SUSTAINABLE AVIATION FUEL

State of Play

ONE YEAR ON FROM THE AUSTRALIAN SAF ROADMAP

November 2024

BOEING FOREWORD

Forecasts indicate a **75 percent increase** in Australian jet fuel demand by 2050 and a need for over **42,000** new commercial aircraft globally for the same period. Aviation plays a vital role in supporting the country's economy facilitating tourism, trade, and business travel as well as cargo transportation, emergency response and national defence. However, this also highlights the critical importance of working together to progress sustainability across the sector.

The Asia-Pacific region, which has the highest level of passenger traffic, is expected to continue increasing at about 4.2 percent per year over the next two decades, accounting for the largest growth rate worldwide. Additionally, approximately 80 percent of aircraft carbon emissions are emitted from flights of over 1,500 kilometres for which there is no practical alternative mode of transport. Boeing has been addressing this through a multi-pronged decarbonisation strategy across the pillars of:

- Fleet renewal
- Operation efficiency
- Renewable energy
- Advanced technologies and
- Market-based measures such as offsets.

While each of these levers is required, it is evident that Sustainable Aviation Fuel (SAF) will play the most significant and rapid role in decarbonising the sector. In 2023, Boeing and CSIRO collaborated to develop the Sustainable Aviation Fuel Roadmap for Australia, which demonstrated the country's prime position to establish and scale its own SAF production industry while unlocking a range of other benefits including, job creation and strengthening national fuel security. The report has since informed policy and contributed to development of a domestic SAF industry.

We are proud to continue our 35-year partnership with CSIRO in producing this SAF State of Play Report, which captures progress and insights that have emerged over the last twelve months including:

- Several projects now progressing towards blending and production of SAF
- Federal and state government action driving positive policy development
- Boeing affirming SAF has no technical issues for use in all our military aircraft
- The finance sector collaborating on innovative funding approaches.

Collaborating with our customer airlines, government, research, industry and business has significantly contributed to the aviation industry's goal of net zero carbon emissions by 2050. We hope this State of Play Report will inform ongoing efforts in supporting sustainable aviation together.

Maria Fernandez

President of Boeing Australia, New Zealand and South Pacific

CSIRO FOREWORD

Science has never been more important as the profound challenges facing the planet become increasingly urgent and complex. As Australia's national science agency, CSIRO works with partners to harness the power of science and technology to develop sustainable, scalable solutions. As we confront challenges like reducing emissions in the aviation sector, we must also look to seize the incredible opportunities they present.

Following our joint release of the Sustainable Aviation Fuel Roadmap with Boeing in August 2023, this report provides insight into notable evolutions within and beyond the Australian SAF sector in the year since the roadmap's release.

Global momentum toward Sustainable Aviation Fuel (SAF) is gathering pace, and Australia's unique resources position us well to contribute to this transition. Achieving cost-competitive SAF solutions in Australia will require active partnerships, thoughtful policy interventions, and industry commitment. In particular, a nuanced understanding of domestic feedstock availability, feedstock competition, and infrastructure scalability is critical to positioning Australia as a leader in this space. These challenges underscore the need for targeted investment and tailored frameworks that align with Australia's specific conditions, as SAF production scales from beyond pilot phases.

With CSIRO's extensive history in biofuels, carbon reduction, and energy innovation, we are committed to supporting a SAF industry that balances economic and environmental needs. Our research continues to identify key opportunities across the SAF value chain, including carbon accounting and cost-efficient scaling mechanisms, aimed at maximising the benefits of local production and creating new growth opportunities for Australian industry.

This report, together with original roadmap, reflects a vision of a sustainable aviation future and provides an actionable foundation for the Australian SAF sector to continue building momentum. Together with regular engagement across a passionate industry, these reports seek to help to navigate the complex landscape of SAF, fostering a future where aviation supports both connectivity and sustainability.

Kirsten Rose

Deputy Chief Executive
CSIRO

DOCUMENT PURPOSE

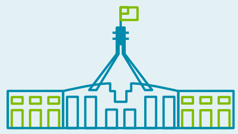
Boeing and CSIRO released the Sustainable Aviation Fuel Roadmap in August 2023, outlining the opportunities and challenges for Australia in developing a domestic sustainable aviation fuel (SAF) industry using Australian feedstocks.

Since the roadmap's release, many international and domestic events have occurred, including changes in policy, R&D, investment and industry uptake.

This State of Play report seeks to provide an overview of major developments in the SAF sector in the 12 months since the roadmap was released, to both observe the impact of the report and monitor major changes impacting the industry.

SAF KEY DEVELOPMENTS

SAF policy continues to progress globally, de-risking investment in SAF and helping the sector to decarbonise



Federal and state government action is driving policy development in Australia

Boeing affirming SAF has no technical issues for use in all our military aircraft

Australia's finance sector is increasingly engaged in developing innovative approaches to scale SAF

Industry development is occurring in Australia, with SAF blending on-shore to commence in 2025

THE GLOBAL STATE OF PLAY

POLICY AND MANDATES

Globally, approximately 44 SAF policies have been adopted or are under consideration, together accounting for over 65% of jet fuel use.

NOTABLE ANNOUNCEMENTS

JUNE 2022 ICAO launched the ICAO Assistance, Capacity-building and Training for Sustainable Aviation Fuels (ACT-SAF) programme to create opportunities for States to develop their full potential in SAF.

NOVEMBER 2023 ICAO's Third Conference on Aviation Alternative Fuels. Governments from over 100 countries set a goal for aviation fuel to be 5% less carbon intensive than conventional jet fuel by 2030.

NOVEMBER 2023 Boeing announced partnership with US Government to catalyse SAF development across Asia-Pacific Economic Cooperation (APEC) nations, identifying feedstock availability and optimising production.

POLICY AT A GLANCE

MALAYSIA 1% in 2023, 47% by 2050.

NORWAY 0.5% in 2020, 30% by 2030.

UK 2% in 2025, 10% by 2030, 22% by 2040.
PtL: 0.2% by 2028, 0.5% by 2030, 3.5% by 2040.
HEFA-cap: Lowers to 35% of SAF from 2040.

USA 45Z tax credit (US$0.35 per gallon),
Inflation Reduction Act 2022. Commences Jan 2025.

EU 2% in 2025, 6% by 2030, 70% by 2050.
Synthetic: 1.2% by 2030, 5% by 2035, 35% by 2050
Awaiting Member State approval.

GERMANY PtL: 0.5% by 2026, 1% in 2028, 2% in 2030.

BRAZIL Mandate expected 2027, will target cutting sector's total 2026 emissions by 1%, rising to 10% by 2037.

JAPAN 10% by 2030. Introduced May 2023. Proposed exemptions and investments for SAF production.

INDIA Under consideration. 1% by 2027, 2% by 2028, 5% by 2030 (international flights only).

INDONESIA 1% blend, increasing to 47% by 2050.

SINGAPORE 1% by 2026, 3-5% by 2030.

TURKIYE International blend mandate 1% 2025-26, 5% 2030.

REPUBLIC OF KOREA 1% by 2027.

THAILAND 1% by 2027.

KEY

Existing mandate or policy
Prospective mandate or policy

* US$1.75 per gallon for facilities that satisfy wage and apprenticeship requirements

INDUSTRY PROGRESS

Significant funding has been put towards the development of new plants, in addition to international initiatives such as the global SAF registry and clearing houses, with the majority of activity focused in Europe, the UK and US.

2023

NOVEMBER 2023 NETHERLANDS
Macquarie Asset Management invests US$192.7 million in SkyNRG.

NOVEMBER 2023 SWEDEN
Preem will invest US$527.6 million to convert Lysekil oil refinery to SAF and RD (HVO). Begin 2024, complete 2027.

JANUARY 2024 NORWAY
Norsk e-Fuel offtake agreement with Norwegian and Cargolux Airlines. Total volume: 140,000 tons SAF. In addition, the airlines will support development of two production facilities by 2030. Norwegian Airlines will invest US$5 million into Norsk e-Fuel to secure early access. Norsk e-Fuel targeting supply of e-fuels by 2026.

JANUARY 2024 USA
LanzaJet opens Freedom Pines Fuels Plant, world-first ethanol to SAF production facility (10 m gal/year).

FEBRUARY 2024 USA
Eight new partners join United Airlines' Sustainable Flight Fund, totalling 22 partners and over US$200 million invested.

APRIL 2024 UNITED KINGDOM
UK Department for Transport launched UK SAF Clearing House. Based in University of Sheffield.

MAY 2024 USA
Fulcrum BioEnergy shut down waste-to-jet fuel plant in Nevada due to a lack of funding.

MAY 2024 FRANCE
Groupe ADP invest US$20 million in LanzaJet to continue building SAF tech capacity.

2024

JUNE 2024 GLOBAL
IATA is developing a global SAF registry, enabling purchase regardless of production location, with certainty of claiming enviro benefits. 17 airlines, one airline group, six national authorities, three OEMs, one fuel producer supporting development. Launch: Q1 2025.

JUNE 2024 ENGLAND
BP is scaling back plans for development of new SAF and RD biofuels projects at existing sites, pausing planning for two projects while continuing to assess three for progression.

JULY 2024 USA
Sustainable Aviation Fuel Financing Alliance (SAFFA) investment fund to be set up to accelerate SAF production. Total US$200 million between Airbus, Air France-KLM Group, Associated Energy Group, LLC, BNP Paribas, Burnham Sterling, Mitsubishi HC Capital Inc. and Qantas.

US DoE and National Renewable Energy Laboratory released first two parts of their State-of-Industry report: State of SAF Production Process and HEFA Pathway.

JULY 2024 NETHERLANDS
Shell to pause SAF and RD facility construction in Rotterdam due to difficult current market conditions for biofuels in Europe due to oversupply, cheap imports and low demand growth for biodiesel, as well as technical problems. Cost: US$600 m-US$1 bn. Capacity was: 820,000 t/y.

JULY 2024 EUROPE
European Union Aviation Safety Agency launched EU SAF Clearing House. Network of facilities across Europe.

SAF PRODUCTION CAPACITY

Global SAF production capacity is expected to triple in 2024 and continue to rise sharply to meet rising demand, with HEFA-SAF output eight-fold that of AtJ or FT.

0.5 Mt
Global output 2023*

3.1 Mt
Estimated global output 2024 ICAO high+** scenario 1.07% of total aviation fuel need of 280 Mt

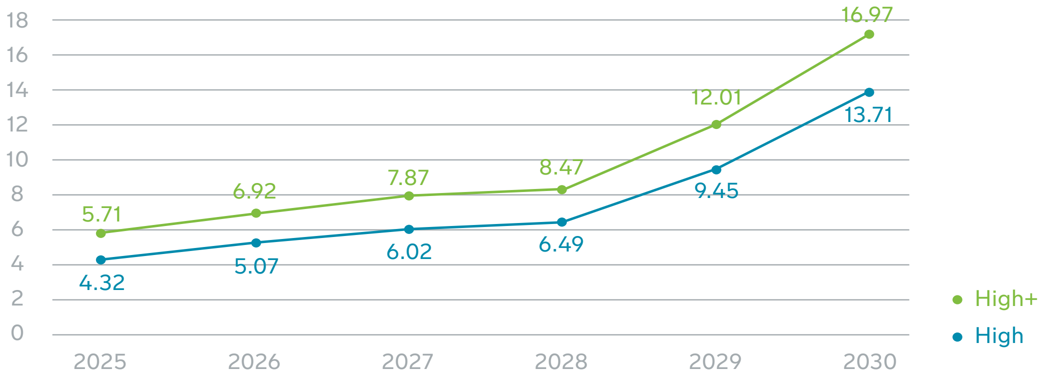
16.9 Mt
Estimated global output 2030**

7 new facilities
2024 YTD (two x USA, Germany, Kenya, South Korea, Colombia, Sweden)***

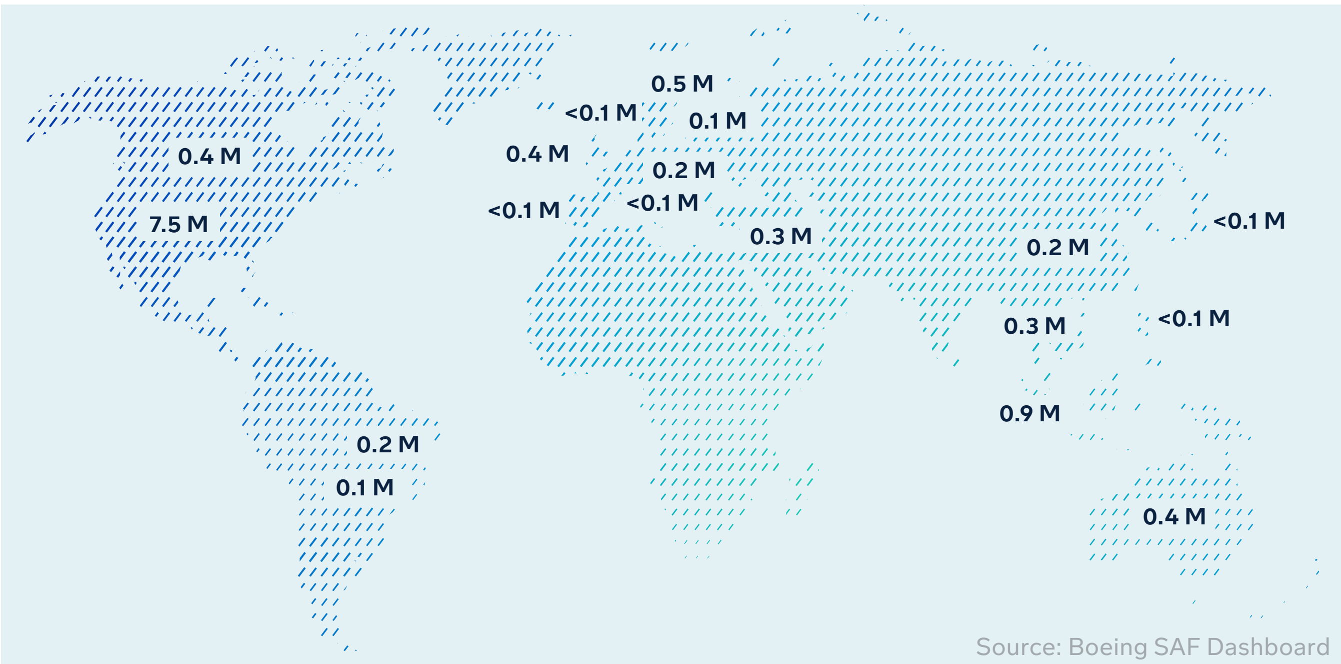
Largest facility
3,250 m L/y (859 m gal/y)
Singapore, Neste oil***

Largest producer
4.5 bn L/y (1.19 bn gal/y) USA***

SAF PRODUCTION VOLUMES BY ICAO SCENARIO (Mt)**



CUMULATIVE CAPACITY (T) ANNOUNCEMENTS, 2030



Source: Boeing SAF Dashboard

*(IATA) https://www.iata.org/en/pressroom/2024-releases/2024-06-02-03/
** https://www.icao.int/environmental-protection/Documents/SAF/ICAO%20SAF%20short-term%20projections%20-%20methodology%20and%20results.pdf
*** (ICAO) https://www.icao.int/environmental-protection/GFAAF/Pages/Production-Facilities.aspx

RESEARCH AND TECHNOLOGY PROGRESS

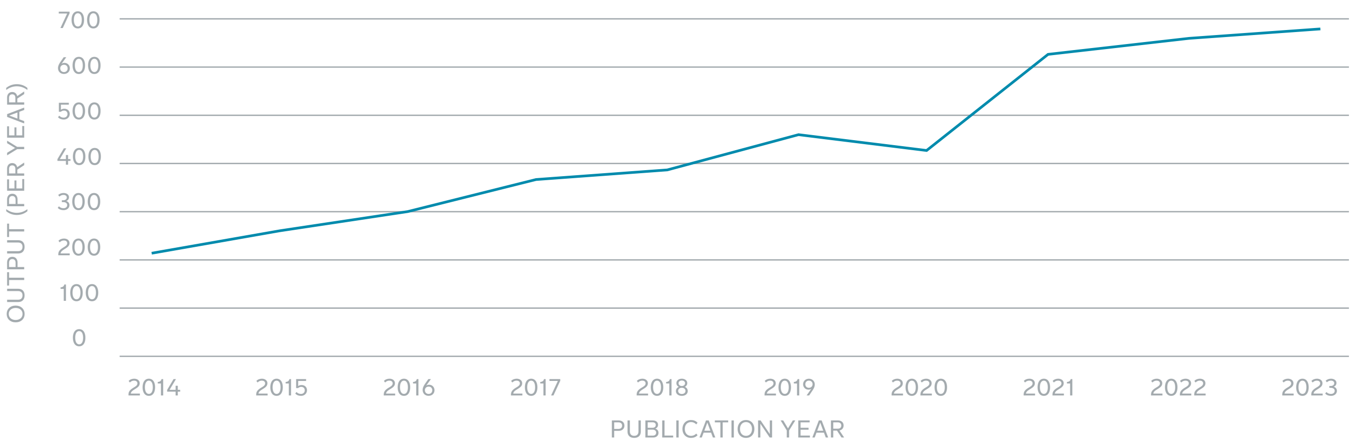
New conversion pathways continue to be explored and feasibility studies undertaken, while major players aim to realise 100% SAF.

8+3 conversion processes approved

11 conversion processes under evaluation

64 feasibility studies undertaken to date globally

GLOBAL PUBLICATION OUTPUT



Leading institutes, by proportion of publications in top 10% of citation count

Imperial College London England

Massachusetts Institute of Technology (MIT) USA

National Renewable Energy Laboratory USA

East China University of Science & Technology China

Swiss Federal Institutes of Technology Domain Switzerland

King Abdullah University of Science & Technology Saudi Arabia

Sri Ramakrishna Mission Vidyalaya College of Arts & Science India

Oak Ridge National Laboratory USA

'Flight 100': World-first transatlantic flight on 100% SAF (88% waste oils and fats HEFA, 12% Synthetic Aromatic Kerosene from plant sugars). Virgin Atlantic Boeing 787, LHR to JFK. Nov 2023, England.

Work Group 13 formed to coordinate 100% SAF testing to inform ASTM International. Includes Boeing (lead), Airbus, Dassault Aviation, GE Aerospace, RTX's Pratt & Whitney, Rolls-Royce, Safran and others. May 2024, USA.

Boeing Research & Technology (BR&T) Center opened in Nagoya with a focus on digital simulation toolset, composites, SAF and hydrogen fuel. April 2024, Japan.

'ECLIF3': World-first in-flight study of impact of 100% SAF on both engines of a commercial aircraft, showing reduction in soot particles and formation of contrail ice crystals. June 2024, France.

Boeing announced that all military aircraft manufactured by the company can operate on a 50% blend of SAF. July 2024, USA.

APPROVED CONVERSION PROCESSES

ATSM* Reference	Process	Possible Feedstocks	Maximum Blend
D7566 Annex A1	Fishcher-Tropsch hydroprocessed synthesised parrafinic kerosene	Coal, natural gas, biomass	50%
D7566 Annex A2	Synthetic parafinic kerosene from hydroprocessed esters and fatty acids (HEFA)	Vegetable oils, animal fats, used cooking oils	50%
D7566 Annex A3	Synthesised iso-paraffins from hydroprocessed fermented sugars	Biomass for sugar production	50%
D7566 Annex A4	Synthesised kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	Coal, natural gas, biomass	50%
D7566 Annex A5	Alcohol to jet synthetic paraffinic kerosene	Ethanol, isobutanol and isobutene from biomass	50%
D7566 Annex A6	Catalytic hydrothermolysis jet fuel	Vegetable oils, animal fats and used cooking oils	50%
D7566 Annex A7	Synthesised paraffinic kerosene from hydrocarbon – HEFA	Algae	50%
D7566 Annex A8	Synthetic paraffinic kerosene with aromatics	C2-C5 alcohols from biomass	50%
D1655 Annex A1	Co-hydroprocessing of esters and fatty acids in a conventional petroleum refinery	Vegetable oils, animal fats, used cooking oils with petroleum	5%
D1655 Annex A1	Co-hydroprocessing of Fischer-Tropsch hydrocarbons in a conventional petroleum refinery	Fischer-Tropsch hydrocarbons and petroleum	5%
D1655 Annex A1	Co-processing of HEFA		10%

*ASTM International - formerly known as American Society for Testing and Materials, is a standards organisation that develops and publishes consensus technical international standards for a wide range of materials, including fuels.

GLOBAL PROGRESS ON SAF FEASIBILITY STUDIES

2023
ICAO published guide for feasibility studies for Sustainable Aviation Fuel.

SEPTEMBER 2024
Fiji Airways, The Fiji Sugar Corporation Limited, Lee Enterprises Consulting, and Asian Development Bank to explore sustainable aviation fuel production in the Pacific.

SEPTEMBER 2024
Boeing and RSB publish South East Asia Feedstock Study

Rice husks and straw are identified as the region's most promising SAF feedstocks when considering both availability and sustainability.

Many potential feedstocks are available in the region and addressing sustainability risk can unlock significant environmental and economic benefits for Southeast Asia.

Significant further potential likely to be uncovered in future research.

Source image top left: International Civil Aviation Organisation

SAF IN MILITARY AIRCRAFT

In July, Boeing released a No Technical Objection letter (NTO) for military customers. This affirms how SAF can be used on all Boeing military platforms.

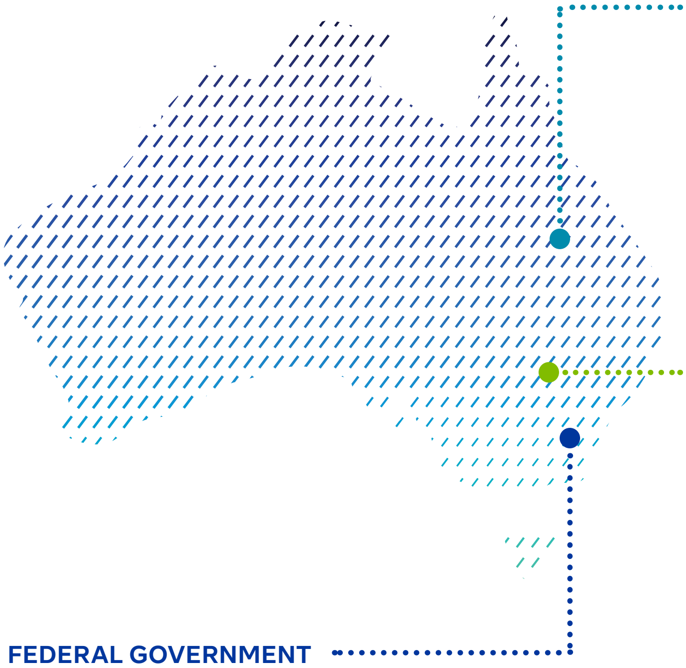
This provides guidance that Synthetic Aviation Turbine Fuels (SATF), including SAF, can be used at the approved blending limits as a drop-in replacement for conventional jet fuels in all Boeing military aircraft. This is important in paving the way for interoperability, increasing alignment in fuel standards, and supporting our customers in their SAF and SATF inquiries.

Click here to read more

THE DOMESTIC STATE OF PLAY

POLICY AND REGULATORY PROGRESS

Recent federal and state announcements have shown an increase in government action in prioritising the transition away from fossil fuels for hard-to-abate sectors.



QLD GOVERNMENT

JULY 2024 QLD Government announced new investments in SAF projects including a multi-seed crushing and processing facility at Yamala and funding for feasibility studies for Wagner and Liquid Power ($760 k each).

QLD AND NSW GOVERNMENT

In-progress. NSW and QLD Governments are developing or increasing the ambition of their renewable liquid fuels strategies.

NSW GOVERNMENT

MARCH 2024 NSW Government released SAF Investment Prospectus with a detailed discussion paper released in July.

APRIL 2024 NSW Government Net Zero Manufacturing Initiative's Low Carbon Product Manufacturing Stream provides opportunity for up to $100 m for SAF-related initiatives.

FEDERAL GOVERNMENT

MAY 2023 Aus-US Climate, Critical Minerals and Clean Energy Transformation Compact and Australia-California MoU both highlight SAF's role in climate action and supporting the clean energy transition.

JUNE 2023 Establishment of Australian Jet Zero Council announced. Workplan released December 2023.

MAY 2024 Transport and Infra-structure Net Zero Consultation Roadmap released, including transport sector-wide measures which will support aviation.

AUGUST 2024 Federal government released the Aviation White Paper, with 56 initiatives across 10 topics including four initiatives and 14 actions towards maximising aviation contribution to net zero, in line with the Federal Budget (as above). Includes undertaking an impact analysis process to inform a decision on a SAF or LCLF mandate.

Federal Budget 2024-25 Federal government highlighted low-carbon liquid fuels (LCLFs) as having a key role in the transition to net zero:

- $18.5 million over four years from 2024-25 to develop certification scheme for LCLFs (incl. SAF and RD) in the transport sector.
- LCLF consultation to identify options for production incentives to support establishment of domestic LCLF industry.
- $1.5 million over two years from 2024-25 to undertake regulatory impact analysis of the costs/benefits of introducing LCLF mandates or other demand-side measures.
- $1.7 billion Future Made in Australia Innovation Fund for deployment of innovative tech and facilities linked to priority industries, including LCLFs.

INDUSTRY PROGRESS

Cross-sectoral collaboration and funding grows as the domestic industry steps towards its first operational facility, with many initiatives based along the north-east coast.

2023

FEBRUARY 2023 KWINANA
BP plans to convert refinery to generate 580m L/y (153 m gal/y) of SAF and RD by 2030, production to commence in 2026.

MARCH 2023 MIRIAM VALE
Idemitsu (JPN) signed agreement with J-Oil Mills (Japan) & Burnett Mary Regional to jointly explore SAF output using pongamia oil, for use in Japan aviation.

MAY 2023
Qantas announced a $400 million climate fund to provide direct investments in sustainability projects, including $290 million for domestic SAF industry in partnership with Airbus.

NOVEMBER 2023 NEWCASTLE
Australian Defence Force showcased their support through The Roulettes' aerobatic display performance using 'Neste MY' SAF.

2024

FEBRUARY 2024 TOWNSVILLE
Project Ulysses. LanzaJet and Jet Zero Australia sign licence and engineering agreement to advance country's first ethanol to SAF and RD plant.
Capacity: 102 m L/y (27 m gal/y).

MARCH 2024
Department of Defence will target converting an air force base to use SAF for up to 12 months and trial RD, possibly in a naval vessel, in response to the federal Defence Strategic Review. Site yet to be selected.

APRIL 2024
Accenture, Fortescue, McKinsey, Commonwealth Bank, ING Australia, Deloitte, IMC and Raytheon Australia joined Qantas' SAF Coalition, taking total members to 11 since inception in 2023, each committing to address 400 t – 1000 t carbon emissions.

APRIL 2024 TOOWOOMBA
Wagner Sustainable Fuels and Boeing collaborate for Australia-first blending facility. Construction underway for operation by early 2025.

JULY 2024 GLADSTONE
Oceania Biofuels cancels proposed $500 m SAF and RD biofuels project.

JULY 2024 BRISBANE
Ampol, GrainCorp, IFM Investors sign MoU to explore establishment of integrated Aus renewable fuels industry. Ampol and IFM progress feasibility assessment for Lytton Refinery from prior assessment with ENEOS. GrainCorp explore supply of local canola oil feedstock crushing capacity. Potential capacity: 500 m L/y.

AUGUST 2024 BRISBANE
Boeing invests in Wagner Sustainable Fuels to support the development of its production facility.

NOVEMBER 2024 WHYALLA
Zero Petroleum, the South Australian Government, Adelaide Airport and Qantas sign letter of intent to explore low carbon aviation fuel opportunities.

RESEARCH AND TECHNOLOGY PROGRESS

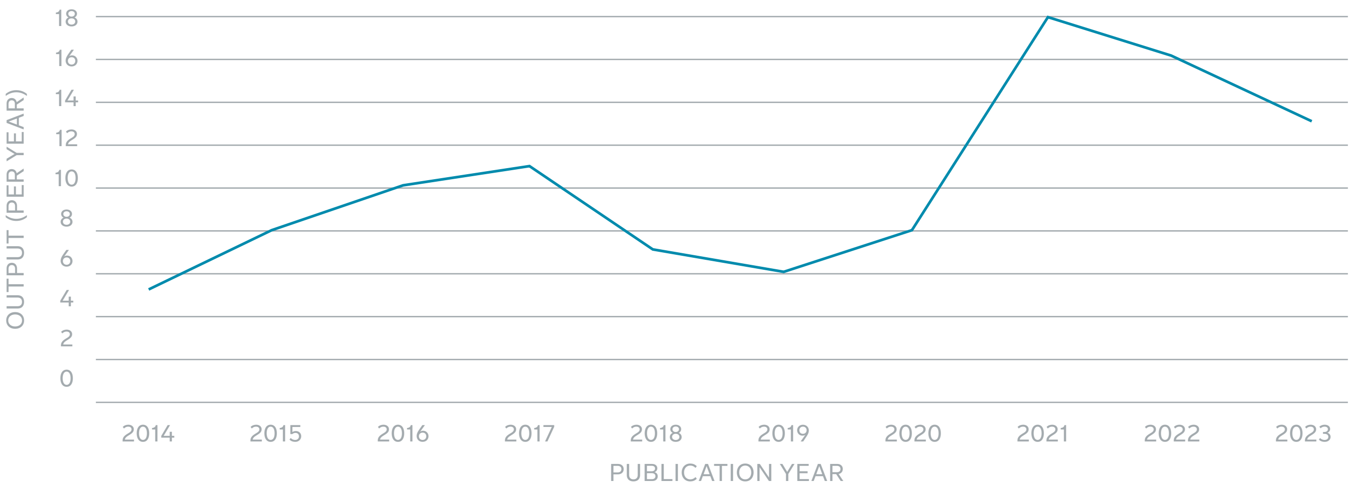
Domestic R&D continues to inform Australia's existing and potential feedstock opportunities, in addition to many targeted research projects. ARENA helps to fuel innovation.

JUNE 2022 NSW Decarbonisation Innovation Hub was launched to support researchers, industry and government in critical sectors to collaborate and increase uptake of decarbonisation technologies.

JULY 2023 ARENA announced the SAF Funding Initiative of up to $30 million to support the development of Australia's SAF industry. Applications closed November 2023.

NOVEMBER 2024 CSIRO and Nufarm announce the Biomass Oil Project, which aims to scale research that makes use of a plant's leaves and stems to create oil for biofuels.

AUSTRALIAN PUBLICATION OUTPUT



Leading institutes, by output (Articles, Reviews and Proceedings Papers)

University of Technology Sydney (UTS) 10

University of New South Wales (UNSW) 8

Monash University 7

Central Queensland University 7

University of Sydney 7

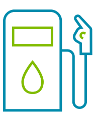
Royal Melbourne Institute of Technology (RMIT) 6

University of Adelaide 5

University of Queensland 4

ARENA FUNDING ANNOUCEMENTS

The ARENA Sustainable Aviation Fuel Funding Initiative seeks to support the development of a SAF industry with production from renewable feedstocks in Australia. The initiative will fund Australian activities that seek to: (1) advance the technology readiness level and commercial readiness index of SAF technologies for at-scale deployment, (2) facilitate a pathway to the technical and commercial viability of producing SAF from renewable feedstocks, or (3) build industry capacity in the production of SAF from renewable feedstocks.



OCTOBER 2024 ARENA announced allocation of $9 million to Jet Zero Australia to support development of their alcohol-to-jet facility in Townsville.

Further funding announcements by ARENA around its SAF funding initiative are anticipated in late 2024.

PROGRESS ON RECOMMENDATIONS

PROGRESS ON ROADMAP RECOMMENDATIONS

The roadmap proposed five immediate term (2023-2025) recommendations to inform the development of Australia's SAF industry. The events outlined in this document have contributed in part towards realising these recommendations, however further action is required.

Recommendation	Progress	Notable events
1. Consider policy frameworks and tools that support domestic distribution and use of certified SAF with clear long-term support strategy for industry.	Strong	Federal Budget and Aviation White Paper confirm intent to consider the impact of a mandate or target, develop certification scheme, and introduce market-based approach to recognise SAF use in emissions accounting arrangements. State-based funding to build momentum: QLD Industry Partnership Program, NSW Net Zero Manufacturing.
2. Encourage the signalling of local demand for SAF across government, commercial and defence users, giving investors certainty to establish new plants.	Moderate	Multiple publications highlighting an expected growth in SAF demand (e.g. NSW SAF Prospectus). Williamtown Air Show – ADF demonstration of Neste MY SAF in The Roulettes' aerobatic display performance. Aviation White Paper outlines that the Federal Government is committed to establishing a domestic SAF production industry. ADF has announced commitment to transitioning to low carbon renewable energy and has trialled SAF blends.
3. Educate consumers on the role and benefits of SAF, building social license for investment and demand for fuels.	Moderate	Recognised as a key work item in Australian Jet Zero Council initiatives with SAF knowledge centre in proposal stage. Extensive Roadmap media outreach post-launch across radio, newspaper, TV and online, with a cumulative potential reach of 2.5 m in the first three days, which has grown to 17 m. Six references to the Federal Government's Aviation White Paper, launched August 2024. Aviation White Paper states SAF initiatives will be complemented by industry activities to support social licence and educate consumers.
4. Invest in R&D to support emerging technologies and improve feedstock availability and sustainability understanding.	Moderate	Access to the $1.7 billion Future Made in Australia Innovation Fund to support the development of LCLF production technologies. ARENA Sustainable Aviation Fuel Funding Initiative of up to $30 million. Funded projects announced from October 2024. Feasibility studies underway or completed for multiple sites: Ampol, Graincorp, Lanzajet, Wagner & Liquid Power.
5. Scale-up of biogenic SAF production in appropriate locations, increasing market supply and driving cost reductions.	Moderate	No active domestic plants to date. Multiple projects in planning or construction: LanzaJet & Jet Zero, Townsville; Wagner & Boeing, Toowoomba. Project discontinued: Oceania Biofuels, Gladstone.

Strong   Moderate   Weak

EMERGING INSIGHTS IN THE AUSTRALIAN ECOSYSTEM

INTRODUCTION

Since Boeing and CSIRO's joint release of the Sustainable Aviation Fuel Roadmap in August 2023, many significant global and domestic developments have occurred, including shifts in policy, R&D breakthroughs, investment growth, and increasing industry uptake.

In order to better understand the nuanced changes within the Australian SAF sector – and therefore the opportunity as it stands today – a roundtable was held with 40 leaders representing 28 organisations across Australian research, industry and government.

On the following pages, are the key insights from the roundtable discussion, highlighting priorities and precautions for Australian SAF stakeholders to consider as the sector continues to progress. These insights are aggregated viewpoints from group discussions and do not necessarily represent the views of CSIRO or Boeing. While they were discussed within the group, they do not necessarily represent the viewpoint of all participants and should not be taken as such. Other insights include those from a SAF Finance Roundtable event coordinated by Boeing in September 2024.

COST AND MARKET UNCERTAINTY

SAF production costs remain higher than conventional fossil jet fuel and stakeholders are concerned about how to absorb costs going forward, as fuel can account for a significant part of a flight's cost. This price sensitivity makes it difficult to pass costs onto consumers, especially in competitive markets. Additionally, SAF plant proponents face commercialisation challenges and market uncertainty due to cost of capital, supply unknowns and reluctance of buyers to commit to long-term off-take agreements. Opportunities exist for innovative and effective policy mechanisms to be developed to reduce these cost differentials and a holistic approach will be required in Australia due to the lack of any current domestic production.

Nuancing respected international frameworks for the Australian context

Many international tools and methodologies have been developed with data inputs and assumptions that are not nuanced to reflect Australia's assets and conditions. The ICAO's SAF Rules of Thumb, for example, were developed using U.S costs and data. Significant opportunity exists to contextualise these Rules of Thumb for Australia, which could provide useful insights to both policy makers and prospective SAF producers around pilot and n^{th} scale facilities. The U.S. DOE's Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model faces similar limitations for Australia. Further work to integrate Australia's variables will empower decision makers locally and communicate Australia's potential to international stakeholders.

Transition pathways to minimise capital requirements

A gradual transition pathway that utilises phases, intermediates and existing infrastructure is likely to be a more palatable and practical approach to scaling SAF, whilst continuing to address technical, economic and supply challenges. This could involve small levels of co-processing at Australia's small number of existing refineries and greater onshore blending of SAF, as currently being pursued by Wagners Sustianable Fuels from 2025.

Market interdependencies

SAF's market dynamics are not independent, but rather are likely to be notably impacted by changes in broader markets such as other low carbon liquid fuels (LCLFs). The cost of producing SAF in Australia will likely be impacted by factors such as feedstock availability, adaptability of existing infrastructure and supply chains, cross-jurisdictional policy and carbon-trading mechanisms amongst others. A better understanding of how these interdependencies may play out and affect a local LCLF market is needed and will form the basis of ongoing research and techno-economic modelling.

Cost of living

Cost of living pressures create the need for exploration into how policy settings can be designed to ensure affordability and accessibility of air travel while supporting SAF adoption and other sustainability measures. Roundtable attendees suggested that a range of approaches to minimse the cost impost to consumers should be considered, one of which could include a levy on international travel, similar to that being pursued in Singapore. In this scenario, the proceeds could be directed entirely into SAF project development.

Carbon accounting and monetisation

Mechanisms like book and claim systems offer a financial opportunity to monetise SAF's carbon reduction benefits. Australia, with its strong sustainability frameworks, could become a leader in trading SAF's carbon attributes globally. Such systems would enhance the competitiveness of SAF and create new revenue streams for producers. In the short-term there is significant opportunity to consider the establishment of 'green lanes', (specific air routes that prioritise flights using SAF), including with allies such as New Zealand and the United States of America. There is also opportunity to further pursue voluntary purchasing of SAF to reduce scope three emissions, including by large corporate organisations or government departments who have set operational emissions reduction targets that include scope three elements such as business travel.

Government offtakes

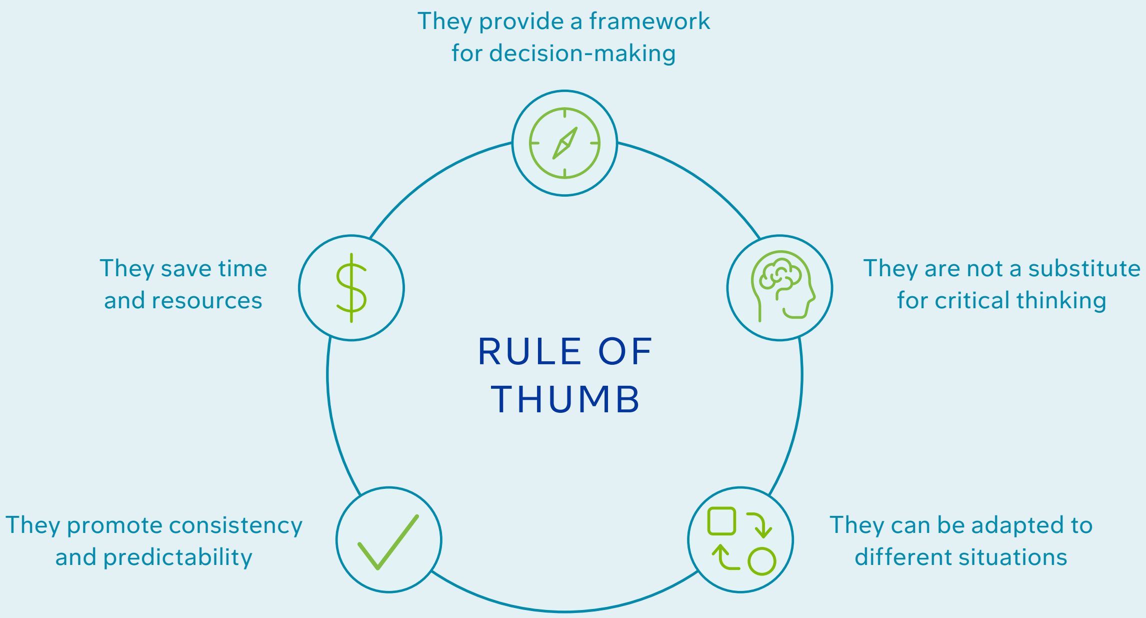
Establishing SAF as part of a national energy security strategy could strengthen resilience to global supply chain disruptions. Roundtable members highlighted that government-backed long-term procurement agreements would provide stable demand for producers, making SAF more financially viable. Whilst there are current restrictions that need to be considered, the Australian Government's Defence Future Energy Strategy provides strategic guidance.

Private financing requirements

Feedback from the finance sector has indicated that certainty of feedstock supply and longer offtake agreements would be most useful in reducing risks of investment in a domestic SAF industry. This requires a change, given current airline offtake agreements are generally between 1 and 3 years. Integrating a blended finance approach would also be useful, including exploring the opportunities across the APAC region associated with export credit financing.

NUANCING THE ICAO RULES OF THUMB FOR AUSTRALIA

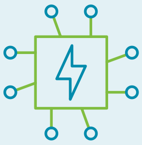
A consortium of global experts from CAEP, Washington State University and Hasselt University developed a set of heuristics of 'Rules of Thumb' for SAF. These can be utilised to make order of magnitude estimations related to SAF costs, investment needs and production potential that can inform project developers and policy design. The Rules of Thumb provides the impact of feedstock costs, fuel yield, facility scale (total distillate and SAF), total capital investment and minimum selling price for n^{th} plant and pioneer facility scales.



These rules of thumb were calculated using U.S. costs and financial assumptions and could change and can be seen in Appendix 1. There is an opportunity to contextualise these Rules of Thumb for Australia, using location-specific costs and data inputs. Such information would not only be useful for potential suppliers, but could also provide useful insights to inform public and private investment, both domestically and internationally, in the sector given they would provide big picture trends.

FINANCING THE SCALE UP OF SAF

Finance is a key pillar that will enable the scaling of a domestic SAF industry. In conjunction with optimum technology pathways, feedstock supply and sustainability assurance and a robust policy framework, private and public finance are both fundamental.



Technology

Feedstock and Sustainability

Policy

Economics and Commercial agreements

In September 2024, Boeing held a Finance Roundtable in conjunction with the New South Wales Decarbonisation and Innovation Hub to explore innovative approaches to financing the scale up of SAF. Approximately 50 delegates from the finance sector were in attendance and a range of key insights emerged:

INSIGHTS

Is aviation an attractive sector for investment? Aviation is largely seen as an attractive sector for investment, with certain caveats:

- It's important to recognise how aviation has decarbonised over time, particularly through more efficient aircraft
- The finance sector recognises the need for the net zero transition and its role in this
- A massive quantum of capital will be required
- There is a need for a clear demand driver to de-risk investment (e.g. mandates)
- Attracting a broader range of investors is critical
- Different pillars of the finance sector have varied areas of expertise (e.g. agribusiness expertise)
- Creating opportunities for early stage investors would increase attractiveness over the long term
- Creating interdependencies between SAF and carbon markets is required
- A key challenge is the need to take a portfolio view of an aviation investment.

Views on in-sector vs out of sector abatement?

- These are interrelated and linkages should be created
- The question of consumer willingness to pay remains important
- Offsets in the near term play a role, but insector action is critical to achieve the sector's long term aspirational goal of Net Zero by 2050
- Contracts for difference or a Guaranteed Strike Price could be considered.

What scope is there to develop financial instruments to de-risk projects?

- Need to explore potential for finance to play a part in different elements of the SAF supply chain
- SAF accounting has a role to play, to minimse the need to transport SAF and to encourage scaling
- Corporate offtake and commercial scope three emissions reduction through SAF could help to decrease the cost differential and drive scale
- Blended finance is critical – commercial banks will need to partner with public bodies, including the CEFC
- Lessons can be learned from other sectors – The Capacity Investment Scheme (CIS) is an Australian Government initiative that aims to encourage new investment in dispatchable renewable energy generation and storage.

What characteristics of policy does the finance sector look for?

- Stability
- Simplicity
- Transparency
- Duration – to encourage long term offtake arrangements and feedstock supply
- Integrated suite of policies on both supply and demand sides.

FEEDSTOCK AVAILABILITY AND COMPETITION

As outlined in the CSIRO-Boeing SAF Roadmap (2023), Australia has significant potential to produce SAF from domestic feedstocks. The Roadmap outlined that in 2025, Australia would have enough feedstocks to produce 60% of local jet fuel demand using biogenic feedstocks, growing to 90% by 2050 as biogenic sources continue to grow and hydrogen production ramps up.

The accessibility, location and existing uses of these feedstocks does, however need to be considered. Much of Australia's canola production, for example, is exported for biofuels, creating competition between domestic use and export markets. There is also a broader challenge of unlocking the more abundant – but economically and logistically challenging – second generation feedstocks, and the underutilisation of waste-based feedstocks like municipal solid waste (MSW). Global feedstock price volatility, due to international policies, adds further complexity.

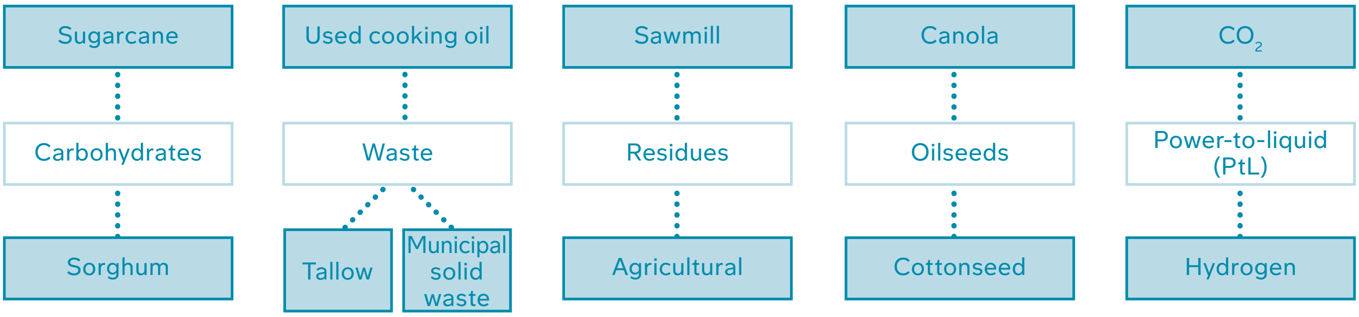


Figure 1: Potential feedstocks for Australian SAF Production

Matching feedstocks with technologies

Not all feedstocks are interchangeable across technologies, with the risk of uncompatability or uneconomic efficiencies if not optimised. A more informed understanding of the suitability and complementarity of feedstocks across technologies and pathways, in relation to their current and potential availability could benefit the industry in their feedstock and location choices.

Feedstock competition

Cross-industry competition for feedstocks is likely to grow due to concurrent need for biofuels across transport modes including maritime, road and rail as well as other decarbonisation efforts. As demand grows, efficient allocation and sourcing will be critical. Roundtable attendees suggested that there is an imperative need for governments to take a holistic approach to feedstocks, including through the development of a National Feedstock Strategy.

Narrowing options

Over the last 12 months, the industry has developed a clearer idea of the more attractive feedstock options. With this narrowed scope, a more in-depth understanding of cost contributors and levers, practical blockers and potential solutions could help to inform targeted policy relief. This type of analysis could also help to understand co-product opportunities, aggregation point mechanics, optimal logistical pathways, and further the understanding of pre-cursors and local densification.

Driving value

Working with the agriculture sector will be important to understand the key opportunities that this industry could present as a value add for farmers. Quantification of the circular economy benefits associated with the diversion of 'waste' feedstock materials from landfill is also important.

Power-to-liquid planning

There is a lack of agreement on how hydrogen and CO_2 will be sourced and scaled, and how it could be integrated with biofuel production. For example the integration of green hydrogen into biofuel production can enhance the efficiency of our carbon, producing more fuel from our bioresources, whilst providing a pathway to scale green hydrogen production. Ongoing availability of CO_2 will also need considered planning to inform scaling efforts and build social acceptance.

TECHNOLOGICAL GAPS AND INFRASTRUCTURE NEEDS

While HEFA technology is proven globally, other promising fuel synthesis technologies, such as gasification and alcohol-to-jet, lack the scale and demonstration evidence to attract investment. High capital costs and limited infrastructure, especially in biorefineries and storage facilities, further complicate efforts to scale SAF production. Overcoming these barriers will require significant investment and strategic alignment between government and industry.

Leveraging existing infrastructure

Existing facilities in established industries can be leveraged to minimise unnecessary investment. For instance, Australian and international oil and gas, agriculture, hydrogen, maritime, and waste management industries each have infrastructure that can help to scale the Australian SAF sector more efficiently and affordably in its early stages. The use of existing refineries to begin co-processing, and even the potential for international infrastructure such as refineries (e.g export of syn-crude to international markets such as Singapore) provide near term opportunties.

PROS AND CONS OF CO-PROCESSING IN THE AUSTRALIAN CONTEXT

Co-processing of SAF at existing fossil fuel refineries can be viewed as a more economical and efficient short-term pathway for SAF production. The ASTM D1655 standard permits co-processing of SAF in three ways to ensure adherence to established standards for quality and safety.

1. 5 vol% co-processing of mono-, di-, and triglycerides, free fatty acids, and fatty acid esters.
2. 5 vol% co-processing of hydrocarbons derived from synthesis gas via the Fischer-Tropsch process using iron or cobalt catalyst.
3. Co-processing (including co-fractionation) of hydrocarbons derived from hydroprocessed mono-, di-, and triglycerides, free fatty acids, and fatty acid esters (up to 24 vol% of the feed and 10 vol% of the product).

The International Civil Aviation Organization (ICAO) considers SAF produced via co-processing as compliant with CORSIA regulations.

Pros

- Existing infrastructure can be utilised
- Co-processing can contribute to production in the short-term as SAF industries scale
- Capital costs are reduced.

Cons

- Australia has limited existing refining capability
- Co-processing on its own won’t be enough to meet increasing SAF demand
- Carbon reduction is limited by low blending limits
- Enables ongoing fossil fuel use which will delay rapid SAF scaling and affect the sector’s ability to reach its long term aspiration goal of net zero by 2050.

Building cross sectoral relationships

The energy and agriculture industries do not operate as collaboratively as they may need to, to launch Australia’s SAF sector. Greater collaboration between energy and agriculture will allow for improved feedstock supply integration such as waste management, R&D collaboration, sharing of infrastructure and joint policy advocacy, while accelerating other required outcomes such as shifting public perceptions and supporting rural or indigenous communities.

Recognising benefits beyond biofuels

Beyond biofuels, investors can overlook the additional benefits of cultivating some feedstocks, which can hinder investments in certain options. For instance, benefits in mixed agriculture (agroforestry and silvopasture), could improve the green credentials of feedstocks, the output of a farm, or be rewarded through policy for realising co-benefits. Improved understanding - and quantification - of these benefits can help to spur investment in the sector.

SUSTAINABILITY AND SOCIAL PERCEPTIONS

SAF producers face increasing scrutiny regarding sustainability claims posing reputational risks. To build consumer and industry trust, SAF must meet rigorous global sustainability standards. Public awareness around the environmental benefits of SAF also remains low, necessitating efforts to improve education and transparency.

Evidence based information

Greenwashing remains a concern in sustainability-related industries, particularly in those that are more visible to consumers such as the airline industry and airports. Clear communication built off sound research, both existing and new, around the net impacts of a transition to SAF will be important in earning the trust of users and regional communities, ensuring regulatory compliance, attracting investment, and ultimately supporting sustainability goals. Collective industry advocacy to international frameworks like SBTi and the GHG Protocol to more effectively consider SAF could be an important step in reducing greenwashing risks and ensuring global consistency. Where possible, Australia should align with international sustainability standards to reduce reporting burden, particularly on airlines.

Promoting Australia's credentials

International awareness or recognition of Australia's ESG credentials is limited, despite strengths existing in areas (e.g renewable energy, low intensity agriculture). While Australia continues to improve environmental policies and industry practices to progress its ESG capabilities, better promotion of the country's current ESG credentials can help to encourage Australian SAF and feedstock uptake in international markets.

Long term sustainability planning

Given the nascency of the large-scale use of bioresources for purposes such as SAF production, there is a lack of understanding of the long-term impacts that this may have. As demand for these resources (e.g plant matter, agricultural crops, forestry residues, animal by-products, and waste) grows and climate change intensifies, better insight is required into the long-term implications for biomass use and management.

Early Indigenous and community engagement

There is a risk that Indigenous and local communities will not be engaged early and adequately by the required stakeholder groups. This can result in limited benefits for those communities, opposition to establishing regional bioeconomies, or foregone learnings for SAF stakeholders who do not seek council from Indigenous communities. Early and thorough engagement with these communities can result in benefits for the communities themselves, as well as SAF organsiations.

Feedstock legitimacy

Feedstock legitimacy may be questioned by prospective customers. It will be important for aviation to work with waste management and other upstream industries to track and better understand impacts of changes in feedstock end-use, to thereby measure net ESG impacts and share findings with customers and the public accordingly. Mapping feedstock availability against sustainability concerns could help to inform policy directed at supply side challenges.

CONCLUSION

The Australian SAF Industry Roundtable, held by CSIRO and Boeing in October 2024, served as an opportunity for leaders across the Australian ecosystem to reflect on recent changes, discuss current issues for the sector and ideate about the path forward. The discussion found that Australia has an opportunity to lead in areas of the SAF value chain, however further efforts are required to effectively coordinate around a path forward.

Nevertheless, the discussion highlighted that continued collaboration and coordination both within and outside of the Australian SAF sector will be important in leveraging existing infrastructure and fostering cross-sector synergies – particularly with agriculture, energy, and waste management sectors – to progress the advancement of the Australian SAF industry.

Roundtable participating organisations

Airlines for Australia and New Zealand (A4ANZ)	Graincorp
Ampol	Grains Research and Development Corporation (GRDC)
Australian Renewable Energy Agency (ARENA)	The International Air Transport Association (IATA)
Bioenergy Australia	IFM Investors
Biofutures (Queensland Government)	Jet Zero Australia
Boeing	Lanzajet
BP	Neste
Brisbane Airport	Qantas
The Clean Energy Finance Corporation (CEFC)	Sustainable Aviation Fuel Alliance of Australia and New Zealand (SAFANNZ)
The Commonwealth Scientific and Industrial Research Organisation (CSIRO)	University of New South Wales
The Department of Climate Change, Energy, the Environment and Water (DCCEEW), Australia	University of Queensland
The Department of Defence, Australia	Virgin Australia
The Department of Infrastructure, Transport, Regional Development, Communications and the Arts, Australia	Viva Energy Australia
Deutsche Bank	Wagner Sustainable Fuels

APPENDIX

Appendix one

The summary tables one and two below provide the most likely costs and facility scales based on the Techno Economic Assessment (TEA) models, existing literature values and expert opinion. Summary Table three provides estimates on CO_2 abatement costs, obtained with the use of MSP information and the life cycle emission reductions associated with each fuel.

Source: https://www.icao.int/environmental-protection/Pages/SAF_RULESOFTHUMB.aspx

Summary Table one Feedstock infomation
Technology, feedstock type and price, yield, total annual distillate scale, annual SAF production for both n^{th} and pioneer facilities.

Processing technology	Feedstock	Yield (ton distillate/ton feedstock)	Feedstock price	Total capacity (million L/year)		SAF production (million L/year)	
				n^{th}	pioneer	n^{th}	pioneer
FT*	MSW	0.31	$30/ton	500	100	200	40
FT*	Forest residues	0.18	$125/ton	400	100	160	40
FT*	Agricultural residues	0.14	$110/ton	300	100	120	40
ATJ	Ethanol	0.60	$0.41/L	1000	100	700	70
ATJ	Isobutanol-low	0.75	$0.89/L	1000	100	700	70
ATJ	Isobutanol-high	0.75	$1.20/L	1000	100	700	70
HEFA	FOGs	0.83	$580/ton	1000	-	550	-
HEFA	Soybean oil***	0.83	$809/ton	1000	-	550	-
FT	CO_2 from Direct Air Capture (DAC), H_2	0.24	$300/t $6/kg	1000	-	200	-
FT	Waste CO_2, H_2	0.24	$300/t $6/kg	1000	-	200	-
Pyrolysis**	Forest residues	0.23	$125/ton	400	100	180	40
Pyrolysis**	Agricultural residues	0.21	$110/ton	400	100	180	40

*feedstock price is for pre-processed feedstock
**pyrolysis ASTM approval is pending
***2013-2019 average price of soybean and canola oils

Summary Table two SAF facilities infomation
Total capital investment (TCI), capital cost, and minimum selling price (MSP) for the n^{th} and pioneer facilities for each pathway.

Processing technology	Feedstock	TCI (million $)		Capital cost ($/L total distillate)		MSP ($/L)	
		n^{th}	pioneer	n^{th}	pioneer	n^{th}	pioneer
FT*	MSW	1428	813	2.9	8.1	0.9	2.1
FT*	Forest residues	1618	1088	4.0	10.9	1.7	3.3
FT*	Agricultural residues	1509	1267	5.0	12.7	2.0	3.8
ATJ	Ethanol**	328	117	0.3	1.2	0.9	1.1
ATJ	Ethanol, agricultural residues	581	170	0.6	1.7	2.2	2.5
ATJ	Isobutanol-low**	332	94	0.3	0.9	1.3	1.5
ATJ	Isobutanol-high**	410	110	0.4	1.1	1.7	1.9
HEFA	FOGs	448	-	0.4	-	0.8	-
HEFA	Vegetable oil	456	-	0.5	-	1.0	-
FT	DAC CO_2 H_2	3366	-	3.4	-	4.4	-
FT	Waste CO_2 H_2	3209	-	3.2	-	3.5	-
Pyrolysis***	Forest residues	1038	594	2.6	5.9	1.3	2.1
Pyrolysis***	Agricultural residues	1084	619	2.7	6.2	1.3	2.2

*feedstock price is for pre-processed feedstock
**alcohol feedstock is corn-based
***pyrolysis ASTM approval is pending

Summary Table three CO_2 abatement costs

CO_2 abatement costs for n[th] and pioneer facilities for each pathway (compared with the CORSIA baseline of 89 gCO_2e/MJ).

Processing technology	Feedstock	Life cycle emissions (gCO_2e/MJ)*	Abatement cost ($/$tCO_2e$)	
			n[th]	pioneer
FT	MSW	32.5*	210	840
FT	Forest residues	8.3*	420	990
FT	Agricultural residues	7.7*	520	1170
ATJ	Corn ethanol	90.8*,**	no CO_2 abatement	no CO_2 abatement
ATJ	Agricultural residues ethanol, stand alone	39.7*	1020	1190
ATJ	Agricultural residues ethanol, integrated	24.6*	780	910
ATJ	Isobutanol-low, corn	77.9*,**	2100	2510
ATJ	Isobutanol-high, corn	77.9*,**	3220	3680
ATJ	Isobutanol-low, sugarcane	33.1*,**	420	500
ATJ	Isobutanol-high, sugarcane	33.1*,**	640	730
HEFA	FOGs	18.2*	130	-
HEFA	Soybean oil	64.9*	640	-
HEFA	Brassica carinata	13.0*	160	-
FT	DAC CO_2, green H_2, wind electricity	7***	1390	-
FT	DAC CO_2, green H_2, solar electricity	25***	1780	-
FT	DAC CO_2, green H_2, grid electricity	279***	no CO_2 abatement	-
FT	Waste CO_2, green H_2, wind electricity	31***	1510	-
FT	Waste CO_2, green H_2, solar electricity	49***	2190	-
Pyrolysis****	Forest residues	25.7***	370	750
Pyrolysis****	Agricultural residue	0.2***	270	550

*Based on default life cycle emissions provided in the ICAO document 'CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels'.
**Includes ILUC values, which can be subtracted with the use of low LUC risk practices as defined in the ICAO document 'CORSIA Methodology for Calculating Actual Life Cycle Emissions Values'.
***Life cycle emissions obtained from external references; not CORSIA.
****Pyrolysis ASTM approval is pending.

Literature review – Methodology

To assess publication output, a search was conducted using Web of Science and the results were analysed on InCites. The search sought to uncover:

- Australian publication output over the past 10 years
- Leading Australian organisations by publication output over the past 10 years
- Global publication output over the past 10 years
- Leading global organisations by publication output over the past 10 years

Below is a list of included and excluded keywords in conducting the search.

Return publications that include the word:
Sustainable aviation fuel*, OR
Biojet fuel*, OR
Bio jet fuel*, OR
Alcohol to jet, OR
Power to liquid*, OR

Sustainable OR renewable NEAR
Aviation fuel*, OR
Jet fuel*, OR
Rocket fuel*, OR

Aviation OR jet OR aeroplane* OR aircraft, AND
Bio fuel*, OR
Biofuel*, OR
Bio diesel*, OR
Biodiesel*, OR
Cellulosic ethanol, OR
Green fuel*, OR
Gasif* NOT coal*, OR
Pyrolys* NOT coal*, OR
Fisher Troupe, OR
Fischer Tropsch, OR
Synthetic Paraffinic Kerosene, OR
Food versus fuel*, OR
Competition for feedstock*, OR
Competition for biomass, OR
Bio refiner*, OR
Biorefiner, OR
Direct air capture, OR

Fuel, AND
Biogenic feedstock*, OR
Biomass feedstock*, OR
Biomass waste*, OR
Wood processing residue*, OR
Wood waste*, OR
Forest* residue*, OR
Forest* biomass, OR
Agriculture* residue*, OR
Sugar*, OR
Bagasse, OR
Tallow, OR
Algae, OR
Energy crop*, OR
Miscanthus, OR
Cellulosic cover crop*, OR
Waste feedstock*, OR
Municipal solid waste*, OR
Urban waste*, OR
Industrial waste gas*, OR
Oil feedstock*, OR
Fat feedstock*, OR
Vegetable oil*, OR
Palm oil*, OR
Animal fat*, OR
Cooking oil*, OR
Gutter oil*, OR
Oil cover crop*, OR
HEFA, OR
Hydroprocessed esters and fatty acid*, OR
Alcohol*, OR
Ethanol, OR
Isobutanol, OR
Life cycle assessments, OR
Land use management, OR
Sustainable land management

NOT coal OR shale

AND Publication year = 2014 to 2023

AND Document type = Article OR review OR proceeding

Quotation marks (“”) denote specific phrases, so that the search only returns results using those exact words in that exact order.

Asterisks (*) allow for results consisting of any characters following the asterisk.

For example, “flesh and bone” will return results using the entire phrase, and not results only including flesh or bone. “Geo*” would return results including geography, geographic, geoscience, geode, etc.

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