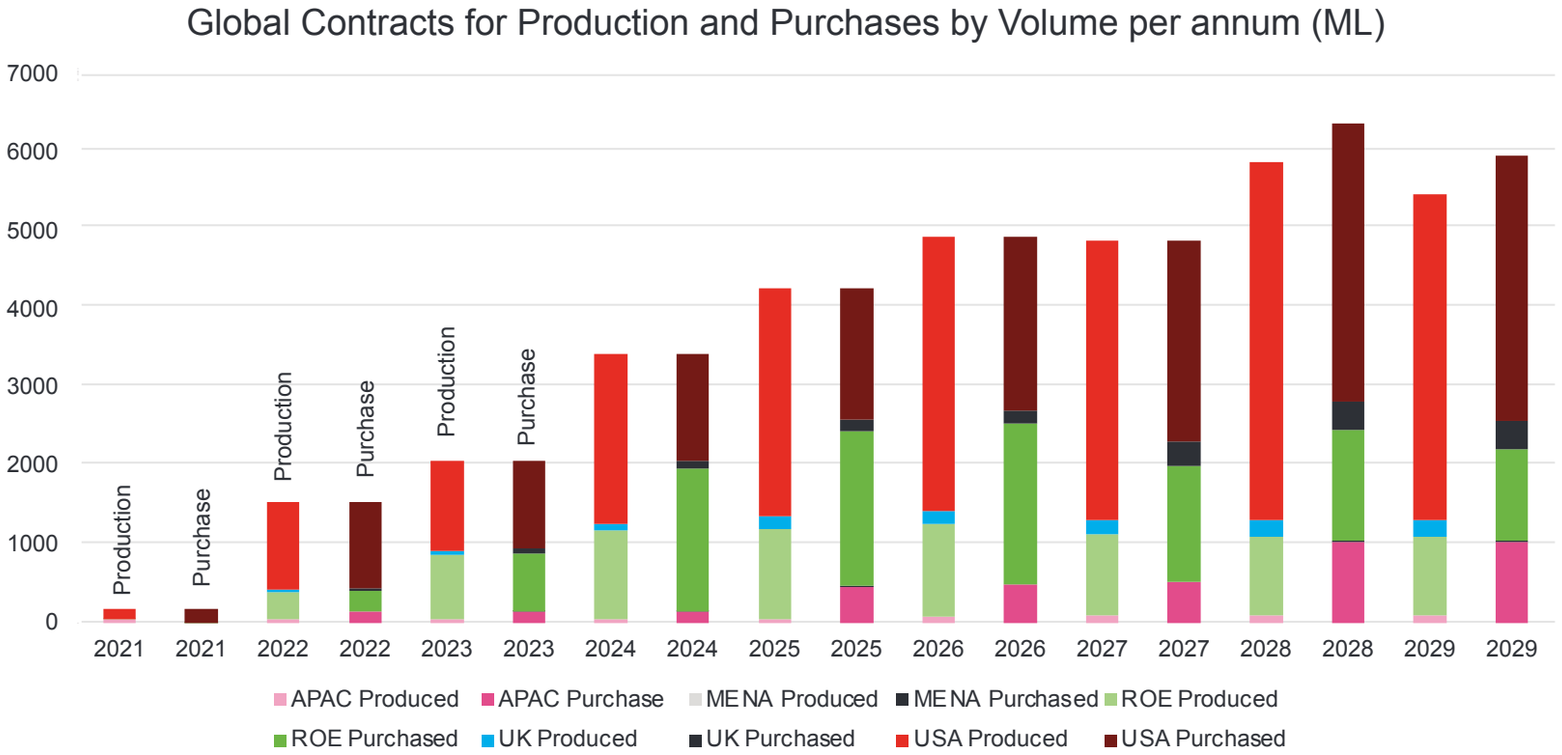




Global SAF Production and Offtake

The global SAF market continues to grow year on year from 2022 onward. The graph below shows the announced annual production and offtake volumes in each calendar year since 2021. This data reflects a growth trend in annual production and consumption of SAF, based on start and end years of contract announcements. It does not capture the total facility size.

This data demonstrates the geographic split in the production and offtake of SAF, with the US dominating the production market, while APAC and the UK trend towards net imports (UK% of global total called out). The production and purchase expectations are further explained in the State of the Market section of this pack, and demonstrate annualised production and purchase volumes based on facility start dates.



Production share by region				
Region	**2025**	**2026**	**2027**	**2028**
APAC	1%	1%	2%	2%
MENA	0%	0%	0%	0%
ROE	27%	24%	21%	17%
UK	4%	3%	3%	4%
USA	68%	71%	73%	78%

Purchase share by region				
Region	**2025**	**2026**	**2027**	**2028**
APAC	11%	10%	11%	16%
MENA	0%	0%	0%	0%
ROE	46%	42%	30%	22%
UK	4%	3%	7%	6%
USA	39%	45%	53%	56%

Note(s): The announced projects reflect the contents of the database – missing values for offtake destinations may result in minor differences between production and purchase offtake volumes. The location data is assumed based on the headquarters of the producing/purchasing company, and therefore may only be taken as indicative given the cross-border nature of the aviation industry

Sources: ISHKA Database values

Part III:

Regional SAF Market Comparison

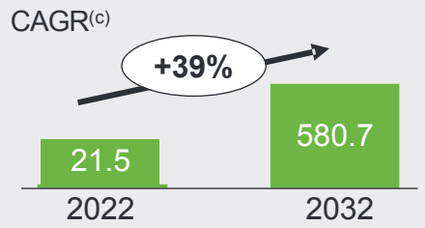
The State of the Market: US

An overview of the US SAF market shows that the US is the biggest beneficiary of fiscal incentives for SAF production, provided by the government. The region has the largest volume of announced offtake agreements, as of June 2024.

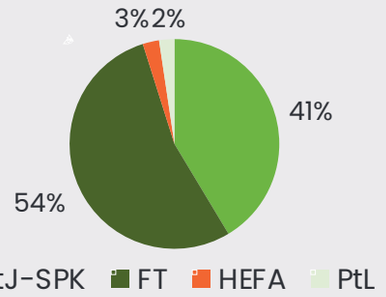
Market Overview

The SAF Grand Challenge, aims to meet the goal of supplying sufficient SAF to meet 100% of aviation fuel demand by 2050. Initiatives such as the IRA support SAF growth, emphasising collaboration, finance and policy actions, but lack long-term planning certainty as a key concern is whether these incentives will remain active long enough to substantiate the case for long-term investment.

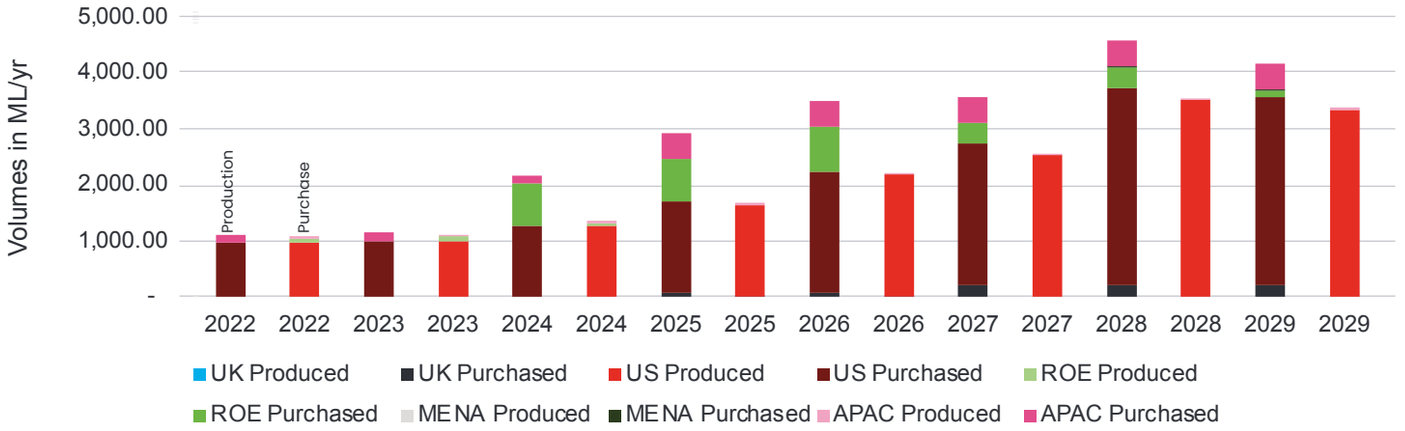
SAF Market Size (US$ mn), FY22–32F (a)



SAF production volumes to date by technology (in %)(c)



US Contracts for Production and Purchases ML/yr



Top 5 Producers forecasted in 2028(b)

Producers`	Production Capacity in KT/per year	Year of Commercialisation
Gevo	983.1	2022
ECB Group	600	2022
Blue Blade Energy	408.7	2022
DG Fuels	264	2028
Raven SR	250	2025

Notes: (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources. (d) Where 'multiple pathways' is shown, the SAF production facility utilises two or more of the established pathways identified on slide 7.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum , https://www.spglobal.com/commodityinsights/en/oil/refined-products/jetfuel/010224-global-saf-production-set-to-double-in-2024-with-future-growth-policy-dependent

The State of the Market: US

Market drivers and insights

Government funding/incentives

- The **US Renewable Fuel Standard (RFS)**, established in 2005, promotes the use of renewable fuels in transportation. The RFS offers **an "opt-in" approach, allowing SAF to generate compliance units** without aviation fuel generating compliance obligations, whilst also refraining from imposing a mandated SAF use obligation.
- The **U.S. Sustainable Aviation Fuel (SAF) Grand Challenge** aims to produce 3 billion gallons of SAF by 2030 and 35 billion gallons by 2050. As a supportive measure, the U.S. government has implemented tax credits for SAF production, providing up to $1.75 per gallon through 2027. The goal is to achieve a minimum of a 50% reduction in life cycle greenhouse gas emissions (GHG) by 2030.
- The Inflation Reduction Act of 2022, includes a **two year tax credit for those who blend SAF**, a subsequent **three-year tax credit for those who produce SAF**, and a **grant program of $290 million over four years** to carry out projects that produce, transport, blend, or store SAF, or develop, demonstrate, or apply low-emission aviation technologies.
- The IRA is expected to help the US achieve its ambitious SAF Grand Challenge goals and replacing 100% of jet fuel demand with US produced SAF by 2050.
- The **US Sustainable Skies Act 2021** allows a business-related tax credit through 2031 for each gallon of SAF used by a taxpayer in the production of a qualified mixture
- Producers of SAF in the US are eligible for **$1.25-1.75/gallon** tax credits. SAF that decreases GHG emissions by more than 50% is eligible for an additional $0.01 per gallon for each percentage point the reduction exceeds 50%, up to $0.50 per gallon.

Other key insights

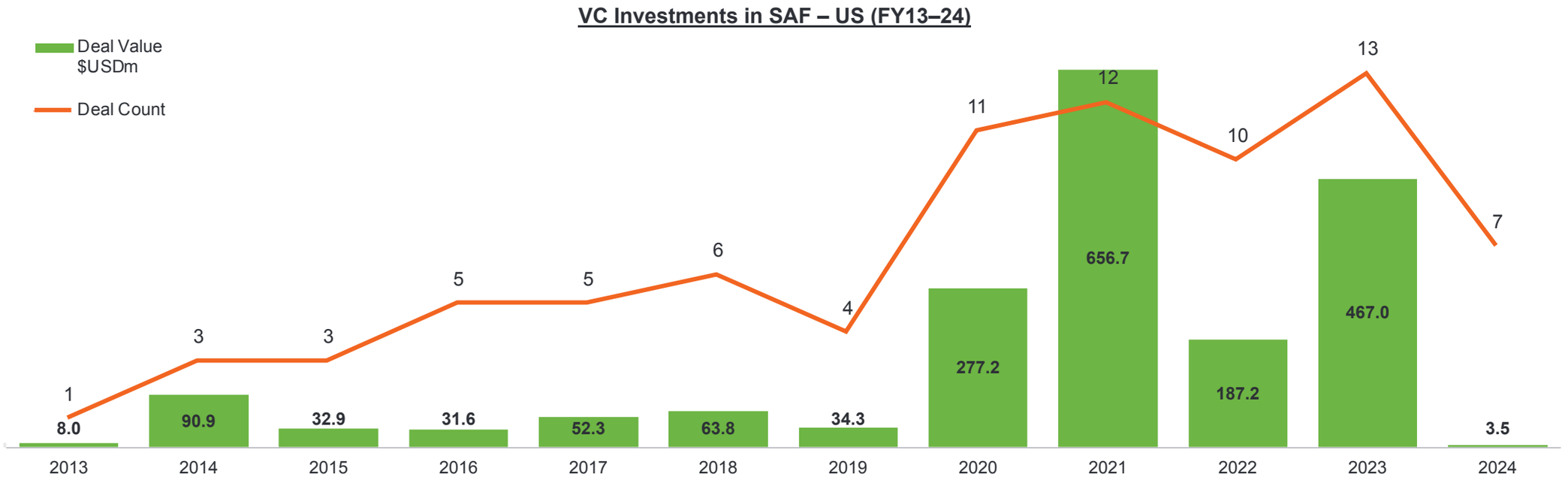
- The US market is estimated to grow at a CAGR of **39%** from **$21.5M in 2022 to $580.7M in 2032**.
- **Gasification and Fischer-Tropsch and Alcohol-to-Jet fuel** are the main feedstock technologies in production encompassing 95% of the market. **HEFA** is only a small share of the total volume owing to projects with low average production capacity (~160ML).
- To reach a domestic SAF production capacity of 27 Bgal (77 Mt), the US would have to deploy around **250 SAF refineries by 2050**, representing a **cumulative CAPEX investment of 400 billion USD**.
- The updated version of the U.S. Department of Energy's Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET) model will provide another methodology for SAF producers to determine the lifecycle GHG emissions rates of their production for the purposes of qualifying for the SAF Credit for SAF sold or used during calendar years 2023 and 2024. Incentives in the Inflation Reduction Act are helping to scale production of low-carbon fuels and cut emissions from the aviation sector.
- **In 2023, Boeing and the U.S. Government** launched an initiative to advance Sustainable Aviation Fuel among APEC Economies
- In January 2024, **LanzaJet opened its facility, Freedom Pines in Georgia with a production capacity of 10 million gallons per year**. The project was made possible a mix of strategic investors and climate-focused investors who provided the necessary financing

Notes: (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum, IATA Fact Sheet: EU and US policy approaches to advance SAF production

Venture Capital SAF Investments in US

There was a surge in venture capital deals activity in the US in 2021, ahead of the announcement of the Inflation Reduction Act.



Key Deals

- United Airline Ventures (USD$100m SAF fund) has a portfolio of investments, including in SAF startups 1PointFive and Cemvita. Additionally United made investments paired with purchase agreements of 1.5 billion gallons from Alder Fuels and 900 million gallons from Fulcrum BioEnergy, among others.
- United is just starting to make the first investments from its new fund public, including $5 million to Viridos, an algae-based fuel producer.

Source(s): Government websites by countries, geographical SAF reports, Pitchbook

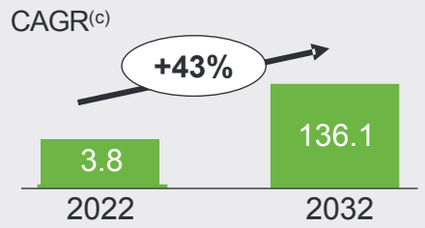
The State of the Market: UK

An overview of the UK SAF market shows an increase in the expected production through offtake agreements in 2023. However, a supply gap remains as production does not keep up with anticipated demand, suggesting that more production capacity could be required.

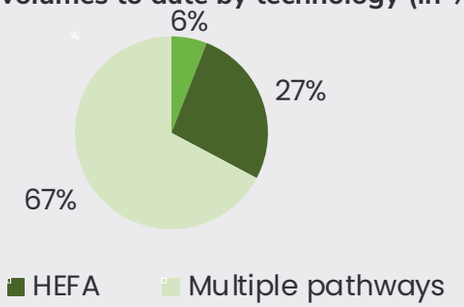
Market Overview

The UK SAF market has been accelerated by the Jet Zero strategy and the SAF mandate which aims to deliver 10% SAF (as a share of total jet fuel) by 2030, rising to 22% in 2040. Starting in 2025, approximately 230,000 tonnes SAF will be required to meet the government commitment, rising with the mandate through to 2040.

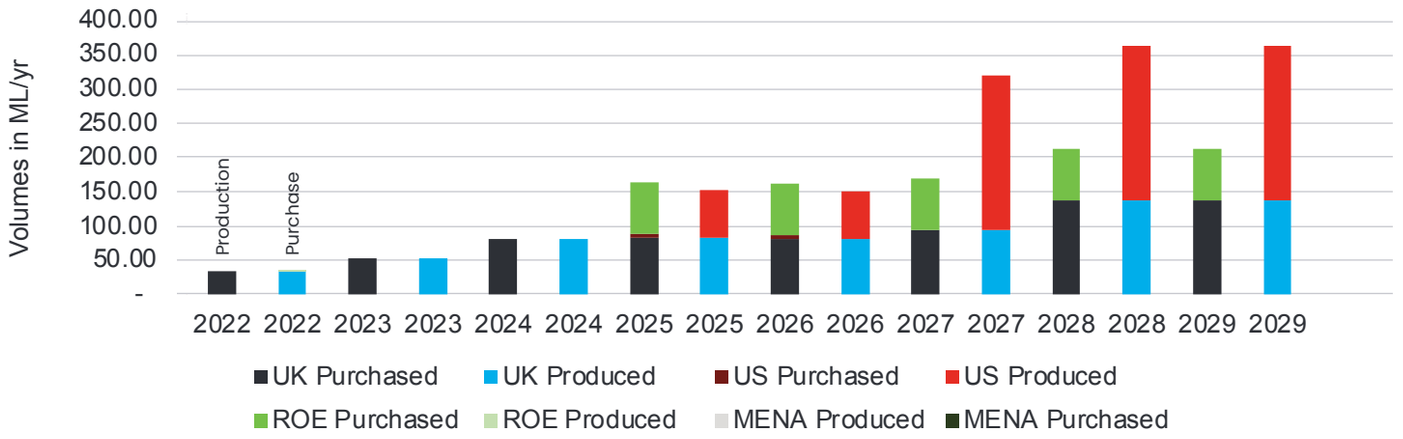
SAF Market Size (US$ mn), FY22–32F (a)



SAF production volumes to date by technology (in %)(c)



UK Contracts for Production and Purchases ML/yr



Top Producers forecasted in 2028(b)

Producers`	Production Capacity in KT/per year	Year of Commercialisation
Shell	67.72	2025
P66hillips	41.70	2012
LanzaJet UK Ltd	37.50	2025
Firefly Green Fuels	35.00	2025

Note(s): (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources. (d) Where 'multiple pathways' is shown, the SAF production facility utilises two or more of the established pathways identified on slide 7.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum

The State of the Market: UK

Market drivers and insights

Government funding/incentives

- In July 2022, **the government announced it would introduce a SAF mandate from 2025**, requiring **at least 10% of UK aviation fuel to be from sustainable sources by 2030** and set out an ambition to see **five commercial plants in construction** by 2025.
- **In 2024**, the UK government announced the full policy detail of the **SAF mandate which will deliver 10 % of all jet fuel in flights taking off from the UK from sustainable sources by 2030 and 22% by 2040**. Under this SAF mandate, a target of **2% SAF blending will be introduced from 2025**.
- The **SAF mandate will obligate fuel suppliers to supply SAF in the UK** and therefore will create the necessary demand to incentivise the supply of SAF to the aviation industry. **Removing support for SAF from the RTFO will better adhere to the polluter pays principle** so that the obligation falls on the jet fuel supply chain rather than the road fuel supply chain.
- To drive innovation and diversification, a separate **obligation on power-to-liquid fuels** will be introduced at 0.2% from 2028, rising to 0.5 % in 2030 and will reach 3.5% of total jet fuel demand in 2040.
- The mandate will also include a cap on the feedstocks that are used in the **hydroprocessed esters and fatty acids (HEFA) process**. HEFA is currently the only commercially available SAF, however, it is dependent on limited feedstocks that cannot deliver the UK's long-term SAF goals alone.
- The Government's **£135 million Advanced Fuel Fund** is supporting the growth of 13 groundbreaking SAF projects across the country. The UK government announced in April 2024 a consultation for a **revenue-certainty mechanism** that will give potential SAF producers confidence that their investments will pay off. The consultation includes a preferred option of a **guaranteed strike price (GSP)**, which guarantees a pre-agreed price of SAF supplied to the UK market – giving producers the confidence that they will receive a certain price for the SAF they make.
- In 2021, through the **UK Green Fuels, Green Skies** initiative by the government, £15 million was allocated to early-stage development of UK SAF plants.

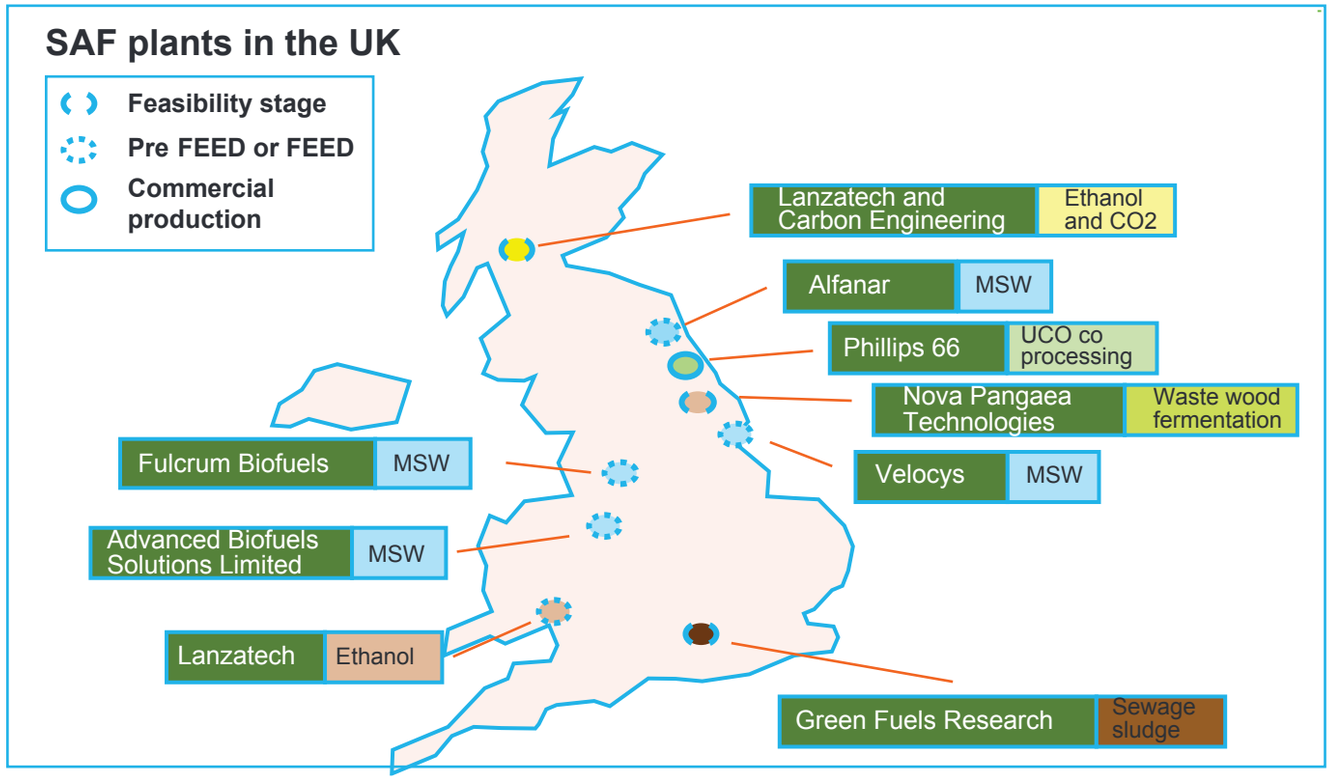
Other key insights

- The UK SAF market size is estimated to grow at a CAGR of **43%** from **$3.8M** in 2022 to **$136.1M** in 2032.
- From our analysis on the Ishka database, **the UK may have a SAF production deficit in the medium to long-term**, based on announced contracts. This deficit will likely be driven by strong demand from airlines who are UK-based (but may operate and bunker internationally). As such, **the supply gap in the UK may be met by unannounced capacity from new facilities, or imports of SAF**. In the latter case, the UK could be competing within a **highly contested imports market** in the face of global demand from EU and other regions.
- Support **policy mechanisms which incentivise investment** in SAF production **will be required** to scale up capacity.
- The **world's first commercial 100% SAF transatlantic flight** (Virgin Atlantic's Boeing 787) took off from Heathrow in Nov 2023 – backed by ~£1 million in government investment.

Notes: (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum, IATA Fact Sheet: EU and US policy approaches to advance SAF production

Current UK SAF Landscape



The UK Government's SAF policy

SAF mandate target of 10% SAF by 2030
From 2025 jet fuel suppliers will be mandated to blend an increasing proportion of SAF in their mix, starting at 2%. A sub-mandate for PtL has been set at 0.5% by 2030.

Over £200m of funding committed to date
The Advanced Fuel Fund re-opened in Spring 2023 and awarded £53 millions of funding to 9 projects.

Additional policy under exploration
In April 2024, the Government announced a consultation for a revenue-certainty mechanism for UK SAF plants.

A UK clearing house to approve fuel
A new body to expedite the development of new fuels and support their certification.

Jet Zero Council collaboration
A SAF delivery group brings together fuel producers, airlines, airports and other SAF experts.

Strong sustainability criteria
The focus of UK SAF policy is predominantly on waste to reduce potential sustainability concerns.

Key Deals

- **Fuel producers for AFF Window 2 (announced in Nov 2023) which received funding are** – Abundia Biomass-to-Liquids (£4,484,000), Arcadia e-Fuels (£12,341,000), Alfanar Energy (£8,664,000), Carbon Neutral Fuels (£1,376,000), Esso Petroleum Company (£6,065,000), Nova Pangaea Technologies (£9,063,015), OXCCU Tech (£2,814,000), Willis Sustainable Fuels (£4,721,000) and Zero Petroleum (£3,492,100).
- **Fuel producers for AFF Window 1 (announced in Dec 2022) which received funding are** – Alfanar Energy (£11,001,000), Lanzatech UK Ltd (£24,960,843), Velocys plc (e-Alto) (£2,523,094), Fulcrum BioEnergy Ltd (£16,764,000) and Velocys plc (Altalto) (£27,000,000).

UK SAF Market Overview

The government has confirmed new targets to ensure 10% of all jet fuel in flights taking off from the UK comes from sustainable sources by 2030 through its SAF mandate. There are some barriers to investment that are not fully addressed through the existing policies of which the key remaining barriers is the risk of revenue certainty.

The combined weight of price, technology and feedstock risk is unattractive for both debt and equity investors. The industry argues policy and financial support is needed to achieve the 10% SAF mandate due to the price premium between SAF and conventional jet fuel, as well as competition from cheaper SAF production elsewhere. The 2025 target and trajectory to 2030 must balance the need to deliver emission reductions by utilising SAF that is readily and commercially available, while also creating the environment for new technologies to develop and start contributing to a more diverse SAF mix that will secure the medium and long-term supply of SAF. It must also recognise the overall constraints on feedstock availability and the demand from other transport modes and other sectors of the economy. The decision on the overall trajectory has therefore been taken alongside the HEFA cap, the PtL obligation and the buy-out prices.

A mixture of the following financial and policy incentive schemes can help bridge this pricing gap and stimulate private investment:

Financial incentives

A price support mechanism, such as a Contract for Difference, floor pricing for certificates or a "cap and floor" on revenue would support price stability. This could be funded by UK ETS revenue. In April 2024, the government consulted on a **revenue certainty mechanism** which would reduce the risks of uncertain revenues for emerging SAF plants.

Blended finance, de-risking private investment through government grant funding, concessional financing or Green Bonds. E.g. UKEF and UKIB could deploy credit wraps and guarantees around structures.

Tax incentives could be deployed to create production or generate tax credits, similar to the US IRA. Under The Hydrocarbon Oil Duties Act 1979 (HODA), unblended SAF HODA would be treated as a "substitution" for the fuel that it is replacing (i.e. kerosene). It would therefore have the same tax code and would not be subject to duty.

Grants can help overcome the cost hurdles in the development process. The UK government announced a further eight projects to receive grant funding under the Advanced Fuels Fund (AFF). This scheme is now supporting 13 plants with investment of £135m. Through such investment, UK is on track to deliver the Jet Zero commitment to have five commercial SAF plants under construction by 2025.

Policy incentives

Regulatory incentives, additional provisions under the upcoming SAF mandate, or Regulated Asset Base (RAB) model, as proposed for new nuclear. To permit support for RCFs and nuclear derived fuels into renewable transport fuel obligation schemes, the government tabled an amendment through the Energy Security Bill to amend the Energy Act and allow these fuels to be supported. The bill achieved Royal Assent on 26 October 2023.

Supply-side incentives, through a government waste strategy to ensure that there is sufficient feedstock waste for SAF production within the UK. A buy-out price will allow suppliers to comply with the obligation in situations where eligible SAF cannot be supplied and protect consumers from spikes in SAF prices. Fuel made from HEFA will be capped to incentivise the development of new technologies and diversify the feedstock mix. **Mandate auto-ratchet (MAR)** and its HEFA cap adjusts when there is an oversupply in the market, to bring the price of SAF back closer to the buy-out price.

A buyer of last resort mechanism, whereby the government or other public bodies purchase surplus product. This would allow suppliers to sell the fuel at brown kerosene prices and have the premium covered by a buyer of last resort at a minimum floor price.

In October 2022, DfT commissioned an independent report by Philip New to help understand the conditions needed to create a viable long-term sustainable aviation fuel (SAF) industry in the UK. Some further work done by Philip, focusing on the potential for an industry led revenue certainty mechanism was presented to the Jet Zero Council SAF commercialisation sub-group in August 2023.

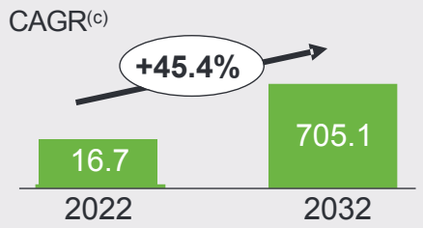
The State of the Market: Rest of Europe

An overview of the Rest of Europe has shown a resurgence in the announced offtake contracts by producers in the region after the announcement of SAF incentive schemes in 2021, with some of the world's largest producers of SAF located in Europe.

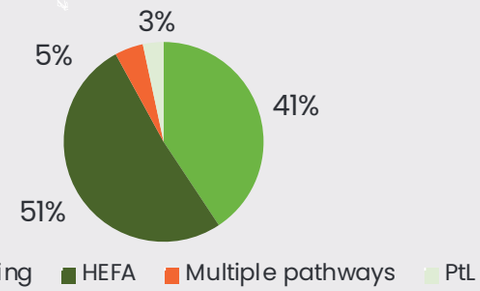
Market Overview

ROE SAF market is being accelerated by the ReFuelEU proposal. 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, and a sub-mandate for Power-to-Liquid SAF.

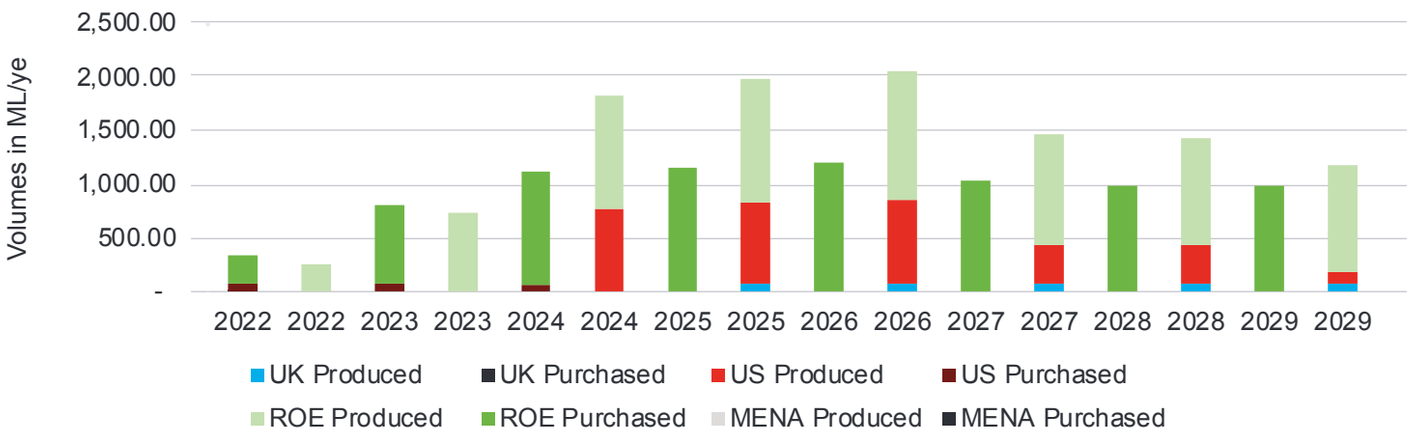
SAF Market Size (US$ mn), FY22–32F (a)



SAF production volumes to date by technology (in %)(c)



ROE Contracts for Production and Purchases ML/yr



Top Producers forecasted in 2028(b)

Producers`	Production Capacity in KT/per year	Year of Commercialisation
Neste (Finland)	362	2007
Shell (Netherlands)	256.9	2024
OMV(Austria)	183.1	2007
TotalEnergies (France)	80	2024
SkyNRG (Netherlands)	75	2024

Note(s): (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources. (d) Where 'multiple pathways' is shown, the SAF production facility utilises two or more of the established pathways identified on slide 7.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum

The State of the Market: Rest of Europe

Market drivers and insights

Government funding/incentives

- In 2021, the European Commission launched the **RefuelEU initiative, a key component of the Fit for 55 package**, aimed at boosting the production and uptake of sustainable aviation fuels (SAF). The initiative **mandates a 5% blend of SAF in aviation fuel by 2030**, with a phased implementation starting in **2025 with a 2% minimum volume**. This mandate will progressively increase in five-year intervals, **reaching 70% by 2050**. Additionally, aviation fuel suppliers must ensure that all fuel made available at EU airports contains a **minimum share of synthetic fuels**, which will also increase progressively alongside SAF until 2050. Specifically, from **2030 onwards, 1.2% of fuels must be synthetic, rising to 35% by 2050**.
- Several European countries have implemented blending mandates for SAF and synthetic aviation fuels. As of October 2023:
  - **Norway** has had a 0.5% SAF blending mandate since 2020, with plans to increase it to 30% by 2030.
  - **Sweden** has had a 1% SAF blending mandate since 2021, also aiming for a 30% blend by 2030.
  - **France** introduced a 1% SAF blending mandate in 2022, with plans to increase it to 2% in 2025 and 5% in 2030.
  - **Germany** has a 0.5% synthetic aviation fuel blending mandate starting in 2026, with a target of 2% by 2030.
- In 2023, the European Commission announced plans to support the uptake of SAF via a revenue certainty mechanism linked to its Emission Trading Scheme (EU ETS). **€2 billion of funding** will be made available for SAF purchases that are compatible with the Renewable Energy Directive (RED) on a first-come-first-served basis.

Other key insights

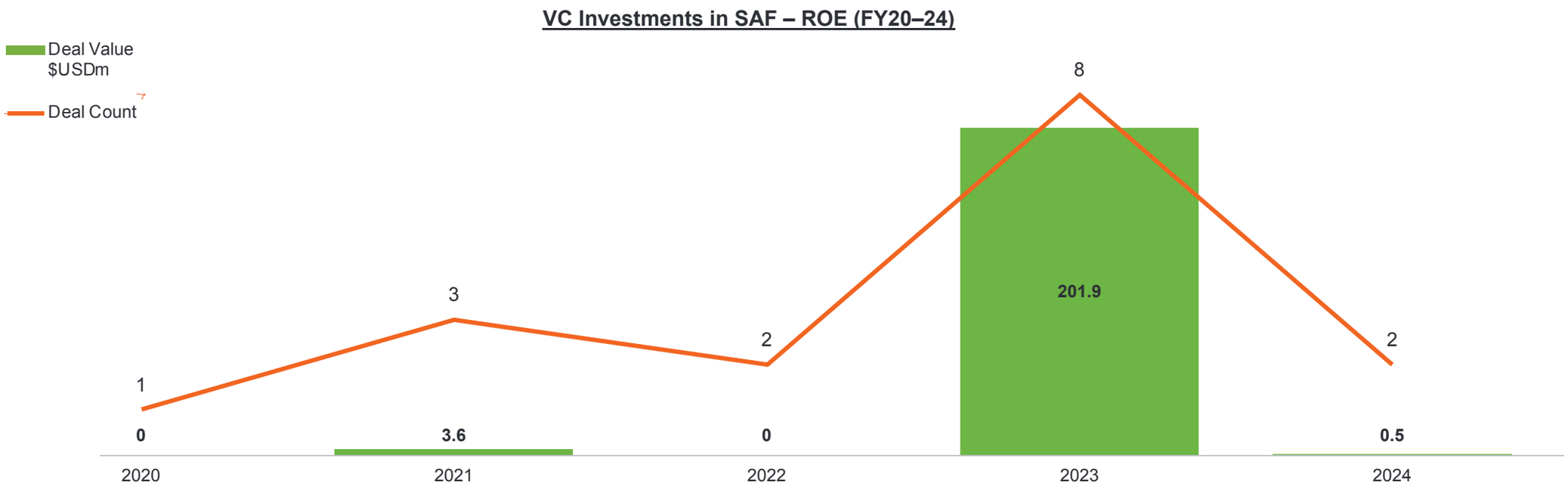
- The ROE SAF market size is estimated to grow at a CAGR of **45.4%** from **$16.7M** in 2022 to **$705.1M** in 2032.
- According to the supporting study for the ReFuelEU Aviation initiative, with the introduction of a SAF blending mandate at EU level, **demand** for aviation fuel at EU airports would amount to around **46 million tonnes in 2030**. In order to reach 5% of SAF by 2030 for all flights departing from EU airports, **approximately 2.3 million tonnes of SAF would be required**.
- To support the uplift of SAF, 20 million SAF allowances will be granted for free until 2030.
- To promote decarbonising in the aviation sector and to better inform the public, as of 2025, there will be an **EU label for the environmental performance of flights**.
- As per SkyNRG's SAF Market Outlook in 2023, SAF announcements expected to reach operation **could supply up to 3.2 Mt SAF by 2030**, and are predominantly **HEFA based (80%)**, with some projects based on more novel pathways (AtJ, FT and PtL) coming online post-2025.
- As of 2020, Swedish oil refiner and renewable fuels producer Preem AB has selected Haldor Topsoe's HydroFlex renewable fuel technology to **produce clean renewable diesel and jet fuel at its Gothenburg refinery**.
- As of 2021, German startup, Atmosfair has introduced the **world's first power-to-liquid plant producing carbon neutral renewable electricity-based synthetic aviation fuel, or e-kerosene**, in Emsland in northern Germany.
- Corporate targets have also been announced by European airlines. For instance, the International Airlines Group (IAG) and Ryanair have committed to use 10% and 12.5% SAF by 2030 respectively.

Note(s): (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum, SkyNRD Sustainable Aviation Fuel Market Outlook, May 2023, EASA

Venture Capital SAF Investments in ROE

The Rest of Europe saw a spike in investment in 2023, in line with adoption of the Refuel EU initiative, which instituted minimum SAF targets from 2025, and growing requirements out to 2050



Key Deals

- **SkyNRG** secured $190.9 million (€175 million) from **Macquarie Asset Management** in 2023, which will include building SAF production facilities in Europe and the U.S. by 2030. It has established partnerships with **KLM Royal Dutch Airlines** and **Boeing,** among others and envisions €4 billion worth of SAF purchases.
- **Metafuels** secured $8 million in seed funding in 2023 from **Energy Impact Partners (EIP)** and **Contrarian Ventures** in its first round. Metafuels will use groundbreaking technology for eSAF, which is made using renewable electricity.
- The market has also seen innovative producers receive funding, such as **SNL BioSolutions**, which can produce SAF and other oils through a fermentation-based process. The company has received US$0.43 million through its acceptance in the Venture Lab program at the BioInnovation Institute.

Sources: Government websites by countries, geographical SAF reports, Pitchbook

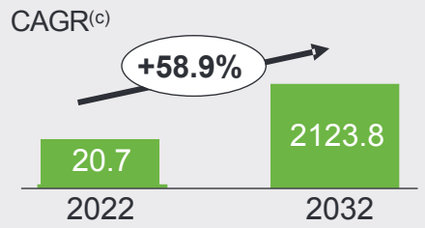
The State of the Market: Asia Pacific

The Asia Pacific (APAC) region is expected to grow the fastest during the forecast period with countries like Singapore and Australia deploying incentive schemes and funding to spur growth in the region.

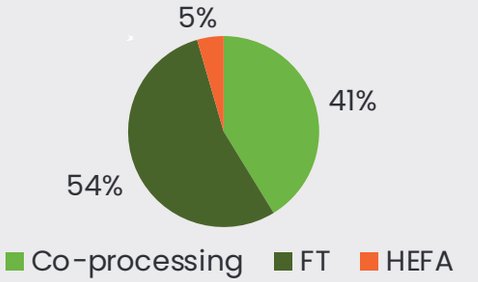
Market Overview

APAC's SAF market is emerging due to 10% SAF mandate in Japan, and government funding in Australia, New Zealand and Singapore, however there is still limited production capacity to meet market demand. SAF production facilities have been announced in Singapore, Malaysia and Japan and there is strong political and investor interest in the region which is likely to enable significant growth in the coming years.

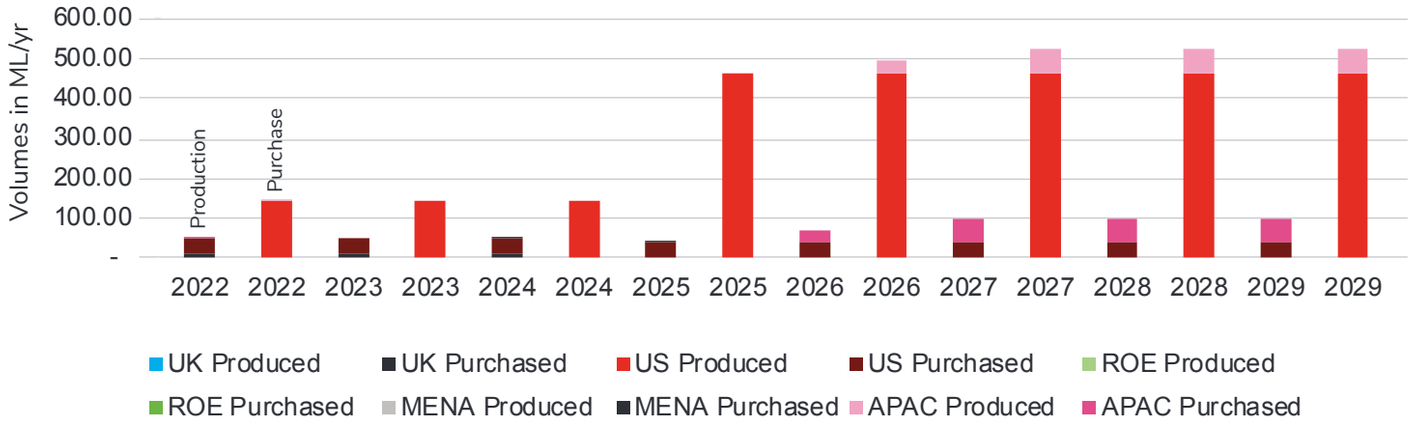
SAF Market Size (US$ mn), FY22–32F (a)



SAF production volumes to date by technology (in %)(c)



APAC Contracts for Production and Purchases ML/yr



Top Producers forecasted in 2028(b)

Producers`	Production Capacity in KT/per year	Year of Commercialisation
Wasteful (Philippines)	30.2	2025
Neste (Singapore)	27.5	2025
Petronas Draganan Bhd	23	2025
BP (Australia)	8	2025

Note(s): (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources. (d) Where 'multiple pathways' is shown, the SAF production facility utilises two or more of the established pathways identified on slide 7.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum , ADB

The State of the Market: Asia Pacific

Market drivers and insights

Government funding/incentives

- The historical funding initiatives by governments in the APAC region to support the SAF market have included notable announcements. For instance, **ARENA, the Australian Renewable Energy Agency, unveiled the SAF Funding Initiative in 2023, aimed at providing up to A$30 million (~$20m) in support for the production of sustainable aviation fuel in Australia, utilising renewable feedstocks.**
- **India** aims to have 1% SAF in aircraft turbine fuel by 2027, doubling to 2% in 2028, while **Singapore** has put in place targets for all outbound planes from Singapore to use SAF from 2026.
- Several SAF announcements were made across the region in the first half of 2023. Government trials, funding and developing mandates are prompting an increasing number of fuel producers and airlines to look at SAF.
- **Malaysia** has established an SAF blending mandate starting with 1% and reaching 47% SAF blending mandate by 2050.
- In 2023, it was announced that **Japan** will be mandating 10% of aviation fuel for international flights using Japanese airports to be sustainable starting in 2030.
- There is **no set SAF mandate as yet in Philippines, China, New Zealand or Australia**.

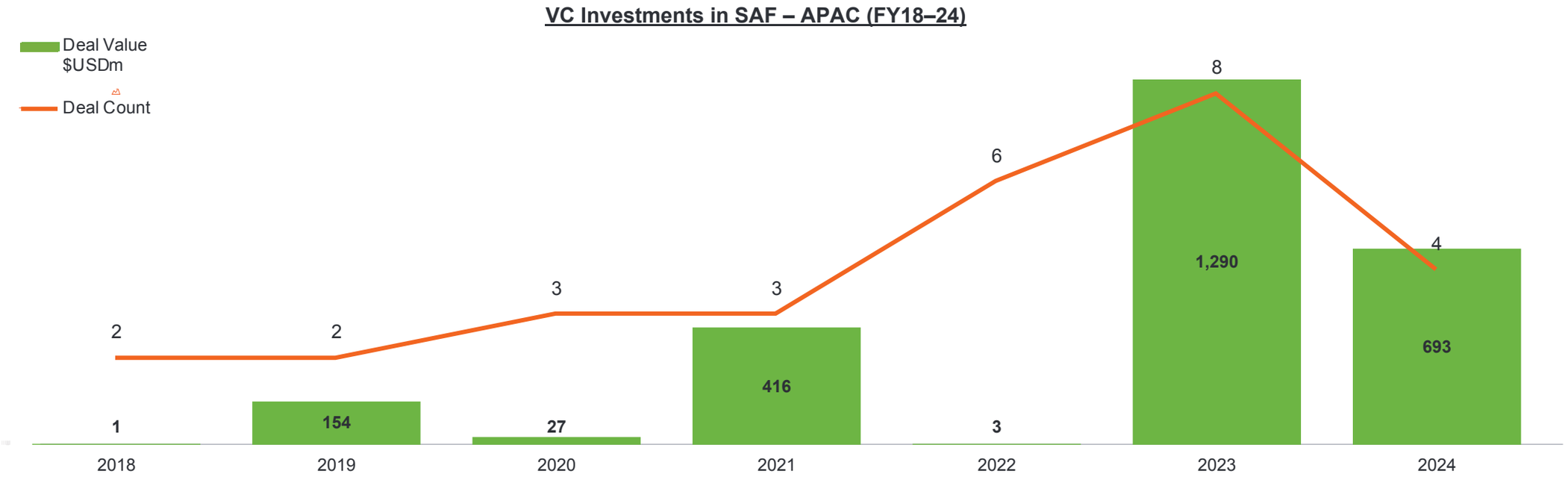
Other key insights

- APAC's SAF market size is estimated to grow at a CAGR of **58.9%** from **$20.7M** in 2022 to **$2123.8M** in 2032.
- **Malaysian Aviation Group (MAG)** has signed a SAF offtake agreement with Petronas Dagangan, as part of efforts to develop the green fuel on a commercial scale in Malaysia in May 2023.
- **In July 2022, Singapore Airlines** initiated a one-year pilot program for SAF in collaboration with ExxonMobil and Nest.
- In 2023, Japan's leading airlines, All Nippon Airways and Japan Airlines, expanded their SAF purchases by adding supplies from Itochu Corp, a trading house based in Japan, and Raven SR, a sustainable fuel producer from the US.
- **In 2023, Indian Oil Corp** announced the plan to set up an 80,000-metric-ton per year SAF plant with LanzaJet in Haryana.
- In 2022, Qantas and Airbus established a $200 million fund to support Qantas' goal of using a minimum of 10% SAF in its fuel mix by 2030 after the airline placed a multibillion-dollar order for Airbus narrowbody and widebody planes. The Queensland refinery was the fund's first investment.
- In 2023, **Cathay Pacific** committed to developing four power-to-liquid production facilities in **China** alongside the State Power Investment Corporation.
- **In March 2023, Qantas and Airbus** announced the plan to invest A$2 million ($1.34 million) of an initial A$6 million (US$4 million) capital raising in a biofuel refinery planned to be set up in Australia's Queensland state that would convert agricultural by-products into SAF.

Note(s): (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources.
Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum

Venture Capital SAF Investments in Asia Pacific

The APAC region has seen growth of SAF investment, prompted by an increasingly favourably policy environment in key territories, including India, Japan, Australia and Singapore.



Key Deals

- **Avaada Group** has secured US$1.07 billion from **Brookfield Renewable's Brookfield Global Transition Fund (BGTF)** to support its green hydrogen and green ammonia ventures in India. This investment is part of Avaada's ongoing US$1.3 billion fundraising plan. There have been no announcements on how much of this funding will finance SAF production facilities.
- **Japan Hydro Powtech** which uses innovative hydrolysis technology, raised approximately 510 million yen(US$2.8m) in Series B funding.

Sources: Government websites by countries, geographical SAF reports, Pitchbook

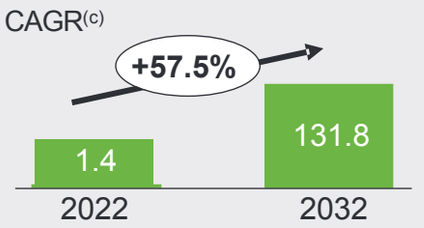
The State of the Market: Middle East & North Africa (MENA)

MENA region is still in the early stages of SAF development with no significant production capacity to date, however the uptake in SAF offtake purchase agreements has been followed by announced feasibility studies for production in the UAE and Egypt.

Market Overview

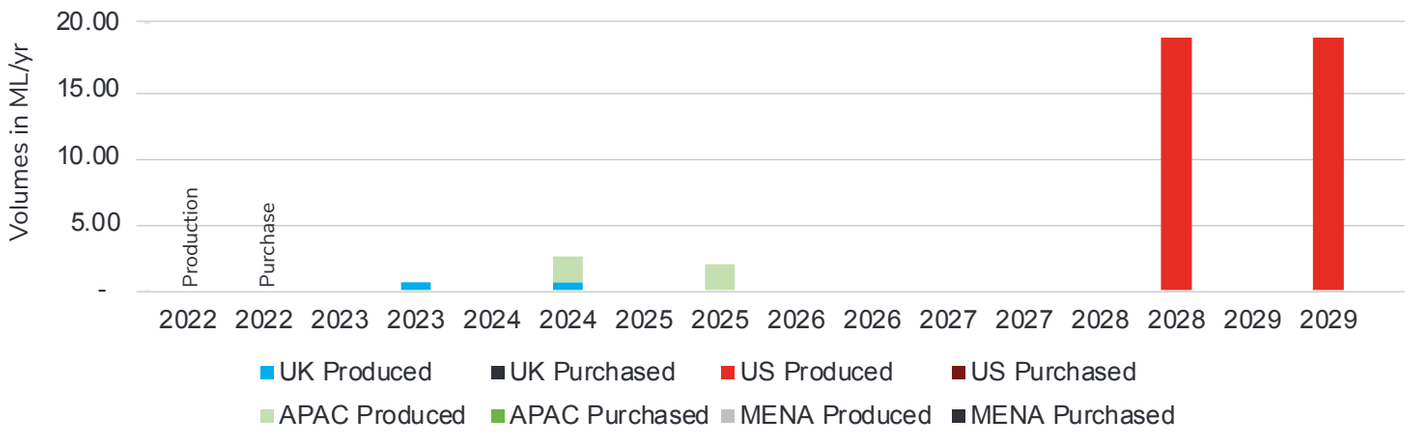
MENA's SAF market is running behind other regions in terms of targets, policy support and underdeveloped infrastructure. However, UAE (after the recent rollout of its National SAF Roadmap) and Egypt are in planning phases to understand the requirements to begin the production of SAF.

SAF Market Size (US$ mn), FY22–32F (a)



No significant production volume in MENA

MENA Contracts for Production and Purchases ML/yr



Currently no SAF producers

Dubai entered into a Memorandum of Understanding (MoU) with N.V.Besix S.A., Marubeni Middle East and Africa Power Limited (MAMEA) and ENOC Marketing to develop SAF at the World Governments Summit 2024.

As of October 2023, ADNOC Refining has received ISCC System GmbH's International Sustainability Carbon Certification (ISCC) to produce SAF at the operator's Ruwais refining complex on the coast of the Arabian Gulf.

Note(s): (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources. (d) Where 'multiple pathways' is shown, the SAF production facility utilises two or more of the established pathways identified on slide 7. (d) As per the Apollo report, the MENA market size only encompasses the UAE. This is likely due to limited SAF activity across the region.

Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum

The State of the Market: Middle East & North Africa (MENA)

Market drivers and insights

Government funding/incentives

- The **UAE** has launched the "**BIOjet Abu Dhabi**" initiative to promote the production of biojet fuels and has provided funding for research and development of SAF technologies.
- In 2023, the **Dubai government's airline, Emirates** became the world's first airline to run an A380 demonstration flight using 100% SAF.
- **The UAE created a roadmap for the production of SAF and renewable hydrogen** from **PtL technologies** by 2050 in partnership with the **World Economic Forum**.
- **Feasibility studies have also been announced in both the UAE and Egypt**, but no production capacity currently exists.
- The **UAE** has recently included significant H2 plans in its revised energy strategy, aiming for 1.4 Mt of H2 production by 2031, while Oman has announced plans to produce at least 1 Mt of H2 annually by 2030.
- **Saudi Arabia** aims to produce 2.9 Mt by 2030, focusing on blue H2, requiring carbon capture and storage technology.

Other key insights

- UAE's SAF market size is estimated to grow at a CAGR of **57.5%** from **$1.4M** in 2022 to **$131.8M** in 2032.
- The UAE is expected to have the potential to produce as much as 11 million tonnes of PtL by 2050.
- Emirates has successfully tested a flight with **100% SAF fuel.** Etihad Airlines has tested a flight with **40% SAF fuel**. This strong interest has seen **various airlines in the MENA region agreeing purchase deals** with producers in other territories.
- Recent agreement has been made between the **UAE and Shell**, which will represent the first blended SAF supply through Dubai International Airport and **Abu Dhabi National Oil Company** (Adnoc), which is set to provide SAF to Abu Dhabi International Airport.
- **In 2023, Neste and ENOC Group** palnned to collaborate on exploring the possibilities of supplying and purchasing SAF in Dubai and the wider MENA region in the coming years.

Note(s): (a) Market size and CAGR values have been sourced from the Apollo reports: "SAF Market Estimates and Forecasts". (b) Demand and supply analysis of SAF announced offtake and production contracts has been calculated using data from Ishka database by the year of announcement. Production capacity may include fuels other than SAF. (c) SAF production volumes to date by technology are from the Ishka database and verified through publicly available sources.
Sources: Government websites by countries, geographical SAF reports, Ishka, World Economic Forum

Part IV:

Conclusion

SAF Market Barriers in the UK

There are four major barriers to SAF production within the UK as noted in the Philip New report. Without tackling at least one of these issues in earnest, we could see investors overlooking the UK market for more favourable international investment opportunities.

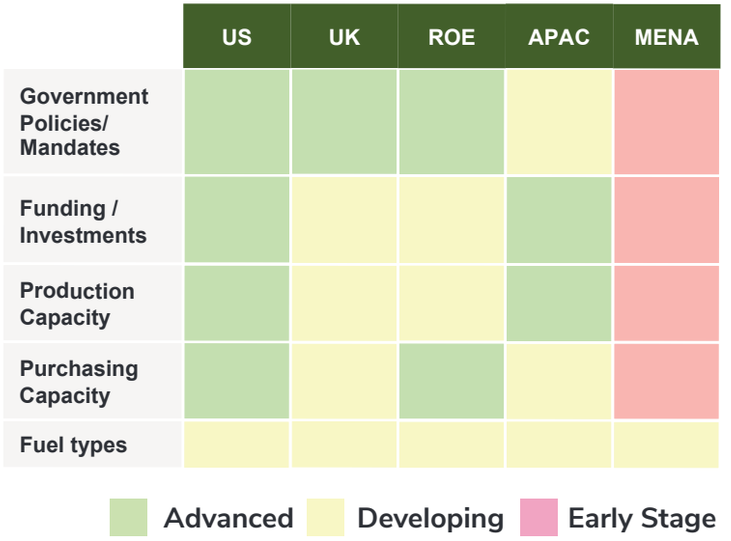
	Price Risk	Technology Risk	Feedstock Risk	Opportunity Cost
Market Barriers	• There is a significant production cost differential between SAF and fossil jet fuel. • Whilst the proposed SAF mandate provides a demand signal, it is not sufficient to ensure price stability. • Without some form of price certainty, there is no reference price against which to measure the bankability of a project.	• The pace of SAF development and scalability of production facilities needs to be assessed against potential technology obsolescence and technological interface risk. • Identifying the most suitable interventions will depend on the technology readiness level of SAF, which is less mature than other technologies utilizing CfDs at scale.	• There is a risk of **not having enough feedstock available** to produce the quantities of SAF required to meet the mandate.	• SAF will have to compete with other decarbonisation technologies seeking capital injections with higher expected returns, lower levels of risk and higher levels of policy support, such as CCUS. • There is a risk of capital flight to international projects given stronger incentives and tax credits (e.g. the US' Inflation Reduction Act).
Possible Intervention	• **Price support mechanisms** could be agreed by government or private entities in the form of Contracts for Differences (CfDs), floor pricing for certificates, or a "cap and floor" on revenue. • The government could be a "**buyer of last resort**" to provide suppliers with the confidence to produce SAF over the long term.	• **Price support mechanisms** could be agreed by government or private entities in the form of CfDs, floor pricing for certificates or a "cap and floor" on revenue. • **Grant funding** or innovative **blended financing mechanisms** for the development of SAF production facilities could de-risk investment by the private sector (both for nascent technologies and offtake uncertainties).	• A government **waste strategy** could be considered to ensure that there is sufficient feedstock waste for SAF production within the UK.	• Price support mechanisms in the form of CfDs, floor pricing for certificates, "cap and floor" on revenue, and government as a "**buyer of last resort**" could provide suppliers with the confidence to produce SAF over the long term. • **Systems-level policy coherence** linking SAF with DACCs, CCUS, biomass, and other technologies. • **Grant funding** or innovative **blended financing mechanisms**.

Conclusion

SAF is already in use today throughout the UK, with 26 million litres of SAF being supplied in the last year. However, the UK market is still in an earlier development stage compared to other more mature markets.

International comparison

- The UK SAF market is lagging in comparison to other mature markets primarily due to **incentives and targeted investments**, such as the US IRA (2022) and the EU's RefuelEU initiative (2021), driving growth.
- These clear market signals saw **VC investment increase significantly in the US** within a year of the IRA's announcement and a **resurgence in EU production offtake agreements in 2022**.
- The majority of **top SAF producers are based in the US**, with a few large producers such as Neste located in Finland. Top purchasers are located in several countries including the US, UK, Japan, France, and Australia.
- **APAC** is expected to have the largest global market share by 2032 and investors are pursuing a strategy of a smaller number of larger-scale production facilities, yet limited offtake agreements for supply appear to be agreed to date.
- However, the **MENA** SAF market, for the most part, is still within its infancy with minimal funding support. Although with ADNOC's recent ventures into SAF could incentivise investment across the region.



UK perspective

The UK market possesses a number of competitive advantages in fuel production and has started to make inroads into increasing its SAF production capacity. The UK has the potential to play a leading role – particularly in the development and deployment of SAF made from carbon-containing waste streams, a technology close to deployment readiness. The UK is leading the way in creating markets for 2g SAF (much of the potential 2g SAF capacity announced so far globally is UK-based). However, major risks still exist for those looking to invest.

Risks to UK SAF Production	Price Risk	Technology Risk	Feedstock Risk	Opportunity Cost

- At current rates, **a supply gap remains as production is unable to keep up with anticipated demand in the coming years** through domestically produced fuel. Even then, these speculative production statistics are contingent on measures being put in place to **deliver price certainty and diminish production capacity concerns** for SAF production facility investors.
- To meet the 2030 mandate and meet anticipated demand, the UK will need to **rely on imports**, which will be challenging given anticipated supply constraints in other markets.
- **Therefore**, if the UK wants to capture its share of the global SAF market, de-risk ability to achieve the SAF mandate, and entice investors to the UK, the risks associated with investment into production facilities need to be resolved.

Source(s): Department for Transport, Government Response to Developing a UK Sustainable Aviation Fuel Industry Report

Annex I: Offtake Contract Lengths

Using data from the Ishka database, the table below illustrates the proportion of production/offtake agreements by contract length in each of the regions evaluated in this report. The highest proportion in each region is called out in the table.

In this instance, for all regions excluding MENA (where there were limited contracts), the most common contract length noted was <5 years long. In addition, a sizeable proportion of all announced activity had no expected contract durations (N/A).

Offtake Agreement Length	USA	UK	ROE	APAC	MENA
N/A	11%	17%	30%	31%	100%
<5 years	47%	42%	50%	50%	0%
6-10 years	33%	25%	20%	19%	0%
11-15 years	2%	17%	0%	0%	0%
16-20 years	7%	0%	0%	0%	0%

Source(s): Ishka Database