In collaboration with Kearney

Financing Sustainable Aviation Fuels: Case Studies and Implications for Investment

WHITE PAPER

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Foreword

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This white paper is part of the World Economic Forum's Airports of Tomorrow initiative, launched in 2023 to focus on the energy, infrastructure and financing requirements of the aviation industry as it transitions to net-zero carbon emissions by 2050. The initiative is a collaboration with Airports Council International (ACI) World.

To help aviation get to net zero and reduce its impact on climate change, an increasing number of sustainable aviation fuel (SAF) production facilities are developing worldwide, but many projects still face investment challenges. A key areas of focus for us in 2024 was on how these facilities can progress to the construction phase and full scale-up.

We have undertaken a series of regional roundtables and expert interviews with business leaders in the aviation, energy and finance industries, as well as policy-makers, to obtain insights on the latest risks that project developers face across the project lifecycle for a number of SAF production pathways, adding to our and the industry's previous work in this space.

We have looked at the capital requirements needed to bring these facilities to life and, most importantly, potential ways to unlock this funding. This report collates best practice guidance on how to approach SAF investment and reduce risks, focusing on common challenges in securing financing and early success stories.

Delivered in partnership with Kearney, this report brings together views and insights from our extensive Airports of Tomorrow community. We thank our partners and industry sponsors for their support.

Executive summary

Ten financial levers can be explored to scale-up SAF production and bridge additional capacity needed to reach 2030 demand.

Reaching the anticipated level of demand for SAF in 2030 would require an additional 5.8 Mt of production capacity to secure final investment decisions by 2026.

By 2030, demand for global SAF is expected to reach 17 million tonnes per annum (Mt/a), representing approximately 4-5% of total jet fuel consumption. This demand projection includes government-mandated volumes and voluntary commitments by airlines. However, current SAF adoption remains limited, with only three airlines – Air France-KLM, DHL and IAG – consuming over 1% of SAF in their fuel mix as of 2023. Government policies, such as the US SAF Grand Challenge and the European Union's ReFuelEU mandate, aim to boost demand either through incentives or mandates, but further production scale-up will be essential to meet these targets.

SAF production capacity appears to be lagging behind projected 2030 demand. By the end of 2024, installed SAF capacity globally is likely to have reached 4.4 Mt, with an additional 6.9 Mt of capacity expansion planned through both greenfield projects and retrofitting existing facilities. Reaching the anticipated level of demand in 2030 would thus require an additional 5.8 Mt of SAF production capacity, which would need to secure final investment decisions (FID) by 2026.

Different technological pathways for SAF production bring unique CapEx requirements and scalability challenges, influenced by feedstock availability and technological maturity. The four principal production technologies are summarized below – each varies significantly in cost, maturity and capital requirements:

1. **HEFA (hydroprocessed esters and fatty acids)**: The most mature and cost-effective pathway, HEFA is expected to dominate SAF production to 2030. Its lower CapEx requirements are due to existing infrastructure and proven technology, although HEFA faces feedstock constraints.

2. **Alcohol-to-Jet (AtJ)**: AtJ is an attractive option, especially in regions with ample ethanol infrastructure. However, AtJ facilities face higher capital costs due to the need for on-site ethanol processing and specialized equipment for alcohol dehydration and oligomerization.

3. **Gasification-Fischer Tropsch (G-FT)**: G-FT offers high scalability but requires complex infrastructure to handle solid feedstocks like biomass. This pathway is CapEx-intensive due to the need for gasification, syngas cleaning and carbon capture technologies.

4. **Power-to-Liquid (PtL)**: Although PtL holds potential for large-scale SAF production, its CapEx requirements are the highest. PtL relies on renewable electricity, electrolysis and CO_2 capture, all of which are energy- and cost-intensive.

To scale-up SAF by 2030, this report presents three investment scenarios based on different technology mixes. These scenarios indicate that the industry may require between $19 billion and $45 billion in CapEx by 2030, depending on the proportion of HEFA in the production mix. Advanced pathways such as PtL and AtJ are expected to gain greater market share under more ambitious decarbonization strategies, although HEFA is likely to remain dominant in the near term.

The SAF refinery lifecycle involves five critical phases: conceptualization, pre-feasibility, FID, construction and commissioning. Each phase presents distinct financial challenges. The HEFA pathway's maturity allows for faster timelines, while AtJ and G-FT projects face extended development periods. Navigating policy, market, technology and feedstock risks, particularly through long-term policy consistency and feedstock security, is essential to attract capital investment.

Based on early success stories, at least 10 financial levers can be explored to mobilize the necessary investment:

1. **Research and innovation grants**: Early-stage, high-risk SAF technologies need grants from governments and philanthropic organizations to reduce upfront costs and make projects more attractive to private investors. Programmes such as the UK's Advanced Fuel Fund enable SAF developers to advance engineering and work with technology providers to de-risk their projects.

2. **Multilateral development bank support**: Multilateral development banks (MDBs) can offer valuable expertise, particularly in developing regions with complex regulatory landscapes. They conduct feasibility studies and may invest through debt or equity as projects near FID, exemplified by support from the European Bank for Reconstruction and Development (EBRD) for KazMunaiGas and Air Astana in Kazakhstan.

3. **Guarantees and insurance**: Loan guarantees, first-loss capital and insurance solutions such as currency risk insurance can help mitigate risks for SAF projects. For example, the US Department of Energy's Loan Programs Office supports SAF production through financial guarantees, improving bankability and lowering interest rates for projects.

4. **Strategic investments**: Collaboration with airlines, airports, OEMs and energy players fosters a supportive ecosystem and provides demand assurance. Recent investments from airlines, energy companies and other investors illustrates how strategic partnerships enhance bankability.

5. **Long-term offtake agreements**: Securing binding, long-term offtake agreements with airlines and corporations provide stable revenue and reduce demand uncertainty, a critical step for reaching FID. For example, IAG's 14-year agreement with PtL producer Twelve ensures consistent revenue, strengthening the project's appeal to investors.

6. **Book-and-claim mechanisms**: This approach allows individual and corporate travellers to take a more active role in funding SAF projects, through scope 3 emissions certificates, thereby increasing demand and diversifying revenue. A number of book-and-claim systems are being developed, with an increasing number of supplier-corporate partnerships such as those established by World Energy. Collective procurement platforms are also gaining traction.

7. **Private equity investment**: Private equity capital can accelerate commercialization and scale SAF projects rapidly. These investors typically bring both capital and operational expertise. EcoCeres, for instance, raised substantial funding from Bain Capital, which facilitated significant production capacity expansion.

8. **Infrastructure investors**: SAF projects seeking large-scale capital can attract infrastructure investors who often have lower capital costs and a long-term investment horizon. Such investors provide substantial funds and management expertise, enabling the construction of large SAF facilities. Brookfield Asset Management's $1.1 billion commitment to Infinium demonstrates the pivotal role that infrastructure investors can play in scaling-up SAF production.

9. **Tolling model**: SAF facilities using a tolling model can mitigate market risks by charging a fixed fee for refinery capacity while customers supply feedstock and retain ownership. Although this model is still nascent for SAF, it has worked successfully in other sectors (e.g. Cedar's tolling agreement for liquified natural gas), potentially enabling projects to secure debt financing at more favourable terms due to predictable cash flows.

10. **Green bonds**: Issuing green bonds tied to SAF production can offer a powerful tool for raising impact-driven capital. Green bonds help SAF projects meet environmental standards and they are attractive to impact investors.

New greenfield SAF refineries will be critical if the industry expects to meet its 2030 climate goals. The combination of collaboration structures and financing models presented in this report can help break down barriers to boost SAF production and the sustainability of flying in the future. None of these models will work in isolation – to scale-up SAF, project developers will need to explore as many of these options as possible.

1 Capital requirements to meet 2030 demand

Total estimated CapEx required to fulfil demand for SAF by 2030 ranges between $19 billion and $45 billion, depending on the technology pathways deployed.

1.1 Capacity requirements to meet 2030 demand for SAF

By 2030, the expected demand for SAF is estimated to amount to around 16 million tonnes per year, based on current demand commitments from airlines.

The first step in quantifying the financing needs of the future SAF industry is assessing the scale of production volumes required to meet SAF demand from airlines.

Demand: airline commitments

By 2030, the expected demand for SAF is estimated to amount to around 16 Mt/a (million tonnes per annum), based on current demand commitments from airlines.[1] This represents ~4-5% of total jet fuel demand in 2030 (~370 Mt).[2] Assuming this demand translates into supply, and depending on the lifecycle emissions of the SAF used in 2030 and the complementary savings achieved through greater engine efficiency, the global vision agreed at the International Civil Aviation Organization (ICAO) for a 5% reduction in the carbon footprint of international aviation by 2030 may thus be achieved.

There is, however, significant disparity in how this commitment might be met across regions and airlines. More than 80% of this demand is driven by 15 airlines. Cargo carriers such as FedEx, DHL and UPS have the highest SAF targets by 2030, with the most ambitious passenger airlines sticking to an average target of 10% SAF by 2030, well aligned with the World Economic Forum's Clean Skies for Tomorrow ambition. Of these, only three airline groups (Air France-KLM, DHL and IAG) were already consuming SAF for more than 1% of their total fuel demand in 2023, with DHL leading the way at 3% of their 2023 fuel consumption (see spotlight below).

CASE STUDY 1

DHL leading the way as number one SAF consumer

DHL has a commitment to reduce GHG emissions to below 29 million tonnes of carbon dioxide-equivalent (Mt/CO_2e) by 2030. This represents a 42% reduction in scope 1 and 2 emissions and 25% in scope 3 emissions, compared to its 2021 baseline of 39 Mt/CO_2e.

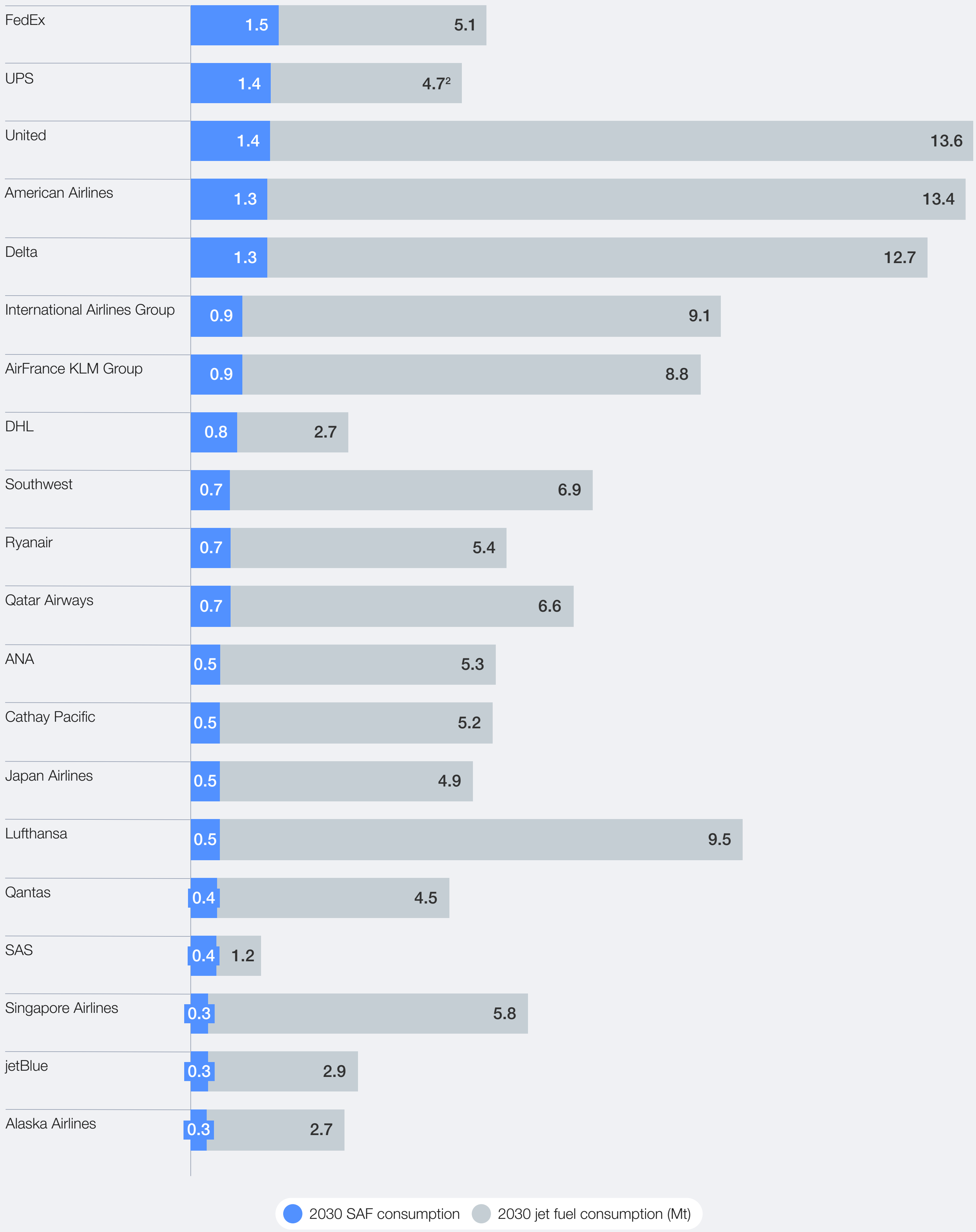
An important part of the company's emissions reduction strategy is to use more SAF – consequently, DHL has set an ambitious goal to reach 30% SAF blend by 2030.

In 2023, DHL used 72,000 tonnes (72kt) of SAF, which represented ~3% of their total fuel consumption – making them the number one SAF consumer in absolute terms.

To achieve their SAF ambition, DHL has partnered with Air France-KLM Martinair Cargo to purchase ~25kt of SAF, with bp and Neste to buy ~630kt of SAF up to 2026, and with World Energy to secure ~530kt of SAF between 2023 and 2030.

Several airlines focus more on overall carbon reduction targets and do not disclose explicit SAF blend targets, highlighting that SAF is one of a basket of measures that aircraft operators can take to reduce their emissions alongside fleet renewal, operational efficiency and market-based mechanisms such as offsets. Figure 1 shows the 20 airlines with the highest explicit SAF blend targets. They represent more than 90% (15.3 Mt) of all global voluntary commitments (16.3 Mt).

FIGURE 1 | **Estimated SAF and jet fuel consumption by top 20 SAF consumers, 2030 (million tonnes, Mt)[1]**



Notes: 1. Estimates based on forecast 2030 fuel consumption and voluntary commitments. **2.** UPS has a goal of 30% SAF by 2035, which is used here for 2030.

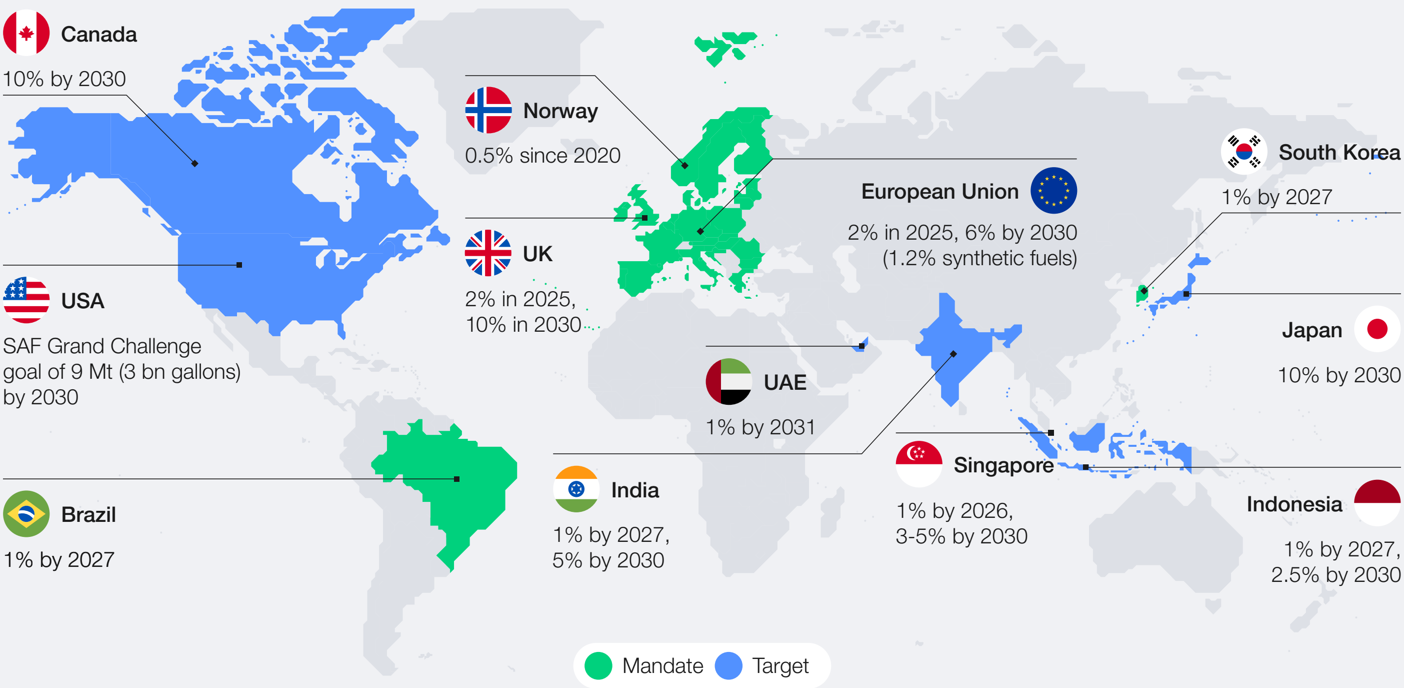
Source: US Energy Information Administration (EIA), airline annual reports and press releases; excludes airline-specific fuel efficiency programmes. Also see endnote #1.

Total demand for SAF mandated and targeted by governments is expected to reach 17.1 million tonnes per year by 2030 – roughly 5% of jet fuel demand.

Demand: mandates and targets

As public announcements from airlines are not necessarily binding, it is also important to look at mandates and targets introduced by countries to understand SAF demand in 2030. The EU, United Kingdom, Brazil and Korea announced mandates which will be ramped up towards 2030. These mandates represent a total estimated demand of 5.3 Mt/a. In addition, several other countries have declared SAF targets by 2030. Examples include the US,[3] Canada, Singapore, Japan, India, Indonesia and the United Arab Emirates (UAE). Based on these targets, an additional demand of 11.8 Mt/a is expected. As a result, total mandated and targeted demand is expected to reach 17.1 Mt/a in 2030 (~5% of 2030 jet fuel demand).

FIGURE 2 **Non-comprehensive overview of SAF mandates and targets, by country**



Note: Data accurate as of October 2024.

Sources: Various.[4]

Supply

By the end of 2024, installed SAF capacity globally is likely to have reached 4.4 Mt/a.[5] The total annual SAF capacity at these facilities is anticipated to expand by another 1.3 Mt towards 2030. In addition, 5.6 Mt/a of new SAF-specific capacity could come online by 2030, based on projects that have already passed final investment decision (FID).

When factoring the total mandated and targeted demand by 2030 (estimated above at 17.1 Mt), another 5.8 Mt/a of SAF production capacity would therefore need to be installed globally to match demand (see Figure 3).

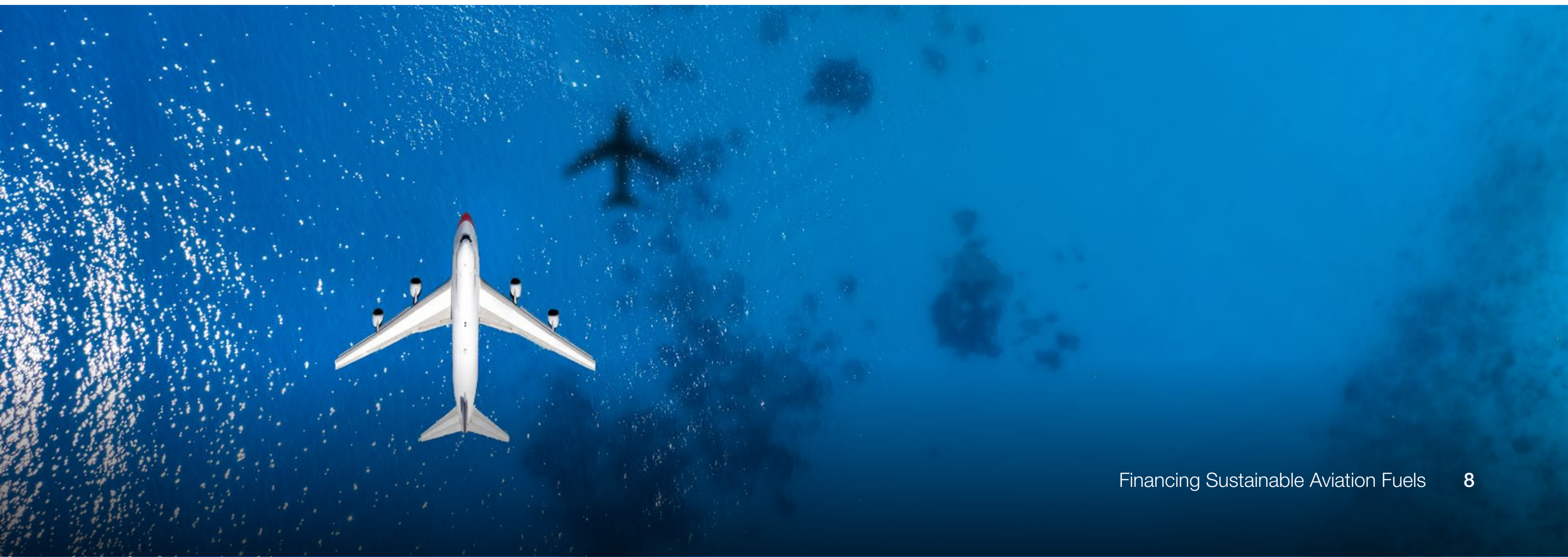
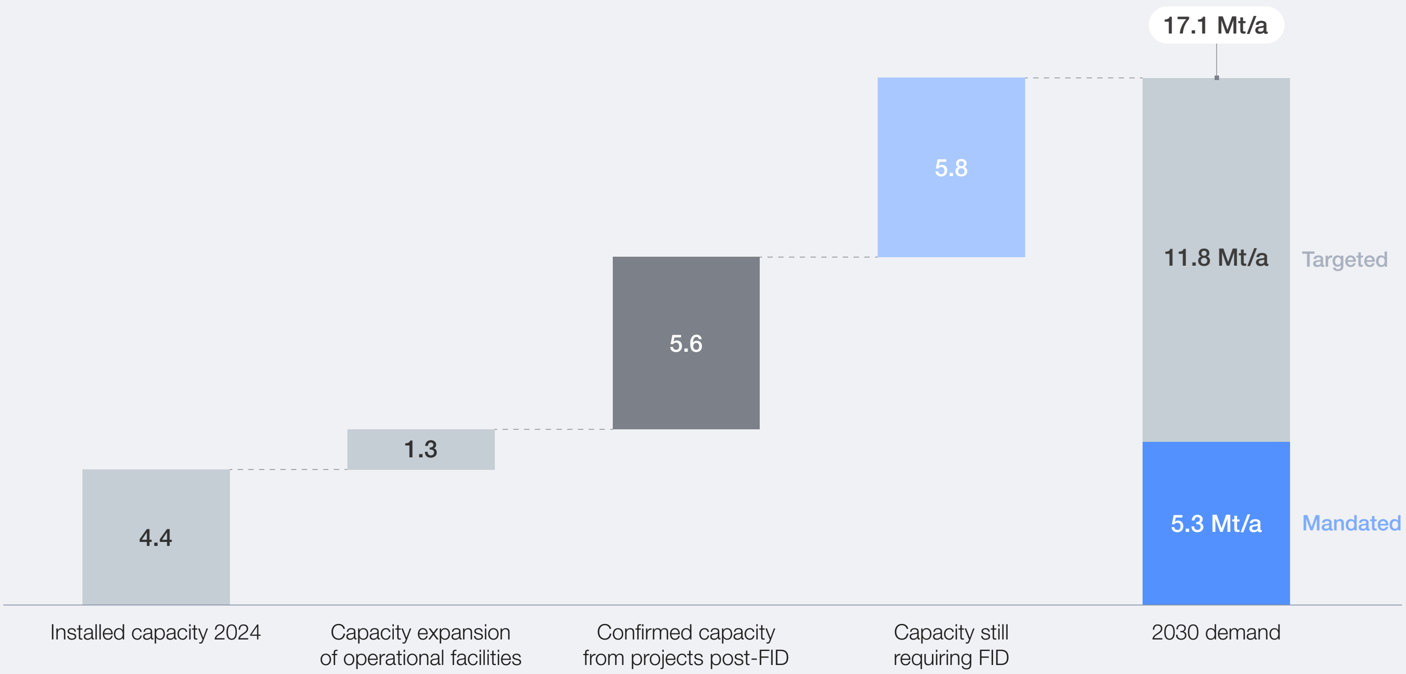


FIGURE 3 | **Overview of SAF capacity ramp-up needed between 2024 and 2030**



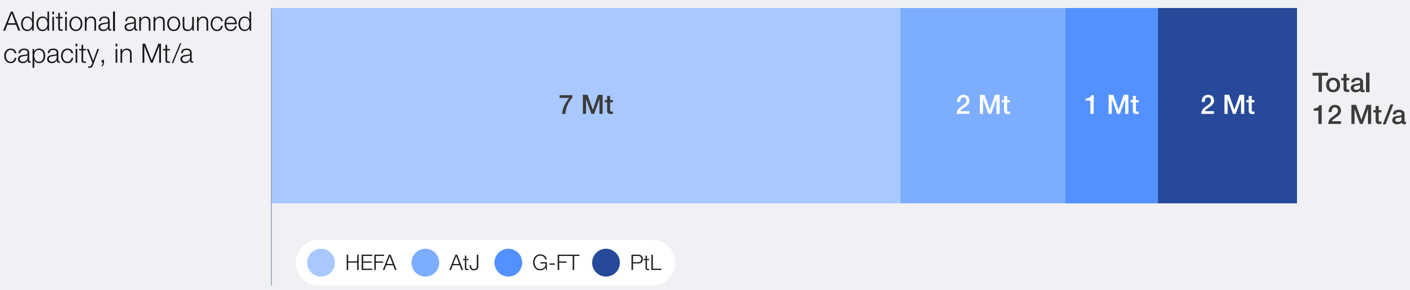
Note: Mt/a = million tonnes per annum. FID = final investment decision.
Sources: Kearney analysis, S&P Platts, International Energy Agency (IEA), airline announcements. Capacity figures include co-processing.

Based on stakeholder consultation and rate of deployment to date, it can take, on average, four to six years for a greenfield SAF production facility to reach its full capacity; consequently this 5.8 Mt of capacity would need to pass FID stage by the end of 2026. Alternatively, reducing the production slate of renewable diesel, currently more profitable and highly sought-after, or opting for the retrofitting of existing fossil fuel refineries could provide a capacity boost, but increasing demand for biofuels in road transport may lead project developers to different revenue optimization strategies.

Regional imbalances will also need to be mitigated. In Europe in particular, current installed capacity will account for 1.7 Mt of annual SAF production. This is only one third of the 5.1 Mt of expected mandated demand driven by ReFuel EU and the UK. As a result, Europe will need to either significantly expand local capacity or rely heavily on imports, most likely from the Americas or Asia.

As of August 2024, a total of 12 Mt of SAF capacity had been announced in the pipeline. To bridge the demand-supply gap identified above, nearly half of this announced capacity would need to pass FID soon. Whereas HEFA currently accounts for 99% of installed capacity, HEFA only represents ~60% of the announced, non-operational capacity, followed by AtJ and PtL each at ~15% and G-FT at 10% (see Figure 4).

FIGURE 4 | **Overview of currently announced SAF capacity (pre-FID)**

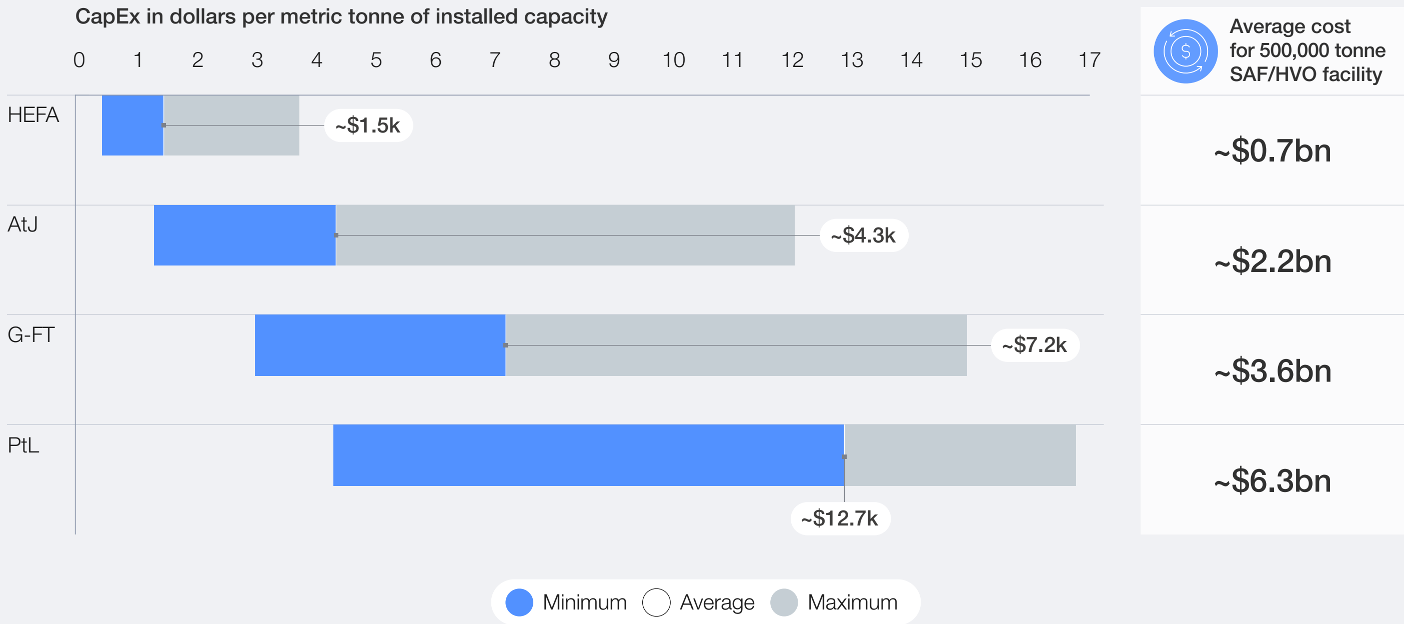


Notes: HEFA = hydro-processed esters and fatty acids, AtJ = Alcohol-to-Jet, G-FT = Gasification-Fischer Tropsch, PtL = Power-to-Liquid.
Sources: Kearney analysis based on market engagement, S&P Global Biofuels Value Chain Service.[6]

1.2 Cost requirements by pathway

Each SAF pathway comes with distinct capital expenditure (CapEx) drivers, largely influenced by the complexity and maturity of the technology and the required infrastructure. Figure 5 provides a boxplot overview of the estimated CapEx of greenfield production facilities, based on a survey of project developers. While the early stage of production makes some of these numbers uncertain, as expected HEFA appears to be the least CapEx-intense pathway, followed by Alcohol-to-Jet and Gasification-Fischer Tropsch. Power-to-Liquid remains the most expensive SAF pathway today.

FIGURE 5 **Overview of CapEx requirements for greenfield SAF refinery, by pathway ($/tonne)**



Notes: 1. HVO = Hydro-treated vegetable oil. **2.** Pricing for PtL is approximate, given lack of reliable datapoints.

Source: Kearney analysis and disclosure from ~50 SAF bio-refineries with minimum capacity of 80kt.

HEFA is expected to remain the most efficient pathway for SAF production until 2030, due to its technological maturity and relatively moderate capital investment requirements.

This analysis has predominantly focused on the main SAF production pathways currently being developed and approved for SAF use in aircraft. To reach sufficient scale, it is important to continue to look at alternative solutions within a pathway as well as completely new pathways. For instance, to expand existing pathways further, such as HEFA, research is being done to overcome feedstock constraints. Examples include Brazilian energy company Acelen Renewables looking into macauba palm oil and GAFT, a Dutch company specializing in green air fuel technology, converting feedstocks using electrolysis and fermentation.

Additional production pathways are also being developed, with companies such as Firefly Green Fuels planning to use hydrothermal liquefaction to transform sewage waste feedstock into SAF. As it is difficult to estimate costs for these nascent technologies, they have not been included in this analysis. It is also worth noting that securing ASTM certification for SAF use in aircraft will be an essential condition to attract investment.

HEFA

HEFA is expected to remain the most efficient pathway for SAF production until 2030, due to its technological maturity and relatively moderate capital investment requirements compared to other SAF pathways. Its efficiency is largely attributed to the use of established hydro-processing technology, which has been employed in the production of most refined fuels for decades, including renewable diesel and jet fuels.

While capital investment for an AtJ facility is generally higher than for HEFA, the pathway remains attractive, especially in regions with abundant ethanol production and infrastructure.

The primary infrastructure needed for a greenfield HEFA facility includes:

1. **Feedstock pre-treatment** to reduce the risk that feedstock impurities poison catalysts and reduce process efficiency. The complexity of these facilities depends on the variety and quality of feedstocks used. Facilities with more homogeneous feedstock may have lower CapEx for pre-treatment compared to plants that can handle a wider range of oils or fats.

2. **Hydro-processing units** that convert lipid-based feedstocks into jet fuel through hydrogenation and isomerization. While commercially proven, these steps still represent a significant portion of the capital expenditure, given the high pressures and temperatures required for the reaction.

3. **Hydrogen production** as a critical input for the hydro-processing reaction. Hydrogen is subject to market availability if supplied from external facilities or can be produced on site, but that will significantly increase the CapEx needs.

Alcohol-to-Jet

While the capital investment for an Alcohol-to-Jet facility is generally higher than for HEFA, due to the complexity of the conversion process, the pathway remains attractive, especially in regions with abundant ethanol production and infrastructure.

Factors that influence the CapEx requirements for an Alcohol-to-Jet SAF refinery are:

1. **Ethanol production**: While many Alcohol-to-Jet facilities rely on external suppliers for ethanol, there may be a strategic or logistical need to integrate ethanol production facilities into the overall SAF project, especially in regions where a stable ethanol supply chain is not yet fully developed. On-site ethanol production significantly increases CapEx requirements, driven by the need for biomass handling, fermentation and distillation.

2. **Alcohol dehydration and oligomerization**: These units are needed to convert alcohols into hydrocarbons and represent a significant portion of the capital expenditure, as they must operate at high temperatures and pressures; they also involve catalysts that need to be replaced periodically.

3. **Feedstock handling**: Given that ethanol is a liquid feedstock, handling and storage infrastructure is less complex than for the lipid-based feedstocks used for HEFA. However, because ethanol is more volatile and flammable, the facility must invest in specialized storage and transport, particularly in case ethanol supply chains are not well developed. Being able to deal with different types of alcohol, such as butanol, would also add to the CapEx requirements.

Gasification-Fischer Tropsch

The Gasification-Fischer Tropsch (G-FT) pathway currently represents a high-CapEx option for SAF production, primarily due to the complexity and scale of the process equipment required. The technology involves the gasification of solid feedstock into syngas (a mixture of hydrogen and carbon monoxide), which is then converted into hydrocarbons through the Fischer-Tropsch process.

The key steps in the Gasification-Fischer Tropsch production that drive CapEx are:

1. **Feedstock pre-treatment and handling**: Different feedstocks require specific pre-treatment steps. Biomass is typically more heterogeneous and challenging to process. In addition, biomass is bulky, has lower energy density and degrades over time, requiring complex supply chain and storage capabilities. In contrast, municipal solid waste or industrial waste streams are generally cheaper to procure, despite having their own challenges, such as regulatory requirements, sorting and cleaning.

2. **Gasification**: This process converts carbon-rich feedstocks into syngas at high temperatures. The infrastructure needed for this represents a large portion of the investment due to the high temperatures and pressures involved. This method also requires complex emission control systems to manage the release of gases and particulate matter, which increases the overall capital investment.

3. **Syngas cleaning and conditioning**: Syngas produced from gasification contains impurities such as sulphur, tar and particulates that must be removed. The syngas cleaning and conditioning stage involves various filtration, scrubbing and chemical processes, each requiring specialized equipment. This phase is critical for ensuring the longevity and efficiency of the Fischer-Tropsch catalysts, but it significantly increases CapEx due to the complexity and precision required.

4. **Fischer-Tropsch reaction**: After syngas is produced it is converted into hydrocarbons through the Fischer-Tropsch process. Fischer-Tropsch reactors require high-capacity infrastructure designed to operate continuously under elevated pressures and temperatures, which also drives significant energy consumption.

The PtL pathway comes at a significantly higher CapEx than other SAF pathways, but unlike the bio-fuels alternatives, it could be easily scaled-up.

5. **Carbon capture and storage (CCS)**: Given the large volumes of CO_2 generated during gasification, integrating CCS technology is becoming increasingly important for achieving negative or near-zero lifecycle emissions. Implementing CCS requires additional capital investment in gas separation, compression and storage infrastructure. In some cases, the CO_2 removed can be reused in other industrial processes, which could offset some operational costs.

Power-to-Liquid

The Power-to-Liquid (PtL) pathway, which produces fuels also known as e-fuels or eSAF, comes at a significantly higher CapEx compared to other SAF pathways. This is driven by the complexity and energy intensity of the process, which involves multiple steps to convert renewable electricity, water and CO_2 into synthetic fuels. Significant innovation will be needed over the years for this pathway to become cost competitive with traditional jet fuel. The benefit however is that this pathway, unlike the bio-fuels alternatives, could be easily scaled-up.

The main infrastructure components that drive CapEx for PtL are:

1. **Electrolysers for hydrogen production from water electrolysis**: These are powered by renewable electricity (e.g. solar or wind). These are currently expensive and require significant energy, resulting in the largest contributor to overall CapEx.

2. **Renewable energy infrastructure**: PtL facilities depend on renewable electricity for electrolysis and other processes. Some projects can use existing grids via power purchase agreements (PPAs), reducing upfront costs. Others may need to build onsite solar or wind farms, where feasible, increasing CapEx but improving long-term energy security. As electrolysers need continuous operations and renewable energy is intermittent, energy storage solutions, such as batteries, can further raise CapEx.

3. **CO_2 capture and conditioning**: PtL pathways need a reliable CO_2 source, which can come from industrial emissions, biomass or direct air capture (DAC). Industrial CO_2 capture usually involves lower CapEx due to higher CO_2 concentrations but requires proximity to emitters. In addition, there are regulatory limitations if CO_2 is captured from industrial processes originated from burning fossil fuel. DAC offers location flexibility but involves significantly higher CapEx due to its energy-intensive process and advanced filtration systems.

4. **Reverse water gas shift and Fischer-Tropsch (FT) synthesis**: After hydrogen and CO_2 are produced and captured, they are converted into syngas and further into hydrocarbons. Unless facilities can rely on existing capacity in close proximity, this will also contribute to overall CapEx.

1.3 Investment needs to meet 2030 demand

The total estimated CapEx commitment required to fulfil demand for SAF by 2030 ranges between $19 billion and $45 billion.

To estimate the total investment requirements to meet the envisaged 2030 SAF demand, three different scenarios have been modelled. The difference in scenario is driven by their pathway mixes:

- **Scenario 1**: HEFA remains the dominant pathway at 99%, assuming feedstocks allow this scale, with some small trials of AtJ, similar to today's existing pathway mix.
- **Scenario 2**: Alternative pathways are showing promising results, slowly taking away some share of HEFA, similar to the pathway mix of projects that recently passed FID.
- **Scenario 3**: Advanced pathways beyond HEFA are scaling-up more quickly, especially with AtJ and PtL gaining more significant market share, each representing ~15% of the pathway mix.

Multiplying the total required capacity of 5.8 Mt (Figure 3) with average investment costs (Figure 5), the total estimated CapEx commitment required to fulfil demand for SAF by 2030 ranges between $19 billion and $45 billion.

TABLE 1 **Overview of total estimated CapEx by scenario**

Scenario 1	% mix	SAF capacity (Mt)	Yield (max SAF)	Plant capacity (Mt)	Cost/tonne ($)	Cost ($ billion)
HEFA	99%	5.75	48%	12.11	$1,500	$18
AtJ	1%	0.06	46%	0.13	$4,300	$0.6
G-FT	0%	–	60%	–	$7,200	–
PtL	0%	–	60%	–	$12,700	–
Total						**$18.6**
Scenario 2	**% mix**	**SAF capacity (Mt)**	**Yield (max SAF)**	**Plant capacity (Mt)**	**Cost/tonne ($)**	**Cost ($ billion)**
HEFA	81%	4.73	48%	9.96	$1,500	$14.8
AtJ	3%	0.20	46%	0.43	$4,300	$1.8
G-FT	6%	0.34	60%	0.57	$7,200	$4.0
PtL	9%	0.54	60%	0.90	$12,700	$11.5
Total						**$32.2**
Scenario 3	**% mix**	**SAF capacity (Mt)**	**Yield (max SAF)**	**Plant capacity (Mt)**	**Cost/tonne ($)**	**Cost ($ billion)**
HEFA	60%	3.49	48%	7.34	$1,500	$10.9
AtJ	15%	0.87	46%	1.88	$4,300	$8.1
G-FT	10%	0.58	60%	0.97	$7,200	$6.9
PtL	15%	0.87	60%	1.45	$12,700	$18.5
Total						**$44.5**

Sources: Kearney analysis based on market engagement, S&P Global data.

2 The project lifecycle and funding needs of a SAF refinery

Financing for a SAF refinery faces a range of policy, market, technology and feedstock risks. This mix of high risks and long payback periods makes for a challenging combination.

2.1 Overview of the SAF project lifecycle

The journey from conceptualization to final investment decision typically spans two-and-a-half to five years.

To fully operationalize a SAF refinery, an operator must navigate through five critical phases (see Figure 7):

1. **Conceptualization and pre-feasibility**, during which an initial SAF plant idea is explored and a conceptual design completed.

2. **Feasibility and front-end engineering and design (FEED)**, to complete technical project specifications and evaluate the likelihood of project success from a techno-economic perspective.

3. **Project financing and final investment decision (FID)**, when budgets, costs and returns are scrutinized to decide whether to progress to construction.

4. **Construction and implementation**, during which a SAF facility is built.

5. **Commissioning and operation**, during which all SAF plant components are installed and tested according to requirements, and fuel production is gradually ramped up to nameplate capacity.

The journey from conceptualization to final investment decision typically spans two-and-a-half to five years. Following this, it generally takes an additional two to three years to reach the commissioning stage, with another couple of years required to achieve full-scale operations.

As of August 2024, there were 90 refineries, both greenfield and retrofitted, that had produced at least one batch of SAF. In addition, around 60 refineries had passed FID and were under construction. More than 200 additional refineries have been announced and find themselves between conceptualization and preparing for the FID.

The funding requirements associated with each project development phase vary. Conceptualization does not often require significant funding. The first significant capital expenditure that a SAF refinery needs is usually for the front-end engineering and design. FEED is a major undertaking as it results in detailed documents needed for creating the engineering, procurement and construction (EPC) contracts, and the costs depend significantly on the complexity of the technology. Once that has passed, fees are limited to legal and advisory fees to help inform and pass the investment decision. This investment decision is the moment where the multi-million or billion dollar investment, depending on capacity and technology, is confirmed.

FIGURE 6 | **Project lifecycle of a greenfield SAF production facility**

1 Conceptualization and pre-feasibility	2 Feasibility and front-end engineering and design (FEED)	3 Project financing and final investment decision (FID)	4 Construction and implementation	5 Commissioning and operation
200+ SAF refineries			~60 refineries	~90 refineries
Identification and preliminary assessment of potentially viable project opportunity that aligns with strategic objectives and market demand.	A comprehensive analysis of the project's technical, financial, environmental and social aspects is conducted.	Lenders and investors commit to providing funding for the project, based on agreed-upon terms and conditions. This phase concludes with the final investment decision by operator.	Contractors are engaged, materials and equipment are procured, and construction activities are undertaken according to the project schedule and specifications.	Revenue generation begins. Debt payments are made to lenders and investor returns are distributed to investors, based on cashflows and financial performance.
$0.5-2m for feasibility studies, initial market research and concept development.	Typically, **$10-15m** for engineering, licensing and feasibility studies. Costs can exceed **$100m** for FOAK advanced pathways.	**$15-30m** for legal fees, financial advisory and support to negotiate and finalize financing and off-take agreements.	Cost depends on pathway selected, ranging from **$0.7bn** for a 500kt HEFA plant up to **$6+bn** for a 500kt PtL plant.	
HEFA: 6-12 months FOAK: 12-24 months	12-18 months	12-18 months	24-36 months	HEFA: 6-12 months FOAK: 12-24 months

Could run slightly in parallel

Note: FOAK = first-of-a-kind. Fully mature and operational plants are also included in this figure.

Sources: Kearney analysis, expert interviews, S&P Global.

> To invest in new technology, investors will want to be reassured that the production pathway has the potential to be used safely in aircraft.

The overall timeline can vary significantly, influenced by several key factors, some of which include factors affecting CapEx requirements as discussed above:

- **Technology readiness level**: The maturity of the chosen production pathway plays a significant role in determining the project development timeline. The HEFA pathway has been successfully proven at a commercial scale and there are early indications of viability for Alcohol-to-Jet facilities. Nevertheless, technical challenges in developing HEFA can also be faced, affecting project timelines and ultimately FID. Facilities using Gasification Fischer-Tropsch and Power-to-Liquid are likely to take substantially longer to be built.

- **Location of the facility**: The choice of location is crucial, as it directly impacts access to essential resources such as cheap renewable energy or green hydrogen, abundant feedstocks and fuel distribution infrastructure. Feedstocks often lie in regions where the infrastructure, regulatory environment and supply chains may be less mature, increasing the likelihood of disruptions and project delays.

- **Experience of the operator**: Operators with experience in constructing and managing large-scale chemical plants can often expedite the project lifecycle, particularly in the initial phases. An operator working on their third or fourth plant may be able to streamline certain processes, reducing the overall timeline. However, finding EPC operators with the appropriate expertise and risk management is challenging, especially as multiple plants look to scale-up simultaneously.

- **External capital requirements**: Securing adequate investment is a complex and time-consuming process. In most cases, multiple sources of financing will be necessary. This will require multiple investors and financing/developing institutions. If a developer can invest substantial equity into the project, this can simplify and accelerate the fundraising process, potentially shortening the project financing phase.

If the proposed technology is not ASTM-approved, this will significantly add to the complexity of project financing. Achieving technical certification entails a four-step approach from fuel specification review to full aircraft and engine testing, which can take three to six years and cost up to $6 million.[7] To invest in new technology, investors will want to be reassured that the production pathway has the potential to be used safely in aircraft.

2.2 Fundraising challenges across the project lifecycle

Each phase is characterized by multiple risks, summarized into four main categories:

– **Policy risk**: longevity of incentives, instability and inconsistency of policies, including unclear or short-term mandates, incentives that favour use of renewable fuels in sectors other than aviation, incompatible regional standards, issues in granting operations or environmental permits and trade barriers.

– **Market risk**: uncertainty and volatility in SAF prices when no fixed-price structure exists, vague or non-binding demand signals, short-term or small number of offtake agreements, offtaker creditworthiness, risk of buyers or producers defaulting and lack of alignment on book-and-claim systems.

– **Technology risk**: technical maturity of FOAK plants, as well as challenges in achieving cost-competitive production and scaling-up operations.

– **Feedstock risk**: feedstock availability (e.g. used cooking oil for HEFA, biogenic CO_2 for PtL), high and volatile price levels and sustainability concerns (e.g. indirect land-use change, competition with food).

Figure 8 provides a high-level overview of which risks are most pertinent for each stage, though it is important to note that the above risks are often interconnected, with policy longevity and consistency being a major driver of the willingness to enter into long term offtakes, as an example.

FIGURE 7 **Overview of key risks by phase**

1 Conceptualization and pre-feasibility

2 Feasibility and front-end engineering and design (FEED)

3 Project financing and final investment decision (FID)

4 Construction and implementation

5 Commissioning and operation

Policy risk

Stability/longevity – limited stability of SAF policies which are not in line with SAF lifecycle, better incentives for other renewable fuels (e.g. biodiesel) resulting in repurposing of SAF facilities

Certification – absence of globally aligned sustainability certification schemes (e.g. CORSIA/GREET/RED)

Permitting – permits not secured on time

Market risk

Commitments – uncertainty around mechanisms related to mandated demand, limited certainty coming from voluntary demand commitments

Off-take – limited appetite to enter into long-term agreements

Default – existing customers default or exercise the exit clause

Scaling – limited scaling potential driven by too large green premium

Technology risk

First-of-a-kind plants – uncertainty driven by low technical maturity of proposed technology, especially FOAK facilities (e.g. G-FT, PtL)

Competitiveness – preference for alternative pathways (e.g. UK HEFA cap) or emergence of cheaper production hubs

Construction – delays driven by operational execution challenges

Scaling – limited economies of scale driven by operational challenges

Feedstock risk

Availability – feedstock sourcing challenges and high prices driven by constrained supply, especially for HEFA pathway

Sustainability – concerns around sustainability of feedstock, especially for HEFA and AtJ

Source: Kearney analysis for Airports of Tomorrow, building on stakeholder input.

SAF facilities present significant challenges due to a combination of high risk and long payback periods. Pension funds, asset managers and commercial banks each face this challenge differently.

1 Conceptualization and pre-feasibility

SAF facilities present significant challenges due to a combination of high risk and long payback periods. For first-of-a-kind (FOAK) facilities, it can take up to eight years from a project's inception to becoming operational, leading to delayed returns and increased uncertainty. Pension funds, asset managers and commercial banks each face this challenge differently. While long-term investors, such as pension funds and asset managers, may be more willing to accept extended payback periods, they are often hesitant to invest in high-risk projects such as early-stage SAF facilities. At the same time, banks, which typically seek quicker returns and lower risk, are even less inclined to participate, as these long timelines and heightened risks do not align with their investment models until projects are closer to commercialization and present a clearer path to revenue generation.

2 Feasibility and front-end engineering and design

During the feasibility and FEED phase, SAF projects encounter steep financial and regulatory challenges. High-cost projections put pressure on the business case and can skyrocket depending on the technical viability of the project. The uncertainty surrounding regulatory frameworks exacerbates these financial pressures. Incentives and policies for SAF production can shift over time or vary significantly by regions. In addition, regulatory timelines do not necessarily align with lengthy project lifecycles. This regulatory fluidity makes long-term planning and financial forecasting difficult for financiers.

Furthermore, SAF production facilities venturing into emerging markets face additional "first-in-market" risks. These markets may have unclear or evolving regulations concerning SAF, adding another layer of complexity to the already challenging task of navigating local policies and ensuring compliance. Scalability concerns, particularly related to feedstock availability and prices, also present significant challenges. The lack of alignment on certification standards across different regions and frameworks further complicates the ability to scale-up operations effectively.

3 Project financing and final investment decision

In the final investment decision phase, the key challenge is securing substantial capital under high-risk conditions. As funding needs grow, attracting investment becomes tougher due to heightened risks, including uncertainties in demand and supply, cash generation capacity and operational success. Project financing is subject to demonstrating economic returns. With uncertain market prices and unclear willingness to pay for the SAF premium, this becomes highly challenging.

Offtake agreements aim to overcome this challenge but are difficult to firm up as fuel represents one of the main operating costs for airlines and can affect competitiveness in a low-margin market. Airlines are not the only offtaker, however, as intermediaries such as commodity trading firms or infrastructure asset owners may also sign agreements and thus reduce the counterparty risk that an airline may bring. This intermediary role is especially pertinent in the tolling model, covered later in this report.

These investments into SAF are often in competition with investments into other clean energy investments, requiring return on investments to be in line with those of other technologies for SAF to be attractive. Additionally, there are ongoing concerns about the availability and cost of feedstock, which represent a significant portion of the total operational expenditure. Uncertainty in feedstock supply can further complicate the financial planning and risk assessments necessary for securing the required capital.

4 Construction and implementation

The construction and implementation phase presents a host of operational and financial risks that need to be meticulously managed. The process of building SAF production facilities is inherently complex, involving advanced technologies and significant logistical coordination. This phase is fraught with potential pitfalls, including construction delays, cost overruns and technical difficulties that could jeopardize the project timeline and budget. Additionally, the implementation phase requires the alignment of various stakeholders, including contractors, suppliers and regulatory bodies, each of which may present unique challenges.

Regulatory hurdles can lead to delays if environmental approvals and permanent operation permits are not secured in a timely manner. Revenue risk will still apply, driven by uncertainty in policies and overall market developments; hence ensuring that the construction remains within budget is critical, as any overruns could strain the developer's financial resources and affect investor confidence. The high-risk nature of this phase requires robust risk management strategies to safeguard against unforeseen complications that could derail the project.

5 Commissioning and operation

In the commissioning and operation phase, fundraising challenges persist as the project shifts from construction to active production. Investors at this stage seek assurance that the facility can operate efficiently and meet its production targets. Any technical difficulties or delays during commissioning and operation can raise concerns about the project's ability to generate consistent revenue, which in turn could result in late-stage plant closures. Bankable process guarantees from the process licensors and EPC contractors are essential to progressing past this stage.

Scaling-up production to meet market demand also requires additional capital, particularly to address any gaps in the supply chain, such as feedstock procurement or logistical capabilities. This need for further investment can be challenging if previous phases have already strained financial resources. Investors will be closely scrutinizing the facility's initial performance, and any early operational issues could hinder the ability to raise additional funds needed for scale-up.

Moreover, the ongoing high costs of SAF production compared to conventional fuels can exacerbate fundraising difficulties, as investors may question the long-term profitability and sustainability of the project at scale. High costs could also limit the scaling-up opportunities once demand by higher-paying first movers is met.

3 Levers for attracting more funding into a SAF production facility

Ten levers can help accelerate investment in SAF – drawn from existing success stories, they comprise public, private and blended finance.

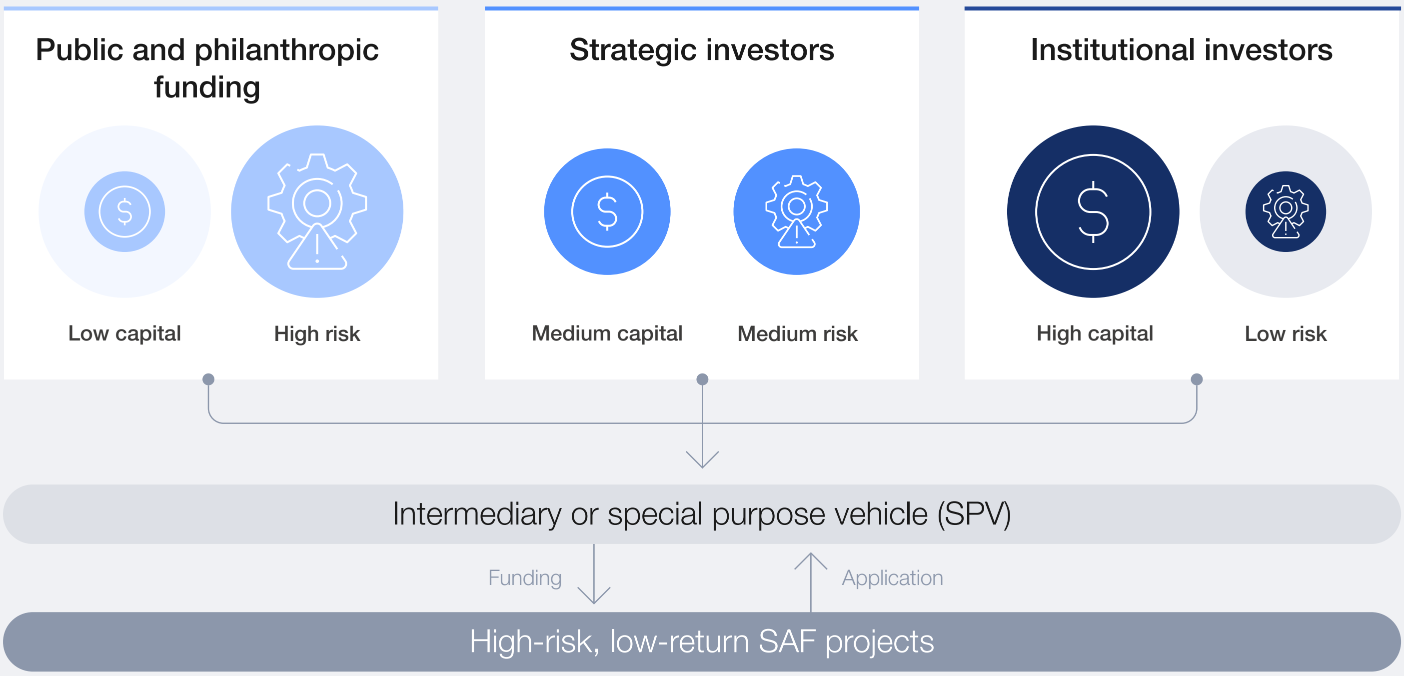
Attracting capital for SAF refineries is a challenging process that requires engaging with a wide range of stakeholders and exploring a myriad of financial instruments and mechanisms (see Figure 9). Based on a range of regional roundtables and interviews within the Forum's Airports of Tomorrow community, 10 levers learned from existing success stories have been identified to help accelerate investments in SAF.

These options should not be pursued in isolation. SAF producers and investors must work together in combining them to provide the best mix of financing and de-risking levers. When both public and private capital are deployed, this is referred to as blended finance.

Blended finance is the strategic use of development finance, philanthropic money and public funds to mobilize private capital flows that would not have otherwise been deployed.[8] It is typically used to finance sustainability projects in emerging markets, but increasingly it is deployed in established markets for new technologies such as SAF. The aim is to provide a balanced risk allocation between commercial, industry and public/philanthropic funding.

The upcoming Finvest Hub initiative, announced by ICAO alongside its goal for a 5% reduction in the carbon footprint of international aviation by 2030, goes in this direction. It will serve as a matchmaker between new projects and public and private investors. In addition, ICAO will work to establish a climate finance initiative or funding mechanism that could attract public capital.

FIGURE 8 **Overview of blended finance investment structure**



Source: Airports of Tomorrow, Organisation for Economic Co-operation and Development (OECD).

The first three levers in attracting finance presented below are related to public funding. Levers four to six are directed more towards the wider industry ecosystem that can help bridge between public and institutional investors. Levers 7-10 are directed towards attracting higher-capital, lower-risk types of investment.

Lever 1

Apply for research/innovation grants to develop first-of-a-kind facilities

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
Low	High	High	High

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
High	High	High	Low	Low

“Grants work well as they are non-repayable and give SAF producers freedom in how they use the funds to achieve project objectives.

Governments and, sometimes, philanthropies can provide critical funding for early-stage, high-risk SAF technologies. This type of investment is critical as the risk profile is too high for most other investors such as institutional investors, industry players and commercial banks. Their support is most often in the form of research or innovation grants.

Governments are interested as they can invest in initiatives that are directly linked to public policy goals and political manifestos, such as reducing carbon emissions, enhancing national energy security and stimulating broader economic growth through the creation of local jobs.

For the recipient, grants work well as they are non-repayable and are usually available for a broad range of activities. This gives SAF producers freedom in how they use the funds to achieve project objectives. While grants are non-repayable, they come with accountability measures such as reporting and performance evaluations to allow governments to track the impact of their investments.

Government grants are likely to be provided to aspiring SAF producers who have not yet secured large equity investments. Amounts range from a few hundred thousand dollars to multi-million dollar grants.

CASE STUDY 2

UK's Advanced Fuels Fund investment into Alfanar Energy

What? The £165 million Advanced Fuels Fund (AFF) was launched by the UK Government in December 2022 as part of a broader strategy to promote the development and commercialization of SAF within the UK.

It targets SAF pathways that can deliver at least 70% fewer greenhouse gas emissions than conventional jet fuel. AFF complements other UK government efforts, including mandating at least 10% SAF use in aviation by 2030.[9]

The fund is aimed at all development stages up to the start of construction. The proposed plant must already be at a technological readiness level (TRL) of 5 (pilot plant) to be eligible to apply; and it must achieve a TRL of at least 6-8 (small demonstration, large demonstration or FOAK commercial scale) once operational.[10]

How? A total of £135 million was invested across 13 projects (four AtJ, four G-FT and six PtL projects). The selection of projects was defined by four criteria:

1. **Project relevance** (5%): Clarity of the project objectives and relevance to the fund's objectives.
2. **Technical approach** (30%): Assessment of the credibility, innovation and progress of the technological approach, fuel certification and the expected environmental impact of the proposed plant.
3. **Commercial approach** (20%): Assessment of the economic viability, including potential benefits in job creation, revenues and the broader impact of future deployment and export opportunities.
4. **Project implementation** (45%): Assessment of readiness, skills, management, detailed planning and financial feasibility of the project, ensuring it can be successfully executed with the allocated funds.

Impact: The Lighthouse Green Fuels project developed by Alfanar is one of the largest investments made by the AFF, with just under £20 million in funding spread across two tranches. Before this, the Lighthouse Green Fuels project had secured ~£2 million from previous UK government funding competitions. The funding allowed Alfanar to advance its engineering and engage with technology providers. The funding was critical to Alfanar since the development of the project had started before any SAF legislation (e.g. SAF mandate) had been announced or put in place.

Lever 2

Leverage local expertise of multilateral development banks to navigate developing markets

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
High	High	High	High

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
High	High	High	Low	Low

> MDBs provide valuable technical expertise and capacity-building support in the early stages of a project.

Multilateral development banks (MDBs) and development finance institutions (DFIs) can play a crucial role in supporting SAF projects, especially in markets with more complex regulatory and operational environments. Their support typically unfolds across two main stages:

1. **Early-stage support**: MDBs provide valuable technical expertise and capacity-building support in the early stages of a project. They might support in conducting feasibility studies including market analysis, feedstock assessment, technical feasibility, infrastructure reviews and regulatory assessments. If investable projects have not yet been identified, MDBs can support policy-makers in developing an overall SAF roadmap. MDBs can also play a role in fostering cross-industry collaborations that bring together the aviation, energy, financing and policy sectors.

2. **Investment-stage support**: As projects move closer to FID, MDBs often show strong willingness to invest either through debt or equity. In addition, they could also provide loan guarantees or other de-risking mechanisms. Having been involved early, MDBs gain a deep understanding of the project's risk profile, making them well-positioned to make informed investment decisions.

The International Finance Corporation (IFC – part of the World Bank Group), FMO (Dutch Entrepreneurial Development Bank), IDB Invest (part of the Inter-American Development Bank Group), the Asian Development Bank (ADB) and the European Bank for Reconstruction and Development (EBRD) are among the most active MDBs and DFIs in climate blended finance. Many of these players, such as the IFC and EBRD, are committed to aligning 100% of their board-approved real sector operations with the Paris Agreement. This has resulted in an increase in the activity of these institutions in climate-related investments, including SAF.

Beyond overall market viability and ensuring alignment to sustainability goals, MDBs typically put particular focus on the following criteria when scanning for the right opportunities in SAF:

1. **Geographical focus**: MDBs will have a clear regional focus based on the donor profile of the bank.

2. **Social impact and inclusivity**: MDBs prioritize projects that tackle social challenges and foster inclusivity, such as creating jobs, promoting gender equality and supporting marginalized communities.

3. **Cross-industry collaboration**: MDBs cultivate long-standing relationships with diverse industry stakeholders, making investments more appealing when they engage multiple clients across the aviation and energy space.

CASE STUDY 3

EBRD's collaboration with KazMunaiGas and Air Astana

What? EBRD's geographic focus is centred around Central, Eastern and South-Eastern Europe, including Turkey, Eurasia and Southern and Eastern Mediterranean. On SAF, one of its focus countries is Kazakhstan where EBRD has actively supported KazMunaiGas and Air Astana in analysing the feasibility of producing SAF locally.

How? This funding was triggered by EBRD's support of KazMunaiGas's decarbonization plans over the past few years and a recent investment made by EBRD in Air Astana. The support from EBRD was mainly in the form of financing for an initial feasibility study which included:

1. **Decarbonization strategy definition**: Identifying decarbonization targets specific to the aviation sector, benchmarking Kazakhstan's goals against global standards and offering recommendations to enhance ambition.

2. **SAF market analysis**: Conducting a demand and supply assessment, examining feedstock availability and defining SAF project parameters.

3. **Technology and economic evaluation**: Offering an overview of viable technologies, conducting a techno-economic assessment in collaboration with technology providers.

4. **Offtake and regulatory development**: Creating a template for SAF offtake agreements and suggesting regulatory reforms to support SAF market development.

Impact: The study identified Alcohol-to-Jet as the most promising pathway to scale-up SAF in Kazakhstan, which is now being further explored. In the future, if a project reaches FID, EBRD could play a financing role in line with its mandate to support low-carbon transitions. EBRD could also help coordinate additional investment from multiple stakeholders to scale-up SAF production. To attract other investors, EBRD can play a role in offering other de-risking measures such as first-loss capital or loan guarantees.

Lever 3

Secure guarantees or insurance instruments to enhance credit profile

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
Medium	High	High	High

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	High	High	High	Low

Public capital plays a critical role in mitigating technical and operational risks.

Early-stage FOAK SAF facilities often face heightened risks. Even after securing government grants, patient capital and potential technical assistance from MDBs, additional targeted de-risking measures will be needed to counter some of the technical and operational risks. Public capital plays a critical role in mitigating these risks, employing a variety of financial instruments that make SAF projects more bankable and appealing to private investors. The following five interventions are key tools used to reduce risk and support the viability of SAF projects in their nascent stages, although their availability for SAF is constrained to certain regions and often allocated competitively:

1. **Loan guarantees**: A promise by a guarantor (e.g. a government or development bank) to cover the loan in case of default, reducing lender risk and improving access to credit.

2. **Government underwriting**: The government commits to cover certain risks or losses, often to catalyse investment, especially in developing markets.

3. **Insurance solutions**: Specialized insurance products (e.g. political risk or currency risk insurance) that mitigate specific project risks to attract private capital. Examples include completion guarantees, where project sponsors agree to provide subordinated financing or equity contributions if needed to ensure construction is completed. Guarantors should have investment-grade ratings in order to credibly deliver such solutions, and governments may provide such options if no reliable guarantors exist.

4. **First-loss capital or guarantee**: A layer of capital that absorbs initial losses in a project, protecting other investors and encouraging further participation.

5. **Concessionary loans**: Loans provided at competitive interest rates in markets where such loans are not typically available, or with more lenient terms (e.g. longer tenure), making it easier for projects to finance debt and attract private capital.

CASE STUDY 4

US Department of Energy loan guarantee program

What? The US Department of Energy (DoE)'s Loan Programs Office (LPO) is a federal initiative that provides financial support to accelerate the commercialization and deployment of innovative energy projects and technologies. By providing loans, loan guarantees and other forms of financial assistance to innovative, large-scale renewable energy, advanced transportation and energy efficiency projects, the LPO aims to accelerate closing the gap between early-stage innovation and market adoption.

How? As of August 2024, 211 active applications across a wide range of industries were submitted with a total of $296 billion of loans requested.[11] The application is a multi-step process:[12]

1. **Pre-application**: LPO meets with potential applicant to discuss project eligibility, application process and applicant questions.
2. **Application and review**: LPO establishes project eligibility and readiness to proceed, followed by programmatic, technical and financial evaluation.
3. **Due diligence**: LPO and applicant engage third-party advisors to cover technical, market, financial, credit, legal and regulatory reviews and negotiate term sheet.
4. **Conditional commitment**: LPO offers term sheet for loan or loan guarantee. The offer is contingent on the borrower satisfying certain conditions.
5. **Financial close**: LPO and borrower execute definitive financing documents, subject to additional conditions ahead of loan disbursement.
6. **Monitoring**: LPO monitors project and acts as trusted party for the life of the loan.

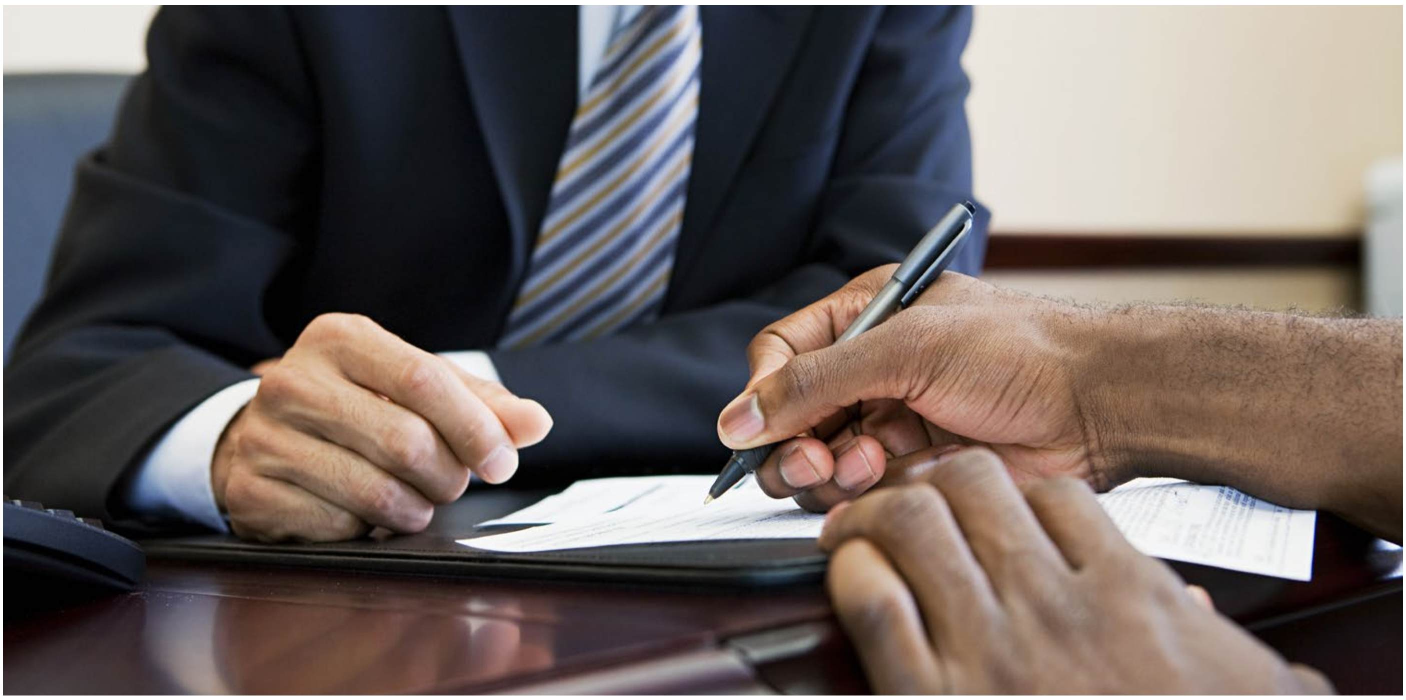
It is important to note that while the LPO can lend up to 80% of project cost by statute, it is more common to see a loan-to-value of 50-70%. As a result, project developers need to ensure enough equity investments have been secured to unlock the additional guarantees.

Impact? By October 2024, the DoE LPO had supported 67 projects with a total of $65 billion awarded. Just over half (37 projects at $37 billion) had been through loan guarantees. In October 2024, the US DoE LPO also announced nearly $3 billion in loan guarantees for two SAF projects.

In addition, many US producers are in the process of securing approvals. For example, World Energy has been invited to submit a Part II Application for a ~$2 billion loan guarantee for its planned Houston production facility through the Title 17 Clean Energy Financing Program.

Securing an LPO loan guarantee has significant benefits. First, it will drive more interest from institutional lenders, as companies securing loan guarantees are considered reliable and future-proof, having successfully completed a thorough due diligence process. Second, it results in lower interest rates driven by the de-risking nature of the loan guarantee.

At the date of publication of this report (February 2025), after the new US administration took office, it is unclear whether the US DoE Loan Programs Office and wider federal funding programmes, including for SAF, will be taken forward in their current form, and the implications for SAF projects awaiting support are not yet known.



Lever 4

Attract strategic industry investors to build an ecosystem for future scale

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
Medium	High	High	Medium

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

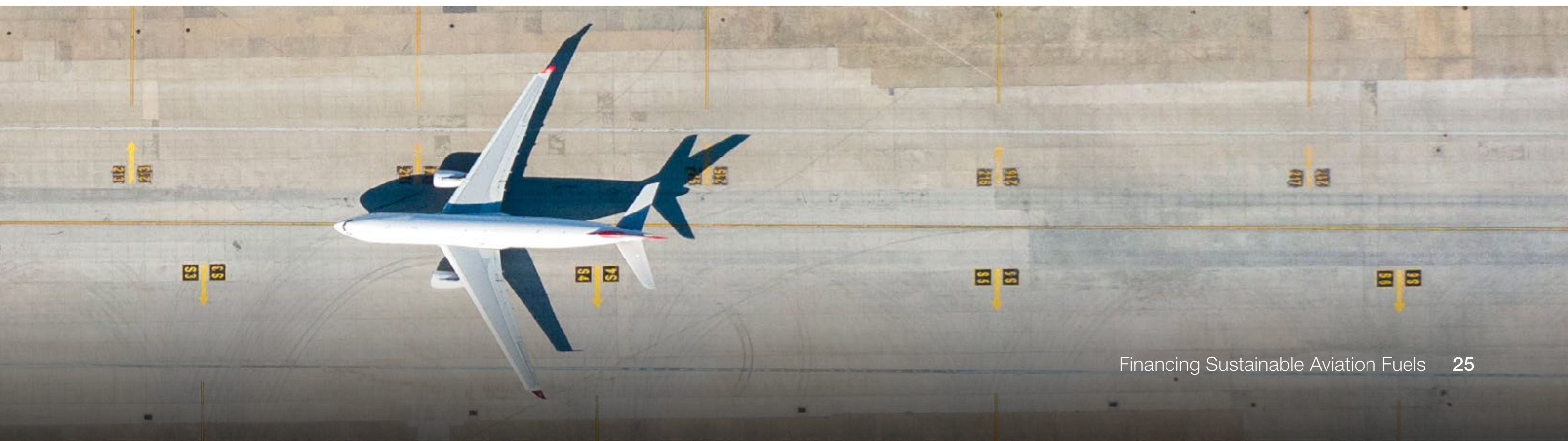
Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	Medium	High	Medium	Low

Strategic industry investors, such as airlines and OEMs, have other motivations beyond pure financial returns – many of them likely see SAF as a 'licence for aviation to operate'.

Strategic industry investors, such as airlines and OEMs, are investors that have other motivations beyond pure financial returns. Many of them likely see SAF as a "licence for aviation to operate". SAF is essential for these industry investors to maintain their operational legitimacy and meet regulatory and stakeholder expectations regarding sustainability.

These investors want to accelerate the commercialization of projects with significant scaling-up potential while balancing the overall risk-profile. As a result, it is likely that AtJ and G-FT are the most likely investments, although PtL is becoming increasingly attractive as the technology matures, as shown by recent investments. Strategic industry investors include the following:

1. **Airlines**: Airlines see SAF as (one of) the most important decarbonization levers. While often criticized for "not doing enough", several airlines have put more skin in the game by investing directly in SAF producers and carrying some of the risks. Through these investments, on top of carbon savings, airlines hope to gain preferential access to SAF produced in the future to meet voluntary and government commitments, and potentially lock-in attractive market prices.
2. **OEMs**: Aircraft are currently certified to fly with up to 50% SAF blend. Ensuring there is sufficient and affordable access to SAF will facilitate orders for conventional aircraft and align with developing green aviation taxonomies, while zero-carbon emission propulsion is developed.[13]
3. **Airports**: Airports see growing pressure from airlines to ensure physical supply of SAF. As a result, they may invest in SAF infrastructure and potentially even projects, to attract airlines committed to sustainability and provide an incentive in an increasingly eco-conscious industry.
4. **Energy and oil companies**: SAF offers a solution to move away from fossil fuels, especially when blending limits will be lifted. By being early movers in SAF, energy companies and fuel suppliers can protect their market share in aviation fuel as demand for green alternatives grow, while reducing the impact of their operations.
5. **Feedstock suppliers**: SAF can unlock new revenue streams and strong demand signals for feedstock products. These companies could opt for vertical integration, ensuring that their agricultural or waste products are used in SAF production.



CASE STUDY 5

Strategic investments in LanzaJet

What? Between 2021 and 2024 LanzaJet managed to secure funding from a wide range of investors. Beyond financiers (e.g. Breakthrough Energy, Microsoft's Climate Innovation Fund, Mitsui & Co. and Mitsubishi UFJ Financial Group), investors include airlines (e.g. All Nippon Airways, British Airways and Southwest Airlines), airports (Groupe ADP), OEMs (Airbus) and energy players (e.g. Shell and Suncor Energy).

How? LanzaJet purposefully built a varied group of strategic investors, including prominent global companies, to create the ecosystem needed for scaling-up the SAF industry. All Nippon Airways was one of the first strategic investors back in 2019. The carrier recognized early on the need for the full industry to come together to share the risks across the value chain. One of the latest investments, made by Airbus in 2024, demonstrates the importance aircraft manufacturers can play in SAF scaling-up while developing hydrogen and battery-electric aircraft. Equity investments raised through these strategic investors form a key source of funding for projects such as the Freedom Pines plant. For that plant, this funding was complemented by a $50 million grant from Breakthrough Energy Catalyst, a $50 million loan from Microsoft Climate Innovation Fund and a $14 million grant from the US DoE.

Impact: These different sources formed a robust blended finance model, helping LanzaJet achieve multiple objectives:

1. **Close the green premium**: By attracting loans and grants, LanzaJet was able to reduce the green premium of SAF vs. Jet A fuel, making their products more competitive in the market.
2. **Spread risk across the value chain**: The involvement of such a diverse set of investors has enabled LanzaJet to move the risk related to SAF scaling-up from the SAF producers to the full SAF value chain.
3. **Improve confidence in Alcohol-to-Jet technology**: These strategic investments helped prove to larger investors that the technology works at scale and as a result increased the likelihood of attracting more funding for future plants (beyond FOAK).

Lever 5

Secure long-term offtake agreements to pass FID

Funding Source		
Public funding	**Industry funding**	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
High	High	High	High

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	Low	High	Low	Low

One of the biggest hurdles to FID is obtaining secure long-term offtake agreements. If set up in the right way, these offtake agreements provide a predictable revenue stream for the project developer and significantly reduce demand uncertainty, making the project more attractive to investors.

As explained in the World Economic Forum's *Scaling Clean Technology Offtakes: A Corporate Playbook for Net Zero*,[14] published in May 2024, a bankable offtake agreement is characterized by the following key components:

Offtake agreements provide a predictable revenue stream for the project developer and significantly reduce demand uncertainty, making the project more attractive to investors.

1. **Offtake credibility**: Banks look for companies with long-standing credit history, a healthy P&L and plans to use the committed volumes.

2. **Offtake T&Cs**: Currently, contracts are often non-binding Memorandums of Understanding (MoUs). For a project to reach FID, contractually binding agreements are needed.

3. **Offtake duration**: The contract needs to cover the tenure of debt financing (e.g. 8-14 years), and the duration of any incentives supporting offtakes would ideally be aligned with the tenor of the contract.

4. **Offtake pricing**: Pricing should be roughly in line with other competitive offtake agreements to avoid contract breaches from offtakers as well as suppliers. As the SAF market is still nascent, lenders generally expect a fixed offtake price set in the contract. Offtake agreements often have a risk-sharing mechanism in place between producers and offtakers.

With regards to the negotiated volumes, investors often require at least 70-80% of annual capacity to be covered by offtake agreements. Some lenders even require 100% of the SAF produced to have reliable offtake covering the full loan tenor. This reliability is also defined by the creditworthiness of the offtakers. Airlines on average have a lower credit rating and spreading the risk of default across multiple parties is an important de-risking consideration.

If there is a merchant portion (i.e. no offtake contract portion), lenders would expect thorough market due diligence on the feasibility of selling the merchant portion and generating stable revenue for the project throughout the loan tenor. However, because the SAF market is still nascent and SAF does not have a well-established market price, lenders may find it difficult to accept the merchant risk.

Consequently, lenders may choose to finance only based on the revenue generated from the offtake agreement, excluding revenue from merchant or spot sales from the debt sizing. This approach could result in smaller loans than project sponsors may desire.

Risk-sharing can take many forms. Five pricing or contract structures for SAF offtake agreements have emerged (see Table 2). In general, the higher the risk-sharing, the better the overall bankability of the offtake agreement.

TABLE 2 **Overview of different contract structures**

	Flat/fixed pricing	Jet fuel – plus premium	Cost-plus	Take-or-pay	Ownership
Description	Contracts where price of SAF is locked in for agreed-upon quantities, regardless of change in jet-fuel market price or cost of inputs.	Offtakers take agreed-upon quantities at the price based on the market index of fossil jet fuel (e.g. jet fuel price monitor), plus a green premium.	Offtakers take agreed-upon quantities at the price of input costs at the time of production, plus a margin.	Offtakers pay for the products on a regular basis, whether or not they actually take delivery of the products.	Offtakers take any quantity at the cost of production, in exchange for investment capital and risks (mainly through JV).
Risks shared by offtakers					
Security of supply	✓	✓	✓	✓	✓
Feedstock risk			✓	✓	✓
Technology risk				✓	✓
Construction risk					✓
Considerations	– Uncommon as risky for producer	– Most common pricing – Expected to grow more challenging as gap widens between HEFA feedstocks and Jet A indices	– Adopted by some SAF producers and common among energy players – Less risky for producers with feedstock constraints	– Very high risk for offtakers, but growing as strongest bankable signal towards financiers	– Adopted by a few large energy players – Unlikely to be adopted by airports and airlines, due to capital investment needed; but some may be able to take an equity stake in SAF plants.

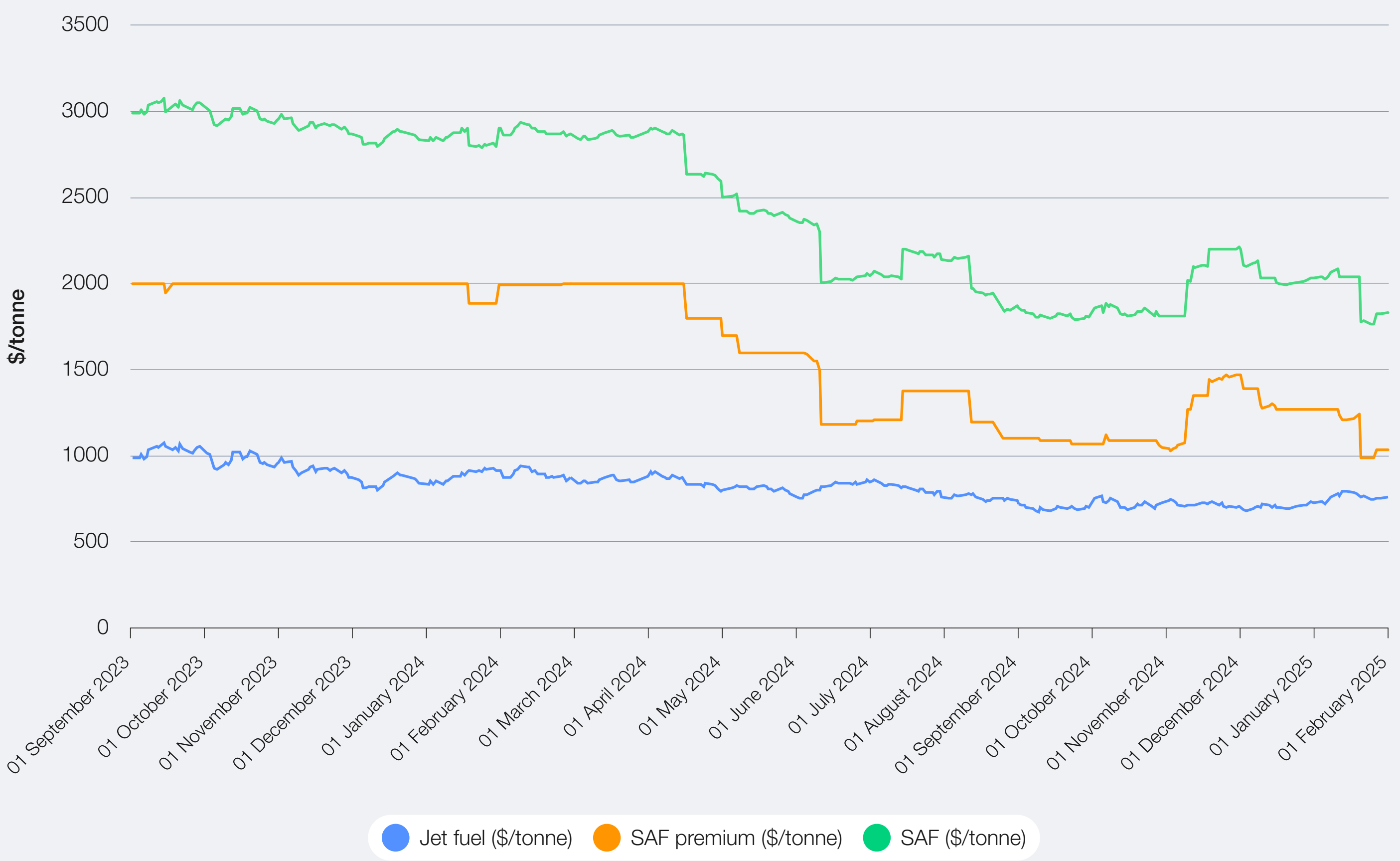
Sources: World Economic Forum, *Scaling Clean Technology Offtakes: A Corporate Playbook for Net Zero*.

A SAF premium of 2-3x and a blend of 10% SAF would see the price of a ticket increase by ~3-6%.

One of the challenges associated with offtakes often mentioned by industry is price. Today's SAF premium is posing a challenge to voluntary adoption and could potentially drive demand for air tickets down, especially in emerging markets where the sector is now growing, SAF mandates are not in place and competition between airlines is high. It may also drive opposition to higher mandated blends that governments could introduce to stimulate the market.

Since regulations change frequently, airlines' decisions to offtake more SAF compared to conventional jet fuel will be driven by price competitiveness. Based on SAF market prices between 2023 and 2024, SAF remained two to three times more expensive than conventional jet fuel (see Figure 9). Assuming fuel represents a quarter to a third of the ticket price,[15] a SAF premium of 2-3x and a blend of 10% SAF would see the price of a ticket increase by ~3-6%. The more this gap can close over time, the more likely voluntary demand will grow. Nevertheless, some airlines have already accepted and passed on this price premium and actively use and offtake SAF.

FIGURE 9 **Overview of jet fuel and SAF prices in Europe, including price premium**



Notes: 1. All prices are quoted as CIF (cost, insurance and freight price, i.e. the price of a good at the border including insurance but before duties); based on north-west Europe (NWE) prices. **2.** The bottom line is the cost of jet fuel; the middle line is the premium payable for SAF; the sum of these two = the top line, which is the cost of SAF in NW Europe.
Source: S&P Global Commodity Insights (formerly Platts).

CASE STUDY 6
IAG off-take agreement with Twelve

What? In February 2024, International Airlines Group (IAG) announced its largest SAF purchase agreements with Twelve, a Power-to-Liquid SAF producer and one of the winners of the World Economic Forum's UpLink Sustainable Aviation Challenge. Both parties agreed on a 14-year contract during which IAG will be supplied with 785,000 tonnes of e-SAF.

How? The collaboration between IAG and Twelve began in 2020, when Twelve joined IAG's Hangar 51 start-up accelerator programme to bring its innovative technology to market. Since then, the following four factors have accelerated the signing of their most recent offtake agreement:

1. **Technological rigour**: Twelve delivered e-SAF to the US Air Force, which conducted significant testing to demonstrate the technology. IAG undertook a range of site visits to Twelve's labs, testing and production facilities.

2. **Financial backing**: Twelve had secured $130 million Series B funding and received conditional funding (pending offtake agreement) of up to $645 million by TPG Rise Capital.

3. **Commercial traction**: Twelve had secured partnerships with Alaska Airlines for scope 1 and Shopify and Microsoft for scope 3 credits.

4. **Strategic alignment**: IAG and Twelve worked closely together on product development (including lifecycle assessments), ensuring the SAF from Twelve fits within IAG's broader decarbonization plans.

Impact: The duration, volumes and structure of the offtake agreement significantly improved the overall bankability of Twelve's projects. As a result of this, Twelve managed to unlock up to $645 million in funding, of which the majority ($400 million) was in project equity led by TPG Rise Climate and $200 million was in Series C financing. In addition, Fundamental Renewables, a clean energy investment firm, issued a $25 million construction loan, while Sumitomo Mitsui Banking Corporation, a multinational bank, provided a $20 million green loan. All these investments combined mark one of the largest financing rounds to date in the PtL fuel space.

Lever 6 Engage in book-and-claim to facilitate investments

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
High	High	High	High

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	Low	High	Medium	Medium

Another promising way to procure SAF and allow the cost of scaling-up SAF to be shared across a wider stakeholder group is through buying SAF credits transferred through a book-and-claim registry. A book-and-claim system allows buyers in one part of the world to pay for the green premium and receive the associated credit of using SAF, even though the physical SAF is used in another location. Unlike carbon offsets, which compensate for emissions already released through investing in out-of-sector projects, such as afforestation, the procurement of SAF using book-and-claim is a "carbon inset", meaning that companies can invest in a project that reduces the carbon emissions of the aviation sector directly. Book-and-claim tools can facilitate this process.

> The benefit of book-and-claim is that it allows for revenue diversification, by attracting players throughout the value chain, and spreads the SAF premium across a wider range of stakeholders.

A wide range of organizations can get involved in book-and-claim to inset their scope 3 emissions, including corporate travellers. Businesses often have significant scope 3 emissions arising from employees' travel (category 6). In addition, shippers or freight forwarders can play a big role in reducing the carbon footprint of products being shipped by air. The role of other players such as financiers, lessors or airports with scope 3 is also being explored.

The benefit of book-and-claim is that it allows for revenue diversification by attracting players throughout the value chain. In addition, it spreads the SAF premium across a wider range of stakeholders. The World Economic Forum has published guidelines on the establishment of a SAF credit (SAFc) system. To prevent double counting, the SAFc system follows strict accounting rules: according to book-and-claim registry standards[16] and best practice, the scope 1 claim must be retired prior to the scope 3 retirement, to ensure accurate accounting of carbon reduction claims.

It is important to note that there are several open questions related to the recognition of SAF as an eligible scope 3 emissions reduction strategy under the Greenhouse Gas (GHG) Protocol and Science Based Targets initiative (SBTi), with unclear accounting implications for stakeholders across the value chain. This includes guidelines for airports, some of which are already reporting aircraft-related well-to-tank emissions as scope 3, but further guidance is needed to confirm the best way to report emissions.

Both the GHG Protocol and SBTi guidance are expected to be updated in 2025, providing more clarity and certainty to book-and-claim transactions in the future. Even without updated guidance, however, many organizations are disclosing the emission savings related to SAF's environmental attributes (SAFc) separately as part of their annual reports. It is expected that, once formally recognized, book-and-claim systems may become more popular with corporates, as they will be able to leverage SAF to achieve their formally recognized net-zero ambitions.

A SAF registry is often needed to unlock the potential of book-and-claim systems and ensure consistency and transparency in the process, thus avoiding double-claiming and double-counting. A registry is a database that records the issuance, transfer and retirement of SAF certificates, thereby logging transactions. There has been a rise in the number of registries in recent years. Examples include:

- RSB Registry, created by the Roundtable on Sustainable Biomaterials Association (RSB)
- SAFc Registry, created by the Sustainable Aviation Buyer's Alliance (SABA)
- ISCC Credit Transfer System, created by the International Sustainability and Carbon Certification (ISCC) initiative
- The International Air Transport Association (IATA) is also working on a SAF registry.

It is critical that SAF producers transfer these SAF credits to a registry to ensure they meet robust sustainability standards. At the point of blending with fossil jet fuel to meet fuel standards, a SAF producer needs to decouple the environmental attributes from the physical fuel. Afterwards, the environmental attributes are entered into a SAFc registry as scope 1 and scope 3 claims associated with a specific batch of SAF. These claims are transferred to the buyer after the registry validates the required documentation for the claims. Documentation for entering SAFc onto the registry requires in-depth proof of sustainability information, including independent verification of compliance with a fuel certification scheme (e.g. the ICAO-recognized RSB CORSIA certification), as well as independent certification of carbon intensity, the feedstock supply chain and facility management systems.

CASE STUDY 7

SAF certificates through Sustainable Aviation Fuels Buyers Alliance (SABA)

What? Led by the Rocky Mountain Institute (RMI), the Environmental Defense Fund (EDF) and Neoteric Energy and Climate (now part of the Center for Green Market Activation), the Sustainable Aviation Buyers Alliance (SABA) is driving increased investment in adoption of SAF, helping businesses reduce their air travel-related carbon emissions.

How? SABA collaborated with aviation customers, airlines and fuel producers to create a robust and transparent system for businesses to purchase SAF certificates through SkyNRG, or to purchase fuel directly from SAF producers such as World Energy through a first-of-a-kind joint procurement process.

World Energy, one of the leading fuel producers, sells a bundled Scope1/3 product. If a scope 3 customer buys the SAFc, the customer has the flexibility to allocate the scope 1 to its airline partners, as it chooses. If an airline buys the bundled product, they typically sell the scope 3 to their corporate partners looking to reduce their business travel emissions and the emissions from the movement of freight or goods. Scope 1 and scope 3 claims are associated with the same batch of SAF, and their retirement must be closely coordinated to ensure that the scope 1 claim is retired prior to or in parallel with the scope 3 claim, consistent with current RSB Book-and-Claim Manual rules.

Impact: In April 2024, SABA announced the largest ever collection of deals to purchase SAF certificates. In total, close to $200 million of investment has been raised across a wide range of players, including AstraZeneca, Autodesk, Bain & Company, BCG, Deloitte, JPMorgan Chase, Live Nation, McKinsey & Company, Meta, Morgan Stanley, Netflix, Novo Nordisk, Samsung Biologics, Watershed and Workday, alongside SABA founding organization RMI. These commitments are equivalent to approximately 50 million gallons of high integrity SAF, or roughly 3,000 fully loaded passenger flights from New York City to London.[17]

CASE STUDY 8

Microsoft and OMV decarbonizing business travel & logistics (corporate & fuel supplier collaboration on SAF certificates)

What? Microsoft and OMV signed an agreement to help Microsoft reduce its scope 3 indirect emissions caused by business air travel and supply chain logistics.

How? Microsoft and OMV collaborated to define a specific volume of scope 3 aviation-related greenhouse gas emissions that Microsoft would like to reduce through SAFc. OMV translated this into physical SAF production volume required to meet Microsoft's ambition. This volume was produced through the simultaneous processing of bio-feedstock alongside crude oil in OMV's refinery in Schwechat, Austria. This co-processing model used sustainable and regionally sourced raw materials (e.g. used cooking oil) to produce up to 5% SAF alongside the refinery's fossil-based kerosene output, which is physically delivered into Vienna Airport's fuel storage. The environmental attributes (i.e. GHG emissions reduction values) connected to this specific production volume formed the basis for the registration of SAFc. These SAF credits were reliably transferred via the ISCC Credit Transfer System to ensure full traceability and credibility. Microsoft then retired the SAFc and will use it for reporting lowered emissions in its sustainability report.

Impact: This corporate offtake sent a strong early demand signal from the voluntary market for SAF production in Europe. For Microsoft, it was crucial to explore and demonstrate maximum additionality following ISCC certification, thereby supporting committed European fuel suppliers such as OMV on their transition journey, going beyond any mandates. This agreement reinforced OMV's SAF growth ambitions, including the recent FID for its large-scale SAF/HVO plant in Petrobrazi, Romania.

Additionally, the agreement enables Microsoft to drive SAF adoption beyond the US, aligning with its global business and emissions footprint. While thinking globally, Microsoft valued the local sourcing of feedstock for the SAF in this agreement. Finally, the close collaboration between Microsoft and OMV with digital registry providers (e.g. ISCC) supported the advancement of global industry standards, allowing corporate buyers to directly benefit from the scope 3 emissions reduction opportunities offered by SAFc.

Lever 7

Attract private equity capital to achieve rapid expansion

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
High	High	High	Medium

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	Low	High	High	High

Private equity investors play a pivotal role in scaling-up SAF projects by providing the growth capital required to accelerate commercialization and expand the operational footprint of a business. Unlike early-stage investors focused on research and development, private equity firms typically enter SAF projects when they are on the cusp of commercial viability and poised for rapid expansion. At this stage, SAF producers often require capital not only for infrastructure construction but also for scaling-up their production processes, optimizing supply chains and achieving economies of scale.

In addition to capital injection, private equity investors often bring management expertise and industry connections, helping SAF producers gain access to crucial markets and potential offtake partners, such as major airlines or logistics companies. This hands-on involvement is aimed at rapidly scaling-up production capacity, improving cost structures and positioning SAF companies for a profitable exit, whether through mergers, acquisitions or public offerings.

CASE STUDY 9

Kerogen and Bain Capital investments in EcoCeres

What? In late 2021, EcoCeres raised $108 million in funding from Kerogen Capital, a specialist energy investor. This represented the first external funding round for the company, which had been incubated by Towngas since 2008, and facilitated the carve-out of EcoCeres as an independent business entity. In 2022, Bain Capital made an investment of over $700 million for a significant stake in the company. This investment marks one of Bain Capital's largest transactions in Asia relating to the energy transition. Since the transaction, EcoCeres has been jointly controlled by Bain Capital and Towngas.

How? With SAF a relatively nascent sector in 2021, EcoCeres first had to attract specialist private capital to underwrite its near-term growth plans. Following successful proof points to its thesis, including the introduction of SAF as a new and attractive option within its product mix, it was then able to raise significant capital from a blue-chip investor in the form of Bain Capital. Both investment rounds came after a thorough due diligence process, covering all key aspects of the business including technology, commercial, financial and legal perspectives. EcoCeres worked with a professional due diligence vendor team engaged by Bain Capital and was recognized as a leader in SAF innovation and production.

Impact: EcoCeres has leveraged its investors' industry experience and resources to further accelerate international expansion across Asia Pacific, Europe and the Middle East. This includes earmarking a significant portion of the growth capital from Bain Capital and Kerogen to construct a state-of-the-art production facility in Malaysia. This augments EcoCeres' production capabilities, more than doubling the company's output across two facilities to 750,000 tonnes per annum in total.

Lever 8

Attract infrastructure investors to access cheaper capital

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
Medium	High	High	High

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	Low	High	High	High

Infrastructure investors leverage their reputation and large portfolios to attract cheaper capital and ultimately pass on the savings to SAF projects.

As SAF projects expand into the megaton-scale, capital requirements can skyrocket to multiple billions. In addition, engineering, procurement and construction can span multiple years before production begins. To secure enough funding, developers need to access large amounts of capital with a long-term investment horizon.

Infrastructure investors can play a vital role in providing both capital and management expertise for large projects. These investors pool capital together from institutional investors, pension funds and sovereign wealth funds to invest in large-scale infrastructure, increasingly with a sustainability theme.

While infrastructure investors are more risk-averse than private equity, their cost of capital is generally cheaper. Infrastructure investors leverage their reputation and large portfolios to attract this cheaper capital and ultimately pass on the savings to SAF projects, while taking a more active role in the construction process.

CASE STUDY 10

Investment from Brookfield and Breakthrough Energy Catalyst in Infinium

What? In September 2024, Brookfield Asset Management announced a significant investment commitment of up to $1.1 billion in Infinium, a California-based company pioneering PtL SAF production. The deal includes an initial $200 million for Infinium's Project Roadrunner SAF production site in West Texas and the potential for an additional $850 million in equity, which would enable third party debt capital for future global projects.

How? The investment from Brookfield into Infinium was enabled not only through technological and operational innovation but also through financial and commercial innovation. Firstly, the investment was preceded by a commitment of $75 million of project equity investment by Breakthrough Energy Catalyst, following a rigorous infrastructure investor diligence process that demonstrated confidence around Infinium's project development and technology platform. Secondly, bankable offtake agreements were signed between Infinium and American Airlines (as well as Citi for scope 3 emissions), which were instrumental in attracting the investment from Brookfield. Prior to these recent milestones, Infinium successfully leveraged a number of strategic approaches to help bolster investor confidence, including:

1. Inking investment relationships with industry leaders, including Amazon.
2. Securing long-term offtake deals.
3. Building and operating the world's first commercial-scale PtL production plant, which began shipping product in early 2024.

Brookfield and Infinium worked closely together to define and align on a clear set of milestones and KPIs that need to be met to unlock the additional $850 million in capital, providing certainty and clarity to Infinium on how to successfully scale-up. In January 2025 Infinium secured additional funding from Brookfield and other investors as part of its Series C funding round.[18]

Impact: Through the above investments, Infinium is on track to develop the largest PtL project in North America, once operational, and has de-risked its business model for further scale-up in future projects.

Lever 9

Structure investment through a tolling model to attract more debt

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
High	High	High	High

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	Low	High	High	High

A tolling model may mitigate market risk as the SAF project would receive a fixed tolling fee without being exposed to fluctuations in feedstock costs and SAF prices.

To reach the required scale, SAF projects need to raise significant debt. To facilitate these investments, an emerging investment structure is through a tolling model. Under this model, a SAF facility would provide their refinery capacity to customers (tollers) in turn for a fixed tolling fee. The toller would supply the feedstocks and retain the risks and title to the molecules through the conversion process. The toller would be responsible for shipping and marketing the SAF produced with their feedstocks.

A tolling model may mitigate market risk and provide stable, predictable cash flows as the SAF project would receive a fixed tolling fee without being exposed to fluctuations in feedstock costs and SAF prices. It is important to note that no tolling agreements have been concluded in the SAF space at the time of writing. The claims presented here are thus theoretical and based on the experience of the liquified natural gas (LNG) and electricity industries.

From a lender's perspective, this structure may be appealing. The reduced risk exposure would allow the SAF project to maximize debt financing and secure it at lower interest rates, as lenders would have more confidence in the project's ability to generate steady cash flows, regardless of market conditions. This, in turn, would lower the overall cost of capital for the SAF project, improving its financial viability. Alternative risk-sharing pricing models could also be introduced, should investors have a higher appetite towards exposure to the low-carbon fuel.

The tolling model would also enable a greater role for intermediaries in the value chain. Commodity traders are likely to take on this role as they could source the feedstocks, blend and sell the SAF, depending on the infrastructure they own. They could also leverage risk management tools to hedge their exposure to SAF. The latter option depends on the development of SAF into a liquid and tradable commodity akin to crude oil or LNG, a process which make take several years to come to fruition.

CASE STUDY 11

Cedar LNG tolling agreement between Pembina Pipeline Corporation and the Haisla Nation

What? Cedar LNG is a planned floating LNG liquefaction facility off the coast of British Columbia, co-owned by Pembina Pipeline Corporation and the Haisla Nation. Cedar LNG signed a 20-year agreement with ARC Resources in March 2023, in which ARC would supply natural gas and then receive LNG to sell on the market.

How? The 20-year agreement covers the supply and liquefaction of 200 million cubic feet per day of natural gas, transforming it into the equivalent of 1.5 million tonnes per annum of LNG, representing approximately half of the Cedar LNG facility's total production. As a toller, ARC Resources owns every step of the value chain from natural gas origination upstream to the liquefaction and further to point of sale, insulating Cedar LNG from the risks of both selling LNG downstream and securing feedstock. The facility will be powered entirely with renewable electricity, boosting the sustainability criteria of the LNG produced. The $3.4 billion in capital costs of the project are expected to be financed 60% through asset-level debt from a consortium of banks and 40% as equity, split between Pembina Corp. and the Haisla Nation using committed capital through the First Nations Finance Authority.

Impact: This agreement and tolling contracts with other buyers proved to investors a sufficient mitigation of both the demand and feedstock risks, allowing the project to reach a positive FID in 2024, with deliveries expected to begin in 2028. Cedar LNG will be the world's first LNG facility majority-owned by an Indigenous community.

Lever 10

Issue green bonds to attract impact investors

Funding Source		
Public funding	Industry funding	Institutional funding

Pathways (relevance of guideline by pathway, low = nice to have vs. high = must have)

HEFA	Alcohol-to-Jet	G-FT	Power-to-Liquid
High	Medium	Medium	Medium

Lifecycle (relevance of guideline by pathway, low = rarely applicable vs. high = very common)

Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
Low	Low	Low	High	High

“ Airlines could unlock sustainability-linked bonds where the bond conditions are linked to SAF uptake. This also works as a de-risking mechanism for offtake agreements.

Green bonds are issued by governments, companies or financial institutions to raise funds specifically earmarked for environmentally friendly products. SAF producers can leverage these bonds towards the production, development and infrastructure of SAF.

In addition, airlines could also unlock sustainability-linked bonds where the bond conditions are linked to SAF uptake. This also works as a de-risking mechanism for offtake agreements. Demand signals coming from airlines would be much stronger, as they would be bound to make SAF purchases to ensure access to the bond financing. Airports could also attract sustainability-linked bonds to invest in SAF infrastructure.

To unlock financing through green bonds, SAF producers need to comply with a green financing taxonomy.[19] The aim of such a taxonomy is to prevent greenwashing and help investors navigate and select truly sustainable investments. This is achieved through a standardized framework that classifies and defines what constitutes environmentally sustainable economic activities.

The EU and China have developed extensive green taxonomies to define sustainable activities, including SAF use in aviation for climate goals. In addition, market-based taxonomies exist, but their recognition of SAF in terms of green investments varies. For example, SAF is in scope for the *Common Principles for Climate Mitigation Finance Tracking*, published by the International Development Finance Club (IDFC);[20] however, the Climate Bonds Initiative Taxonomy does not recognize activities under aviation and bioenergy as sustainable.[21]

Green bond issuers typically commit to transparency and reporting to ensure the funds are used appropriately and achieve their goals around carbon emission savings. This might include regular updates on the amount of SAF produced and its lifecycle emissions and other environmental impacts.

CASE STUDY 12

Neste's €2.1 billion of green bond issuances

What? Neste – an oil refining and sustainable fuels company based in Finland – has issued four green bonds in the past four years. The first, issued in March 2021, was a €500 million, 7-year green or sustainable bond with a coupon of 0.75%. The bond offering was allocated to ~120 investors and listed on Nasdaq Helsinki. Neste issued three additional green bonds in 2023.[22] Two, issued in March, were €500 million green bonds with 6-year and 10-year maturities, paying a fixed coupon of 3.875% and 4.250% respectively. In November 2023, Neste issued a €600 million green bond with 7.5-year maturity and a fixed coupon of 3.875%.[23]

How? To access the funds, Neste applied for the bonds to be listed on Nasdaq Helsinki and Euronext Dublin. In addition to the usual process for listing conventional securities, Neste needed to align with sustainable bond frameworks, go through a third-party review and publish annual reports regarding the projects or activities that the bonds finance.[24] To define those activities, Neste developed its own green finance framework to support (re-)financing of eligible assets and projects. Neste ensured compliance with leading principles such as the Green Bond Principles of the International Capital Market Association (ICMA) and the Asia Pacific Loan Market Association's principles.

Impact: The total value of €2.1 billion from the issue of these four green bonds is used by Neste to invest in the development, operation, maintenance and expansion of its renewable and circular solutions. The funds have allowed Neste to expand its production capacities in Singapore, Rotterdam and Martinez, California – financing the Optionality project, the Martinez Renewables Project to produce renewable diesel, and increasing SAF production capacity at the Rotterdam refinery.[25]

CASE STUDY 13

Air France-KLM's €1 billion green bond issuance

What? In January 2023, Air France-KLM issued a sustainability-linked bond for €1 billion, linked to a goal to reduce their scope 1 and 3 emissions by 2025. SAF use is one of four levers defined in the bond issue.

How? The airline first worked with SBTi to adopt an approved trajectory, which includes a target of 10% SAF use by 2030. The bond was linked to an intermediate goal of a 10% decrease in well-to-wake emission intensity based on tonnes of CO_2-equivalent per revenue-tonne-kilometre (RTK), compared to a 2019 baseline. Before issuing the bond, Air France-KLM also built a sustainability-linked financing framework,[26] which received a "best practices" alignment with principles spelled out in a second party opinion from Moody's Investors Services.[27] The bond was offered in two tranches: €500 million with a 3.3-year maturity and 7.25% coupon and a further €500 million with a 5.3-year maturity and 8.125% coupon. The bond was 2.6x oversubscribed, with asset managers taking over 70% across both tranches, and banks and hedge funds taking around 10% each.[28]

Impact: The bond issue showed that investors are eager to subscribe to bonds linked to clear, measurable goals within SBTi-validated trajectories. As it applied specifically to SAF financing, this bond issuance helped mitigate the counterparty risk that offtake buyers may bring, as it created a financial incentive to meet the goal through SAF, reducing the risk that buyers will exit an offtake agreement early. While Air France-KLM selects only fuels certified by RSB or ISCC, future bond issues by other issuers could explicitly include sustainability criteria to strengthen the attractiveness of the bond, if needed.

Conclusion

The capital landscape for SAF investment is complex. The case studies presented in this report highlight a variety of solutions to address financing challenges across different project stages.

SAF represents a crucial pillar in the decarbonization journey of the aviation industry, offering one of the most viable options to achieve the global vision for 2030 agreed by ICAO. To meet the expected demand for SAF by the end of this decade, projects requiring between $19 billion and $45 billion of funding need to pass FID over the next few years. As this report outlines, numerous hurdles still impede the potential for SAF to scale-up. Addressing these barriers requires a multifaceted strategy that combines technological innovation, policy frameworks and innovative financial structures to increase bankability and investment appeal for SAF projects across their lifecycle.

The capital landscape for SAF investment is complex, with significant financial requirements across different project stages, from conceptualization and pre-feasibility to construction and commissioning. Traditional financing sources, such as commercial banks, often see these projects as high risk due to their novelty, extended timelines and reliance on emerging technologies. For SAF to reach scalable production, a shift in financing mechanisms is necessary, leveraging both private and public capital in innovative ways to mitigate these perceived risks and catalyse substantial capital flow into the sector.

TABLE 3 **Overview of applicability of levers across the project financing lifecycle**

Applicability (Low / Medium / High)	Pre-feasibility	Feasibility + FEED	FID	Construction	Commissioning
1. Apply for research/innovation grants to develop first-of-a-kind facilities	High	High	High	Low	Low
2. Leverage local expertise of multilateral development banks to navigate developing markets	High	High	High	Low	Low
3. Secure guarantees or insurance instruments to enhance credit profile	Low	High	High	High	Low
4. Attract strategic industry investors to build an ecosystem for future scale	Low	Medium	High	Medium	Low
5. Secure long-term offtake agreements to pass FID	Low	Low	High	Low	Low
6. Engage in book-and-claim to facilitate investments	Low	Low	High	Medium	Medium
7. Attract private equity capital to achieve rapid expansion	Low	Low	High	High	High
8. Attract infrastructure investors to access cheaper capital	Low	Low	High	High	High
9. Structure investment through a tolling model to attract more debt	Low	Low	High	High	High
10. Issue green bonds to attract impact investors	Low	Low	Low	High	High

Although it is difficult to generalize across a variety of technology pathways, this white paper proposes 10 current and potential financial levers, drawn from case studies and summarized in Table 3, that can be adopted to increase the likelihood of SAF plants attracting investment and progressing to commercialization. Governments, airlines, investors and the wider value chain all have a role to play – both individually and in collaboration – to put these solutions into practice.

The case studies and financial levers presented in this report will set the scene for future convenings of the aviation value chain through the World Economic Forum's Airports of Tomorrow initiative. In 2025, the initiative will continue to explore how these levers can be replicated across existing and soon-to-be-approved SAF production pathways, while deepening the assessment of policy frameworks and their implication on the viability of the solutions presented here.

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Endnotes

1. Kearney analysis based on voluntarily announced 2030 SAF commitments from the following carriers: Scandinavian Airlines/SAS (~35%), FedEx (30%), UPS (30%), DHL (30%), Airbus (30%), Norwegian (20%), Ryanair (12.5%), American Airlines (10%), Delta Air Lines (10%), Air France-KLM (10%), International Airlines Group/IAG (10%), Southwest Airlines (10%), Qatar Airways (10%), All Nippon Airways/ANA (10%), Cathay Pacific (10%), Japan Airlines/JAL (10%), Qantas (10%), JetBlue (10%), Alaska Airlines (10%), WizzAir (10%), TAP Air Portugal (10%), Virgin Atlantic (10%), Finnair (10%), Hawaiian Airlines (10%), SkyWest Airlines (10%), United Airlines (10%), Lufthansa Group (5%), Singapore Airlines (5%), Malaysia Airlines (5%), Aeromexico (5%), Philippine Airlines (5%), GOL Airlines (1% -2025), AirCanada (1% -2025).
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