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Sustainable Aviation Fuel (SAF) Market Map

Asia-Pacific

DECEMBER 2024

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Executive Summary

The Sustainable Aviation Fuel (SAF) market in the Asia-Pacific region presents substantial strategic opportunities across the entire value chain.

The aviation industry is a major contributor to worldwide greenhouse gas (GHG) emissions, accounting for approximately 2-3% of total carbon dioxide (CO_2) emissions. As international travel continues to grow, emissions from aviation are expected to rise, with projections emissions could double or triple 2019 levels.

SAF is emerging as a key lever for emissions reduction with the potential to cut lifecycle carbon emissions by up to 80% compared to conventional jet fuel.

The International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) serves as a critical catalyst for SAF adoption globally.

Mandating participation from 2027 for countries that account for over 90% of international aviation emissions, CORSIA establishes a robust regulatory framework that encourages long-term development in SAF production and infrastructure.

Countries such as Australia, Japan, and Singapore are already demonstrating a commitment to CORSIA by opting into voluntary participation beginning in 2025, further highlighting the regions willingness to engage with sustainable aviation.

Diverse feedstock options and advanced commodity market capacity offers the Asia-Pacific region a strategic advantage in developing SAF production facilities.

SAF can be derived from various sources, including biogenic feedstocks like crops, vegetable oils, and fats, as well as non-biogenic sources such as waste gases and hydrogen. The primary production pathways - Hydroprocessed Esters & Fatty Acids (HEFA), Alcohol-to-Jet (AtJ), and Fischer-Tropsch (FT) - present multiple avenues for engagement along the value chain.

Currently, the HEFA pathway leads SAF production due to its lower capital requirements and feedstock accessibility. However, the anticipated limitations in HEFA feedstocks are expected to drive diversification towards alternative pathways like AtJ and FT, creating opportunities for early participants in innovative technologies and processes.

One of the primary challenges facing the Asia-Pacific SAF market is sourcing low-cost, low-carbon intensity feedstock. The region grapples with issues such as underdeveloped feedstock collection methods, traceability and sustainability challenges, and a limited presence of global players to build and develop the market.

These obstacles present opportunities for the creation of efficient feedstock collection and supply chain infrastructure. Companies that forge strong local partnerships and enhance traceability systems will be well-positioned to capture value in this expanding market. Strategic collaborations between biofuel producers and feedstock suppliers are already emerging to address these challenges.

This market map aims to share Tegro's analysis of the SAF market throughout the Asia-Pacific, and provide stakeholders with valuable insights into the primary elements of the SAF supply chain and key stakeholders throughout.

We hope that by providing in-depth considerations of SAF production pathways, feedstock availability and focus across countries, and the respective stakeholders innovating toward SAF supply and demand, we will invite cross-jurisdictional collaboration and investment, and further position Asia-Pacific nations to capitalize on the significant growth projected in this industry.

While HEFA-based SAF is expected to dominate in the near-term, feedstock limitations will likely spur innovation and diversification in production methods. Those who position themselves across various segments of the SAF supply chain, from feedstock production and collection to refining and distribution, will be strategically positioned to benefit from this growth.

By tackling feedstock constraints, developing efficient supply chains, and pioneering innovative production technologies, stakeholders can play a vital role in advancing SAF production and adoption in the region while realizing substantial returns.

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The Fuels Landscape

Asia-Pacific nations are increasingly recognizing the strategic security benefits of shifting from traditional fuels and petrochemicals toward biofuels, renewable diesel, and SAF. These bio-based fuels are emerging as vital alternatives to fossil fuels due to their lower carbon emissions and diminished dependence on petroleum imports, which enhances energy resilience and security across the region.

However, the surging demand for SAF is driving up feedstock prices, which poses challenges for the broader biofuels and renewable diesel industries. Yet, advances in SAF production technologies - such as catalytic conversion and electrochemical processes - are improving efficiencies and lowering costs across all biofuel sectors.

In parallel, the rapidly growing SAF market is spurring investments and innovations, leading to the development of new technologies and alternative feedstocks. This shift is transforming the energy landscape, reshaping commodity markets, and creating fresh opportunities for investors and stakeholders throughout the region.

The table below provides a comparison of traditional and emerging fuels.

	Diesel	Jet Fuel (Kerosene)	Biodiesel	Renewable Diesel	SAF
Feedstock	Crude oil	Crude oil	Vegetable oils, animal fats	Plant-based oils, animal fats, waste cooking oil	Plant-based oils, animal fats, municipal solid waste, algae, etc.
Production Process	Refining crude oil	Refining crude oil	Transesterification of triglycerides	Hydroprocessing of plant-based oils or animal fats	Hydroprocessing of various feedstocks
Chemical Composition	Hydrocarbons	Hydrocarbons	Fatty acid esters	Hydrocarbons	Hydrocarbons
Blending Requirement	No	No	Can be blended with diesel	Can be blended with diesel	Can be blended with jet fuel
Storage Stability	High	High	Lower	High	High
Energy Used in Refining	High	High	Lower	Higher	Varies based on feedstock and process
Application	Transportation, power generation	Aviation	Transportation	Transportation	Aviation
Environmental Impact	High	High	Lower	Lower	Lower
Regulatory Approval	Widely approved	Widely approved	Widely approved	Widely approved	Increasingly approved
Current Cost	Varies with crude oil prices	Varies with crude oil prices	Can be more expensive than diesel	More expensive than diesel	More expensive than jet fuel

Aviation Market Dynamics

Carbon credits

ICAO has established CORSIA, a market mechanism that drives sustainability in the aviation sector, primarily through carbon offsetting.

CORSIA requires airlines to offset emissions exceeding 85% of their 2019 baseline by purchasing carbon credits, or Eligible Emissions Units (EEUs), that meet strict standards.

Initially, only carbon credits from the American Carbon Registry and Architecture for REDD+ Transactions were allowed. Recently, ICAO expanded this to include credits from Gold Standard, Verra, Global Carbon Council, and Climate Action Reserve.

These additional standards provide roughly 13 million eligible credits, but demand is projected to reach up to 100 million credits annually by 2027, underscoring an urgent need for expanded issuance of Letters of Authorization (LoAs).

A LoA is an official document provided by an emissions unit program (such as a carbon offset project developer) that verifies the legitimacy and ownership of a particular emissions reduction unit. LoAs serve as an assurance that carbon offset credits, generated under CORSIA, are real, additional, and have not been double-counted by another country or sector. LoAs are critical for maintaining the environmental integrity and transparency of the offsets used in the CORSIA scheme.

CORSIA Phases

Pilot Phase

(2021-2023)

Voluntary

First Phase

(2024-2026)

Voluntary

Second Phase

(2027-2035)

Mandatory for countries that account for over 90% of international aviation emissions

The LoA requirement has significantly constrained credit supply. A LoA certifies the transfer of emission reductions and includes a Corresponding Adjustment (CA) to avoid double-counting.

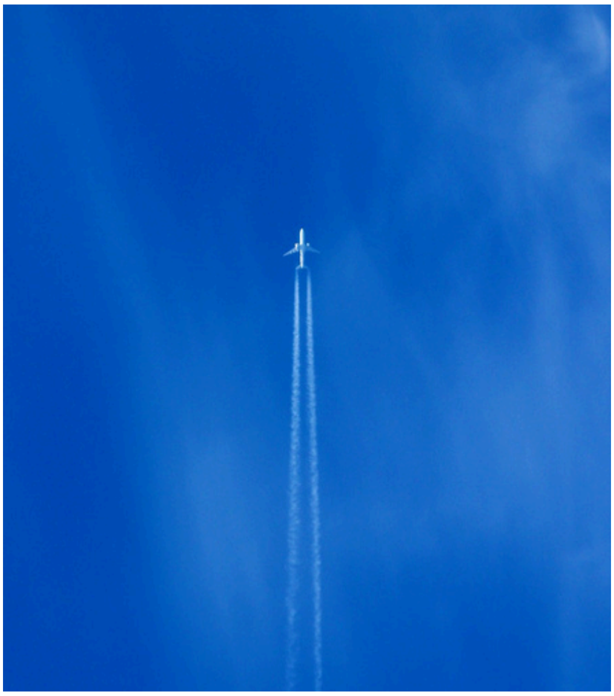
This adjustment deducts the credit from the host country's emissions balance, allowing only the buyer to count it toward climate goals, ensuring transparent reporting under the Paris Agreement.

However, obtaining LoAs remains challenging, as there is no standardized process, and approvals are delayed due to host country commitments that are only updated biennially. These gaps create risks of delays or reversals, compromising contract stability and leading to calls for insurance mechanisms to manage risks like revocation or double-counting.

For CORSIA to succeed and the aviation industry to meet its climate targets, streamlined LoA processes and investments in supporting infrastructure are essential.

Collaboration with host countries to simplify LoA issuance and maintain market transparency will be crucial to meeting the anticipated demand for compliant credits and upholding market stability.

While CORSIA offers a market mechanism for airlines to reduce their carbon emissions, it places significant emphasis on carbon offsetting, which can shift focus away from more structural changes within the aviation industry, such as investments in SAF.



CORSIA will generate significant demand for carbon credits. This demand has the potential to drive growth in credit markets and consequently create opportunities for project developers and investors alike. This increased demand is likely to boost the development of new carbon credit projects.

According to a report from the International Emissions Trading Association (IETA) and Allied Offsets, the potential compliance demand for 2024 and 2025 is estimated to range between 17 and 80 million credits per year.

Australia, Cambodia, Indonesia, Japan, Malaysia, New Zealand, the Philippines, the Republic of Korea, Samoa, Singapore, Thailand, and Vanuatu will participate voluntarily in the CORSIA scheme from 2025.

European Union regulations

The ReFuelEU Aviation initiative is a regulatory scheme introduced by the European Union (EU) to support the decarbonization of the aviation sector by promoting the use of SAFs within Europe. The scheme, part of the EU's broader Fit for 55 package, aims to reduce GHG emissions by mandating airlines to use a minimum percentage of SAFs on flights departing from EU airports.

APAC airlines operating out of EU airports must purchase SAF in line with ReFuelEU mandates, placing them at a competitive disadvantage compared to airlines operating primarily in regions with no similar mandates.

For many APAC-based airlines that rely heavily on the EU market for transit and tourism, the additional cost of SAF impacts profitability, especially given the SAF supply is limited and therefore more expensive in regions outside the EU.

SAFs under ReFuelEU must be derived from renewable sources, including waste, residue-based biofuels, and **Power-to-Liquid (PtL)** synthetic fuels. Fuels derived from food and feed crops are excluded, consistent with the EU's sustainability criteria. This can make compliance with ReFuelEU's criteria difficult, as APAC suppliers may need to import compliant SAF or pay a premium for SAF that meets EU criteria.

As a result, APAC countries that produce alternative SAFs from palm oil or other regionally abundant feedstocks face additional regulatory hurdles to comply with ReFuelEU, which could also constrain supply availability and drive up costs.

The impact of ReFuelEU is leading APAC countries to research and develop region-specific SAF feedstocks that meet both regional and international sustainability standards, such as algae and waste-to-fuel pathways, to lessen dependency on EU-compliant fuels. This is discussed more in the **'Feedstocks' section**.

From a regulatory perspective, we expect to see APAC regulators and industry stakeholders exploring bilateral agreements or SAF standards that align with ReFuelEU criteria, thereby facilitating cross-region SAF production, reducing compliance costs, and ensuring long-term access to EU markets.

Reducing Aviation Emissions

ICAO has recognized that technology and market-based measures will be needed for industry decarbonization. This will be achieved through multiple levers, including:

- Efficiency gains
- SAF
- Carbon offsetting
- New propulsion systems such as electric batteries and hybrid aircraft
- The use of hydrogen

The purpose of this market map is to detail how the APAC region is developing and progressing SAFs as a lever to decarbonize.

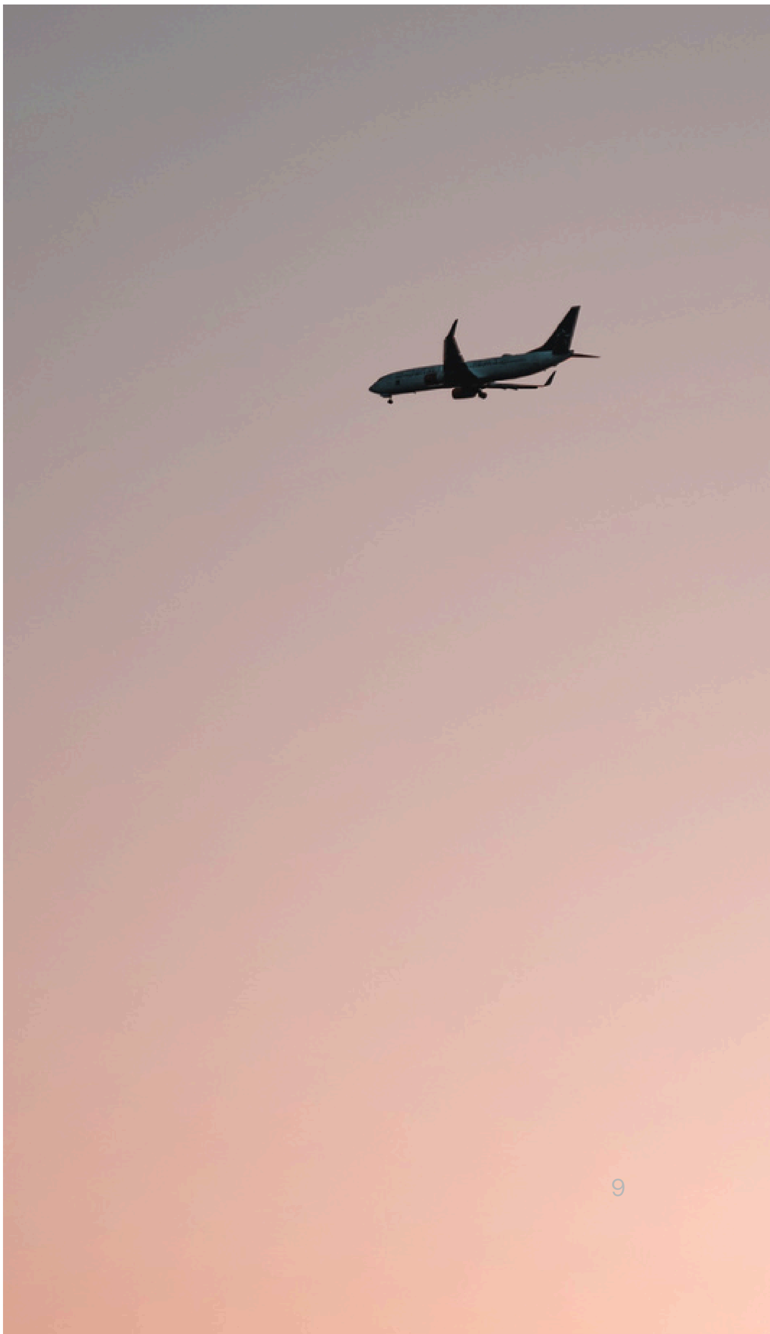
SAF is a synthetic hydrocarbon drop-in fuel derived from non-fossil feedstocks that can reduce lifecycle carbon emissions by up to 80% compared to conventional jet fuel. It is required to meet sustainability criteria in addition to technical certification.

Prioritizing drop-in SAFs ensures seamless integration with current aircraft and fuel distribution networks without compromising safety or efficiency.

Due to the industry's strict safety and quality standards for aircraft fuel, and the practice of refueling aircraft in different locations, harmonized technical specifications across different countries need to be maintained. The widely used ASTM D1655 standard defines the requirements for Jet A-1 fuel, covering various aspects such as composition, stability, and additives.

To maintain alignment with this standard the industry has adopted the "drop-in" fuel concept, which allows for the use of alternative fuels that are fully compatible with conventional jet fuel and existing aircraft systems.

This approach is crucial for maintaining safety, avoiding the need for separate handling infrastructure, preventing additional costs associated with non-drop-in fuels, and will be the primary decarbonization path for the industry in the near-term.

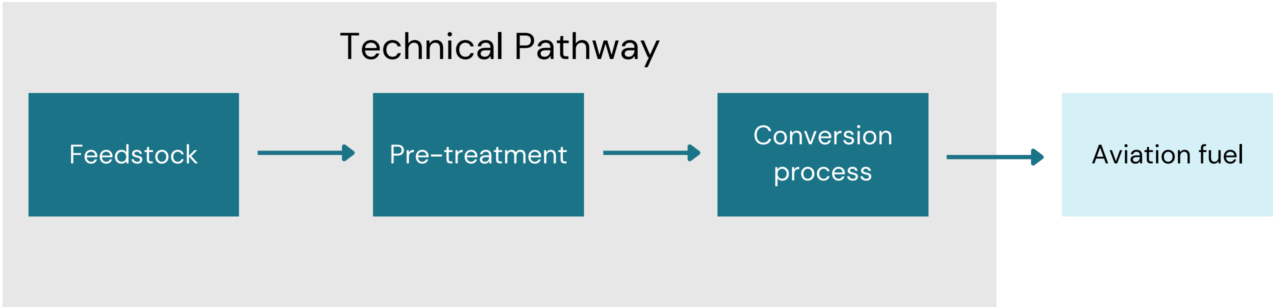


Producing SAF

A fuel "production pathway" contains a sequence of stages, starting with feedstock production, followed by its pre-treatment (to achieve the requirements of the conversion processes), and finally the conversion processes to produce aviation fuel.

The feasibility of fuel production is strongly linked to the configuration of the production pathway, which includes the transport of products through the stages.

SAF Pathway Concept



Technical Pathways

A technical pathway is defined by the type of technology used to convert a feedstock into aviation fuel.

SAF can be produced from a variety of feedstocks which fall into two main categories: biogenic feedstocks such as crops, vegetable oils and fats, agricultural and sawmill residues, and municipal solid waste (MSW), or non-biogenic sources such as waste gases, hydrogen and CO_2 through a process known as Power-to-Liquids or PtL.

As of July 2023, ASTM International has approved 11 technical routes based on Hydroprocessing Esters & Fatty Acids (HEFA), Alcohol-to-Jet (AtJ), and Fischer-Tropsch (FT), representing different processes for production depending on the type of feedstocks.

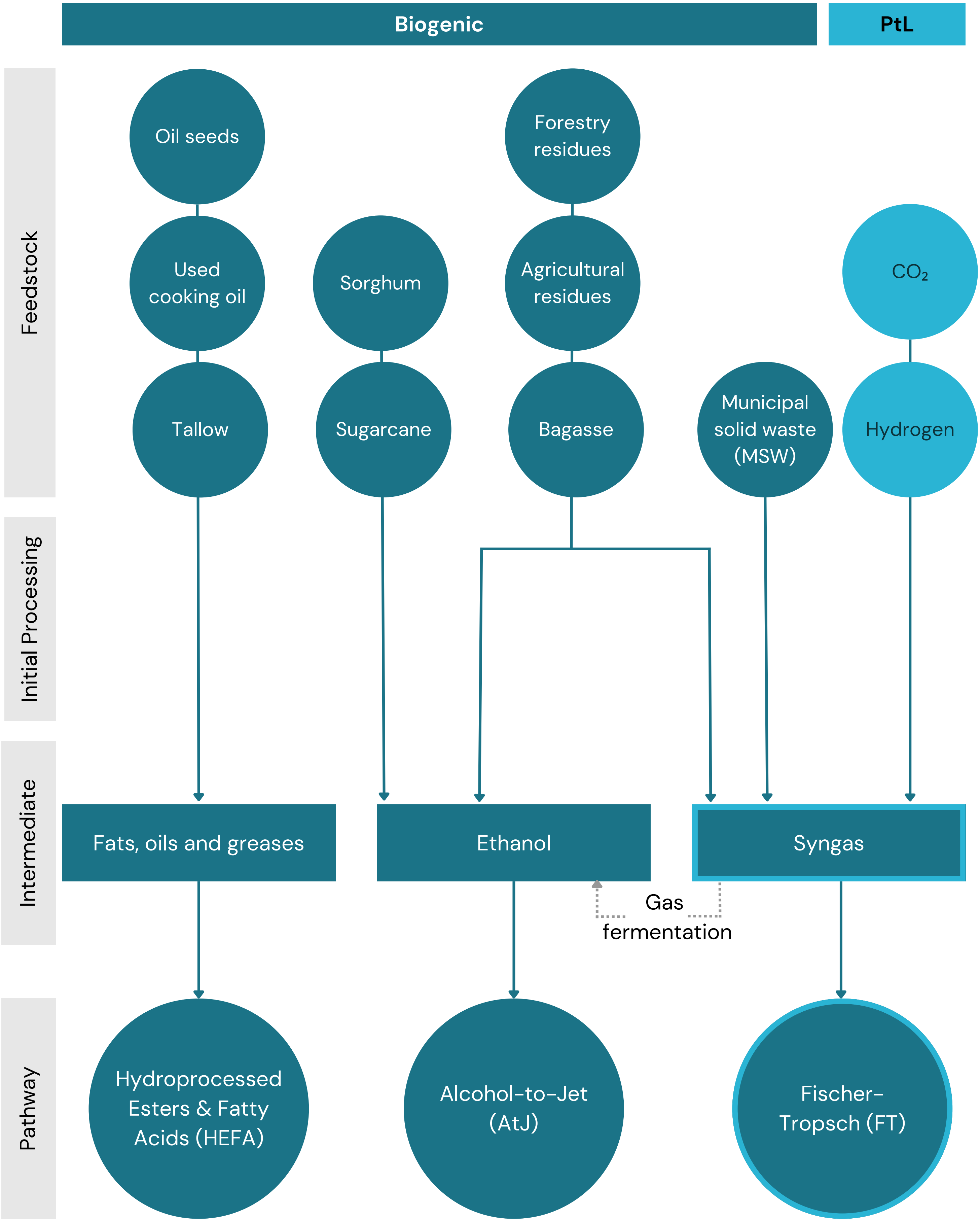
Feedstocks that are derived from biogenic sources, such as waste oils and fats, are the only alternative to jet fuel that are fully commercially available today.

The PtL pathway, which converts renewable electricity into liquid fuels (through FT), is nascent. If produced through the Fischer-Tropsch conversion process, it can be considered approved for use in aircraft by the ASTM.

The production of PtL has a favorable lifecycle emissions balance, while using water and land more efficiently than the production of aviation alternative fuels made from biomass. The main outstanding challenge for commercial scale PtL production is the production cost compared to that of conventional aviation fuel.

This section has focused on the three most popular pathways for simplicity, as shown overleaf.

SAF Feedstocks and Pathways



Map adapted from CSIRO (2023) Sustainable Aviation Fuel Roadmap

Feedstocks

The production of SAF starts with one of five main families of raw materials used to replace a proportion of the crude oil feedstock:

1. Oils and fats
2. Sugar and cereal
3. Municipal solid waste (MSW)
4. Wood and agricultural residue, or
5. Renewable energy and carbon

Each of these feedstocks uses a particular technical pathway, as outlined on the previous page.

From a technical perspective, SAF must have an energy content comparable to conventional jet fuel, which is typically between 43 and 48 MJ/kg. This high energy density is important for long-range flights.

Feedstocks need to be capable of producing hydrocarbons in the aviation jet fuel range, which requires catalytic processes to create long-chain molecules.

For this process to occur, hydrogen is essential. The more oxygenated the feedstock, the greater the hydrogen requirement - with vegetable oils demanding the least, carbohydrates more, and carbon dioxide the most. This manifests itself in the availability of the different types of SAF — the closer the feedstock is to a hydrocarbon, the less hydrogen is required, making it more accessible.

There are two ways of producing SAF, with standalone units or through co-processing. Standalone units use sustainable feedstocks to produce the synthetic kerosene (SK), that is then blended with conventional jet fuel to produce SAF.

With standalone units the feedstock is converted in a biorefinery into SK and then certified to the relevant annex in the ASTM D7566 standard. This SK is then blended up to 50% with conventional jet fuel and certified to ASTM D1655 or Defence Standard 91-091 and is supplied as a conventional jet fuel.

When producing SAF through co-processing up to 5% sustainable feedstocks are being processed alongside fossil feedstocks through hydro-processing in a refinery.

Traditionally, feedstocks used for biodiesel production were derived from edible crops such as wheat and palm (known as **'1st Generation'** feedstocks).

Concerns around feedstocks being used for fuel rather than food, as well as their carbon intensity, have shifted focus towards more sustainable feedstocks for new generation biofuel production.

Advanced feedstocks are those that do not compete directly with land use for food crops and typically have low carbon intensity. These are mostly derived from lignocellulosic feed such as agricultural or forestry residues as well as industrial or municipal wastes (**'2nd Generation'** feedstocks).

Biofuel Feedstock Constraints

To meet growing demand, biofuel producers must secure a supply of low-cost and low-carbon intensity feedstock.

Even as feed supply continues to grow in relatively untapped markets like Asia, it may not be sufficient to supply the roughly 24 million tons of SAF production expected by 2030 (IATA). This will be compounded if local demand in Asian markets increases faster than local collection.

As the gap between SAF production capacity and availability of feedstock widens, the land grab for sustainable feedstock is intensifying.

This is playing out through the APAC market and we expect to see a number of constraints emerge throughout the supply chain.

Underdeveloped Collection Methods

The collection of Used Cooking Oil (UCO) and agricultural residues (such as rice stalks) for biofuel production is nascent, which means that collection infrastructure, standards, and the supply chain are still underdeveloped.

Players in these segments are relatively new and many are still navigating through challenges around local operations and regulatory volatilities.

Feedstock Potential and Constraints

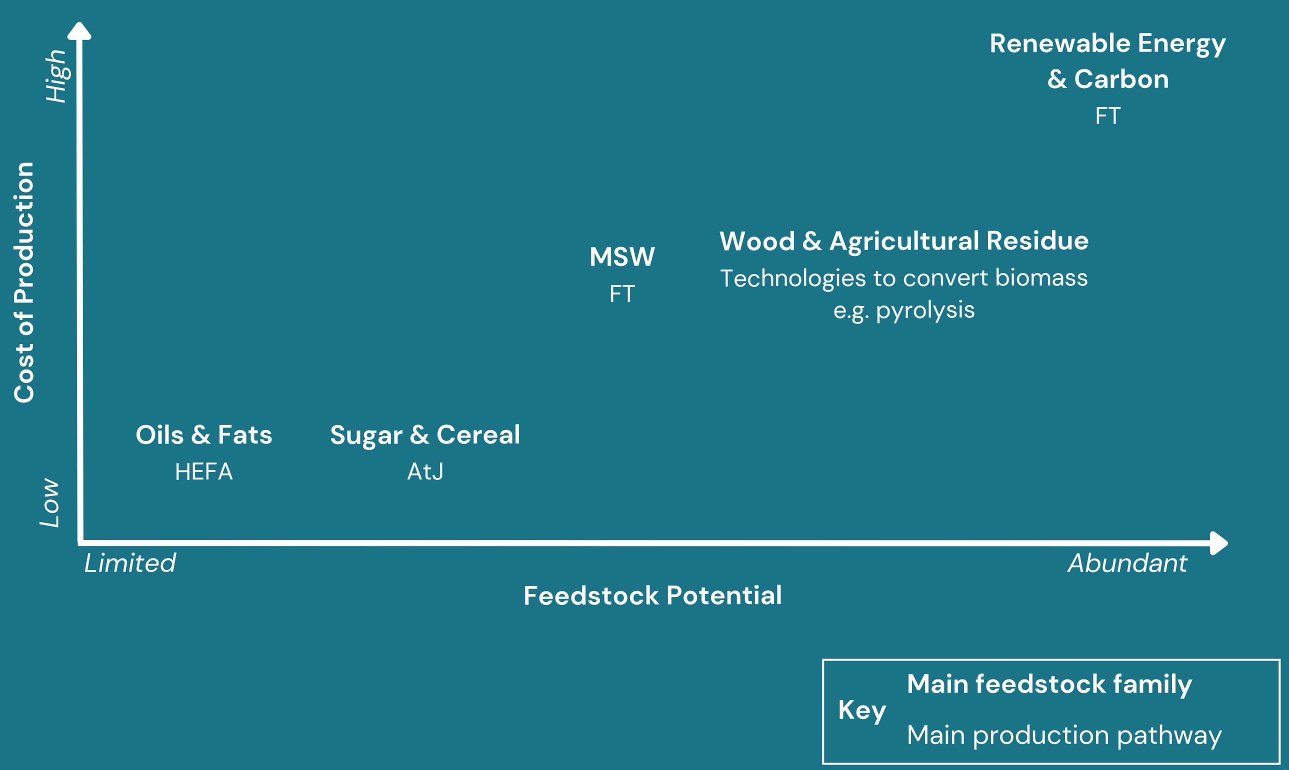


Figure adapted from BP

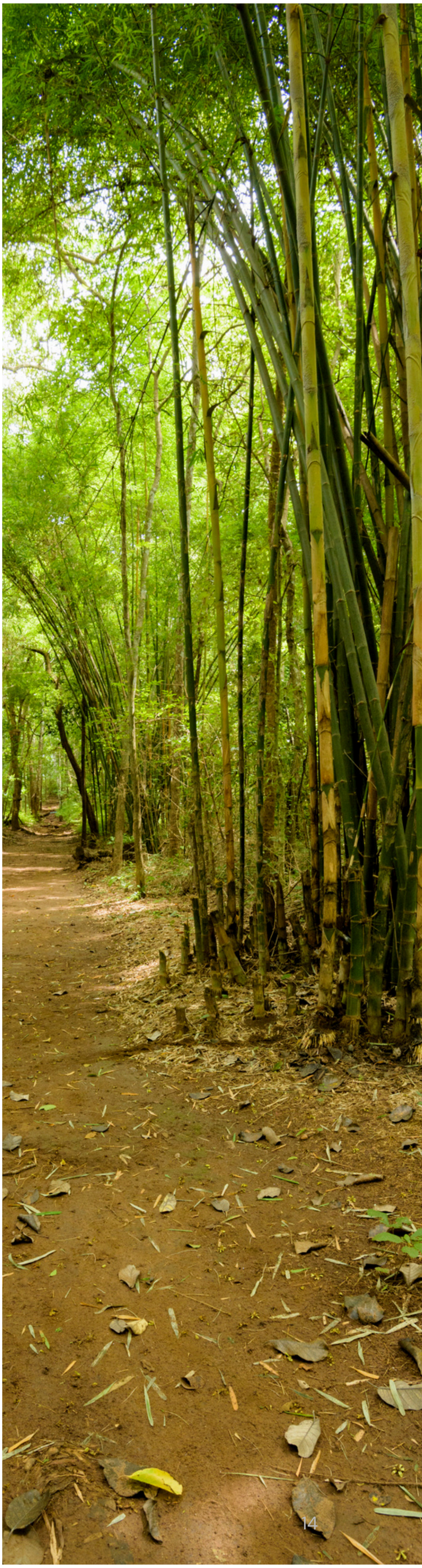
Traceability Issues
Local biofuel production operations, particularly in countries like Indonesia, struggle with feedstock traceability, contributing to increased pressure on feedstock acquisition processes and costs in an already tight market.

Limited Local Presence of Global Players
Effective supply chain management is crucial for aggregating feedstock from diverse sources across APAC countries. Aggregation activities that are currently undertaken include collecting used cooking oil from factories in Indonesia and Malaysia and gathering palm-based wastes from mills in Kalimantan and Sumatra.

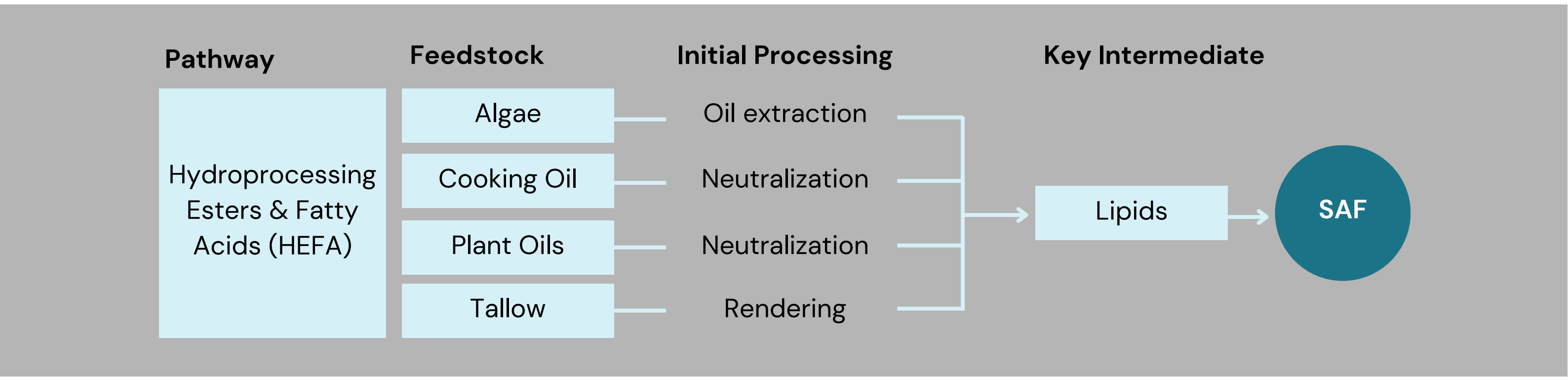
With a sizable portion of volume collected from small, independent sources or collectors, a strong local presence is required to maintain a direct relationship with feedstock sources. For most international biofuels producers, local presence in these markets is limited, leading to heavy reliance on local partners.

To overcome feedstock supply challenges, new strategic relationships are forming between biofuel producers and feedstock suppliers. Examples include Bangchak partnering with Thanachok Oil Light (a Thai used cooking oil aggregator) to build a SAF plant, and BP's plans to purchase NuSeed Carinata Oil for processing and trading.

Biofuel players are increasingly moving across the value chain to capture higher value in biofuel production and gain strategic control over feedstock supply. Major integrated agribusinesses like Wilmar, Cargill, and Bunge are actively diversifying into feedstock aggregation and processing, reshaping the industry landscape.



Hydroprocessing Esters & Fatty Acids (HEFA) Pathway



The HEFA pathway currently dominates SAF production due to its lower capital costs and the availability of feedstocks with energy densities similar to fossil fuels. HEFA synthetic paraffinic kerosene is the primary commercial pathway for SAF production, utilizing waste fats, oils, and greases as feedstocks.

Feedstock prices have been volatile due to their limited availability. The preference for UCO over other feedstock types (due to having a lower carbon intensity), has driven up prices significantly between 2019 and 2022.

Feedstock availability and procurement costs are now the main considerations for HEFA production approvals and have a direct impact on the pace of substitution for conventional jet fuel with SAF.

The limited availability of current HEFA feedstocks necessitates the rapid development of large-scale sustainable alternatives.

Several high-energy crops are being approved and explored as HEFA feedstocks, including algae, camelina, pennycress, tallow tree, and carinata. Cover crops like carinata are particularly promising, as they can contribute to sustainable farming practices without requiring additional land.

While HEFA-based SAF currently dominates the market, with IATA predicting that nearly 85% of upcoming SAF facilities in the next five years will use the HEFA process, the limited availability of feedstocks is expected to drive diversification away from this production pathway. It is expected that HEFA will peak at 10% of industry needs.

Beyond 2030, SAF production from AtJ, Municipal Solid Waste (MSW), and second-generation biomass is anticipated to increase significantly, addressing the need for more sustainable and scalable feedstock options.

Graphic adapted from ICAO, EASA, World Economic Forum, Airbus

Alcohol-to-Jet (AtJ) Pathway

AtJ is a method whereby sugary and starchy biomass, such as sugarcane and corn grain, are converted into ethanol or other alcohols through fermentation, which can then be transformed into jet fuel.

Currently, AtJ is perceived as less cost competitive than HEFA due to the higher cost of alcohol production. Despite having the potential to reduce up to 95% of carbon emissions, the prohibitive cost of AtJ production limits the extent of commercialization.

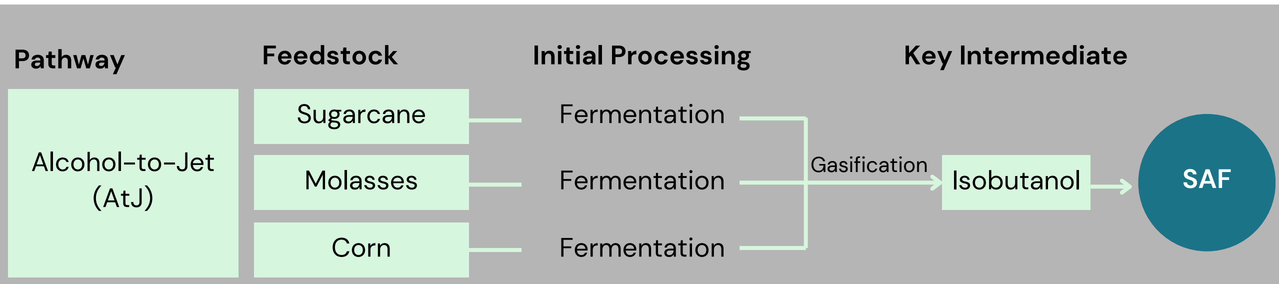
AtJ feedstocks are easy to grow and transport by train, however one key feedstock, sugarcane, must be processed into ethanol within 48 hours of being cut. To achieve low logistical costs, reduce carbon emissions from transport and make better use of infrastructure, ethanol plants benefit from being placed close to feedstock production mills as well as to refineries.

The APAC region has significant potential for AtJ feedstock production. India and Thailand, two of the world's three largest sugar producers, along with China, are well-positioned to supply the necessary raw materials for AtJ production.

Demand from sectors such as ground fuelled vehicles and petrochemicals however means that there is currently limited feedstock available to aviation. As ground fuels move more towards electrification this will free up feedstock supply for the aviation sector which in turn is expected to lead to commercial SAF production.

Another consideration with the AtJ pathway is that the reduction in carbon intensity is not as strong when compared to the alternative technologies. Implementation of solutions such as carbon capture and storage technology will be key to lowering GHG emissions. Other options to evaluate include the use of biogas in place of natural gas in mills and converting farm machinery to run on biofuels rather than fossil fuels.

While the AtJ pathway offers promise for APAC, ReFuelEU Aviation does not currently allow for ethanol as a direct feedstock for SAF. While AtJ is not yet widely accepted under ReFuelEU, its potential for future approval remains under discussion, especially as technology advances and ethanol from waste or lignocellulosic sources becomes more feasible.



Graphic adapted from ICAO, EASA, World Economic Forum, Airbus

Fischer-Tropsch (FT) Pathway

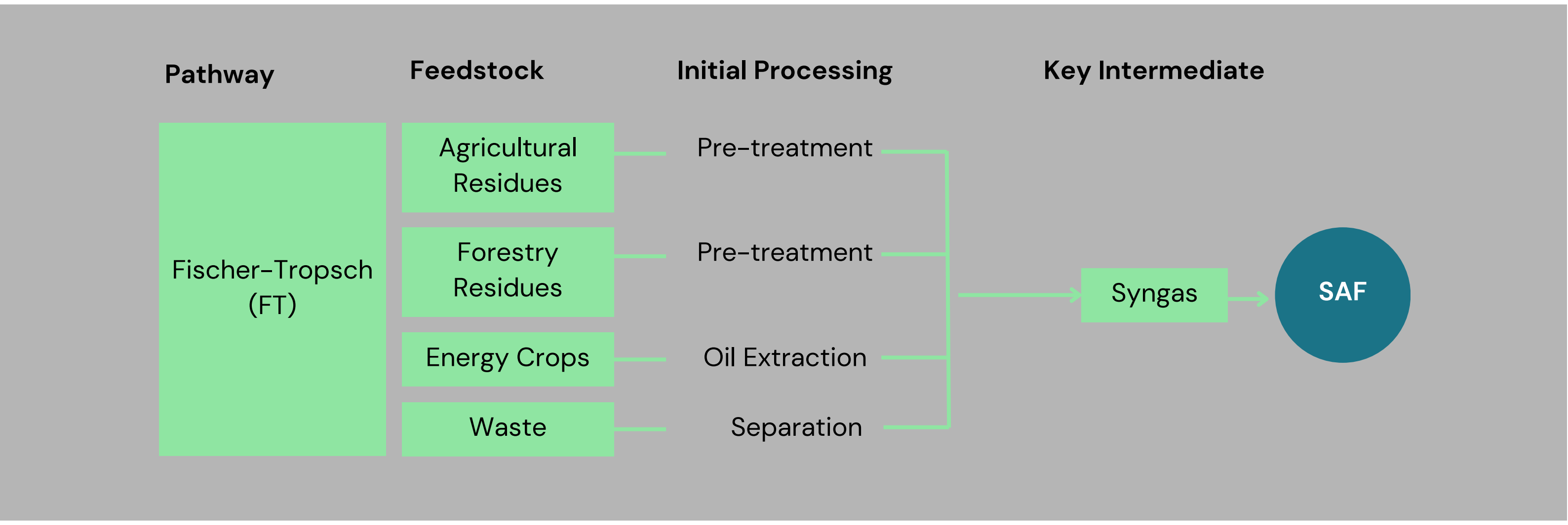
The FT pathway can utilize a wide range of feedstocks, including waste materials and CO_2, potentially reducing competition with food crops. To commercialize this pathway, producers are focusing on technology developments that can reduce the relatively high capital costs.

For SAF produced from MSW using FT technology, the main environmental gain is redirecting waste from decomposing in landfill sites. According to the World Bank, the world generates more than 2 billion tons of MSW annually, which is expected to increase to 3.4 billion tons by 2050. We will increasingly see urban centers like Japan and Singapore focus on MSW for this reason.

While access to MSW as a feedstock is widely available and it is typically a lower cost feedstock than other raw materials, in some regions aviation is in competition with other sectors, including the waste-to-energy industry, for access to MSW.

FT plants are technologically complex and expensive to build and maintain. APAC countries with advanced petrochemical industries (including China, South Korea and Japan) may have an advantage in terms of technology expertise, but high capital costs remain a barrier. In the medium-term, blended and/or government concessions will continue to be required to create these closed-loop processes at an acceptable cost structure.

Reducing the cost of FT facilities over the medium- to long-term will be critical in allowing a strong FT-based production ecosystem to emerge. This would enable low-carbon SAF from a diverse range of feedstocks while optimising infrastructure requirements.



Graphic adapted from ICAO, EASA, World Economic Forum, Airbus

Power to Liquid (PtL)

PtL is an emerging and promising pathway for producing SAF however it is not yet commercially viable. PtL fuels are produced by combining green hydrogen (produced through electrolysis using renewable electricity) with captured CO_2 via the approved FT pathway. This process, while energy-intensive, has the potential to produce truly carbon-neutral fuels if powered entirely by renewable energy. China, with its high renewable energy capacity, is uniquely positioned to deliver this technology.

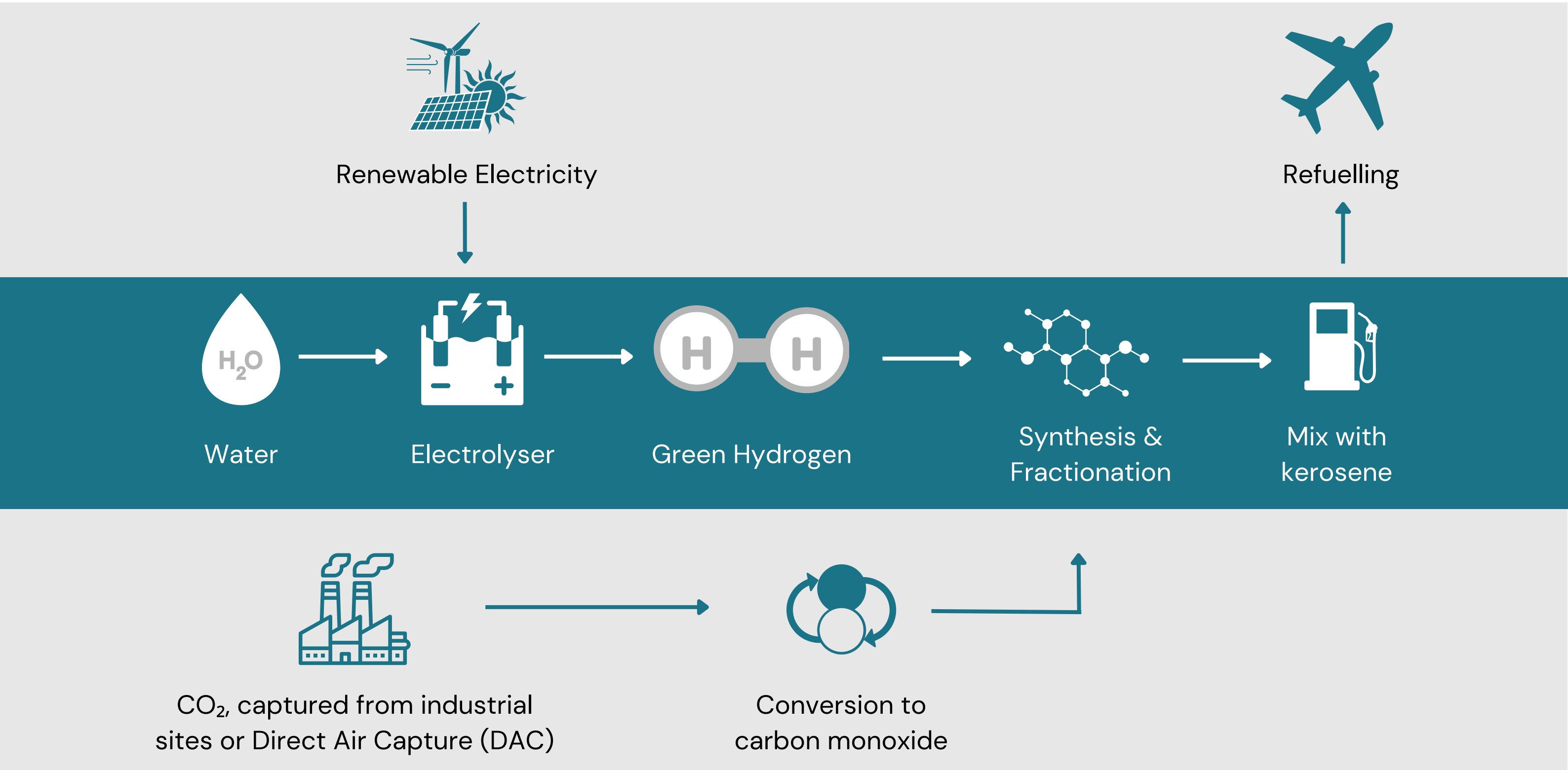


Figure adapted from Airbus

PtL SAF has the potential to reduce lifecycle carbon emissions by up to 90% compared to conventional jet fuel. It also uses significantly less land and water compared to biofuel-based SAF.

Unlike biofuel pathways that rely on limited biomass feedstocks, PtL has the potential for virtually unlimited production once direct air capture (DAC) technology becomes more cost-effective.

PtL fuels can be transported and distributed using existing fossil fuel infrastructure, including pipelines and fuelling stations, reducing the infrastructure burden of this pathway.

While PtL technology shows great promise, currently, PtL SAF production is expensive, with costs estimated to be 3-8 times higher than conventional jet fuel.

However, as renewable energy and carbon capture technologies improve, these costs are expected to decrease.

Scaling PtL requires CDR

Carbon Dioxide Removal (CDR) encompasses a wide range of technologies and methods designed to remove CO_2 from the atmosphere to be stored or used. CDR technologies can play an important role in enhancing PtL SAF production pathways.

The PtL process for SAF production involves synthesizing liquid hydrocarbons from hydrogen and CO_2.

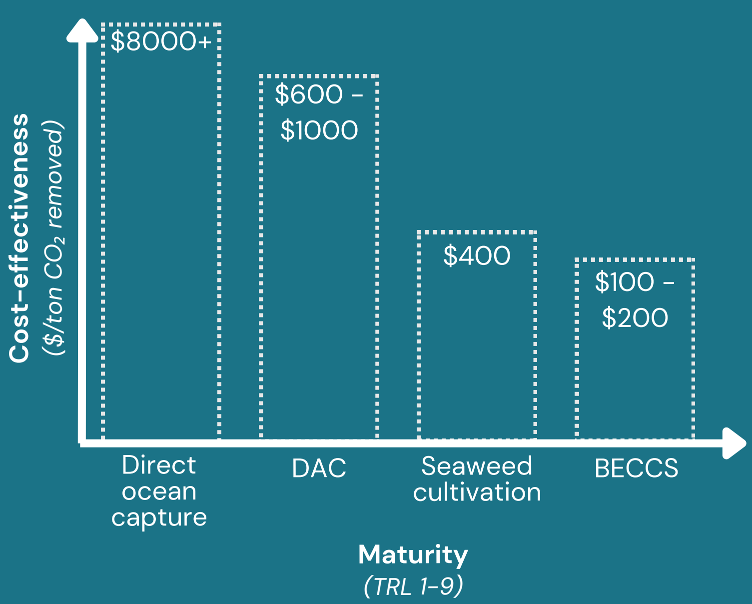
The integration of of CDR technologies provide a sustainable source of carbon for the PtL process. Instead of relying on fossil-based carbon sources, the captured CO_2 can be used as a renewable feedstock for hydrogen creation, delivering a circular production cycle.

Optimizing the efficiency of both CDR and hydrogen production is crucial to making PtL SAF cost-effective and scalable.

By capturing and storing CO_2, these technologies create a negative carbon flow from the atmosphere to geological storage, potentially leading to net negative emissions. However, the global supply of biogenic CO_2, estimated at 320-370 million tons per year, falls short of meeting potential demand from aviation and other hard-to-abate sectors, making CDR methods critical for supplying the necessary volumes.

Several climate beneficial options for sourcing CO_2 are being developed, including CO_2 capture at emissions point sources such as power plants, waste biomass gasification, direct air capture (DAC) of CO_2 from the atmosphere, and oceanwater carbon capture. From a technical perspective, the most mature of these options involve point-source carbon capture while the least mature utilize oceanwater carbon carbon capture.

CDR Maturity Scale



Direct Ocean Capture: Potential for implementation at coastal airports; captured CO_2 could be used for e-fuel production; partnership opportunities for airlines with oceanfront operations.

Direct Air Capture (DAC): Direct source for e-fuel production; potential for on-site airport capture and fuel synthesis.

Seaweed Cultivation: Biomass for SAF production; raw material for aviation bioplastics; hydrogen production could fuel future aircraft; carbon credit opportunities.

BECCS: Dual purpose biomass use for SAF production and CO_2 capture; captured CO_2 applicable for e-fuel production.

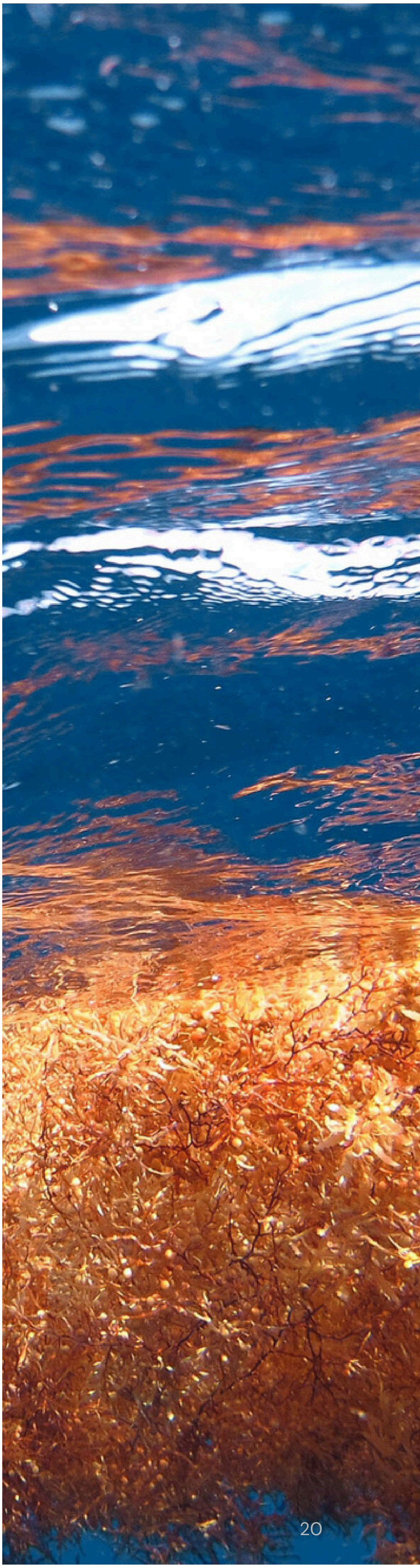
Source: SimpliFlying

Leading airlines and aerospace companies are investing in CDR through partnerships with startups and purchasing carbon removal credits, signalling the industry's readiness to adopt these solutions.

Governments in the U.S., Canada and the EU are implementing tax credits and funding programs to support CDR, providing a favorable environment for the technology's growth and adoption in aviation. The UK and the EU have introduced an e-fuels sub-mandate within their wider SAF mandates.

It is anticipated that DAC will continue to be commercialized as a priority over other CDR technologies due to its ability to address both current and historical emissions and be placed in situ on sites that are undertaking fuels processing, removing transportation and logistics costs and emissions.

Investing in CDR technologies opens dual pathways to potentially develop SAF value chains while also securing carbon credits for compliance regimes, maximizing return on investment and keeping options flexible for future emissions reduction strategies.



Competition For Hydrogen As Capital Is Deployed

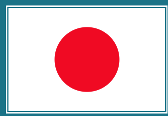
Hydrogen is a crucial component in PtL SAF production, but it's also in high demand for various other decarbonization efforts across APAC. This creates a complex landscape of competing priorities.

We are already seeing long-term contracts for green hydrogen and expect for this to continue.

This is because hydrogen can be a key solution for decarbonizing hard-to-abate sectors like steelmaking, chemical manufacturing, and high-temperature industrial processes. These industries are significant throughout APAC economies and are actively exploring hydrogen as a means to reduce emissions.

Beyond aviation, hydrogen is being explored for use in fuel cell vehicles, particularly for heavy-duty transport and long-distance travel.

Australia, Indonesia, Japan, Singapore and South Korea are considered to have the most advanced green hydrogen strategies among APAC nations.



Japan's Hydrogen Society Promotion Act promises 15-year subsidies for low-carbon hydrogen, both domestic and imported. The impact on SAF production remains to be seen, but the policy signals clear intent.

India is investing ~USD 5.3 billion to establish 15,000 megawatt (MW) of electrolyser capacity for green hydrogen production by 2026. Undertaken via India's National Green Hydrogen Mission, this initiative could help create significant SAF feedstock for PtL production.

The Asian Renewable Energy Hub in Western **Australia**, with BP acquiring a 40.5% stake in 2022, is set to become one of the world's largest renewables and green hydrogen hubs. At full capacity, it is expected to produce around 1.6 million tons of green hydrogen.

Additional to competition for green hydrogen is technical readiness. While electrolysers for green hydrogen production are beginning to be commercially available, large-scale CDR technologies are still nascent.

Countries in APAC are developing national hydrogen strategies to balance these competing demands and de-risk the solutions. For instance, Japan and South Korea are focusing on importing green hydrogen to meet their various decarbonization goals.

While there's significant potential for hydrogen production in the region, particularly from countries with abundant renewable resources like Australia, the competition for this resource is intense and could limit the availability of hydrogen for PtL SAF production and drive up costs.

Recent announcements of various cancellations or postponements for planned green hydrogen projects due to high renewable energy costs, electrolyser availability and costs, and other difficulties point to the challenges in scaling up meaningful supply of green hydrogen.

The success of PtL SAF in APAC will largely depend on how effectively countries can scale up green hydrogen production, manage competing demands, and create supportive policy frameworks. Collaborative efforts, such as the APAC Green Hydrogen Alliance, aim to accelerate the development of a regional hydrogen economy, which could benefit the aviation sector along with other industries seeking to decarbonize.

SAF Distribution

The feasibility of SAF production depends directly on the availability of sustainably produced feedstock at competitive costs, which in turn is a direct function of the existing supply infrastructure, such as roads and storage systems.

Proximity to processing plants and robust infrastructure typically correlates with higher land costs. Conversely, more remote areas offer cheaper land but incur higher transportation expenses for raw materials, significantly impacting the final fuel cost.

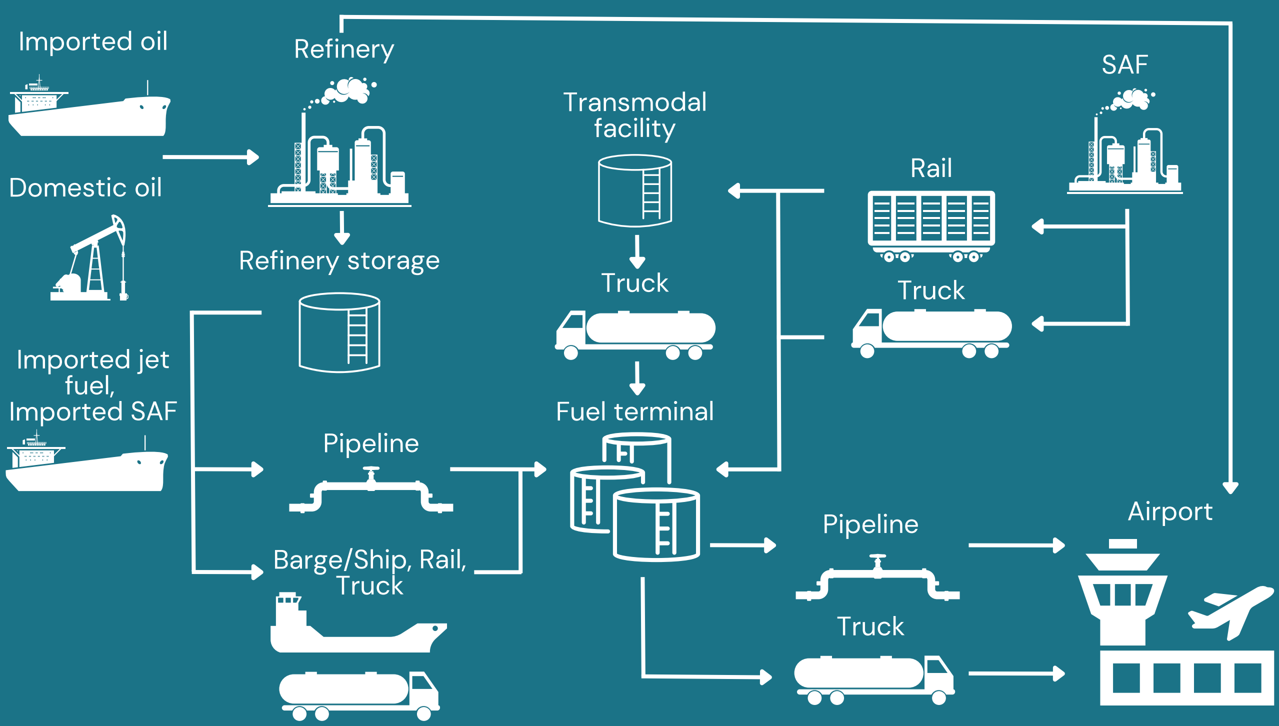
To foster competitive SAF production, it's crucial to expand and enhance transport infrastructure, including roads and storage systems. This improvement not only benefits SAF production but also boosts the overall agricultural sector.

Similar cost considerations apply to waste collection and transport, where the distance between waste sources and processing plants plays a vital role.

However, compared to the challenge of securing adequate feedstock, the infrastructure for SAF transport and storage is a relatively minor concern.

In most cases, particularly in developing nations, SAF is transported from producers to distributors via trucks and blended at terminal facilities.

SAF Distribution Pathways



Adapted from US Department of Energy Alternative Fuels Data Centre

This process requires relatively simple equipment and storage tanks. Given the current production volumes of SAF throughout APAC, more complex transportation methods like pipelines are not yet economically justified.

For producers, an effective feedstock sourcing strategy at the portfolio level is crucial to provide flexibility in production output to meet evolving biofuel market demands. With limited feedstock availability for HEFA production, players will need to place early bets on alternative technological pathways.

For buyers, strategically sourcing biofuels is critical amid the changing regulatory environment. In addition to ensuring a long-term reliable supply, buyers need to ensure that decarbonization is driven by cost-effective initiatives, which has been a key challenge in scaling up adoption.

But this is quickly changing with players enhancing internal procurement capabilities to manage SAF costs, such as hedging. They are also better managing the pass-through cost of SAF to end customers. For example, book and claim systems are being utilized to manage and share with end customers the supply chain costs of procuring SAF.

Book and Claim

Book and claim is a mechanism that decouples the environmental benefits of SAF from its physical delivery.

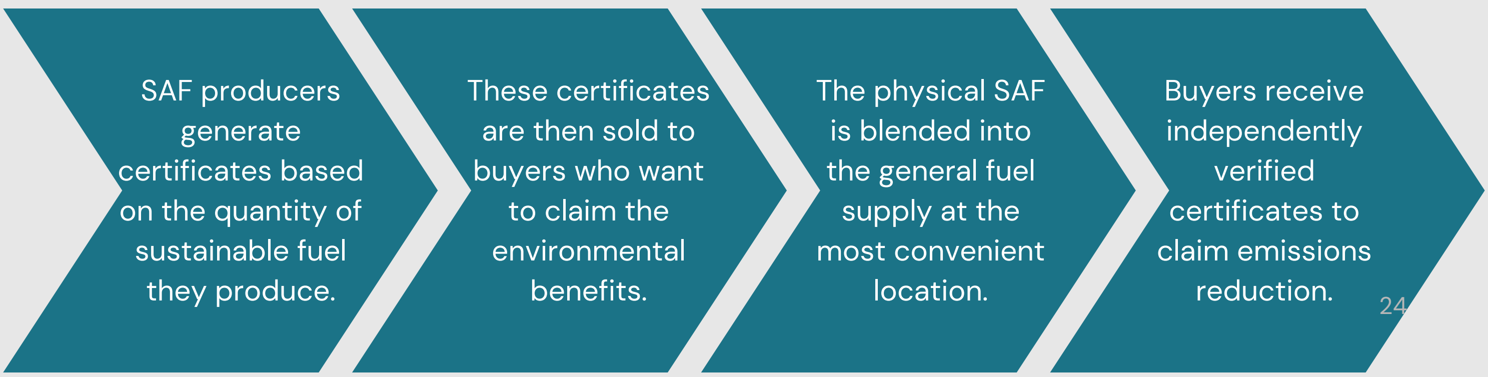
This solution addresses the initial limited supply of SAF versus the growing demand and will enable airlines and operators to purchase SAF without being geographically connected to a SAF supply site - also reducing the overall emissions profile of the fuel.

This mechanism is a bridge to managing the costs of SAF and decoupling decarbonisation from affordability for consumers.

This is especially relevant as consumers, especially in value carriers, will not pay for sustainability. The average margin per seat in Asia is only ~$2USD whereas SAF would require ticket price increases that make the carrier unprofitable. Government support will continue to be critical to delivering SAF adoption through this, and other, mechanisms.

By allowing SAF to be used close to production facilities, supply chain risk is reduced and market liquidity is increased.

How book and claim works



Emerging APAC

The APAC region is rapidly emerging as a pivotal player in the SAF market, leveraging its diverse resources, government mandates, and technological innovation to advance SAF production and usage.

This is critical not only for environmental progress but also for regional security and the protection of vital economic sectors, including the oil industry.

Across APAC, countries are taking varied approaches to SAF feedstocks, drawing on each nation's unique strengths. Malaysia and Indonesia, for instance, are capitalizing on their robust palm oil industries to explore palm oil-based SAF, while Australia and India are focusing on converting agricultural residues and other waste streams into sustainable fuel.

This diversity highlights APAC's unique positioning; each nation's approach is tailored to its economic drivers, technological readiness, and natural resources.

Government policies are also driving SAF growth in the region, with mandates and incentives designed to build resilience in fuel supply chains and reduce dependence on imported fossil fuels. This is especially important for nations aiming to protect their oil industries while transitioning to greener alternatives.

Through strategic investments and supportive policy frameworks, APAC governments are building a foundation for a secure, sustainable SAF supply chain that can meet regional aviation needs and support long-term economic stability.

As these supply chains mature, APAC is well-positioned to become a global leader in aviation decarbonization. The region's commitment to SAF not only underscores its role in shaping the future of sustainable aviation but also ensures that its economic, environmental, and security interests remain aligned amid a global shift toward sustainability.

This section provides a deep dive and pulse check of the government policies, corporate engagement and feedstocks that each nation is pursuing.

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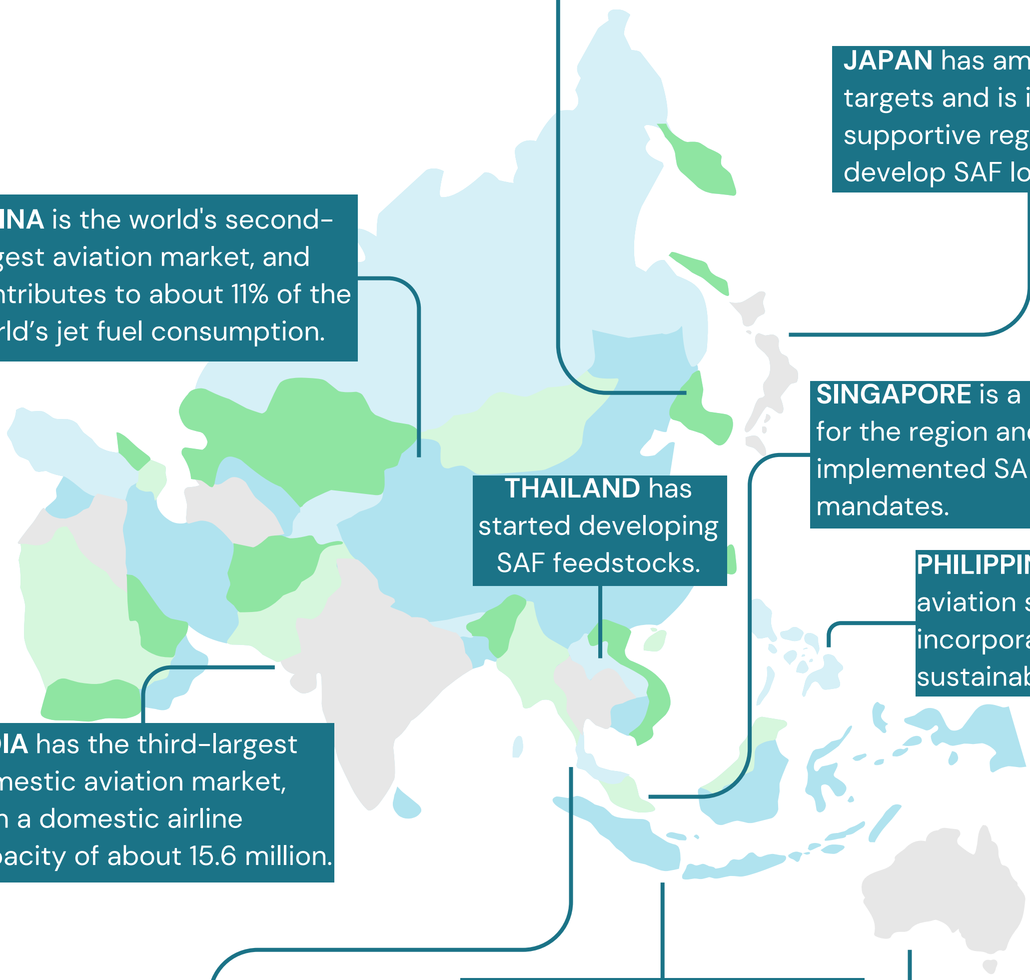
APAC Market Map



SOUTH KOREA will mandate SAF for international flights departing from its airports from 2027.

JAPAN has ambitious targets and is implementing supportive regulations to develop SAF locally.

CHINA is the world's second-largest aviation market, and contributes to about 11% of the world's jet fuel consumption.

SINGAPORE is a key aviation hub for the region and has already implemented SAF targets and mandates.

THAILAND has started developing SAF feedstocks.

PHILIPPINES has a fast growing aviation sector and is incorporating SAF into its sustainability strategy.

INDIA has the third-largest domestic aviation market, with a domestic airline capacity of about 15.6 million.

INDONESIA has established several regulations to promote SAF development and use.

MALAYSIA as a major palm oil producer has established a SAF blending mandate under the National Energy Transition Roadmap (NETR).

AUSTRALIA'S aviation industry accounts for roughly 1% of the country's GHG emissions and is second only to the US in terms of annual emissions from domestic flights.

SINGAPORE

Government Policies
Singapore has taken a proactive approach to promoting SAF adoption.

In February 2024, the government, through the Civil Aviation Authority of Singapore (CAAS), launched the National Sustainable Air Hub Blueprint, outlining a comprehensive strategy to achieve net-zero domestic and international aviation emissions by 2050.

The blueprint includes new rules mandating that all departing flights be required to use SAF, beginning at 1% from 2026, increasing to 3-5% by 2030, spurring investment in SAF production and infrastructure.

In addition to the mandate, Singapore has introduced a SAF levy to support the purchase of SAF and spread the costs across the aviation sector. This levy will vary based on factors such as distance travelled and class of travel.

CAAS will become responsible for delivering the levy by centrally procuring SAF for aircraft departing from Singapore. This centralized approach aims to aggregate demand, enable cost efficiencies and create supply resilience by utilizing a mix of short, medium and long-term contracts.

Feedstocks
The primary SAF production method in Singapore is the HEFA process from used cooking oil, palm oil mill effluent, animal fats and wastes and agricultural and forestry residues

The availability of feedstocks is likely to lead to supply constrains and volatile prices.

Corporate Engagement
To combat potential feedstock supply issues, **Neste** is exploring the expansion of its feedstock pool to include novel vegetable oil and lignocellulosic biofuels.

Neste has an established SAF supply agreement with **Shell Aviation**, who upgraded its facility in Singapore to enable blending of SAF, and is due to deliver the second of two 500-tonne consignments of blended SAF to the Changi Airport for use by Singapore Airlines and its low-cost sibling Scoot.

Shell Aviation has supplied SAF to **Japan Airlines** and **Cebu Pacific** at Changi Airport, **Jet Aviation** and **Bombardier** at Seletar Airport, and **Cathay Pacific** at Hong Kong International Airport.

SAF Pilot at Changi Airport

In 2023, CAAS, GenZero, and Singapore Airlines (SIA) completed a 20-month SAF pilot to understand SAF use and operational readiness at Changi International Airport.

The pilot validated the end-to-end process needed to bring SAF into Changi Airport, including procurement, blending of neat SAF with conventional jet fuel in Singapore facilities and safety certification. The pilot affirmed that SAF can be safely deployed to Changi Airport and uplifted onto flights without any modification to existing airport infrastructure.

The generation of SAF credits for sale to corporates and air cargo companies looking to decarbonize their carbon footprint, is a way to crowd-in financing to share SAF's higher costs.

Under the pilot, SIA purchased 1,000 tons of neat SAF which generated 1,000 SAF credits, corresponding to approximately 2,500 tons of carbon dioxide reductions. These SAF credits were generated through the Roundtable on Sustainable Biomaterials (RSB) Book & Claim System.

The pilot validated that transactions in SAF credits could be conducted in a trusted and transparent manner, laying the foundation for a global marketplace for SAF credits.

About two-thirds of the 1,000 credits generated were sold during the pilot, indicating market demand for SAF credits but also showing that more is needed for wide-scale SAF adoption, including through education, outreach and corporate and government policy support.

JAPAN

Government Policies

The Japanese government has set a target to replace 10% of jet fuel consumption with SAF by 2030.

To achieve this ambitious target, Japan has formed a public-private committee to promote SAF production and utilization.

This committee will contribute to the drafting of SAF legislation and considers a variety of elements including the supply target volume for SAF, the formal definition of SAF, and GHG reduction goals. The committee will also discuss the duration of the initial SAF regulations, target operators, and issues related to program flexibility.

The upcoming SAF regulations are expected to be in place from 2030 to 2034 and apply to jet fuel producers that supply more than 100 million liters annually.

Government Financing

In the realization of the SAF supply target for 2030, upfront investments will be implemented in the form of the Green Innovation Fund (started in FY2021) and Upfront GX Investment Support (started in FY2024).

Upfront GX Investment Support

- Capital investment for construction of large-scale SAF production facilities and development of supply chains to secure raw materials.

Green Innovation Fund

- Development of AtJ technology to produce large volumes of SAF from ethanol.
- Development of large-scale, highly efficient production technology for synthetic fuels using FT synthesis.
- In 2022, **ENEOS** was granted funding from this scheme to develop e-fuel production technology using CO_2-free hydrogen and CO_2.
- **Idemitsu Kosan** was also awarded funding to develop and commercialize its supply chain of SAF using AtJ, and is expected to launch the country's first commercial SAF supply chain by end-March 2027.

Japan's ongoing investment in the SAF value chain will be key to supporting its economy and primary industries such as oil, to transition.

Corporate Engagement

Japan has an active corporate sector, with the establishment of **ACT FOR SKY**, a voluntary organization involving 27 Japanese companies to promote SAF commercialization.

JGC Holdings and **Cosmo Oil** plan to establish a SAF factory in Osaka, producing up to 30,000 kiloliters per year from 2025.

Idemitsu Kosan is involved in research and development efforts to produce SAF from various feedstocks while also exploring ways to leverage its existing refinery infrastructure for SAF production.

Japan Airlines (JAL) Group aims to replace 10% of its fuel with SAF by 2030. JAL, along with **Japan Overseas Infrastructure Investment Corporation** and **Marubeni Corporation**, acquired shares in Fulcrum BioEnergy, a U.S.-based SAF producer.

Japan Airport Terminal Co. Ltd. and **Euglena Co. Ltd.** have signed a Memorandum of Understanding (MoU) to jointly develop a SAF supply chain to Haneda Airport. Euglena will issue its first series of unsecured straight bonds (green bonds) to Japan Airport Terminal to support this development.

Airbus, **Kansai Airports** and **Kawasaki Heavy Industries** (Kawasaki) have signed a MoU to study the feasibility of hydrogen infrastructure at three airports operated in the Kansai region of Japan – Kansai International Airport, Osaka International Airport and Kobe Airport.

All Nippon Airways (ANA) and JAL are importing SAF from South Korea.

Feedstocks

Japan is exploring various SAF production methods and feedstocks:

- Municipal and industrial waste
- Carbon dioxide and hydrogen blend
- Agricultural residues
- Cotton clothing
- Woodchips and microalgae
- Ethanol (through AtJ technology)

IHI Corporation has developed a technology to cultivate microalgae using CO_2 emissions from thermal power plants, creating a circular economy approach to SAF production.

Mitsubishi Heavy Industries has collaborated with **Boeing** and **SMBC Aviation Capital** to commission a study on SAF feedstock availability and production potential in Japan. The report found that while there was domestic feedstock availability, Japan requires additional refining capacity and policy support to fully utilize these resources.

Nippon Paper and **Rengo** are investigating the potential use of woody biomass, a byproduct of their operations, as a feedstock for SAF production.

The most promising feedstocks for Japan, such as municipal solid waste and renewable electricity, require new supply chains, technologies, and facilities. Developing these will take time and investment.

SOUTH KOREA

South Korea is the largest exporter of jet fuel globally, a lot of which goes to Australia, and has ambitions to retain this position for SAF.

Government Policies

South Korea has announced plans to mandate the use of SAF for international flights departing from its airports starting in 2027. All international flights departing from South Korean airports will be required to use a 1% SAF blend in their jet fuel.

The mandate forms part of the governments SAF Expansion Strategy which aims to capture 30% of the global blended SAF export market.

The Strategy sees South Korea's ambition to expand its domestic SAF demand, ensure stable domestic supply capacity and establish a SAF-friendly legal and institutional environment.

To facilitate the adoption and production of SAF, the government has announced various support measures, including:

- Tax breaks and other incentives for local refiners investing in SAF production,
- Development of an incentive system to encourage adoption of SAF, including preferential allocation of transport rights and reduced airport facility usage fees, and
- Easing of regulations on waste recycling to increase the availability of domestic feedstocks.

Feedstocks

The primary feedstocks being utilized by South Korea for SAF production are cooking oil, palm oil and biodiesel. South Korea is also exploring alternative feedstocks like microalgae for future SAF production.

South Korea has ambitious plans for developing a hydrogen-based economy, which should progress the development of hydrogen infrastructure and support the production of e-fuels or PtL SAF.

Corporate Engagement

Korean Air has begun using a 1% SAF blend on a commercial route from Seoul Incheon to Tokyo Haneda, marking the first use of domestically produced SAF by a Korean flag carrier. **S-Oil** and **SK Energy** are supplying SAF for Korean Air's flights.

SK Energy has commenced commercial output from its dedicated SAF production line at Ulsan refinery.

HD Hyundai Oilbank is exporting SAF through Japan's Marubeni utilizing **Korea National Oil Corporation's** storing and shipping facilities. **GS Caltex** is also exporting SAF to Japan through **Itochu** in collaboration with Neste.

AUSTRALIA

Government Policies

The Australian government's Aviation White Paper, 'Towards 2050' includes measures to advance the production and use of SAF and other low carbon liquid fuels.

Key policy initiatives include:

- Increased research into SAF production pathways.
- Consideration of incentives for domestic feedstock and fuel production.
- Development of protocols to track and verify SAF green credentials.
- Expansion of the national Guarantee of Origin Scheme by 2028 to authenticate new fuel production credentials.
- Allocation of AUD30 million to support SAF and renewable diesel production from Australian feedstocks.

The government has committed to consulting with the aviation industry on production incentives and credits, as well as demand-side measures for low carbon liquid fuels, though it has explicitly excluded blending mandates. The government is considering implementing a SAF blending mandate starting 2027, aligning with the second phase of CORSIA, and is developing a regulatory framework.

Australia's government-backed energy financing body, ARENA, continues to provide government funding toward SAF and hydrogen developments.

Corporate Engagement

While the Australian government has not set blending mandates or targets, **Qantas**, Australia's national carrier, has a target of 10% SAF by 2030 and 60% by 2050.

Qantas has also developed the SAF Coalition Program, that uses the book and claim methodology to allow corporations to contribute to the cost of SAF purchasing. Qantas has SAF supply agreements through aircraft deals with Boeing and Airbus.

Jet Zero Australia, backed by a consortium including Qantas, Airbus, and Idemitsu Kosan, is developing a commercial-scale AtJ production facility in Townsville, Queensland. This facility is targeting 100 million liters of SAF annually by 2027 using LanzaJet's AtJ technology.

BP is advancing a SAF project using the HEFA process in Kwinana, Western Australia while **Ampol** and **ENEOS** are conducting a feasibility study for an advanced biofuels manufacturing plant in Brisbane that could produce up to 500 million liters of SAF annually.

Feedstocks

Australia, being an agriculturally abundant nation, continues to focus on biomass as a locally produced feedstock to develop the SAF market. As such, AtJ fuel production is emerging as a promising pathway.

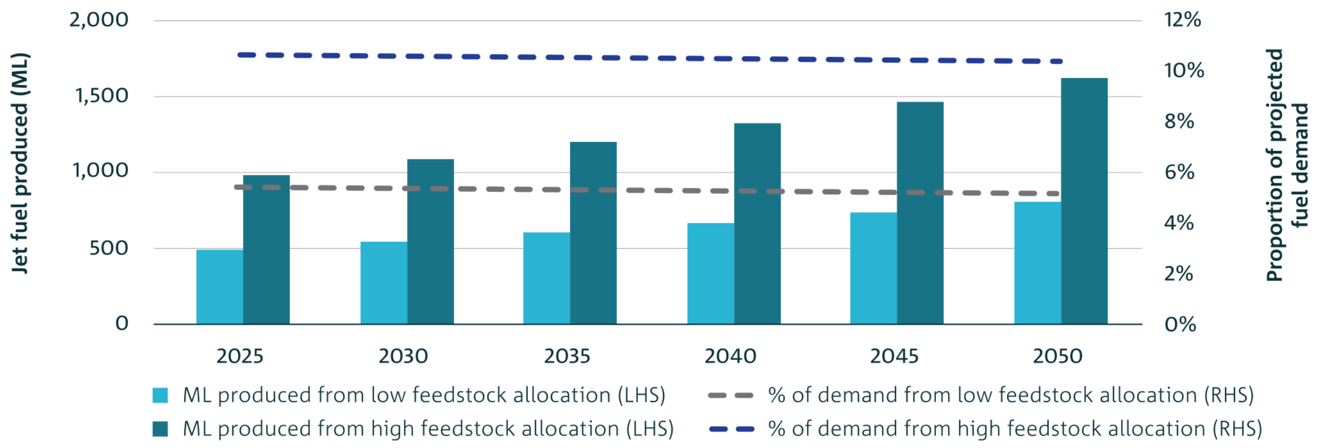
The key agricultural feedstocks identified by CSIRO, Australia's scientific agency, include sugar cane, sorghum, agricultural and forestry residues. Tallow and oil feedstocks are considered high priority for the HEFA pathway.

Bringing this to life are **Ampol** and **IFM Investors** who are progressing a feasibility assessment of a renewable fuels facility in Brisbane and working with **GrainCorp** to explore the supply of feedstocks to the future plant.

With Australia's vast landmass and growing renewable energy portfolio, PtL is also being considered. **HIF Global's** upcoming e-fuel facility in Tasmania, is set to begin production in 2028-2029. The project has been shortlisted for the Australian Government's USD$2 billion Hydrogen Headstart funding program.

HIF has also partnered with **Idemitsu** and **Mitsui** to develop an e-fuels supply chain between HIF facilities and Japan. HIF plans to produce 36,000 barrels (equivalent to 5.7 million liters) of e-fuel per day by 2030.

Potential SAF production from Australian sugar, bagasse and sorghum and contribution toward domestic fuel demand



Sugarcane (sugar and bagasse) and sorghum could supply increasing portions of Australia's fuel demand over time. Utilising 10% of projected sugar and 40% of bagasse production through to 2050 could produce enough SAF to meet 10% of the fuel demand.

CSIRO (2023) Sustainable Aviation Fuel Roadmap

INDONESIA

Government Policies

Indonesia has established several regulations to promote SAF development and use.

The use of bio-jet fuel was mandated in 2016, requiring 2% bio-jet fuel blending in 2016 and 5% by 2025, however the 2016 target was missed.

During 2024, the Co-ordinating Ministry for Maritime Affairs and Investment announced an updated policy position, requiring flights to use SAF in their fuel mix from 2027.

International flights departing Indonesia will be required to use 1% SAF in their fuel mix in 2027. This will rise to 2.5% by 2030, 12.5% by 2040, 30% by 2050, and 50% by 2060.

A 2025-29 Action Plan was also announced, with three main policy pillars of demand, supply and enablers. Under the enablers pillar, there are plans to appoint a national accreditation body for SAF certification and a domestic SAF certification ecosystem.

Under the demand pillar, the country aims to implement pilot SAF offtake agreements for international flights from Ngurah Rai International Airport, and to increase the SAF mandate at Ngurah Rai, the Soekarno-Hatta International Airport, and other major airports. It also plans for a SAF usage mandate for corporate and government travellers.

Feedstocks

Under the Government's 2025-29 Action Plan supply pillar, securing enough domestic feedstocks for SAF production via the HEFA pathway is being prioritized. This includes a proposed domestic market obligation for palm fatty acid distillate and export quota and/or tariff for used cooking oil.

Crude palm oil has been identified as the alternative SAF feedstock that is most widely available within Indonesia. However, SAF produced by this feedstock has life cycle emissions above ICAO, US and EU standards, limiting its global marketability.

Other potential feedstocks including coconut, sugarcane and seaweed are being considered.

State-owned oil and gas company **Pertamina** has developed two palm oil-based biofuels. While these fuels have been tested and certified by Indonesia's Oil and Gas Testing Agency, and meet the ASTM D1655 standards for conventional Jet A-1 fuel, they have yet to receive certification under the CORSIA scheme due to the sustainability concerns of palm oil.

INDIA

Government Policies

The current policy landscape for SAF in India is still in its nascent stages, with no specific policies directly targeting SAF production or use.

However, in 2023, the National Biofuels Coordination Committee set an indicative SAF blending target of 1% in 2027, which could increase to 2% by 2028, initially for international flights.

The government is also considering a 1% SAF blending mandate by 2025, potentially increasing it to 5% by 2030, aligning with India's planned participation in the second phase of CORSIA.

India's government is exploring policy interventions such as incorporating SAF under the National Biofuels Policy and offering viability gap funding to stimulate industry growth.

India has also launched a National Green Hydrogen Mission, to position the country as a leading global hub for the production, use, and export of green hydrogen.

Feedstocks

India possesses substantial feedstock potential for SAF production.

According to estimates by a Clean Skies for Tomorrow report, about 166 million tons of various feedstocks are available annually in India which could potentially yield over 22 million tons of SAF. This would require a mix of feedstocks.

India's competitive renewable electricity costs also make PtL SAF production promising. With the country's solar power costs as low as USD$20-40 per megawatt hour (MWh), PtL SAF production could become economically viable sooner than in other markets.

The AtJ pathway also holds significant potential, given India's established sugar industry. Estimates suggest that surplus sugar production of 3-5 million tons annually could yield 1-1.5 million tons of SAF.

Praj Industries has collaborated with **Gevo** to launch a demonstration facility to process agricultural feedstocks for SAF production.

Corporate Engagement
In 2018, a **SpiceJet** flight used a 25% SAF blend, produced by the **Indian Institute of Petroleum** using Jatropha seeds.

Vistara was the first Indian carrier to operate a commercial domestic flight on a wide-body aircraft using a 17% SAF blend.

Indian Oil Corporation has signed a MoU with **LanzaJet** to explore SAF production using LanzaJet's AtJ technology. The partnership aims to pursue large-capacity SAF production and potentially form a Joint Venture to deploy LanzaJet's AtJ technology in India. It has also supplied SAF for AirAsia India’s commercial passenger flight from Pune to New Delhi.

CHINA

Government Policies

Despite the growing interest in SAF, China's government has yet to implement specific policies or mandates to support its development and use.

The country's 14th Five-Year Plan, released in 2022, sets a target for SAF consumption to exceed 50,000 tons by 2025. This goal, however, isn't binding in nature, and no clear pathways were defined to achieve it.

While the current lack of explicit policy signals from the central government has been identified as a barrier to SAF production and adoption in China, it is expected that China will unveil its policy for SAF use for 2030 shortly.

In 2023, the Civil Aviation Authority of China (CAAC) launched the country's first technical centre for SAF. This centre is tasked with mapping out industry policy, setting up standards for products and quality control, and setting up test facilities for new products. The CAAC is also looking to establish a Chinese certification system for SAF.

China's SAF industry is rapidly evolving, with both state-owned enterprises and private companies working to increase SAF production capacity and obtain necessary approvals for commercial use.

Feedstocks

The HEFA pathway is currently the most dominant pathway of SAF production. According to the Institute of Energy, China holds significant potential for SAF production due to its feedstocks, which, if optimally utilized, could result in an annual production of nearly 46 million tons of SAF annually.

The main feedstocks include:

- Used cooking oil
- Agricultural waste
- Forestry waste
- Municipal organic solid waste
- Industrial waste gas-based ethanol

If China can fully leverage its feedstock potential, it could become a significant global SAF supplier, with production potentially exceeding domestic demand.

In March 2023, **State Power Investment Corporation Ltd** (SPIC) and **Cathay Pacific** signed a memorandum of cooperation covering four SAF production facilities, focusing on a pathway similar to PtL. SPIC has announced SAF production capacity of 400,000 tons per year.

Further, China's significant renewable electricity generation capacity could drive the commercialization and scaling of PtL SAF production. Several provinces, including Shandong, Qinghai, and Sichuan, have developed plans for green hydrogen production.

Corporate Engagement

In November 2022, **Colorful Guizhou Airlines** completed a commercial passenger flight using SAF from Ningbo to Guiyang. During this time, **Sinopec's** Zhenhai Refinery obtained airworthiness certification for China's first large-scale production of SAF from the CAAC.

Airbus and the **China National Aviation Fuel Group (CNAF)** have signed a MoU to intensify cooperation on SAF production, application, and standards formulation. Airbus has further signed agreements with **Xiamen Airlines**, **Zhejiang Loong Airlines** and **Colorful Guizhou Airlines** to promote SAF use for commercial flights in China.

In December 2023, **Air China Cargo** successfully completed the first commercial cargo flight using SAF from mainland China, flying from Hangzhou to Belgium.

Zhuoyue New Energy is a major player in China's biofuel industry and has announced plans to produce 100,000 tons of SAF annually. The company is expanding globally, with plans to establish biofuel refineries in Saudi Arabia and Singapore focusing on SAF production. This includes investing $20 million to develop a biodiesel project in Singapore, aiming for an annual output of 200,000 tons of biodiesel.

Sichuan Jinshang Environmental Protection Technology Co. has announced SAF production capacity of 400,000 tons per year, while **Jiaao Enprotech** has disclosed SAF production capacity of 1,000,000 tons annually. **EcoCeres** has announced SAF production capacity of 50,000 tons per year at its Zhangjiagang facility. **Oriental Energy** has disclosed plans for 1,000,000 tons of annual SAF production capacity in Maoming city.

Junheng Biology received airworthiness approval from CAAC for its SAF in January 2024, becoming the first private refinery to obtain such approval. The company plans to increase its SAF production capacity to 400,000 tons annually by 2025. The company has also successfully conducted the first engine test run using 100% SAF in China.

PHILIPPINES

Government Policies

The Philippine government has demonstrated a commitment to promoting SAF and decarbonizing the aviation industry, with the Department of Energy (DOE) collaborating closely with the aviation sector and international partners to promote SAF adoption.

This includes the development of a SAF roadmap to provide a framework for local SAF production and usage, setting the stage for more concrete policies in the near future.

The DOE has reported increased investor interest in bioenergy projects in the Philippines, due to improved regulations and policies, which could benefit SAF development.

The National Biofuels Board is mandated to recommend the use of biofuel blends in air transport, considering safety and technical viability.

The government has laid out incentives for green hydrogen production including tax breaks and duty exemptions for equipment and materials. The government is also actively considering the revival of the Bataan nuclear power plant and the construction of a new plant, possibly a small modular reactor, which could support hydrogen production for SAF.

Feedstocks

The Philippines is exploring various feedstocks for SAF production including coconut oil. This would leverage the country's abundant coconut resources and significant coconut oil production currently used for biodiesel.

Plant and used oil feedstocks, including forestry and agricultural waste, are also being considered.

The Philippines has limited existing infrastructure for large-scale SAF production, which may slow down the country's aviation decarbonization agenda.

Corporate Engagement

Airbus has committed to collaborating with the Department of Transportation on SAF initiatives and carbon energy extraction from landfills, potentially revolutionizing the aviation sector's energy sourcing.

Cebu Pacific began using SAF in 2022, marking a significant milestone for the country's aviation industry.

WasteFuel Philippines has partnered with **Prime Infra** to develop biorefinery facilities to convert MSW into SAF.

MALAYSIA

Government Policies

In 2023, Malaysia established a SAF blending mandate under the National Energy Transition Roadmap (NETR). It proposes a blending mandate of 1% to begin with, and increasing it to 47% by 2050.

The country has also adopted ICAO's net-zero carbon emissions goal for aviation by 2050, aligning its national objectives with global standards.

The Malaysia Aviation Decarbonisation Blueprint further supports the SAF target put forward by the NETR. The blueprint underscores the need for cross-ministerial and multi-sectoral cooperation to map out necessary incentives to make SAF cost-effective. It also recommends the need for a National Strategy for SAF and 100% SAF-compatible aircraft as some of the ways to decarbonize aviation.

To support SAF development, the Malaysian government announced 10 flagship catalyst projects in 2023, including a Future Fuel Biofuels Hub to be developed in Pengerang, Johor. This hub is expected to serve as a catalyst for creating facilities to produce a range of bio-based products, including SAF, HVO, and biochemicals.

Feedstocks

Malaysia's well-established palm oil industry presents a significant opportunity for SAF production. Palm oil derivatives, including palm oil mill effluent and empty fruit bunches, which are recognised under CORSIA, are being promoted by the Malaysian government.

Used cooking oil is being explored, with an estimated potential of approximately 240 kilotons per annum.

Malaysia is also investing in novel feedstocks such as microalgae with the Sarawak state government (in collaboration with Marubeni Corporation) having identified 10,000 acres of land in Bintulu for algae plantation, with plans to produce significant volumes of SAF by 2030.

To address sustainability concerns, particularly regarding palm oil, Malaysia has implemented the mandatory Malaysian Sustainable Palm Oil (MSPO) certification scheme. The government is actively working to promote the sustainability of its palm oil industry and is addressing challenges presented by international regulations through the scheme.

Like Indonesia, Malaysia's SAF strategy is closely linked to its palm oil industry. However, the country is also looking to diversify its feedstock options to address sustainability concerns and align with global SAF standards.

Corporate Engagement
During 2023, **Malaysia Airlines** operated its first passenger flight using SAF from from Kuala Lumpur to Singapore. The flight utilized a blend of conventional jet fuel and **Neste's** SAF, produced from 100% renewable waste and residue raw materials.

Petronas' PETCO Trading (UK) facilitated the supply deal for this flight while **Petronas Dagangan Berhad** managed product handling and refuelling at KLIA. In July 2024, **Euglena** and Petronas announced plans to build and operate a commercial biofuels production plant, and the Malaysian government announced that Petronas will collaborate with major palm oil producers to manufacture SAF from palm oil waste.

Following the successful flight, a long-term supply of SAF is now available at **Kuala Lumpur International Airport** for airline customers and flights operated by **Malaysia Aviation Group** (parent company of Malaysia Airlines) airlines.

EcoCeres is aiming to start a SAF and renewable diesel facility in Malaysia in 2025, and plans to use used cooking oil as one of its primary feedstocks.

THAILAND

Government Policies
Thailand has targeted SAF production starting in 2026, aiming for 8% by 2036, based on projections of available domestic feedstock from used cooking oil and molasses-derived ethanol. The government plans to adopt AtJ SAF when the blend rate with jet fuel reaches 3%-8%.

Bangchak Corporation is delivering supplies of blended SAF into the fuel pipeline system supplying Bangkok's two international airports, Suvarnabhumi and Don Mueang. The fuel was delivered as part of a pilot programme with **Bangkok Aviation Fuel Services** and **BAFS Pipeline Transportation** to help prepare infrastructure for SAF production and use in Thailand.

The country's first SAF production facility, owned by **Bangchak Corporation**, is scheduled to be online in 2025, with a capacity of 1 million liters per day, exclusively using used cooking oil as feedstock.

Thailand's Alternative Energy Development Plan focuses on reducing GHG emissions through a biofuels consumption target of 2.76 billion liters by 2037, of which 675 million liters would be met through consumption of SAF.

Financial incentives, subsidies, and tax breaks are being offered to airlines that use SAF, with **Thai Airways International** and the state-owned **PTT Public Company** collaborating to test SAF usage for flights from Bangkok to Phuket.

PTT Public Company has entered into a MoU with its subsidiaries to collaborate on SAF production.

Feedstocks
The main feedstock currently being explored for SAF production in Thailand is used cooking oil with both Bangchak Corporation and **Energy Absolute Plc** having announced plans to use this feedstock.

Sumitomo Corporation and **Cosmo Oil** have signed agreements to buy SAF produced by Bangchak Group.

Thailand has extended its biofuels mandate to bolster current feedstock demand and fuel infrastructure while facilitating a long-term transition to SAF. Production will depend on dual feedstock plants of molasses-based and bagasse-based cellulosic ethanol, requiring subsidies to support feedstock production until then.

Challenges

Feedstock availability and contracting dynamics

SAF brings together industries that historically rely on short-term spot and forward trading rather than long-term fixed price arrangements.

With fuel buyers, such as airlines, and feedstock sellers, such as oilseed growers, both looking for flexibility to maintain their competitiveness in a fragmented market, SAF producers face a two-sided challenge to achieve the certainty and risk mitigation required for scaled up production.

This is especially relevant to existing HEFA and biofuel pathways with natural oil prices linked to crude oil prices.

Moreover, the integration of biofuels into supply chains, coupled with global regulatory mandates, has established a de facto price floor for natural oil feedstocks.

This floor represents the minimum purchase price at which suppliers find it economically viable to engage in biodiesel or renewable diesel production. This means that as jet fuel prices rise, SAF profitability is constrained unless natural oils can be sourced below market rates.

The long-term cost of biogenic feedstocks is a key problem for the SAF industry, as input costs are unlikely to reduce significantly, limiting scale and cost efficiency when compared to traditional hydrocarbons.

Achieving cost-efficient feedstock sourcing often requires direct investment or partnerships in non-food feedstock development and production. This strategy presents a short-term opportunity cost as producers could potentially realize greater returns by selling directly to the market.

Decoupling crude oil and SAF feedstock pricing is unlikely anytime soon. Therefore, finding ways to hedge fixed and floating rate pricing and source low cost, reliable feedstocks are key challenges for the industry to overcome.

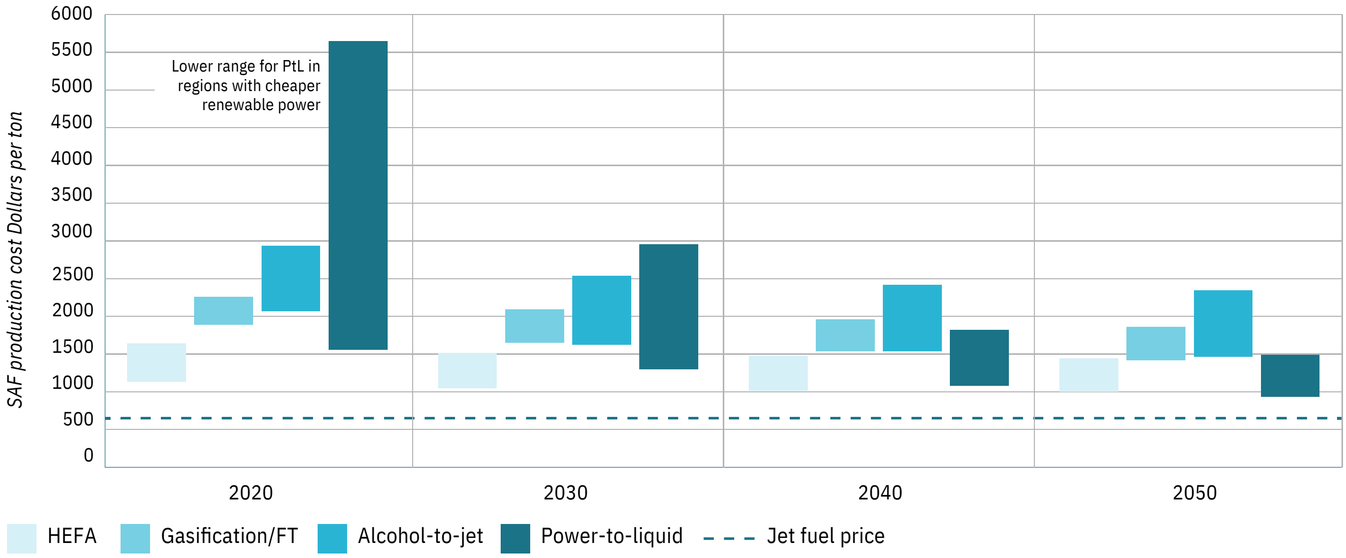
Investors comparing SAF to the early renewable energy industry will need to adjust to including commodity risk management and may struggle to invest in the near-term. This will likely tilt the playing field towards incumbents and strategic players who are able to tolerate risk and volatility to establish a beachhead position.

Levelised Cost of Fuel (LCoF)
LCoF is a key measure for the potential of SAF. Current prices of SAF are 2-3x that of traditional jet fuel. Estimated long-term marginal cost reductions may see AtJ reducing from $2,000-3,000 to $1,500-2,400 per ton by 2050 and HEFA remaining at $1,000 per ton or above.

This points to the fact that, in the longer-term, pivoting to PtL methods will be crucial. While the necessary carbon capture and hydrogen production is currently extremely energy intensive and expensive to produce, the APAC region could benefit from some of the lowest renewable electricity costs, particularly in India and China.

However, challenges remain, including high initial costs, lack of infrastructure, and the need for significant capital investments. Addressing these challenges will require a multi-faceted approach. Government support, in the form of incentives for SAF production and use, will be important. Private investment in new electricity, hydrogen and emerging technologies like Direct Air Capture (DAC) will be key to solving for long-term price competitiveness.

Global SAF Production Costs



World Economic Forum (2020) Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation

Sustainability and Certification schemes

Certification schemes are essential for ensuring SAF sustainability and quality. The Roundtable on Sustainable Biomaterials (RSB), International Sustainability and Carbon Certification (ISCC), and Roundtable on Sustainable Palm Oil (RSPO) are among the recognized schemes for SAF, each with distinct sustainability assessment criteria.

For APAC producers targeting international markets, navigating these varied certification requirements can be complex and expensive, potentially excluding smaller producers due to certification costs. APAC faces the challenge of ensuring certification schemes are appropriate for local contexts while meeting global sustainability standards. Greater harmonization of schemes is necessary to reduce complexity and costs for producers.

High integrity carbon credits

A central challenge for CORSIA lies in achieving a sustainable balance between the supply of and demand for high-quality carbon credits. Current projections indicate that demand for CORSIA-eligible credits will likely outstrip supply as more airlines enter the program, particularly as offsetting requirements increase in the upcoming mandatory phase.

This anticipated shortage of eligible credits presents a potential bottleneck for CORSIA's success, which could limit airlines' ability to meet their offsetting obligations.

While we recognise that reducing, rather than offsetting aviation emissions, through routes such as SAF, is preferable, we are conscious that a reliable supply of eligible credits will need to be sustained to provide market signals for further decarbonization. It is important that there is continued investment in new high-integrity carbon credit projects and careful management of existing ones in order to meet CORSIA's standards.

However, as demand rises, credit prices are likely to increase, which could introduce additional financial pressures on airlines with large emissions footprints. Higher credit prices, while potentially spurring more carbon project development, may ultimately impact airline operations and could lead to increased costs passed down to consumers.

Regional integration

SAF potential is currently limited by regulatory and physical disconnection. This is especially the case in South-East Asia where fragmented national policies and disaggregated airport infrastructure make achieving streamlined and consistent SAF systems a challenge.

Governments and industry participants will need to work closely to align incentives, mandates and reporting systems to ensure the most efficient path to scaling up SAF use in the region.

ASEAN has a unique opportunity to create a regional SAF market with unified mandates and incentives, while emphasising the local advantages of each country to build a diversified network of SAF production, crediting and fuelling facilities. This could serve as a model globally as the market scales.

Investment and Financing Opportunities

SAF is fast becoming another conventional infrastructure investment. This will be enhanced by long-term offtake and contacting agreements between counterparties throughout the SAF supply chain, as well as a combination of government support, financial structuring, and technology de-risking.

In developing economies, SAF faces competing priorities for limited resources. Private sector investors, while increasingly interested in sustainable investments, often require higher returns to compensate for perceived risks. Corporations can develop investment strategies that de-risk SAF by distributing risk throughout the value chain (i.e. through CDR and/or hydrogen) to enable multiple paths to returns.

Investment Opportunities

SAF refining capacity and blending

We are seeing a range of new SAF development companies focused on refining SAF for local aviation. In the future we expect these to build out into platform plays with strong exit opportunities, similar to renewable energy developers in the 2010s. Backing the right team and development program now could see outsized returns for investors willing to take on the risk. Developers today may be focusing on HEFA pathways but could build into technology-based solutions in the medium-term.

Feedstock aggregation

Solutions that roll up and supply large volumes of diverse and sustainably certified feedstocks will be worthwhile investments in South-East Asia where we are seeing growing interest from commodity and traditional oil and gas companies to identify and control feedstock supplies.

SAF credits under book and claim

The ability to separate the physical and environmental attributes of SAF is a key need in the market to optimise SAF usage, cost and environmental benefits. There is likely to be a range of opportunities, from the trading, accounting and management of credits through to insurance and underwriting of the sustainability attributes. This is an early emerging market to watch.

Power to Liquid

PtL is the long-term big bet to solve aviation emissions. While the economics are difficult at present, we see a strong case for accelerated learning curves, capability development and scale. Investment into new technologies, emerging companies and the CO_2 value chain are all attractive places to play for investors looking for long-term climate returns and impact. This means a focus on green hydrogen production, DAC and CO_2 infrastructure.

Financing Opportunities

Green Bonds and SLLs

As an infrastructure-style asset, SAF can be supported by advances in sustainability financing instruments.

As scale increases, we see opportunities for financial institutions, export finance agencies and credit providers to provide financial backing linked to sustainability outcomes. Accessing green loans or bonds can be a scalable opportunity for development of the required assets.

Carbon Credits

Carbon credits can be used to offset the emissions associated with SAF production, providing a financial incentive for investors. As more countries implement carbon pricing mechanisms, the relative cost of e-fuels compared to fossil fuels could become more favourable.

The EU ETS, which includes aviation, provides a model that APAC countries might consider. Carbon can provide a return enhancement as well as a price indication to drive uptake of SAF.

Guarantees of Origin

These certificates verify the sustainability of SAF, enabling companies to claim environmental benefits while providing investors and purchasers confidence in the environmental credentials of the fuel.

Within South-East Asia, there is an opportunity to optimise the cost, return and benefits of different SAF types via enhanced certification.

Blend Guarantees

Blend guarantees ensure that a certain percentage of SAF will be blended into jet fuel, providing a demand certainty for SAF producers. Together, guarantees of origin and blend guarantees work to stabilize the investment environment for SAF production facilities, support producers to secure long-term offtake agreements with airlines, and facilitate market development.

Loan guarantee programmes linked to blend guarantees can help to de-risk investments in SAF production facilities leveraging government support to reduce the risk of default and offer competitive interest rates. Combining loan guarantees with bank liquidity facilities can help to address the high capital needs of production facilities.

Glossary of Terms

Agricultural Residues: Biomass materials left after crop harvesting, such as straw and husks, which can be used as feedstocks for bio-fuel production.

Alcohol-to-Jet (AtJ): A process that converts ethanol or other alcohols into jet fuel. AtJ fuels can be used as drop-in replacements in aviation and contribute to lower emissions.

American Society for Testing and Materials (ASTM): An international organization that develops and publishes standards for materials and products, including SAF. ASTM certification ensures SAF meets rigorous quality and safety requirements for aviation.

Bagasse: The fibrous byproduct from processing sugarcane, which can be used as a feedstock for bio-fuel production.

Bioenergy with Carbon Capture and Storage (BECCS): A carbon removal technique involving the capture and storage of CO_2 produced when biomass is converted to energy, reducing atmospheric CO_2 levels.

Biomass: Organic materials, including plant and animal matter, that can be used as fuel feedstocks for energy production. Biomass can include forestry residues, agricultural residues, algae, and waste materials.

Blending Mandate: A policy requiring a specified minimum percentage of bio-fuel or e-fuel to be mixed with traditional fuels like gasoline or diesel to reduce carbon emissions.

Bio-fuel: A renewable fuel made from organic materials such as plants, algae, or waste. Bio-fuels reduce dependence on fossil fuels and lower carbon emissions when blended with conventional aviation fuel.

Carbon Capture and Storage (CCS): A process capturing CO_2 emissions from industrial sources and storing them underground to mitigate climate change by reducing atmospheric CO_2.

Carbon Capture, Utilization, and Storage (CCUS): A process that not only captures and stores CO_2 but also repurposes it for industrial use, such as in plastics, concrete, or bio-fuel production.

Carbon Dioxide Removal (CDR): Technologies and methods that actively remove CO_2 from the atmosphere for long-term storage or industrial use.

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA): A global initiative by the International Civil Aviation Organization (ICAO) that requires airlines to offset growth in CO_2 emissions from international aviation beyond 2020 levels.

Direct Air Capture (DAC): A technology that captures CO_2 directly from the ambient air, which can then be stored or repurposed, reducing atmospheric CO_2 levels.

Drop-in Fuel: A synthetic fuel that can be used as a direct replacement for conventional jet fuel without modifying aircraft engines or fuel systems, allowing for easy integration with existing infrastructure.

E-fuels: Synthetic fuels produced using renewable energy sources and carbon from the air or industrial sources. E-fuels can be used in aviation as a low-carbon alternative to conventional jet fuels.

Electrolysis: The process of using electric current to split water into hydrogen and oxygen, essential for producing green hydrogen, a renewable energy source for SAF production.

Eligible Emissions Unit (EEU): A carbon credit or emissions reduction unit that meets regulatory standards, such as those set by CORSIA, allowing it to be counted toward meeting emissions reduction targets.

Ethanol: A renewable alcohol fuel typically derived from crops such as corn or sugarcane. Ethanol can be used in the AtJ process to create SAF.

Feedstock: The raw materials, often renewable or waste products, used to produce SAF and other bio-fuels. Examples include used cooking oils, algae, agricultural residues, and municipal solid waste.

- **1st Generation:** Food-based crops or other primary agricultural products traditionally used for human or animal consumption.
- **2nd Generation:** Consist of non-food biomass and materials that are generally waste or by-products.
- **3rd Generation:** Advanced and innovative biological sources that typically include algae (microalgae or macroalgae capable of producing high lipid content for biofuels) and genetically engineered organisms or synthetic biology pathways designed to produce fuel precursors.

Fischer-Tropsch (FT): A chemical process that converts carbon monoxide and hydrogen (syngas) into liquid fuels. This process can use renewable feedstocks or captured carbon for SAF production.

Forestry Residues: Materials left over from logging or forest management, such as branches, bark, and sawdust, which can be repurposed for SAF production.

Green Hydrogen: Hydrogen produced from water through electrolysis using renewable electricity.

Greenhouse Gas (GHG): Gases in the atmosphere that trap heat, such as CO_2 and methane, contributing to global warming. SAF aims to reduce GHG emissions from aviation.

Hydroprocessed Esters and Fatty Acids (HEFA): A type of SAF made from waste oils, fats, and other renewable sources through hydroprocessing.

International Emissions Trading Association (IETA): A global organization promoting market-based solutions to climate change, such as emissions trading systems.

International Sustainability and Carbon Certification (ISCC): A global certification system ensuring sustainability of feedstocks used in SAF production, including compliance with environmental, social, and GHG requirements.

Jet A: A type of aviation fuel commonly used in the United States. It is a kerosene-based fuel designed for jet engines, with a freezing point of -40°C. Jet A is widely used in both commercial and military aviation, though it is primarily a U.S. standard.

Jet A-1: A globally recognized jet fuel similar to Jet A but with a lower freezing point of -47°C, making it more suitable for international flights and colder temperatures. Jet A-1 is the standard jet fuel used internationally for commercial and cargo flights.

Municipal Solid Waste (MSW): Household and commercial waste materials that can be converted into fuel through processes like gasification, contributing to waste-to-energy initiatives in SAF production.

Net-Zero: Achieving a balance between GHG emitted and those removed from the atmosphere.

Power-to-Liquid (PtL): A method using renewable electricity to convert captured CO_2 and water into liquid fuels like SAF, offering a renewable and potentially carbon-neutral option.

Synthesis Gas (Syngas): A gas mixture primarily containing hydrogen and carbon monoxide, produced from waste biomass or captured CO_2 and used as a precursor in fuel production through processes like Fischer-Tropsch.

Sustainable Aviation Fuel (SAF): An alternative jet fuel derived from renewable feedstocks, reducing life-cycle GHG emissions compared to conventional jet fuel.

Tallow: Animal fat that can be used as a renewable feedstock for SAF, often sourced from meat processing waste.

Used Cooking Oil (UCO): Waste oil from cooking that can be recycled as a feedstock for SAF production, reducing the environmental impact by reusing waste products.

Work with Us

The Asia-Pacific region stands at the cusp of a transformative era in sustainable aviation. With major airlines, governments, and energy companies collaborating on ambitious SAF projects, the region is poised to become a significant player in the global SAF market.

From Australia's AtJ initiatives to China's PtL facilities, and Singapore's world-class SAF refinery, the Asia-Pacific SAF landscape offers diverse and promising investment opportunities.

As nations across the region introduce supportive policies, mandates, and incentives, the financial attractiveness of SAF production in Asia-Pacific is set to increase.

For forward-thinking investors, this industry presents a unique chance to participate in the decarbonization of aviation while potentially reaping substantial returns.

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