BRIDGING THE PRICE GAP FOR SUSTAINABLE AVIATION FUEL (SAF)

FEBRUARY 2022

PREPARED FOR
Bioenergy Australia

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Acknowledgements

This report was developed with the support of the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC). This report presents the findings and recommendations of EnergyLink Services Pty Ltd and was prepared to develop recommendations on how to bridge the price gap between SAF and conventional aviation fuel in Australia based on international policy experiences. The views expressed herein are the views of EnergyLink Services and are not necessarily the views of the ARENA or the CEFC.

EnergyLink Services would also like to thank all stakeholders who participated in direct interviews and stakeholder consultations in developing this report.

Executive Summary

Sustainable Aviation Fuels (SAF) is the blanket term used within the industry to describe technology that allows aviation fuel to be developed from sources other than fossil fuels. SAF has gained significant interest from various stakeholders throughout the aviation fuel supply chain, with international airline association agreements and corporate emission reduction targets driving the shift towards lower-emission aviation fuels. However, as the SAF industry is not as mature or scaled as the conventional aviation fuel industry, there is a price gap between petroleum-derived aviation fuel and SAF.

This report has been prepared to review the SAF industry's current state within Australia, and, based on a review of international policy instruments, propose how to bridge the price gap between SAF and conventional aviation fuel in Australia. In addition to the policy review, stakeholders from across the SAF value chain consulted on the development of four key recommendations for bridging that gap. Stakeholders consulted included Government representatives, airlines, airport operators, traditional aviation fuel suppliers, SAF producers, fuel infrastructure owners, airplane manufacturers, academic researchers and international aviation and biofuel professionals.

The recommended policies are designed to support the emergence of the SAF supply chain, guide ongoing policy development for the industry and stimulate demand for SAF throughout Australia. This report builds upon internationally-recognised best practices, as well as lessons learned, to propose recommendations for an Australian context.

Current Policies within Australia

There are several programs at a state level, such as the QLD Biofutures program, that provide incentives to support the uptake and commercialisation of biofuels such as SAF. However, there are currently no direct policies at a federal level to directly drive the uptake of SAF in Australia. The Emissions Reduction Fund/Climate Solutions Fund does include a methodology for the monetisation of emissions reductions arising from SAF usage. However, this mechanism has not encouraged SAF adoption because the available carbon incentive is insufficient to cover the cost difference between SAF and conventional aviation fuel. This report proposes four recommendations to fill the policy void and make SAF viable in Australia.

Bridging the Gap for Sustainable Aviation Fuel in Australia

Recommendation 1: Establishing a Jet Council

Following the lead of the UK and its Jet Zero Council, Australia should establish a 'Jet Council' to connect the State and Federal Government with aviation industry stakeholders to guide the ongoing development of sustainable aviation policies. The Jet Council would work with the various levels of Government to guide and support pathways for SAF R&D in Australia, as well as provide feedback on the design and implementation of policies to overcome existing barriers to SAF development.

Recommendation 2: National Framework for Voluntary Consumer Purchasing

The Federal and State Governments, in collaboration with the previously recommended Jet Council, should establish a national framework for a voluntary consumer purchasing program to enable customers to opt-in to procure a portion of SAF for their flight. These emission reductions would be tracked via a Guarantee of Origin (GUO) scheme, allowing SAF purchasers to be 'credited' with the resulting emissions reduction. This arrangement would be modelled on the hydrogen GUO scheme currently being trialled by the Clean Energy Regulator. Accordingly, customers who opt into purchasing a portion of SAF for their flight would see a corresponding decrease in their scope 3 emissions associated with air travel.

The consensus from stakeholders consulted for this report was that blending SAF into the existing fuel supply points would maintain the required quality standards and provide the lowest-cost method of supplying SAF to airlines. The proposed mechanism would effectively create a certificate associated with each tonne of SAF that is blended into the fuel supply infrastructure. These certificates would be surrendered to match the opt-in SAF purchases of SAF by corporate and Government bodies that have net-zero emission targets or carbon-neutral commitments and want to reduce their aviation emissions.

Pricing Implications

The pricing implications of voluntary SAF purchases have been modelled using publicly available information released by Qantas under the Australian Government's Climate Active program (formerly known as the National Carbon Offset Standard), the National Greenhouse Accounts Factors for the corresponding period, and published aviation fuel pricing data. Using an example flight from Sydney to Melbourne, the cost impacts of 50% blended SAF aviation fuel to a customer has been modelled in ES Table 1.

ES Table 1: Voluntary Purchase Pricing Impacts

	Jet A1	50% Blend Aviation Fuel		
		SAF, 2x Jet A1	SAF, 5x Jet A1	SAF, 10x Jet A1
Estimated fuel cost for Sydney to Melbourne	$18.25	$27.38	$54.76	$100.39
Additional Cost for SAF	$-	$9.13	$36.51	$82.14
Additional Cost per pa.km	$-	$0.013	$0.052	$0.116

ES Table 1 shows that, at twice the price of conventional aviation fuel, there is a minimal increase in the cost per kilometre, with voluntary buyers being charged just over 1c per kilometre travelled by each passenger. These results also emphasise the need to focus on bridging the price gap between SAF and conventional aviation fuel, as cost reductions will drive greater participation by voluntary customers. Also, the above analysis is based on using 50% blended fuel; depending on the prevailing SAF price, this percentage could be adjusted to achieve price outcomes that will be acceptable to voluntary customers, while still creating demand for SAF that can be leveraged for refinery construction.

Recommendation 3: Funding

To minimize the price gap between SAF and conventional aviation fuel, the Government should provide additional funding toward domestic SAF refineries. This funding could be administered through new funding bodies/mechanisms such as the proposed Jet Council, or through existing Government Agencies such as the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC). This support would aid the construction of Australia's first series of commercial plants, in the same way that ARENA and the CEFC helped establish and mature the renewable electricity generation industry.

Approach 1: Capital Funding – Grants and Low-Interest Loans

Government funding could be provided in the form of grants or low-interest loans to reduce the capital or financing costs of a SAF refinery. This helps improve the business case, as capital expenses and financing costs are two key determinants of a SAF refinery's viability.

Approach 2: Production Subsidies

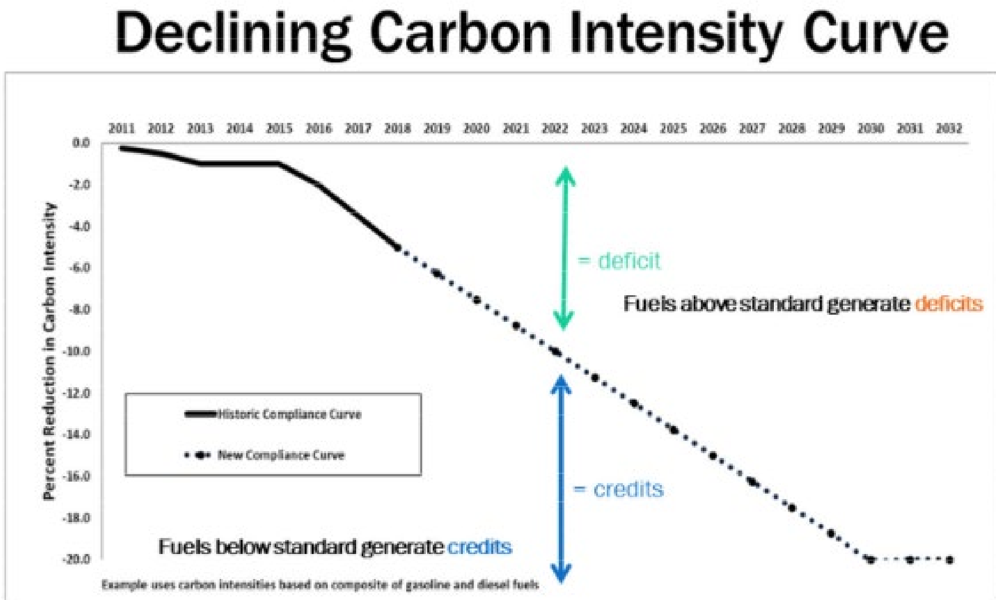
Alternatively, the funding could be targeted to support the operating revenues/margins of a SAF refinery. This approach would be implemented similarly to the fuel security services payment that has recently been offered to Australia's refineries. Under this mechanism, a price subsidy (cents per litre) is provided when refining margins fall below certain thresholds. This could also take the form of a 'reverse auction' in which SAF refineries bid their proposed SAF pricing around a benchmark price (e.g., 2 times the Jet A1 price) and the Government funds the difference between the bid and the benchmark.

Recommendation 4: Emissions Intensity Scheme

SAF mandates are internationally recognised as critical to SAF deployment and industry scaling, and many mandates have been already proposed and implemented around the globe. Currently, the largest, most active international program driving the uptake of SAF (and other types of biofuels) is the Low Carbon Fuel Standard (LCFS) in California. This policy mechanism is based on reducing the emissions intensity of fuels relative to a benchmark over time. In our stakeholder consultations, airlines, traditional fuel suppliers and SAF producers all identified an emissions intensity mandate as the most effective mechanism for driving domestic SAF uptake.

Policy Design

This policy would consider existing aviation fuel to have an emissions intensity of 100, which serves as the basis for comparison with any other type of fuel. Under this policy, all fuel sold would have to meet an emissions intensity benchmark that decreases over time. The emissions intensity of SAF would then be calculated using lifecycle assessments (LCAs) to capture the full array of emissions associated with SAF refining. The emissions intensity of the fuel would determine whether selling the fuel would create a credit or deficit for the fuel suppliers. This mechanism, in the context of the LCFS, is shown below in ES Figure 1.



ES Figure 1: Carbon Intensity Curves (Source: California Air Resources Board, 2020)

ES Figure 1 shows that the benchmark intensity reductions decrease and necessitate greater volumes of SAF over time. For aviation, the decline in emissions intensity would need to be lower and slower than what is shown in ES Figure 1 to allow the SAF industry to develop while protecting the aviation industry's ongoing viability.

Given that pre-COVID aviation fuel sales were over 9 billion litres per annum, reductions in emissions intensity by even a few per cent would require a significant volume of SAF to be blended into the aviation fuel supply system. As a result, it is recommended that initial benchmarks be set at less than 5% so that the target is achievable and not cost-prohibitive. A 2.5% reduction in emissions intensity (i.e., 2.5% of aviation fuel becoming SAF) has been modelled throughout this recommendation and would require approximately 235ML of SAF to be integrated into the aviation fuel supply chain. This volume would be sufficient to warrant the construction of at least 1 SAF refinery in Australia.

Under such an emissions intensity compliance program, emerging costs would be borne by airlines and ultimately consumers (likely in the form of higher ticket prices). However, appropriate penalty prices for credits would ensure fuel suppliers are incentivised to procure SAF, rather than paying a lesser penalty. This would also help protect airlines by setting a 'price ceiling' for the credits and maintaining a level of price certainty for their business planning. The relevant Federal body responsible for regulating this type of program, likely the Clean Energy Regulator, would be able to leverage an entity such as the proposed Jet Council to gain industry insights on intensity targets, rate of escalation and credit pricing.

Policy Applicability

The stakeholders consulted made it clear that, given the logistical (and contractual) relationships involved in fuel supply within major airports, placing obligations on individual airlines would not be practical. As a result, the recommended solution is the 'Californian' approach in which the obligation is placed on aviation fuel suppliers. By choosing the point of fuel sale, all airlines, including international ones, would be indirectly subject to the emissions intensity policy.

Policy Impact

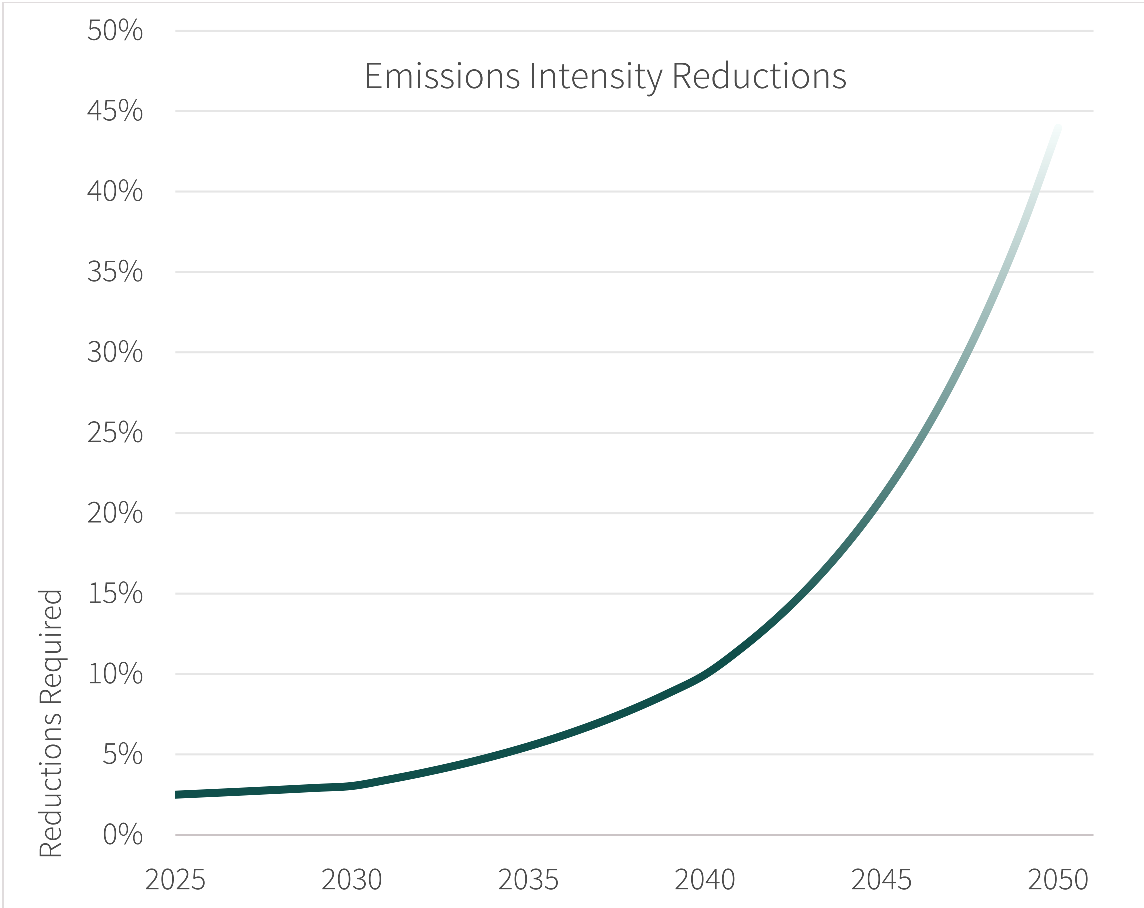
Mandates to procure SAF help drive uptake to the levels set in the relevant policy. However, greater uptake of SAF would increase fuel procurement costs. The expected financial impact on the aviation sector has been outlined in ES Table 2.

ES Table 2: SAF Procurement Cost Impacts (Source: IATA,2021: Commonwealth of Australia, 2021a)

	Jet A1	2.5% Blend Aviation Fuel		
		SAF, 2x Jet A1	SAF, 5x Jet A1	SAF, 10x Jet A1
Cost of procurement ($m)	$7,437	$7,622	$8,180	$9,110
Difference vs BaU ($m)	$-	$185	$743	$1,673
Percentage increase in fuel procurement costs	-	2.4%	9.1%	18.4%

ES Table 2 highlights that it is critical to drive down the price of SAF through industry development, so airlines can benefit from the economies of scale associated with larger production volumes. This helps ensure that a SAF program would neither place disproportionate costs on airlines nor produce unacceptable price rises to their customers.

A proposed emissions reduction trajectory has been illustrated in ES Figure 2.



ES Figure 2: Emissions Intensity Reductions

ES Figure 2 shows that the initial requirements would commence in 2025, giving the industry sufficient time to plan for SAF procurement and supply chain integration. This initial 2.5% requirement would slowly increase to 3% SAF by 2030; the required rate of emissions intensity reductions would then rise at a faster rate in each following decade. This helps minimise the program's costs as the first years will require the most expensive SAF while the industry is emerging. Over time, and as SAF costs drop, the required reductions increase as a greater impact can be achieved at the same price. Also, there are presently limitations on the percentage of SAF that can be blended under the various pathways while still meeting ATSM requirements, so 50% blending is the upper limit of what is currently possible.

Introduction to SAF

Sustainable Aviation Fuel

Overview

Sustainable Aviation Fuels (SAF) is the blanket term used within the industry to describe technology that allows aviation fuel to be developed from sources other than fossil fuels. SAF has gained significant interest from various stakeholders throughout the aviation fuel supply chain, with international airline association agreements and corporate emission reduction targets driving the shift towards lower-emission aviation fuels. However, as the SAF industry is not as mature or scaled as the conventional aviation fuel industry, there is a price gap between petroleum-derived aviation fuel and SAF.

To support the global emergence of SAF industries, various locational, national and international government bodies have implemented policies to foster the uptake of SAF. These encourage the industry to reach a sufficient scale that it can be a critical component of the aviation fuel supply chain without relying on Government support.

The feedstock currently utilised for SAF can include cooking oil, plant oils, municipal waste, waste gases, agricultural residue and non-biological alternative fuels, such as 'power-to-liquid'. The utilisation of SAF as an alternative fuel source is of great interest to many aviation stakeholders. Not only does it help to reduce emissions and environmental impacts, but it also has the potential to create jobs and reduce reliance on imported fossil fuels.

In Australia and New Zealand, the primary commercial jet fuel utilised is a kerosine-grade aviation fuel derived from crude oil (fossil fuel), called Jet A-1 (Qantas , 2013).

Pathways & feedstock

There are currently 9 international ASTM (American Society for Testing Materials) certified pathways to produce commercial-grade SAF, which include:

- Fischer-Tropsch Synthesized Isoparaffinic Kerosene (FT-SPK)
    - Gasification of carbon-containing materials (coal, natural gas, biomass) into syngas, which is then catalytically converted into liquid hydrocarbon fuel blending components (ICAO , 2021)
- Hydrotreated Esters and Fatty Acids (HEFA)
    - Refines vegetable oils, waste oils, or fats (lipid feedstocks) through hydrogenation into SAF through deoxygenation, which is then hydroprocessed to produce a pure hydrocarbon fuel blending component (ICAO , 2021)
- Hydro-processed Hydrocarbons, Esters & Fatty Acids (HC-HEFA)
    - Involves the hydro-processing of bioderived hydrocarbons from oils found in the algae *Botryococcus braunii* (ICAO , 2021)
- Synthesised Iso-Paraffins (SIP)
    - A biological platform that converts sugar feedstock through a fermentation process into a hydrocarbon molecule (ICAO , 2021)
- Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics (FT-SPK/A)

- Gasification of carbon-containing materials (coal, natural gas, biomass) or non-petroleum-based aromatics into syngas, which is then catalytically converted into liquid hydrocarbon fuel blending components (ICAO , 2021)

- Alcohol-to-Jet (AtJ)
    - Utilises dehydration, oligomerization and hydro-processing to convert alcohol into a pure hydrocarbon fuel blending component (ICAO , 2021)
- Catalytic Hydro-Thermolysis (CHJ)
    - Hydrothermal liquefaction that converts fatty acid esters and free fatty acids via catalytic hydrothemolysis with feed water, then subjects them to high temperature and pressure in a combination of hydrotreatment, hydrocracking or hydroisomerisation and fractionation (ICAO , 2021)
- Co-Processing
    - Utilised in existing refineries, fats, oils and greases (FOG) and FT biocrude are processed at a small percentage along with conventional crude oil feedstocks (ICAO , 2021)

The feedstock and maximum drop-in or co-processing blend with conventional aviation fuel is shown below in Table 1.

Table 1: Summary of the current technologies, maximum blend allowed, and most common feedstocks for drop-in SAFs as defined under standard ASTM D7566 (Source: Adapted from (ICAO , 2021)

Technology	Example Feedstocks	Maximum drop-in blend with conventional jet fuel
Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)	Waste (e.g., MSW), coal, gas, sawdust	50%
Hydroprocessed Esters and Fatty Acids (HEFA)	Vegetable oils: • Palm • Camelina • Jatropha • Used cooking oil	50%
Sugars to Synthetic Isoparaffins (SIP)	Sugarcane, sugar beet	10%
Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics (FT-SPK/A)	Waste (e.g., MSW), coal, gas, sawdust	50%
Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ)	Sugarcane, sugar beet, sawdust, lignocellulosic residues (straw)	50%
Catalytic Hydrothermolysis Synthesized Kerosene (CHJ)	Waste oils or energy oils	50%
Hydroprocessed Hydrocarbons, Esters and Fatty Acids Synthetic Paraffinic Kerosene	Oils produced from algae	10%

(HH-SPK, or HC-HEFA)		
FOG Co-processing	Fats, oils and greases (FOG) from petroleum refining	5%
FT Co-processing	Fischer-Tropsch (FT) biocrude as an allowable feedstock for petroleum co-processing	5%

Aviation emissions in Australia & New Zealand

Aviation emissions have been steadily increasing in Australia over the past several decades, in correlation with the industry growth rate of 2.2% (DIRD, 2017). In 2016, commercial aviation emissions totalled 22.02 MtCO_2e, which means that without the impacts from COVID-19, emissions from aviation in Australia would have been an estimated 24 MtCO_2e by 2020 (DIRD, 2017). These trajectories are shown below in Figure 1 and Figure 2.

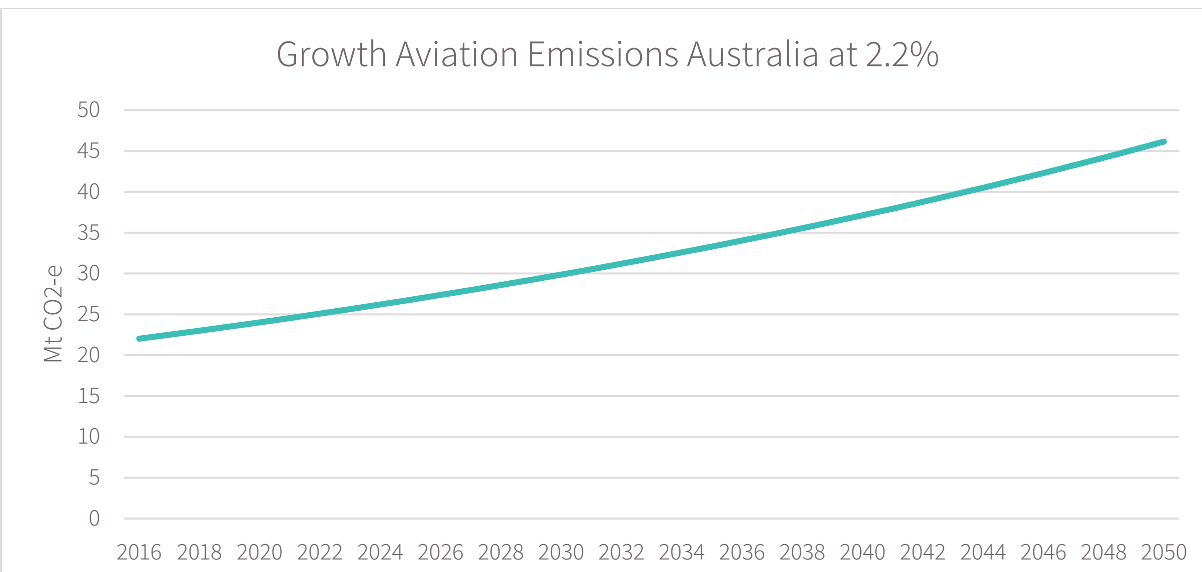


Figure 1: Increase of Australian CO2e aviation emissions at industry growth rate of 2.2% (excluding impacts from COVID-19) (Source: DIRD, 2017)

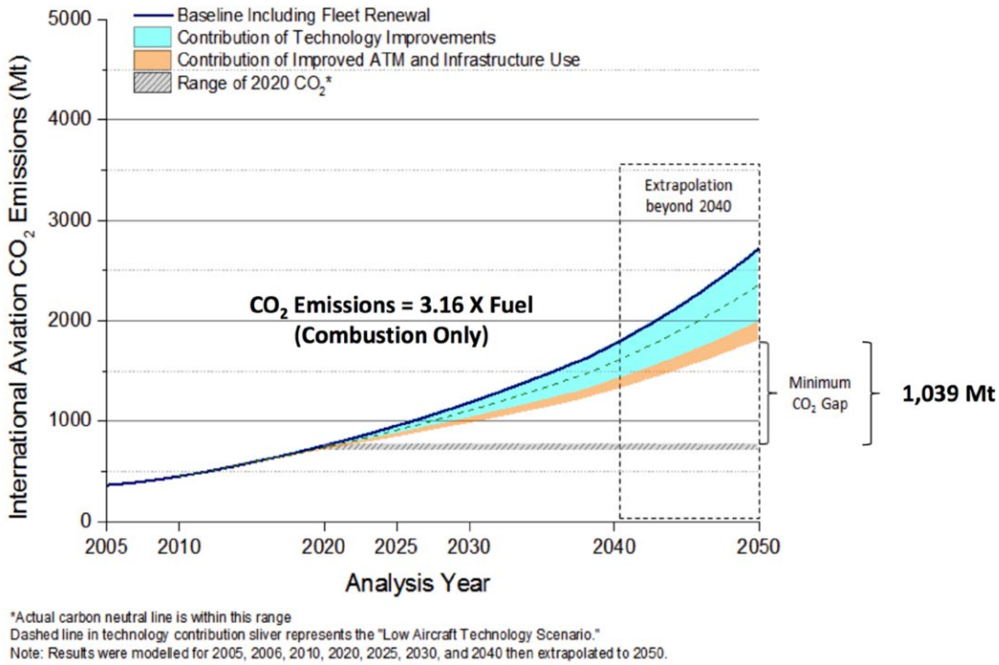


Figure 2: CO2 emissions trend for international aviation from 2005 to 2050. Source: ICAO Environmental Report (Source: ICAO, n.d.)

Industry Challenges

One of the aviation industry's biggest challenges with emission reductions is that it is a particularly difficult sector to decarbonise. During the second half of the 20th century, emissions from aviation increased dramatically on a global scale (Our Word in Data, 2020) This trend correlated with the rapid increase in air traffic volume, measured in revenue-passenger-kilometres (RPK). However, improvements in aircraft design, technology and passenger load factors meant there were also substantive improvements in emission efficiencies over these past 50 years (Our Word in Data, 2020).

That said, aircraft-related technological improvements allow the industry's decarbonisation to get only so far. The International Civil Aviation Organization (ICAO) formally recognised that technology and market-based measures will be needed for industry decarbonisation. However, the successful development and deployment of SAF will be critical to reducing emissions to net-zero over the next 3 decades to the year 2050 (ICAO , 2017).

Aviation emissions

In 2018, aviation accounted for 2.5% of global anthropogenic carbon dioxide (CO_2) emissions (Our Word in Data, 2020). While this may be considered low in comparison to other industries, aviation's overall impact on anthropogenic warming technically sits slightly higher at around 3.5%. This is due to non-CO_2 forcings, such as radiative forcing (RF), which is the measurement of the difference between incoming energy and the energy radiated back into space. The inclusion of RF is neither formally recognised by the Paris Agreement nor accounted for in global calculations (Our Word in Data, 2020).

Moreover, emissions from aviation are expected to grow. Commercial aircraft emissions are expected to triple by 2050, excluding the effects of COVID (Our Word in Data, 2020; EESI, 2019).

Emissions Reductions Initiatives in Australia and New Zealand

Currently in Australia and New Zealand, the four major airlines with international operations have all committed to the International Civil Aviation Organization's (ICAO) global scheme, the Carbon Offset and Reduction Scheme for International Aviation (CORSIA). CORSIA is a global market-based measure that was designed to stabilise and offset international aviation CO_2 emissions from a 2019 baseline (formally revised from 2020 due to the impacts on the industry from the COVID-19 pandemic). These airlines include:

- Qantas Group
    - Qantas Airways
    - Jetstar Airways
- Air New Zealand
- Virgin Australia

Out of these airlines, three have publicly announced their commitment to achieving net-zero by 2050: Qantas Airways, Jetstar Airways and Air New Zealand. However, all four domestic airlines have publicly expressed support for the development of a SAF industry in Australia and New Zealand, including financial investments towards the facilitation of this.

In 2021, Qantas Group committed to purchasing 10 million litres of SAF for flights from Heathrow Airport in 2022, with an option to purchase up to another 10 million litres in 2023 and 2024 (Qantas, 2021). In 2019, the Qantas Group committed to spending AUD50 million towards the development of a SAF industry in Australia and their international ports. Qantas had previously conducted several trial flights utilising SAF; in 2012, they made Australia's first commercial biofuel flight, and in 2018, they conducted the first 15-hour trans-Pacific flight between LAX to MEL using blended biofuel manufactured from Carinata.

In 2018, Virgin Australia partnered with the U.S.-based renewable fuel producer GEVO Inc. to trial and supply SAF through Brisbane Airport's fuel supply infrastructure. Less than a year later, Virgin Australia had already flown more than one million km using biofuels under this trial.

In 2021, Air New Zealand announced their backing for the New Zealand Government's decision to implement a biofuels mandate to reduce carbon emissions within the transport sector. In 2008, they flew the world's first commercial aviation test flight powered by second-generation biofuels.

In 2013, Qantas conducted a Feasibility Study (Qantas , 2013) examining the environmental and economic reasoning behind developing a SAF industry in Australia. Their key findings established that this is technically feasible, but significant challenges would need to be overcome to achieve commercial feasibility for HEFA (Hydrotreated Esters and Fatty Acids) and FT (Fischer-Tropsch) pathways to SAF.

ARENA Bioenergy Roadmap

The Australian Renewable Energy Agency (ARENA) developed a roadmap that will identify the next series of policy and investment decisions for Australia's bioenergy sector during the energy transition. Its primary foci include regional development, energy security and emissions reduction.

The Bioenergy Roadmap highlighted biojet fuels as one of the few options to reduce aviation emissions in the short- and medium-term, with stakeholder collaboration and co-investment needed to support the development of commercial-scale SAF production and advance the industry quickly (ENEA Australia Pty Ltd and Deloitte Financial Advisory Pty Ltd for ARENA, 2021).

Domestic Fuel security

Currently, Australia imports 90% of its liquid fuels. In 2020, the federal government announced the Fuel Security Package, which included AUD200 million worth of investment grants towards building new and additional diesel storage in Australia. For Australia to meet the International Energy Agency's (IEA) minimum 90 days' stock, an additional 780 megalitres of fuel storage is required.

International SAF Momentum

The development and scaling of an international SAF industry are rapidly increasing. During the 39th Session of the International Civil Aviation Organization (ICAO) Assembly, it was recognised that the goal of improving international fuel efficiency by 2% would be unlikely without a comprehensive approach (ICAO , 2017) that includes:

- Development of fuel-efficient aircraft technology
- Improved air traffic management and infrastructure used to reduce fuel burn
- Economic and market-based measures through emissions trading, levies and offsetting
- Investments in the development and deployment of sustainable aviation fuel

The Assembly endorsed the use of SAF, particularly drop-in fuels in the short- to mid-term, as an important means of reducing aviation emissions.

The global SAF market is projected to grow from USD66 million in 2020 to USD15,307 million by 2030.

In May 2021, lawmakers in the United States plan to introduce a bill that creates a tax credit of up to USD$2.00 for every gallon of low-carbon sustainable aviation fuel produced. Such SAF would be formulated from feedstocks such as grease, animal fats and plant oils.

In Europe, the European Commission will soon stimulate growth in the SAF industry through the ReFuelEU Aviation initiative. This will most likely be achieved through legislation that mandates the phased blending of SAF with conventional jet fuel in conjunction with incentives towards increasing capacity production.

Current state of play globally

UK

The UK government has implemented some policies and targets for decarbonizing the aviation industry under its Net Zero Strategy (HM Government , 2021). These targets include:

- net-zero aviation emissions by 2050

- net zero for UK domestic aviation by 2040
- 10% SAF by 2030

Collaboration and investments across the private and public sectors are crucial in attaining these net-zero targets. In 2020, the UK government developed the Jet Zero Council, a coalition between the government and industry that aims to develop and deliver zero-emission transatlantic flights. This will be progressed through investments to establish facilities that produce sustainable aviation fuels and promote the research and development of zero-emission aircraft. The UK government has provided £180 million in funding that will be used to support the construction of SAF plants. They are also supporting the development of zero-carbon aircraft through the Aerospace Technology Institute (ATI) by funding R&D for new aerospace technologies.

Various partnerships have been formed in the UK among SAF producers and the aviation industry, which include Fulcrum BioEnergy with Air BP, Lanzatech with Virgin Atlantic, and Velocys with both British Airways and Shell.

British Airways

International Airlines Group (IAG), which is British Airways' parent company, was the first airline group globally to pledge to achieve net-zero carbon emissions by 2050 under the Flightpath Net Zero strategy (Sustainable Aviation, 2020; IAG, 2021). Over the next 20 years, IAG will invest USD400 million in the development of SAF (British Airways , 2021). British Airways has partnered with Velocys, a SAF producer, to create the Altalto Project, which entails the development of a SAF plant in Immingham, UK (Velocys, 2021). This facility will be Europe's first commercial plant and make Northeast Lincolnshire an international hub for the global SAF market. The facility will convert approximately 500,000 tonnes of household and commercial waste to over 60 million litres of clean sustainable jet and road fuel per annum (Velocys, 2021; Altalto, 2021 and British Airways , 2021). The SAF will reduce approximately 80,000 tonnes in greenhouse gases emissions annually.

British Airways has also partnered with LanzaJet, another SAF producer, to power some of its fleet from late 2022. LanzaJet is currently building its first commercial plant in Georgia, USA and is in the planning stages of constructing a large-scale commercial SAF biorefinery in the UK (LanzaJet , 2021; (British Airways , 2019). They have also partnered with BP under a new sustainability program to supply SAF to flights among London, Glasgow, and Edinburgh during the COP26 climate summit held in November 2021.

USA

SAF production is still in its early stages in the US with one domestic commercial plant and at least two under construction in 2020 (NREL, 2021). In 2019, the U.S consumed approximately 26 billion gallons of jet fuel with SAF accounting for 4.5 million gallons (EIA, 2020).

As part of his Build Back Better Agenda, President Biden has proposed a Sustainable Aviation Fuel tax credit that requires at least 50% reduction in greenhouse gas emissions, thereby helping reduce costs of, and scale up domestic SAF production (White House , 2021). The Departments of Energy, Transportation, Agriculture, Defense, the General Services Administration, the National Aeronautics and Space Administration, and the Environmental Protection Agency will work towards reducing aviation emissions by 20% by 2030 through the production and use of approximately 3 billion gallons of SAF per year (White House, 2021; NREL, 2021).

Some of the key measures being undertaken by the federal government to ensure the SAF targets are met include (White House , 2021):

- The Federal Aviation Administration (FAA) will provide funds totalling USD3.6 million to the Aviation Sustainability CENTer (ASCENT), which will be used in the evaluation testing to ensure the new fuels are safe.
- The Department of Energy (DOE) will allocate USD35 million toward 11 projects focused on developing feedstock and algae technologies, as well as additional funds to advance biofuels, bringing the total fund cost to approximately USD61 million.
- Innovative commercial-scale SAF projects that reduce greenhouse gas emissions can benefit from the USD3 billion being offered by the DOE Loan Programs Office (LPO).

California

California has been the United States' leader in carbon emissions reduction, particularly in the aviation sector. In 2011, the California Air Resources Board (CARB) created the Low Carbon Fuel Standard (LCFS), which focuses on reducing the carbon intensity of fuels used in the state (State of California , 2021). Since then, sustainable diesel and biofuels have led to the success of the LCFS, eliminating approximately 18 million tons of CO_2 (Neste, 2021). Under the LCFS, airlines can affordably purchase SAF due to pricing advantages from credits generated from the use of low-carbon fuels. The price of SAF in California is approximately USD3.74/gal (S&P Global Platts, 2021), including the credits associated with the LCFS. SAF without the credits was 31.86 c/gal, up from -4.08c/gal (S&P Global Platts, 2021) in early November 2021. The price of SAF without credits is so low (and even negative) because the LCFS credits carry sufficient value to cover most or all of the production cost.

SAF production in California began in 2016 at the AltAir Paramount fuel refinery spearheaded by World Energy. The Paramount facility supplied about 1.2 million gallons of HEFA-SPK between 2016 and 2019 (European Union Aviation Safety Agency , 2019). World Energy has reportedly invested approximately $350 million in the expansion of the Paramount facility from 150 million litres to 1.135 billion litres (IRENA, 2021). However, it remains uncertain as to when the added capacity will become available, and biojet fuel will account for only 15% of the added capacity (IRENA, 2021).

In 2016, Air BP created a strategic partnership with Fulcrum BioEnergy with an initial investment of $30 million. The Californian company is building its first plant in Reno, Nevada, which will produce sustainable transport fuel made from household waste. Fulcrum intends to construct additional facilities and ultimately plans to supply North America with more than 50 million US gallons of SAF per year (BP, 2021).

San Francisco International Airport (SFO) and Los Angeles International Airport (LAX) have been at the forefront of improving SAF policy. SAF is currently blended with petroleum jet fuel and delivered to LAX through trucks and to SFO via pipelines. Over the past decade, Neste, an international SAF producer, has delivered approximately 220 million gallons of SAF from its Rotterdam facility to SFO through the existing pipeline infrastructure (Neste, 2021). US airlines contribute 2% of the country's CO_2 emissions and are committed to attaining net-zero emissions by 2050 (Airlines for America , 2021). They have therefore pledged to collaborate with government leaders and the aviation industry to generate approximately 3 billion gallons of SAF for use in 2030 (U.S Department of Energy , 2020).

Progress by Airlines

Several airlines have pledged to increase their usage of SAF in their operations as part of the Airlines for America's 2030 goal. The various progress is outlined below.

Over the years, United Airlines has been committed to SAF. In 2015, United Airlines invested $30 million in Fulcrum BioEnergy, a SAF producer, through a long-term fuel offtake agreement that will have Fulcrum provide the airline with 90 million gallons of low-carbon jet fuel annually (Fulcrum Bioenergy , 2021: United Airlines, 2021). In 2016, United Airlines formed a partnership with World Energy to purchase SAF from World Energy's AltAir refinery for use in its regular operations (United Airlines, 2021). Moreover, United formed the Eco-Skies Alliance program, which allows their corporate customers to pay for the additional cost of SAF. Some of the Eco-Skies Alliance leaders include DHL, Siemens, HP, Deloitte, Autodesk, Boston Consulting Group, CEVA Logistics, DSV and Palantir (United Arlines, 2021a).

In 2019, United Airlines committed $40 million towards the development of SAF and other decarbonisation technologies (United Airlines, 2021). In 2021, they flew a Boeing aircraft from Houston over the Gulf of Mexico by using 100% SAF on one engine and conventional jet fuel on the other (Commercial Aviation Alternative Fuels Initiative, 2021). Honeywell and United Airlines have jointly made a multi-million-dollar investment in Alder Fuels to commercialise a technology that will potentially demonstrate more than 100% lifecycle reduction in aviation fuel's greenhouse gas emissions.

Delta Air Lines has made an agreement with three SAF producers (Gevo, Northwest Advanced Bio-fuels, and Neste) and is committed to replacing 10% of its conventional jet fuel with SAF BY 2030 (Delta , 2019).They invested $2 million in Northwest Advanced Bio-fuels' feasibility study for a plant that would produce SAF and other biofuels ((Delta, 2019; Delta, 2019a). Also, Delta, Chevron and Google have established a memorandum of understanding (MOU) that will track SAF test-batch emissions using cloud computing and increase SAF transparency in the industry (Chevron Corporation , 2021).

American Airlines committed to utilizing 9 million gallons of SAF by 2023 and has been receiving SAF from Neste for more than a year. They have entered into a purchase agreement with Prometheus Fuels and will purchase up to 10 million gallons of SAF (American Airlines , 2021).

Alaska Airlines has agreements with Neste and SkyNRG Americas, with an initial focus on developing SAF production facilities that will supply Western US airports. The airline also offers the purchase of SAF to offset corporate travel on its key routes (Alaska Air, 2021; SkyNRG , 2019).

In the air freight industry, the Cargo Airline Association (CAA) has also been promoting the use of SAF. Amazon Air has purchased 6 million gallons of SAF produced by World Energy (Amazon , 2020). DHL Express has pledged to use 30% of SAF by 2030 (White House , 2021).

Europe

The European Union (EU) has pledged to reduce emissions by 55% from its 1990 levels by 2030, and they are looking to become carbon-neutral by 2050. All industrial sectors across Europe have a duty to contribute to this emission reduction target.

In the aviation industry, the EU Emissions Trading System (EU ETS) has provided a financial incentive for aircraft operators to use SAF instead of conventional aviation fuels. This will reduce their reported emissions and the number of ETS allowances they are required to purchase (European Union Aviation Safety Agency , 2021). The European Commission proposed the ReFuelEU Aviation initiative as part of its 'Fit for 55' package. Under this initiative, fuel suppliers will be required to blend increasing levels of SAF into jet fuels for planes departing from EU airports (World Economic Forum, 2021).

Over the years, various partnerships and goals have been formed to accelerate the uptake of SAF. In 2011, the European Commission and major European stakeholders launched the European Advanced Biofuels Flightpath with the goal to produce 2 million tonnes of SAF by 2020 (European Union Aviation Safety Agency , 2021). However, this target was not met, and an updated roadmap for 2030 is being developed.

A range of SAF production pathways will need to be harnessed jointly to maximize SAF output and emissions reduction by 2030. SAF production levels can achievably account for 10% of EU total jet fuel demand by 2030 (World Economic Forum, 2021). Recent developments, which include policy actions, research initiatives, investments in SAF production facilities, and long-term offtake agreements, aim to increase the uptake of SAF and help reduce the environmental impact of aviation. One of the initiatives is the Horizon 2020 programme, which has supported research and development of pre-commercial production of SAF with a total budget of €25 million ((European Union Aviation Safety Agency , 2021). Some of the collaborative research and innovation projects funded by this program include Bio4A, Jetscreen, Hyflexfuel and BECOOL (European Union , 2020; IRENA, 2021).

Production of bio-based aviation fuel in the EU is dependent on a small number of plants, which account for approximately 2.3 million tonnes per year, with the most developed process being Hydro-processed Fatty Acid Esters and Free Fatty Acid (HEFA) ((European Union Aviation Safety Agency , 2021). The EU is looking to develop approximately 30 SAF plants by 2030 and 250 plants by 2050, as shown in Figure 3 (World Economic Forum, 2021). The conversion and/or reconfiguration of existing facilities such as refiners or pulp and paper mills could lower the cost of building new SAF plants. Currently, 15 SAF plants are being planned across Europe, and 8 new HEFA plants from existing sites are projected to be completed by 2025. The financial support required for SAF deployment will differ depending on the technology. The World Economic Forum report on Guidelines for a Sustainable Aviation Fuel Blending Mandate in Europe has estimated that over the next 15 years, €30 billion from the government, will be required to support the development of new SAF plants from G+FT, AtJ and PtL (World Economic Forum, 2021).

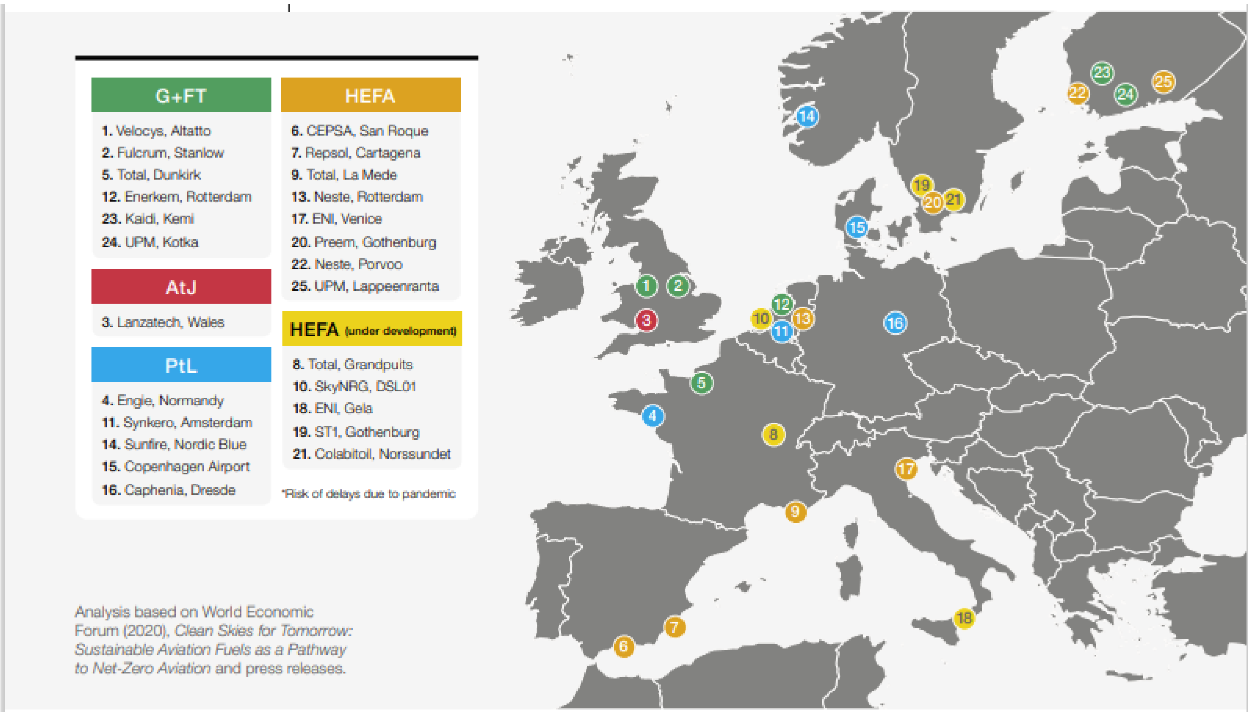


Figure 3: Sustainable Fuel Plants Across Europe (Source: World Economic Forum, 2021)

Several countries, including Finland, the Netherlands, Sweden, France and Portugal, have put in place or are currently planning policy support measures, such as SAF supply obligations. In 2019, the Finnish government introduced a mandate for 30% SAF blending by 2030 as part of its climate target to achieve a carbon-neutral country by 2035 (European Union Aviation Safety Agency , 2019).

In the Netherlands, the BioPort Holland supply chain was formed as part of a partnership between KLM, Neste Oil, Port of Amsterdam, SkyNRG, Schipol Group and the Dutch government (ETIP Bioenergy, 2021). The KLM Corporate SAF Programme launched in 2012 is a collaboration between 16 partners, including Arcadis, Royal Schipol Group, and ABN AMRO, who provide funding to help KLM purchase SAF (KLM, 2021). The SAF is blended with petroleum-derived fuel and pumped into the refuelling systems at Schipol Airport in Amsterdam.

In 2021, Air France and KLM launched the Air France KLM Martinair Cargo SAF Programme, which allowed its cargo customers to support the development and production of SAF. The first customers included Kühne+Nagel, who have invested in SAF for all their cargo shipments on the Amsterdam-Los Angeles route (KLM , 2021).

In Spain, the Bioqueroseno initiative, launched in October 2011, brought the manufacturer Airbus into collaboration with several Spanish ministries and companies involved in the production of raw material, refining technology and aeronautical logistics (ETIP Bioenergy, 2021). The initiative will facilitate the production of bio-kerosene for aviation from second-generation sustainable crops as feedstock (ICAO , 2021). Spain has proposed a 2% SAF mandate by 2025 (ICAO, 2019).

The Aviation Initiative for Renewable Energy (AIREG) was launched in Germany in June 2011 by a group of 20 airlines, biofuel producers, aviation companies and universities. AIREG's main goal is to carry out research activities for climate-friendly aviation fuels. Also in Germany is AUFWIND, launched in 2013, which is a collaboration amongst twelve researchers and aviation engineers to explore the economic and ecological feasibility of producing biokerosene from microalgae (ETIP Bioenergy , 2021).This project has received total funding of €7.4 million, with €5.75 million contributed by the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) via its project management organization Fachagentur Nachwachsende Rohstoffe (FNR).

Norway

Norway has a target for aviation fuel to contain 30% of sustainable content by 2030. The government requires the biomass used in the production of the SAF to be from wastes and residues. In 2015, Norway became the first country to supply biofuel to Oslo Airport. The state-owned airport operator, Avinor, had been blending jet biofuel into the hydrant system at Oslo Airport since 2016, and the project was extended to Bergen Airport in 2017. This proved that the current channels for delivering jet fuels could be used to deliver the jet biofuel; different channels did not need to be developed (European Union Aviation Safety Agency , 2019).

In January 2020, the Norwegian Ministry of Climate and Environment set a mandate that required 0.5% of the aviation fuel sold in Norway to be SAF (BP, 2019). This target is equivalent to 6 million litres of fuel and will lead to an approximate 14,000-tonne reduction of CO_2e in the first year.

Norwegian Air is committed to reducing its emissions by 45% by 2030. To reach this target, it will need approximately 500 million litres of SAF, depending on the renewal of its fleet (Norwegian Air Shuttle, 2020). Currently, their aircraft can fly on up to 50% of certified SAF.

Bridging the Gap in Australia

Barriers to SAF uptake

There are many barriers to the commercial uptake of SAF in Australia and New Zealand that were raised consistently during stakeholder consultations. These barriers can be classified as economic (price-related) or non-economic, as described below.

Economic Barriers

Our stakeholders reported a significant gap between the prevailing market price of SAF and the price for airlines to procure meaningful volumes of SAF. This trend has been driven by two key factors:

1. Scale
2. External markets

Compared to the production of conventional aviation fuel, SAF production is relatively small-scale and relies on the handling of products (feedstocks) that are not as commoditised or established as their fossil fuel-based counterparts. These smaller-scale plants incur greater per-unit costs than larger plants and produce a comparatively more expensive product than conventional aviation fuel due to the difference in industry maturity. From a fuel supplier and airline perspective, the current cost of SAF was prohibitive in facilitating the uptake of meaningful volumes of SAF. This has created somewhat of a 'chicken-and-egg' scenario where demand at current pricing is insufficient to underwrite the construction of a domestic refinery, but the lack of refining capacity and scale/market maturity does not allow the price to fall to levels that generate meaningful demand.

In addition, the global emergence and uptake of the HEFA process, combined with lucrative international incentive programs, has significantly increased the price of some feedstocks used for SAF production. This is further exacerbated by the competition for feedstock between SAF and renewable diesel, both of which can access those incentive programs. These rises in feedstock pricing effectively ensure that SAF prices remain high, emphasising the need for diverse production pathways when developing a domestic SAF industry.

Stakeholders also raised concerns about the current export of feedstocks to international refineries, acknowledging the economic implications of diverting this waste stream, and the need to adapt production strategies to reflect the available resources in different areas. For example, regions with extensive biomass resources may be better suited to FT pathways than regions with extensive sugarcane resources. Stakeholders emphasised the need for this diversity in initial SAF plant construction to ensure that future refinery projects do not erase the benefits from economies of scale through increased competition for feedstocks.

Non-Economic Barriers

Non-economic barriers that hinder the uptake of SAF are primarily related to the interaction between SAF supply chains and existing fuel infrastructure and supply chains. This is particularly pertinent for the distribution of SAF within an airport through existing fuel hydrant infrastructure. As it is not feasible or cost-effective to duplicate supply infrastructure at an airport, it is impossible to track individual SAF molecules through fuel hydrants and into the plane wings. As a result, it is difficult for airlines to count the benefits of SAF procurement. Almost all stakeholders noted this inability to trace SAF in the general fuel supply through airports. This was a key factor in formulating the guarantee of origin (GUO) scheme that underpins the opt-in mechanism described in Recommendation 2: National Framework for Voluntary Consumer Purchasing.

Also, due to the existing infrastructure and ownership structures, SAF producers cannot sell directly to airlines. Third-party involvement is necessary to ensure that all aviation fuel being supplied through existing infrastructure meets the relevant product quality and safety standards. This can create conflicts with traditional infrastructure operators and fuel suppliers over customer relationships, obligations and responsibilities with respect to quality/standards, and pricing. This complex relationship dynamic was noted by all SAF producers and traditional fuel suppliers who were consulted with in preparing this report.

Current Policy Instruments to Support SAF

There are a number of programs at a state level, such as the QLD Biofutures program, that provide incentives to support the uptake and commercialisation of biofuels such as SAF, however there are currently no direct policies at a federal level to directly drive the uptake of SAF in Australia. The Emissions Reduction Fund/Climate Solutions Fund does include a methodology for the monetisation of emissions reductions arising from SAF usage. However, this mechanism has not encouraged SAF adoption because the available carbon benefits incentive is insufficient to cover the cost difference between SAF and conventional aviation fuel. One project was registered in 2015 to create Australian Carbon Credit Units (ACCUs) under this method, yet, no ACCUs have been created to date (Clean Energy Regulator , 2021). However, this mechanism has not encouraged SAF adoption because the available carbon benefits incentive is insufficient to cover the cost difference between SAF and Jet A1. While the benefits associated with carbon monetisation have increased by more than 100% in the previous 12 months, as shown in Figure 4, the higher prices are still not able to cover the cost gap.

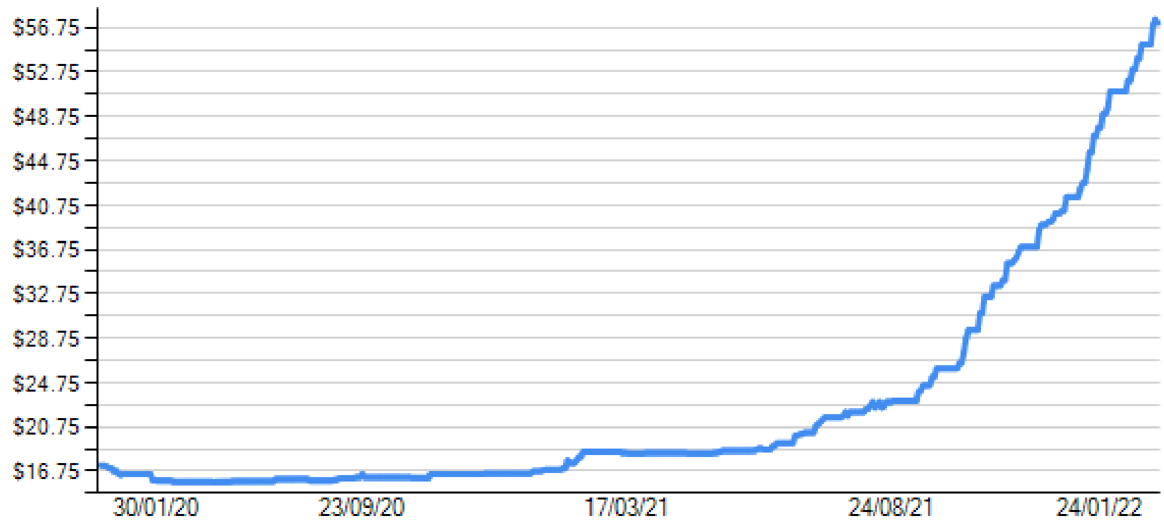


Figure 4: ACCU Price Trends (Jarden 2021)

According to the National Greenhouse and Energy Reporting (Measurement) Determination 2008, there are 3.06-3.32 t_{CO2e} per tonne of aviation fuel combusted, based on the emissions factors associated with kerosene used as aircraft fuel. The emissions vary due to the allowable variation in fuel density. Assuming that all combustion emissions could be avoided — which is unrealistically optimistic — even at the current ACCU price, this would result in a financial benefit of about $180/tonne.

Table 2: Carbon Benefit Calculations

	Upper Fuel Density	Lower Fuel Density
Emissions per tonne of Jet A1	3.32	3.06
Current ACCU Spot Price	$58	
Maximum monetary benefit	$192.29	$177.41
SAF price gap at 10x Jet A1 Price Current ACCU Price	$9,038	
SAF price gap at 5x Jet A1 Price Current ACCU Price	$3,942	
Target price gap at 3x Jet A1 Price	$2,034	
Required ACCU price, 3x Jet A1 Price	$614	$665

Table 2 shows that the current carbon crediting mechanism is not sufficient to provide meaningful financial support for switching from Jet A1 to SAF. The required monetary benefit per tonne of carbon is an order of magnitude larger than the current price. Consequently, additional support mechanisms on both the supply and demand sides will be required to drive SAF uptake in this hard-to-abate area.

Case study of New Zealand

Aviation decarbonisation technologies are currently the subject of R&D in New Zealand, with electric, hybrid and hydrogen aircrafts being developed to reduce emissions for short-haul flights beginning in 2030. However, these technologies are unlikely to decarbonise long-haul travel or play a critical role in achieving net-zero emissions by 2050 (Air New Zealand, 2021). The adoption of SAF has the potential to decarbonise the aviation industry (both long- and short-haul flights). However, New Zealand currently lacks the SAF supply to do so.

The high capital cost of producing SAF means that the aviation industry in New Zealand will require government support investments, collaborations, and studies, as well as policies that promote the uptake of SAF. The SAF Consortium, which includes Air New Zealand, Scion, Z energy, LanzaTech, and LanzaJet, has outlined a roadmap of how New Zealand can establish SAF production. Their analysis identified that New Zealand is strategically positioned to adopt SAF, which will produce socio-economic benefits and reduce emissions by up to 85% compared to petroleum-derived jet fuel (Air New Zealand, 2021).

First, New Zealand must establish an advisory body that will be responsible for decarbonising the aviation industry. This entity would oversee and manage policies and investments that support SAF development. Other countries have created similar advisory bodies, such as the UK's Jet Zero Council. Feasibility studies would be conducted to assess the feedstock supply and determine whether SAF supply would include both local and imported supply. Local production of SAF would result in a lower product price.

Second, a SAF mandate is crucial to encouraging SAF uptake through investments. Such a mandate must ensure investments are solely directed to fuels that will reduce aviation's climate impact, i.e., biofuels that meet strict sustainability criteria. Various countries' mandates require SAF to be blended into the current jet fuel. The SAF Consortium proposed a roadmap, as shown in Figure 5, in which the SAF mandate would increase gradually from a 2.5% mandate in 2025 to 50% in 2050 (Air New Zealand, 2021). This gradual rise is vital to establishing SAF production and creating a manageable transition for producers and suppliers.

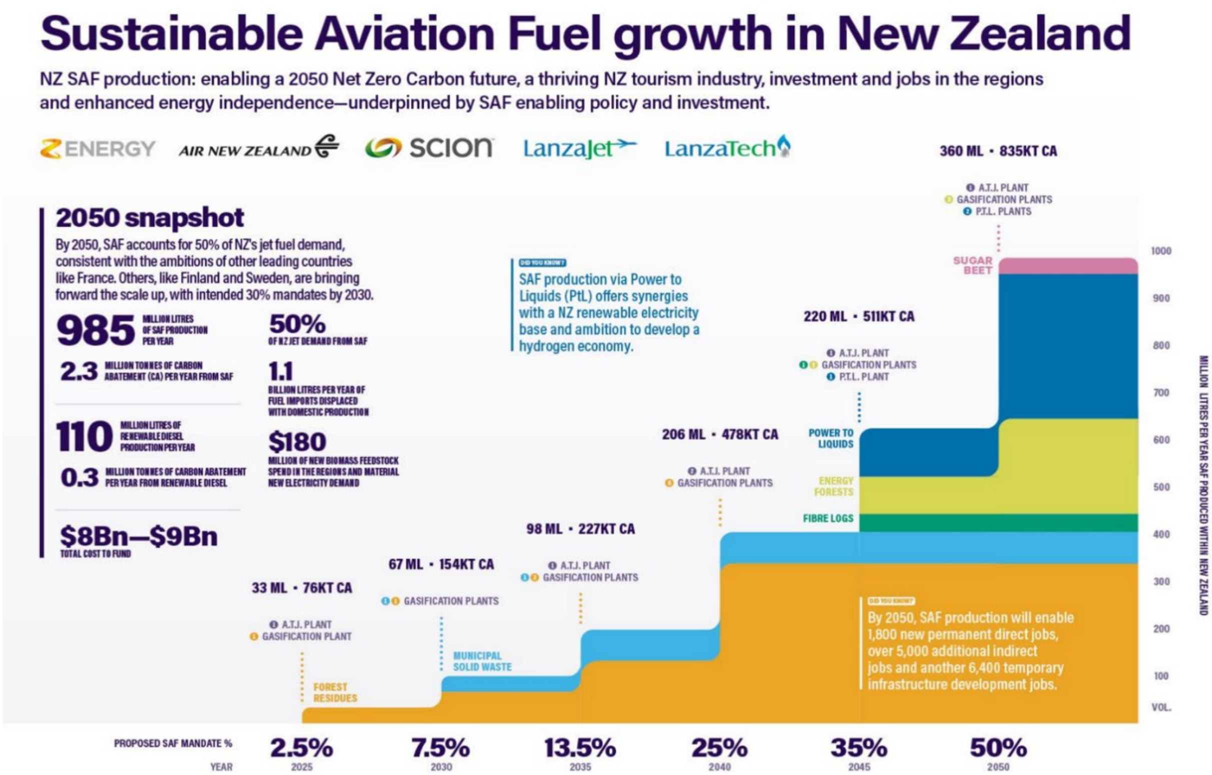


Figure 5: Proposed SAF Mandate (Source: Air New Zealand, 2021)

Benefits of SAF emergence in Australia

While there may be additional costs borne by Government by participating in a voluntary SAF purchasing program, significant benefits would emerge from a domestic SAF production market, including:

- Economic Development
- Regional Development
- Fuel Security

Economic Development

The establishment of a bio-refinery for SAF production would create jobs throughout the design/construction/commissioning phase, as well as for the ongoing operation of the facility. This is demonstrated in the UK, where a 100 ML plant will create 800 jobs during development and 100 permanent jobs for operation (Essar, 2021). The construction and operation of a SAF refinery would also have supplementary effects throughout the feedstock supply chain, allowing additional economic benefits associated with job creation. These effects may be seen in industries surrounding the collection and transportation of feedstock, as well as the distribution of SAF.

There is significant global momentum towards incorporating SAF into the general aviation fuel supply. Recently, key global airlines have announced their goals to use 10% SAF by 2030. This report models the potential economic benefits available if 10% of Australian aviation fuel was SAF. The calculations have been detailed below in Table 3 and Table 4.

Table 3: Australian SAF Fuel Requirements

	Volume (ML)
Annual Aviation Fuel Required in Australia	9434.2
Annual SAF Required in Australia	943.42

Table 4: Employment Outcomes (Calculated using data from I-O factors from New South Wales Treasury, 2020)

	2x Jet A1	5x Jet A1	10x Jet A1
Procurement Cost ($m)	$1,487	$3,718	$7,437
Estimated number of FTE supported by procurement	1,219	3,048	6,097

Based on an NSW Treasury Input-Output model and the expected procurement costs associated with 10% SAF, this type of procurement would support a significant number of jobs. As Australia represents a small percentage of the global aviation fuel market, there would also be significant opportunities to scale up domestic production to export SAF to other countries. Australia could take advantage of the existing relationships and supply chains associated with the trade of fossil fuel-based products into Asian markets and its abundant feedstock availability.

Expanding Australian SAF production with an export focus may represent an attractive industry maturation pathway as the costs of developing and scaling up refineries would effectively be borne by customers in international markets. Using several capital-cost ‘rules of thumb’ published by ICAO, the potential price reductions from SAF plant scaling are shown below in Figure 6.

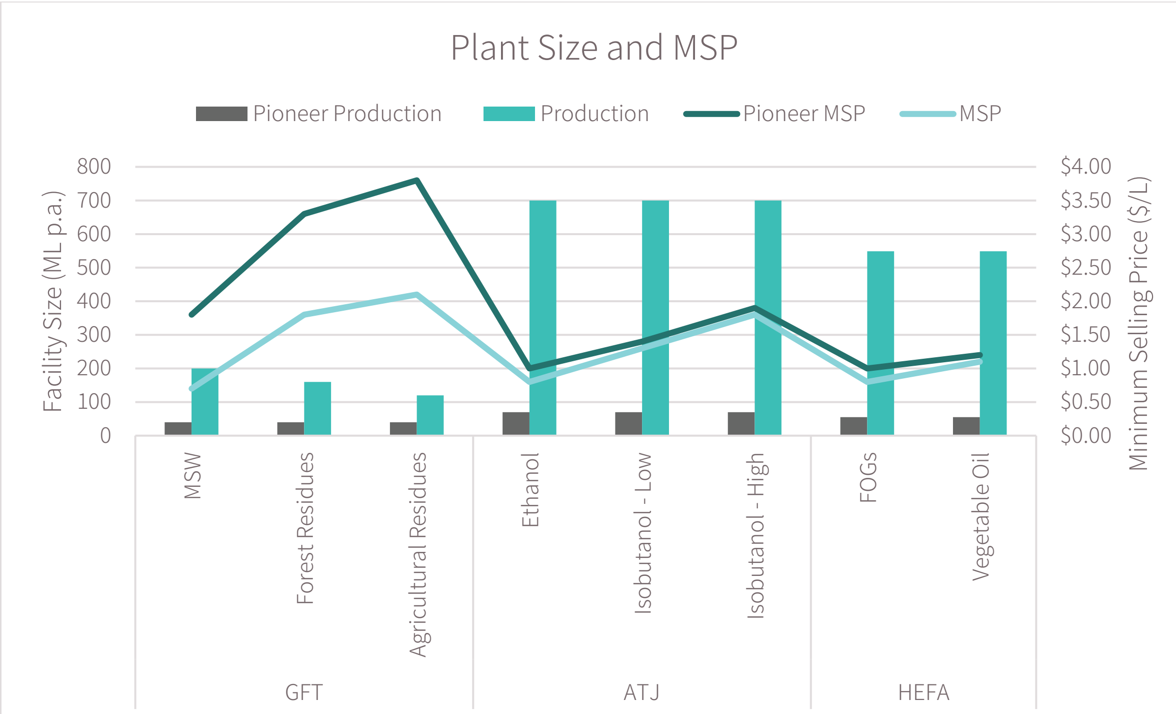


Figure 6: Estimated Economic Benefits of SAF Production (calculated using data from ICAO, 2021a)

Figure 6 shows significant reductions in the minimum selling price associated with the commercialisation and scaling of SAF refineries, particularly for technologies with larger capital costs such as gasification Fischer-Tropsch, which are typically more capital-intensive plants than alcohol-to-jet or HEFA plants.

The construction and operation of SAF refineries also would create benefits for state and federal Governments through increased job creation, development of technology and human capital, and taxation-based financial flows. Additional corporate taxes would indirectly help pay for the Government's SAF support programs.

These benefits would be further extended by the development of a SAF export industry, which would enable Australia to learn from other nations' experiences with integrating SAF into aviation supply chains.

Regional Development

SAF production has the potential to provide substantial benefits through the development and growth of existing regional hubs. While many feedstocks can be used for SAF production under the various approved pathways, they are often concentrated in regional areas, or they use products/waste streams generated in regional areas by primary producers. Stakeholders consulted for this report consistently recognised the key regional benefits of feedstock procurement.

By creating additional markets for products or resources currently considered to be waste streams, regional primary producers can benefit from income diversification and growth, increased financial security, and improved land value due to greater productivity. Placing a value on products typically discarded as waste, such as agricultural residues, may also create new job opportunities for on-farm activities and ancillary support services such as transport and labour, which further support regional development.

Australia currently has many regional hubs with significant dependence on fossil-fuel industries such as coal, gas and oil. These hubs already contain highly skilled workforces that are experienced with traditional fuel types. By supporting SAF refineries that leverage regionally produced feedstocks, these workers could be retained in existing hubs through the transition to a lower-carbon economy.

This would also help support the existing supply chains in the hospitality, finance, housing and transport industries that are already established in these regional hubs. An estimated 300,000 Australian jobs in regional areas are at risk due to decarbonisation and a decline in fossil fuel demand over time (Centre for Policy Development, 2022). SAF production for the domestic and international markets would provide an alternative job source to help minimise dislocation and adverse impacts due to mass worker emigration from existing regional hubs.

Fuel Security

By building domestic fuel production and refining capacity, Australia would become less reliant on imported fuel (or other oil-based refining feedstocks) to meet aviation fuel demand. Therefore, SAF production would increase Australia's fuel security. This is a critical issue given the potential for international events, such as conflicts, natural disasters, trade agreements, economic crises, etc., to disrupt existing fuel supply chains and cause Australia economic harm.

Such a supply-chain crunch recently happened with an emissions control additive, AdBlue, and the Federal Government was forced to provide a grant of $29.4 million to support the short-term production of AdBlue (Australian Financial Review, 2021) to ensure that Australian diesel fleets could continue to operate. Even for a product less integral than the fuel itself, supply-chain disruptions led to such an emergency. Local manufacturing policies can help prevent these types of scenarios.

Fuel security has been a key focus of the Federal Government, which has provided significant funding to existing fossil fuel-based refineries to ensure their continued operation until at least 2027 (Commonwealth of Australia, 2021). Co-locating SAF refineries with other bio-refineries to produce the full spectrum of transportation fuels is beyond the scope of this report. However, there are opportunities to provide biofuels to the greater transport sector while also supporting SAF. For example, expanding ethanol production for alcohol-to-jet pathways could enable greater blending in road fuels. This would also improve Australia's performance against the IEA's minimum 90-day stockpiling obligations and reduce its exposure to the price volatility of imported fuel.

Domestic fuel production for critical end-users such as defence provides an attractive value proposition alongside the fuel security benefits, and the Australian Defence Force is currently developing a future fuels strategy. Many stakeholders viewed Government levers such as Defence fuel procurement as one of the most effective indirect ways to promote a domestic SAF industry without the need for formal Government intervention. Furthermore, given Australia's commitment to net-zero emissions by 2050 and the associated need to decarbonise Defence fuel use, as well as the long service lives and capital intensity of Defence platforms, there will likely be significant volumes of liquid fuels required in 2050 and 2060. These fuels will be necessary to maintain the Defence platforms' existing operational capability, regardless of the electrification or fuel switching that takes place in commercial markets.

As such, the Australian Defence Force would be an ideal customer to voluntarily pay a small premium to support the development of a domestic SAF industry. This would allow Defence to invest in a supply chain that continues to provide relevant liquid fuels over the long term while supporting decarbonisation goals.

Finally, as Australia is a relatively small aviation fuel market relative to global standards, with a traditional refining capacity that only produces conventional Jet A1, there is a risk that percentage blends of SAF would become a business-as-usual component of the imported aviation fuel mix. This would burden Australian consumers with the premiums associated with SAF without capturing the benefits of domestic production.

Recommendations

Deploying Sustainable Aviation Fuel in Australia

This report has been prepared to review the SAF industry's current state within Australia, and, based on a review of international policy instruments, propose how to bridge the price gap between SAF and conventional aviation fuel in Australia. In addition to the policy review, stakeholders from across the SAF value chain were consulted in the development of four key recommendations for bridging that gap. These policies are designed to support the emergence of the SAF supply chain, guide ongoing policy development for the industry and stimulate demand for SAF throughout Australia. This report builds upon internationally recognised best practices, as well as lessons learned, to propose recommendations for an Australian context.

While the Australian aviation industry recognises the need for the sustainable growth of air transport, it faces obstacles stemming from weak national policy support and a lack of long-term climate commitments, which would aid the sustainable energy transition of hard-to-abate sectors such as aviation.

Continued inaction on making aviation more sustainable could pose significant risks, including consumer aversion and phenomena such as the flight-shaming observed in Europe. Further, without a long-term industry-wide plan, future Governments may impose policies that require faster action, leading to greater costs for industry stakeholders and customers as well as sub-optimal outcomes across the supply chain.

Finally, there is no single measure within this report that, in isolation, would be sufficient to bridge the price gap. Appropriate actions must be taken in consideration of all measures' interaction and implications across the broader SAF value chain.

Recommendation 1: Establishing a Jet Council

Following the lead of the UK and its Jet Zero Council, Australia should establish a 'Jet Council' to connect the State and Federal Government with aviation industry stakeholders to guide the ongoing development of sustainable aviation policies. The Jet Council would work with the various levels of Government to guide and support pathways for SAF R&D in Australia, as well as provide feedback on the design and implementation of policies to overcome existing barriers to SAF development.

The establishment of a Jet Council would also be pivotal in implementing the policies outlined in Recommendation 2: National Framework for Voluntary Consumer Purchasing and Recommendation 4: Emissions Intensity Mandate. All stakeholders in the aviation fuel/SAF supply chain must be engaged to ensure the equitable impact of any policy development.

Council Structure

At a minimum, the proposed Jet Council would comprise representatives across the SAF value chain, including:

- Federal Government
    - Federal Government agencies including the Australian Defence Force
- State Governments
- SAF producers
- Aviation fuel suppliers
- Fossil fuel-based aviation fuel producers
- Airlines
- Airport owners/operators
- Industry bodies and representatives
- Aeroplane manufacturers
- Feedstock collectors/suppliers

The broad member base would allow the Jet Council to ensure all stakeholders' views will be considered when advising the Government or helping determine the appropriate targets or policies.

Council Purpose

The Council's scope of work would include:

- Provide ongoing advice to the Government (Federal and/or State) to help inform the development and evolution of SAF policy
- Work with Government and Government bodies (such as ARENA, CEFC etc) to help the industry overcome existing barriers to SAF industry development, e.g., through the provision of Government funding, as described in Recommendation 3: Funding
- Administer the voluntary purchasing program outlined in Recommendation 2: National Framework for Voluntary Consumer Purchasing (subject to its implementation)
- Support the development pathway for SAF technologies to increase R&D activities within Australia

Recommendation 2: National Framework for Voluntary Consumer Purchasing

The Federal and State Governments, in collaboration with the previously recommended Jet Council, should establish a national framework for a voluntary consumer purchasing program to enable customers to opt-in to procure a portion of SAF for their flight. This would be similar to carbon-offsetting options that airlines currently offer to customers. However, the focus would be on *reducing* the emissions associated with air travel, rather than using credits to offset those emissions.

These emission reductions would be tracked via a Guarantee of Origin (GUO) scheme, allowing SAF purchasers to be 'credited' with the resulting emissions reduction. Accordingly, customers who opt into purchasing a portion of SAF for their flight would see a corresponding decrease in their scope 3 emissions associated with air travel.

This arrangement is modelled on the hydrogen GUO scheme currently being trialled by the Clean Energy Regulator. It would be a transparent, Government-administered program to support the accurate reporting of SAF consumption, including under frameworks such as the National Greenhouse and Energy Reporting (NGER) scheme. Under the hydrogen GUO scheme, the carbon intensity of the hydrogen production is listed on a certificate issued to the consumer. When the hydrogen is consumed, the corresponding certificates are cancelled (Clean Energy Regulator , 2021). This type of labelling and carbon intensity calculation would be replicated for a SAF GUO scheme.

With the fuel delivery infrastructure currently in place at major airports, there are constraints on blending SAF on-site due to a lack of storage capacity, fuel hydrant systems, and the flow of fuel from under the awnings into the planes. Duplication of infrastructure is neither cost-effective nor practical to support the delivery of SAF and allow for its allocation to individual planes.

Many stakeholders consulted for this report noted the logistical challenges of integrating SAF and assessing its emissions impact. Their consensus was that blending SAF at the existing fuel supply points would maintain the required quality standards and provide the lowest-cost method of supplying SAF to airlines.

A similar 'opt-in' program is currently being developed in the USA. The Sustainable Aviation Buyers Alliance (SABA) is an initiative by the Rocky Mountain Institute (RMI) and Environmental Defense Fund (EDF) to develop a SAF certificate scheme that would allow large corporate travellers to transparently demonstrate their SAF purchases for reducing air travel emissions. This program also ensures equity in cost allocation, as general consumers are not forced to incur additional costs. The costs are only borne by those who elect to participate, creating a less price-sensitive market for SAF. The program will leverage corporate and government emission-reduction commitments to launch with large corporate flyers representing the cornerstone of demand.

A similar mechanism in Australia could create sufficient SAF demand to support the construction of a domestic SAF refinery. The participation of Federal and State Governments in a voluntary consumer purchasing program would provide a credible signal to large corporate organisations with net-zero targets or carbon-neutral commitments who can engage with airlines to reduce emissions without relying on carbon offsets.

Furthermore, initiatives such as the World Economic Forum's Clean Skies for Tomorrow Coalition prove that there is significant corporate demand for emissions reductions across corporate supply chains, particularly in hard-to-abate areas such as aviation travel.

Policy Design

The proposed mechanism would create a certificate associated with each tonne of SAF that is purchased by airlines and blended into the fuel supply infrastructure. These certificates would be surrendered to match the opt-in purchases of a fixed percentage of SAF offered by the airlines for the relevant blend (e.g., 10% or 50% SAF). The previously mentioned Jet Council, in collaboration with the appropriate Federal regulatory body (e.g., the Clean Energy Regulator), would be responsible for administering the certificate and ensuring that when surrendered, they are appropriately equated with customer purchases. Such oversight would ensure the program's ongoing credibility.

This program would initially allow for SAF to be imported to meet demand, supporting Australia's emerging SAF market based on voluntary purchases. Imports would eventually be phased out to encourage a dedicated supply from domestic SAF refineries. Given the current pricing trends and incentives available in international markets, a SAF production facility's capacity would likely not be entirely devoted to the voluntary purchasing program. Exports would play a critical role in Australian SAF refineries' viability in the absence of comparable emission-reduction incentives, such as those described in Recommendation 4: Emissions Intensity Mandate.

The gradual removal of imported SAF from the program would help mitigate the risk of price shocks to the SAF market, while providing domestic SAF refinery operators with the flexibility to fetch the highest possible prices available in export markets. Meanwhile, it would support the minimum level of demand to facilitate the financing and commissioning of a SAF refinery or refineries in Australia, with additional financial support to be provided through the Federal Government, as described further in Recommendation 3: Funding.

Pricing Implications

The pricing implications of voluntary SAF purchases have been modelled using publicly available information released by Qantas under the Australian Government's Climate Active program (formerly known as the National Carbon Offset Standard), the National Greenhouse Accounts Factors for the corresponding period, and published aviation fuel pricing data. This is shown in Table 5.

Table 5: Estimated fuel consumption per passenger kilometre (Source: *Commonwealth of Australia , 2018*; *Qantas, 2019)*

Item	Quantity	Unit
Passenger kilometres	127,492	Million pa.km
Passenger emissions total	11,937,794	tCO2e
Freight emissions total	1,680,470	tCO2e
Kerosene emissions total (scope 1 only)	12,256,591	tCO2e
Estimated passenger kerosene emissions (scope 1 only)	10,744,149	tCO2e
Kerosene use per passenger kilometre	0.032799	L/pa.km

Table 5 shows that the fuel use per passenger kilometre is relatively low, allowing voluntary purchases by large organisations or carbon-conscious customers at a relatively low marginal cost. Using an example flight from Sydney to Melbourne, the cost impacts of 50% SAF blended aviation fuel to a customer has been modelled in Table 6.

Table 6: Voluntary Purchase Pricing Impacts

	Jet A1	50% Blend Aviation Fuel		
		SAF, 2x Jet A1	SAF, 5x Jet A1	SAF, 10x Jet A1
Cost per litre of fuel	\$0.79	\$1.18	\$2.36	\$4.34
Cost per pa.km	\$0.03	\$0.04	\$0.08	\$0.14
Sydney to Melbourne pa.km	706			
Estimated fuel cost for Sydney to Melbourne	\$18.25	\$27.38	\$54.76	\$100.39
Additional Cost	\$-	\$9.13	\$36.51	\$82.14
Additional Cost per pa.km	\$-	\$0.013	\$0.052	\$0.116

Table 6 shows that, at twice the price of conventional aviation fuel, there is a minimal increase in the cost per kilometre, with voluntary buyers being charged just over 1c per kilometre travelled by each passenger. These results also emphasise the need to focus on bridging the price gap between SAF and conventional aviation fuel, as cost reductions will drive greater participation by voluntary customers. Also, the above analysis is based on using 50% blended fuel. Depending on the prevailing SAF price, this percentage could be adjusted to achieve price outcomes that will be acceptable to voluntary customers, while still creating demand for SAF that could be leveraged for refinery construction.

A 1% uptake by customers (in terms of passenger kilometres) would require the consumption of approximately 41.8 ML of SAF, which would be sufficient to warrant the construction of a SAF refinery in Australia. Also, an initiative such as the Sustainable Aviation Buyers Alliance, discussed earlier in this section, can be replicated in Australia to help drive greater demand for SAF by Australian corporates and Government agencies/bodies. Initial participants would help cover the initial costs of establishing the SAF industry, facilitating the cost decreases associated with scale-up, which subsequently would encourage greater corporate participation in a virtuous cycle.

Recommendation 3: Funding

To help bridge the price gap between SAF and conventional aviation fuel, the Government should provide additional dedicated funding towards the construction of domestic SAF refineries. This funding could be administered through new funding bodies/mechanisms such as the proposed Jet Council, or through existing Government Agencies such as the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC). Under any type of funding mechanism that could be implemented, there must be lifecycle assessments of the SAF to be produced. These would ensure that the lifecycle emissions associated with SAF are lower than those from conventional aviation fuel, in order to prioritise the lowest-carbon SAF options. Such an assessment also provides for seamless integration with Recommendation 2: National Framework for Voluntary Consumer Purchasing and Recommendation 4: Emissions Intensity Mandate once refineries start producing SAF.

This support would aid the construction of Australia's first series of commercial plants, in the same way that ARENA and the CEFC helped establish and mature the renewable electricity generation industry. According to an independent review of ARENA's Competitive Round, the funding helped advance the commerciality of large scale solar by 5 years (EY, 2019).

However, multiple pathways should be explored in Australia as different states/regions have natural competitive advantages. Heavy pathway concentration would increase feedstock prices, creating negative outcomes for SAF pricing. Pathway diversity also reduces the risks associated with technology concentration and the exposure of SAF supply chains to external shocks (e.g., drought or natural disaster for crop residue feedstocks).

Approach 1: Capital Funding – Grants and Low-Interest Loans

Government funding could be provided in the form of grants or low-interest loans to reduce the capital or financing costs of a SAF refinery. This helps improve the business outcome, as capital expenses and financing costs are two key determinants of a SAF refinery's viability.

Further, Government support also helps mitigate financing costs for future plants by demonstrating that SAF refineries are technically and financially feasible in Australia. The current technological advancements combined with lower financial risk as the SAF industry matures will bring down the costs of SAF production in Australia over time. This will gradually drive a greater SAF uptake.

If this approach is chosen, both grants and low-interest loans should be made available to refinery projects, with a proposed sale price of SAF to be included in funding applications. This allows capital to flow to the lowest-cost producers and provide the greatest benefit.

Approach 2: Production Subsidies

Alternatively, the funding mechanism could target the operating revenues/margins of a SAF refinery. This approach would be implemented similarly to the fuel security services payment that has recently been provided to Australia's refineries. Under this mechanism, there is a price subsidy (cents per litre) that is provided when refining margins fall below certain thresholds. This mechanism would work by the Government providing a subsidy per L of SAF produced when the Jet A1 price falls inside or outside of certain ranges.

This could also take the form of a ‘reverse auction’ in which SAF refineries bid their proposed SAF pricing around a benchmark price (e.g. 2 times the Jet A1 price) and the Government funds the difference between the bid and the benchmark. A similar scheme has been implemented for renewable energy in the United Kingdom and would effectively represent a Contract for Difference (CfD) guaranteeing a minimum price for the SAF.

The existing fuel security package will provide support to conventional refineries until 2027, with an option to extend until 2030 (Commonwealth of Australia, 2021). The broader question of what happens to those refineries once the support package ceases is beyond the scope of this report. However, if fuel security is a government priority, there is no reason to exclude bio-based refineries, including SAF refineries, from similar support arrangements, as they help underwrite the ongoing financial viability of refinery operations.

These mechanisms are somewhat more advantageous than grants/low-interest loans as they do not ‘pick winners’ at a technology (SAF pathway) level. Instead, they allow the market to determine the most cost-effective SAF pathway. The lowest-cost plants are the ones that will obtain funding and reach viability given the available Government support.

Airline stakeholders indicated that there was demand for significant volumes of SAF at twice the price of conventional aviation fuel. This ‘per L’ subsidy mechanism should scale down as the costs of refinery construction and operation decrease with each new plant, given the technological advancements and lessons learned over time.

Recommendation 4: Emissions Intensity Mandate

SAF mandates are internationally recognised as critical to SAF deployment and scaling. Many mandates have been proposed and implemented around the globe, including Norway (from 0.5% in 2020 to 30% in 2030) and as a part of the Fitfor55 package in the EU (starting in 2025, the aviation fuel made available to EU airports should contain 2% SAF, increasing to 5% by 2030, 32% by 2040 and 63% by 2050). Both programs have placed an obligation on the fuel suppliers. In our stakeholder consultations, airlines, traditional fuel suppliers and SAF producers all identified an emissions intensity mandate as the most effective mechanism for driving domestic SAF uptake.

Currently, the largest, most active international program driving the uptake of SAF (and other types of biofuels) is the Low Carbon Fuel Standard (LCFS) in California. This policy mechanism is based on reducing the emissions intensity of fuel relative to a benchmark over time.

While more general reductions in emissions intensity in the transport sector are beyond the scope of the report, using a benchmark intensity scheme would facilitate the integration of SAF into aviation fuel supply chains. Also, by using emissions intensity as the key metric, the market can determine the most cost-effective manner by which to achieve reductions. This avoids the Government playing the role of ‘picking winners’ and leads to lower-cost outcomes for all participants.

Policy Design

This policy would consider existing aviation fuel to have an emissions intensity of 100, which serves as the basis for comparison with any other type of fuel. Under this policy, all fuel sold would have to meet an emissions intensity benchmark that decreases over time. The emissions intensity of SAF would then be calculated using lifecycle assessments (LCAs) to capture the full array of emissions associated with SAF refining, including but not limited to:

- Feedstock growth/collection
- Feedstock transport
- SAF refining
- SAF transport
- SAF combustion (biogenic CO_2 treated as zero emissions)

This type of policy requires all SAF sold in Australia to complete an LCA that would be approved by the Government body/agency responsible for administering this scheme. Alternatively, this activity could be monitored and approved by an organisation similar to the Jet Council described in Recommendation 1: Establishing a Jet Council. The results of the LCA, in terms of the fuel’s emissions intensity, would determine whether selling the fuel would create a ‘credit’ or ‘deficit’ for the suppliers. This mechanism, in the context of the LCFS, is shown below in Figure 7.

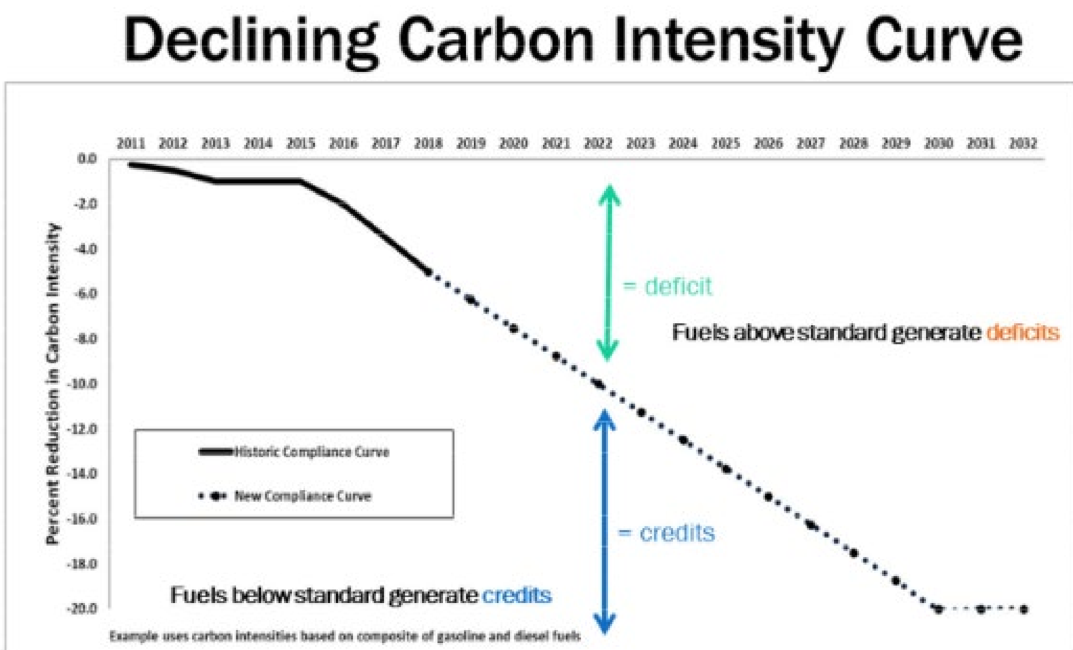


Figure 7: Carbon Intensity Curves (Source: California Air Resources Board, 2020)

Figure 7 shows that the benchmark intensity reductions decrease and necessitate greater volumes of SAF over time. For aviation, the decline in emissions intensity would need to be lower and slower than what is shown in Figure 7 to allow the SAF industry to develop while protecting the aviation industry's ongoing viability.

Because the volume of aviation fuel sold in Australia has dropped dramatically due to the impacts of COVID-19, as shown graphically below in Figure 8, FY19 has been used for calculations as this represents a return to 'BaU' for aviation.

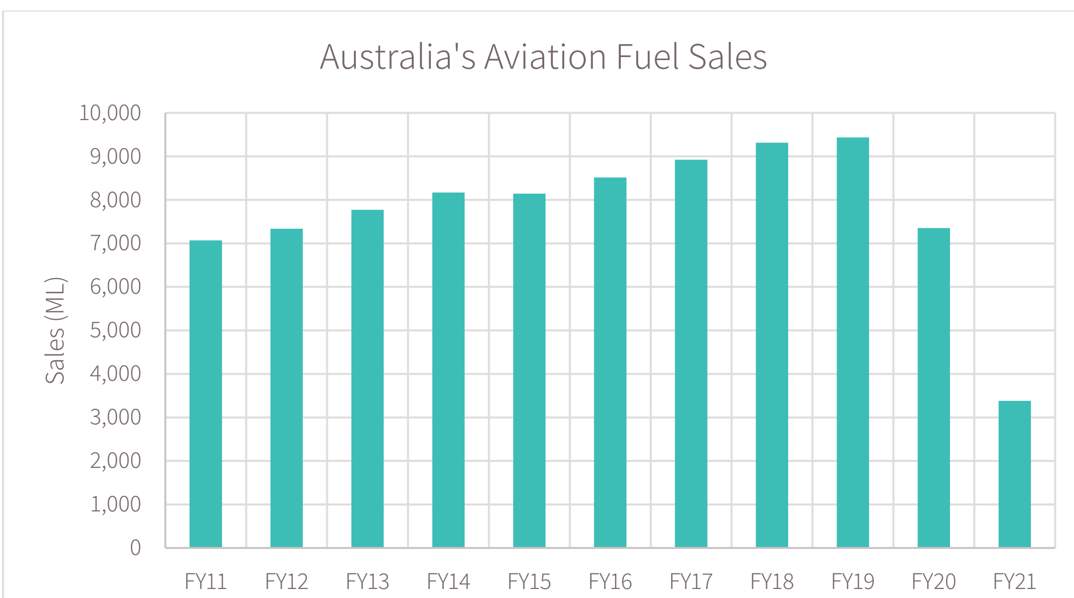


Figure 8: Australia's Aviation Fuel Sales (Source: Commonwealth of Australia, 2021)

Given that pre-COVID aviation fuel sales were over 9 billion litres per annum, as shown in Figure 8, reductions in emissions intensity by even a few percent would require a significant volume of SAF to be blended into the aviation fuel supply system in Australia. As a result, it is recommended that initial benchmarks be set at less than 5% so that the target is achievable and not cost-prohibitive. Stakeholders made it clear that large, rapid SAF mandates (e.g., 20% by 2025) are not practically achievable without substantial cost increases for all customers.

A 2.5% reduction in emissions intensity (i.e., 2.5% of aviation fuel becoming SAF) has been modelled throughout this recommendation and would require approximately 235ML of SAF to be integrated into the aviation fuel supply chain. This volume would be sufficient to warrant the construction of at least 1 SAF refinery in Australia.

While imports would be allowed under this type of arrangement, it is likely that higher prices seen in other markets (e.g., California) will cause SAF to flow to these regions rather than Australia, so long as the benefits under the LCFS exceed the benefits available in Australia. The long-term phase-in of intensity targets compared to current 'business as usual' fuelling scenarios would allow the SAF supply chain to develop and grow. Meanwhile, given the relatively small domestic volume, SAF refineries would have the flexibility to maximise revenue by exporting to higher-value markets overseas.

Under such an emissions intensity compliance program, emerging costs would be borne by airlines and ultimately consumers (likely in the form of higher ticket prices). However, appropriate penalty prices for credits would ensure fuel suppliers are incentivised to procure SAF, rather than paying a lesser penalty. This would be in line with mechanisms seen within existing Federal programs (e.g., the Renewable Energy Target) and state-based schemes (e.g., the NSW Energy Security Safeguard and Victorian Energy Upgrades Program).

A formal penalty price per credit would also help protect airlines by setting a 'price ceiling' for the credits and maintaining a level of price certainty for their business planning. The relevant Federal body responsible for regulating this program, likely the Clean Energy Regulator, would be able to leverage an entity such as the proposed Jet Council to gain industry insights on intensity targets, rate of escalation and credit pricing. This would ensure that all relevant stakeholders' views are considered and balanced in decision-making.

Policy Applicability

A key element of the policy would ensure that any rules and regulations are applied equally across the airline industry, so that no Australian organisation is more advantaged or disadvantaged than another. This report also acknowledges the international airlines operating flights to Australia and the need to ensure easy integration across fuel procurement for both domestic and international travel. This is pertinent to a critical policy question: *where within the supply chain should the obligation on reducing emissions intensity be placed*?

The consulting stakeholders made clear that, given the logistical (and contractual) relationships involved in fuel supply within major airports, placing obligations on individual airlines would not be practical. Airports and fuel infrastructure owners are unable to duplicate the infrastructure (storage tanks, blending and testing facilities, under awning pipelines, etc.) necessary to track individual molecules of SAF throughout the fuel supply chain into individual planes. This would also be particularly challenging for international airline operators whose primary markets are not in Australia and who procure relatively small volumes of aviation fuel. As a result, the solution is the 'Californian' approach in which the obligation is placed on aviation fuel suppliers. By choosing the point of fuel sale, all airlines, including international ones, would be indirectly subject to the emissions intensity policy.

Policy Impact

Mandates to procure SAF help drive uptake to the levels set in the relevant policy. However, greater uptake of SAF, would increase fuel procurement costs. The expected financial impact on the aviation sector has been outlined in Table *7*.

Table 7: SAF Procurement Cost Impacts (I*ATA, 2021*; *Commonwealth of Australia, 2021*)

	Jet A1	2.5% Blend Aviation Fuel		
		SAF, 2x Jet A1	SAF, 5x Jet A1	SAF, 10x Jet A1
Cost of procurement ($m)	$7,437	$7,622	$8,180	$9,110
Difference vs BaU ($m)	$-	$185	$743	$1,673
Percentage increase in fuel procurement costs	-	2.4%	9.1%	18.4%

Table 7 highlights that it is critical to driving down the price of SAF through industry development, so airlines can benefit from the economies of scale associated with larger production volumes. This helps ensure that a SAF program would neither place disproportionate costs on airlines nor produce unacceptable price rises to their customers.

Table 7 also shows that, at the upper end of the price gap target, the procurement cost increase is less than 2.5%. This could be further reduced through a voluntary cost passthrough measure as described in Recommendation 2: National Framework for Voluntary Consumer Purchasing. A proposed emissions reduction trajectory has been illustrated in Figure 9.

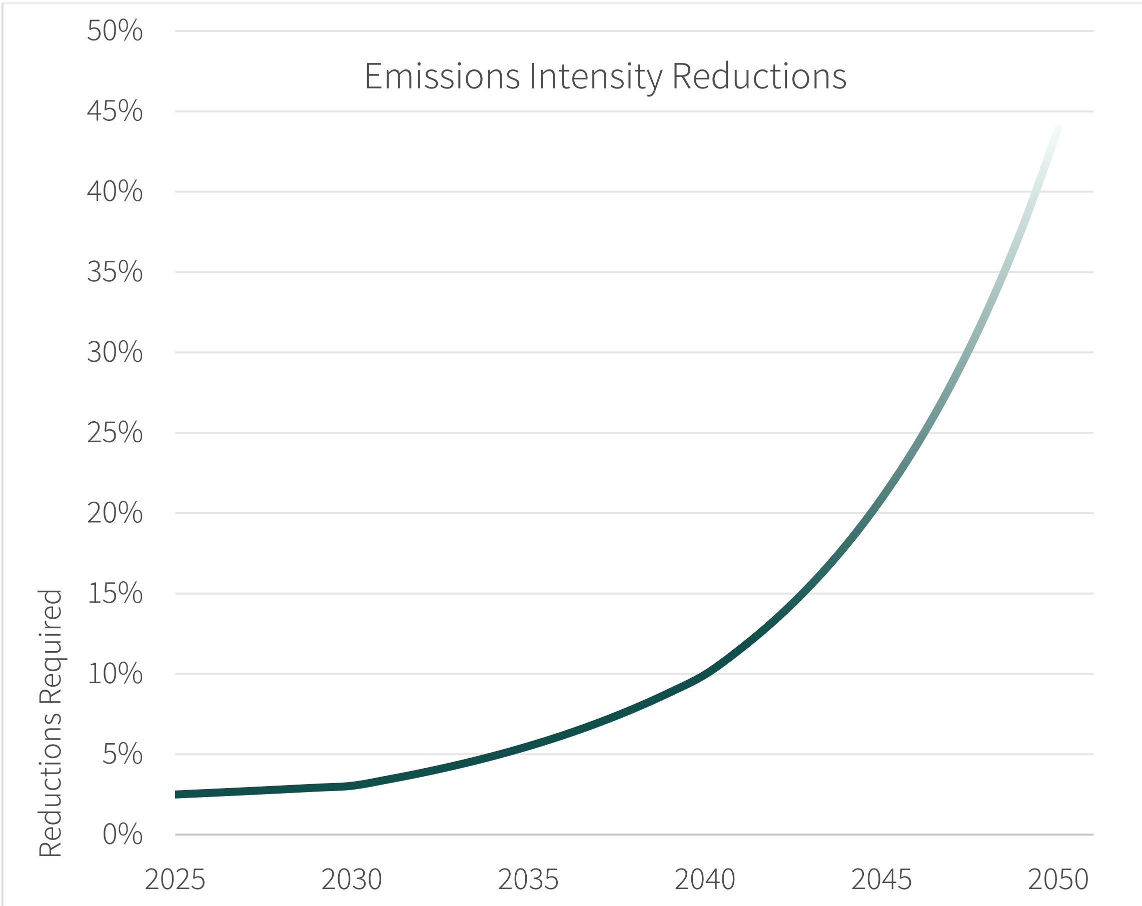


Figure 9: Emissions Intensity Reductions

Figure 9 shows that the initial requirements would commence in 2025, giving the industry sufficient time to plan for SAF procurement and supply chain integration. This is a relatively short timeframe given the required timeline for SAF refinery construction, so this volume of SAF would likely have to be met through imports. This initial 2.5% requirement would slowly increase to 3% SAF by 2030; the required rate of emissions intensity reductions would then rise at a faster rate in each following decade.

This helps minimise the program's costs as the first years will require the most expensive SAF while the industry is emerging. Over time, and as SAF costs drop, the required reductions would increase as a greater impact can be achieved at the same price. Also, there are presently limitations on the percentage of SAF that could be blended while still meeting ATSM requirements, so 50% is the upper limit of what is currently possible.

To reduce the price gap between SAF and conventional aviation fuel as quickly as possible, further Government support would be required. This has been explored further in Recommendation 3: Funding. Further corporate support in the form of voluntary purchases to stimulate SAF demand (and therefore supply) was discussed in Recommendation 2: National Framework for Voluntary Consumer Purchasing

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