Director, Cleaner Fuels Program, Policy Design and Engagement Paper
Department of Infrastructure, Transport, Regional Development, Communications, Sport and the Arts
GPO Box 594, Canberra ACT 2601, Australia

19 December 2025

A Submission to the Cleaner Fuels Program, Policy Design and Engagement Paper (November 2025) and how to maximise Aviation's Contribution to Net Zero.

To Whom it May Concern,

The following is the personal position of the author and submitted in response to the Department of Infrastructure, Transport, Regional Development, Communications, Sports and the Arts' "*Cleaner Fuels Program, Policy Design and Engagement Paper*" (November 2024). It specifically addresses provides an aviation perspective and what the key considerations are for the Cleaner Fuels Program

The body of this letter provides an executive summary in response to the questions raised. Appendix A provides specific responses to the papers questions.

About the Author
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A/Prof Jonathan Coudrick has studied and worked in and around the aviation industry for almost three decades. He is an Honorary Associate Professor of Engineering at the Australian National University, a Senior Member of the American Institute for Aeronautics and Astronautics, a Fellow of the Royal Aerospace Society, and is registered to practice in Mechanical and Aerospace Engineering.

A/Prof Jonathan Coudrick is the Senior Engineering Manager for Nova Systems an Australian owned and operated company and one of four Major Service Providers to the Australian Defence Capability Acquisition and Sustainment Group. He is the previous AIR MSP Portfolio Manager for Nova Systems, where he managed a team providing services that cover eight aircraft types as well as aeronautical ground support equipment and commons for the Australian Defence Force. He is a past Chair of the Mechanical College Board, is a corresponding member of the National Committee for Space Engineering and sits on the Joint Board for Aerospace Engineering (responsible for managing the collaborative strategy between Engineers Australia and the Royal Aeronautical Society Australian Division).

This submission and the underlying research is not funded by any fuel companies, aircraft designers, manufacturers and operators. Nor are any of these funding any of A/Prof Jonathan Couldrick's other work or positions.

[1] Engineers Australia and the Royal Aeronautical Society (Australian Division), "Towards net zero: Supporting Australia's aviation transformation", Policy Advice Paper, November 2025, https://www.engineersaustralia.org.au/sites/default/files/2025-11/Supporting-Australias-aviation-transformation-nov-25.pdf.

Executive Summary

The Australian National University (ANU), in collaboration with Engineers Australia and the Royal Aeronautical Society (Australian Division), has modelled pathways for decarbonizing aviation, emphasizing the critical role of Low Carbon Liquid Fuels (LCLFs), particularly Sustainable Aviation Fuel (SAF), in achieving net-zero emissions by 2050.[2] Aviation is a hard-to-abate sector, and SAF could offset up to 42% of emissions if 11 gigalitres (GL) are available at a weighted carbon intensity (CI) of 15%. Higher CI or lower volumes significantly reduce this potential, underscoring the need to prioritize low-CI fuels.

Key Drivers and Prioritization:

Decarbonisation depends on both fuel volume and CI, measured across the lifecycle ("well to wake"). Emerging technologies like Power-to-Liquid (PtL) and hydrogen, though at lower Technology Readiness Levels (TRLs), must be supported to achieve future targets. A bracketed incentive system is recommended, linking credits to CI rather than volume alone, encouraging cleaner fuels and gradual removal of high-CI options such as Canola HEFA (CI ~83%). Hard-to-abate sectors like aviation and maritime should be prioritized over sectors with viable alternatives (e.g., electrification of road transport).

Production Support and Market Design:

Initial fixed production credits may provide investment certainty, but incentives should evolve to a CI-based system ($/CI·L) with tiered brackets reviewed every 5–10 years. This approach prevents over-rewarding high-CI producers and aligns with international sustainability standards. Production should be prioritized for lifecycle carbon benefits, though imports will remain necessary due to limited supply. Export should not be restricted, as some fuels may be unsuitable domestically but acceptable internationally.

Technology Pathways and Eligibility:

Both established (HEFA, HVO) and nascent pathways should be supported, with prioritization based on CI, scalability, and TRL. Minimum CI thresholds (starting at 50%, tightening to 15–30% by 2050) and sustainability criteria, including indirect land-use change, are essential. Feedstocks like forestry and agricultural residues should be prioritized; arable crops should be deprioritized to avoid food competition and deforestation risks.

Policy and International Alignment:

Australia must align with ICAO's CORSIA framework to ensure international recognition of SAF. Overseas mandates (e.g., EU targets) will influence domestic policy and investment decisions. Intersecting policies include green electricity supply for PtL, hydrogen transition, and regulatory readiness for new technologies. A systems-of-systems modelling approach is recommended to evaluate trade-offs, unintended consequences, and optimize carbon reduction strategies across sectors.

[2] Engineers Australia and the Royal Aeronautical Society (Australian Division), "Towards net zero: Supporting Australia's aviation transformation", Policy Advice Paper, November 2025, https://www.engineersaustralia.org.au/sites/default/files/2025-11/Supporting-Australias-aviation-transformation-nov-25.pdf

Conclusion:
Achieving net zero by 2050 requires a data-driven, adaptive policy framework that incentivizes low-CI LCLFs, supports emerging technologies, and integrates sustainability criteria. Bracketed incentives, international alignment, and lifecycle carbon accounting will be critical to fostering a competitive, future-ready domestic LCLF industry

If you have any questions regarding any of the above, or would like clarification, then please do not hesitate to contact me.

Regards

A/Prof Jonathan Couldrick

Appendices

A. Responses to The Cleaner Fuels Program, Policy Design and Engagement Paper (November 2025)

Appendix A – Responses to the Cleaner Fuels Program, Policy Design and Engagement Paper (November 2025)

Q1. Eligible Fuels

QUESTION 1.1: WHICH LCLF SHOULD BE ELIGIBLE UNDER THE PROGRAM AND WHY?
The Australian National University has undertaken significant modelling of the aviation system and where the ecosystem is possible to decarbonize. This is captured in the Engineers Australia and Royal Aeronautical Society (Australian Division) policy advice paper.[3] The key summary is that by 2050 there needs to be concerted effort on multiple fronts to move aviation towards net zero and Low Carbon Liquid Fuels (LCLFS) will play a key contribution.

For Sustainable Aviation Fuel (SAF),[4] the key drivers for decarbonisation are available quantity and its associated Carbon Intensity (CI). SAF has the ability to offset up to 42% of aviation's carbon contribution by 2050 if 11 giga litres (GL) is available to aviation with a weighted average CI of 15%. If the weighted average is 30%, the maximum carbon offset will reduce to around 36%. Alternatively, if only 6GL is available at 30% CI, the maximum carbon offset reduces to 20%. Therefore, low CI LCLFs need to be prioritised where CI factors in "well to wake" emissions, i.e. from production through to final emissions, see CSIRO's Sustainable Aviation Fuel Roadmap.[5]

To achieve the 11GL volume of SAF, it is likely that numerous feedstocks will need to be supported. However, the high CI LCLF, presumably at higher Technical Readiness Levels (TRL), need to be supported only to a level. It is expected that low CI LCLF will need to be backed in the research phase (due to the lower TRL) to support and encourage eventual adoption. This may include new technology such Power to Liquid (PtL) and Hydrogen. It would be crazy to aim for 11GL if we were not actually offsetting the carbon.

To determine the right balance between volume and carbon intensity a weighted scaling system needs to be created. This is relatively simple activity to create to understand what the volume of SAF would create in actual carbon offset. This could then be extended to factor in other modes of transport (such as maritime and road) to look at where best to prioritise.

Importantly, aviation operators are subject to domestic and international regulations and frameworks, meaning SAF needs to be recognised under different frameworks and different systems, e.g. US book and claim. Therefore, Australia's LCLF production needs to be recognisable internationally, which is expected to require an appropriate verification methodology. For example, Europe has still not determined whether to recognise LCLF as SAF if created from arable feedstock. This is due to historical issues with other policies, such as palm oil production that led to mass deforestation.

[3] Engineers Australia and the Royal Aeronautical Society (Australian Division), "Towards net zero: Supporting Australia's aviation transformation", Policy Advice Paper, November 2025, https://www.engineersaustralia.org.au/sites/default/files/2025-11/Supporting-Australias-aviation-transformation-nov-25.pdf.
[4] LCLF in aviation are also known as Sustainable Aviation Fuel.
[5] CSIRO, "Sustainable Aviation Fuel Roadmap", August 2023, p22-23, https://www.csiro.au/en/news/all/articles/2023/august/sustainable-aviation-industry-Australia

Question 1.2: Should certain types of LCLF be prioritised over others?

Question 1.2a: Should LCLF suitable for particular sectors or uses be prioritised? For example, should sustainable aviation fuel be prioritised over renewable diesel?

Prioritisation off LCLF needs to be directed towards hard-to-abate sectors and the total volume each requires. This needs to project out and factor in future predicted demand in each sector so that they are future ready.

Projections and prioritisation need to factor in policy effects which will have associated lag time in implementation to the realisation of carbon offsets. For example, the car industry is quicker to adapt and implement than maritime and aviation. The car industry has about a 5-year technology implementation cycle, whereas aviation is closer to 20 years for technology introduction, implementation and fleet renewal. For example, aviation is just now implementing LCLF, but hydrogen and electrical transition is more like 10 to 15 years away from implementation and will take a further 10 years to increase market saturation.

Question 1.2b: Should LCLF for certain sectors or uses be de-prioritised due to other viable decarbonisation pathways?

Yes. If there are "viable" alternatives, the sector is not hard-to-abate. However, it is still recognised that they may be costly. By placing financial incentives for LCLF and its prioritisation this will address the hard-to-abate sectors, which will be even costlier in the long run.

Question 1.2c: What market impacts are anticipated by influencing prioritisation of particular fuel types?

The Australian National University has created a first order digital model for predicting the carbon effects of different fuel use (LCLF, electrical and hydrogen). The model allows the macro effects on aviation to be analysed on the current operations of the aviation ecosystem.

This model can be extended to incorporate economics considerations, but it is recommended that only the following macro-economics are considered of supply, demand and incentives (known in aviation as Market Based Measures (MBM). There are too many variables to understand the micro-demand/economics. Until wider government policy is in place (for example around operations, electrification and hydrogen across road, sea and land), the market reactions at the micro level will not begin to settle and even then, these will continue to change over the next 25 years as markets transition.

Question 2 Type of production support

QUESTION 2.1: SHOULD THE PRODUCTION CREDIT BE A FIXED AMOUNT PER LITRE OF PRODUCTION, OR A VARIABLE AMOUNT THAT DEPENDS ON THE MARKET PRICE OF LCLF?

QUESTION 2.1A: ARE THERE ANY POTENTIAL BENEFITS, RISKS OR CONSTRAINTS CONSIDERING THE TWO DIFFERENT PRODUCTION CREDIT OPTIONS BELOW?

No Response

QUESTION 2.1B: WHAT OUTCOMES DO YOU THINK CAN BE DELIVERED WITH THE AVAILABLE FUNDING?

No Response

QUESTION 2.1C: WHAT TYPE OF MECHANISM PROVIDES THE GREATEST INVESTMENT CERTAINTY OR LEVEL OF BANKABILITY TO PROJECTS?

This will depend on the time horizon for funding. For the next 5-10 years it is expected that fixed production support will be beneficial in the main as it will take time for producers, refiners to ramp up. After this time the market may become self-sustaining. However, the trouble with this approach is that will likely incentivise dirtier LCLF at a higher TRLs that can be implemented quickly. Different mechanisms are still required based on the likely future technology requirements, for example Power to Liquid (PtL) is almost essential (See p8 of the CSIRO Saf Roadmap) at a low Carbon Intensity (CI) but is currently a low TRL.

As such it is recommended that any incentive should not be linked to $/L (an amount per litre) but $/CI.L (an amount per carbon intensive litre). This could potentially be implemented in a bracket system with tiered technologies and certain CI/LCLF feedstock. This would be similar to car emissions as applied to car registration costs. This way, the incentive is to create cleaner LCLF that can be recognised internationally.

QUESTION 2.1D: HOW CAN THIS SUPPORT BE STRUCTURED TO PREVENT SUBSTANTIAL UPSIDE TO PRODUCERS?

A bracketed system that recognised certain technologies and cleaner/lower carbon intensity feedstock will allow incentives to be changed over time as new cleaner tech comes on line.

Initially the brackets may be set low to increase supply, which is expected to continue to be short (under supply) out to 2050. By having these brackets reset every 5-10 years, this would create certainty in the market for investment. Having known timeframes and volumes will be required in the near term for such a nascent market that has continually left Australia over the last 15 years with domestic refineries making up about 15% of the market.[6]

QUESTION 2.1E: HOW DO YOU CONSIDER PRICING FOR LCLF WILL BE SET OVER THE SHORT-MEDIUM TERM AND LONGER TERM? WILL PRICING BE MATCHED TO A PREMIUM ON EQUIVALENT FOSSIL FUEL OR PRICE OF IMPORTED LCLF OR BE ON A CARBON ABATEMENT BASIS?

No Response

[6] See https://www.energy.gov.au/publications/australian-petroleum-statistics-2023

QUESTION 2.2: TO DELIVER THE POLICY INTENT OF THE PROGRAM WHILE MAXIMISING THE VALUE FOR TAXPAYERS, DO YOU AGREE THAT PROJECTS WITH THE LOWEST COST SHOULD BE PRIORITISED UNDER THE PROGRAM, WITH THE COST BEING MEASURED EITHER AS PER UNIT OF LCLF PRODUCED OR AS PER UNIT OF CARBON EMISSIONS ABATED?
In reality you Australian needs both per unit of LCLF produced or as per unit of carbon emissions abated.

Initially, it will be a volumetric consideration but it needs to have brackets to incentivise the cleaner (lower carbon intensive) fuel in the long run. By 2050 aviation (and presumably other hard-to -abate sectors) needs a weighted average LCLF under 30% carbon intensity and preferably under 15%. It would be almost negligent to promote Canola HEFA that has a CI of around 83% (see CSIRO SAF Roadmap, Figure 9) in the long term.

Over time the brackets (volumes required by tiered technologies and certain CI/LCLF feedstock) can be updated, e.g. reviewed every 5 years with 10-year implementation guarantees.

If this approach isn't taken it will stifle market takeover at the start and all LCLFs will be beneficial (just not at any cost) but over time the higher CI fuels need to be removed from the system and/or incentivise placed on other technologies for example hydrogen.

QUESTION 2.3: SHOULD THE PRODUCTION CREDIT BE LINKED TO THE QUANTUM OF LCLF PRODUCED, OR THE CARBON EMISSIONS SAVING POTENTIAL OF THE FUEL?
Australia needs both. To start with it will be a volumetric gain but it needs to have brackets to incentivise the cleaner (lower CI) fuel. Over time the brackets can change (reviewed every 5 years). Taking this this approach will promote market uptake at the start where all LCLFs will be beneficial (just not at any cost). Through constant review higher CI fuels need to be removed from the system and/or incentivise placed on other technologies with lower CI, for example PtL and hydrogen.

QUESTION 2.4: WHAT ARE YOUR VIEWS ON THE COST TO DEPLOY LCLF DOMESTICALLY COMPARED TO INTERNATIONALLY? IS THERE A LOCAL PREMIUM FOR DOMESTIC PRODUCTION?
By using lifecycle carbon abatement (known in aviation as "well to wake"), this automatically prioritises (places a premium) on domestic production. This would require a government program to recognise the ability to have known fuels coming from known providers to provide an auditable trail of carbon credit/intensity across the lifecycle.

For example, conventional (non-sustainable) aviation fuel being imported will also need to recognise how it has been transported to Australia. Whereas conventional aviation fuel produced locally and transported locally will be at a premium due to its lower CI or transport footprint. However, this local conventional aviation fuel will still need to compete with imported SAF (albeit likely over a longer distance). Importantly, SAF produced locally (and transported locally) should have a premium/competitive edge domestically. By having competitive forces apply, overtime (as the market matures) the cheapest, cleanest solution will emerge and remove the need for incentives

Importantly, it is not envisaged that Australia will need an export market for LCLF in the next 25 years. CSIRO have already modelled Australia's ability to produce LCLF out to 2050 and there is not enough supply for aviation in isolation, let alone other users such as maritime, home use etc.

Question 2.5: Should the total value of production credits be capped for each project? If yes, what should the capped amount be and why?

Not to start with. However, by placing a time limitation on credits as limited to the various brackets, this allows the brackets to be actively managed, i.e. as cleaner technologies come online more credits can be applied to cleaner brackets. A similar incentive was introduced for solar panel installations on homes, where guaranteed network input amounts were provided for a certain duration. After which, they amount a person received converts to market forces.

The Australian National University has created a first order digital model for predicting how much Sustainable Aviation Fuel (SAF) is needed in the short-, medium- and long-term. By taking a systems-of-systems approach (a relatively well-known method in the 21st century), the federal government can model what caps (in terms of volumes and covered intensity) will achieve in carbon reductions the long term. Furthermore, this can identify what all the levers available to influence carbon reductions, known as Market Based Measures in aviation. Moreover, by taking a data driven approach, this will identify which levers a most effective in the long run to reduce the carbon footprint in the various sectors (individually and collectively).

Question 2.6: Should production be focused on domestic supply only or should export also be permitted? What impact could restriction have for projects or the market?

This question is more economic in nature around the funding incentives applied to volume amounts. By taking a data driven approach, this will identify which levers are more effective in the long run to reduce the carbon footprint in individual sectors and collectively.

From a supply and demand side, there is currently not enough fuel domestically and unlikely to be so for 25 years to meet Australia's domestic demand if we are to reach net zero by 2050. CSIRO have already modelled Australia's ability to produce LCLF out to 2050 and there is not enough supply for aviation in isolation (let alone other users such as maritime, home use etc). As such, Australia will need the option of importing international supply. Restricting import will mean that we won't be able to maintain aviation's carbon footprint (let alone reduce it).

However, there may be some LCLFs that we do not want to use locally that may be valuable internationally. For example, LCLF from arable feedstock may not be acceptable in Australian aviation for some carriers but may be recognisable in Australian maritime or by international (export) customers. Therefore, export options should not be ruled out.

Question 2.7: Is there a role for combined production support with capital grants for first-of-a-kind facilities?

No Response

Question 2.8: What other types of funding or concessional finance could support LCLF projects (e.g. funding from CEFC and NRF)?

No Response

Question 2.9: Is any other support required across the supply chain to enable domestic production of LCLF?

There needs to be the ability to recognise the source/feedstock of LCLF across the supply chain to enable life cycle emissions to be measured, verified and relied upon by the various sectors. This will require an international accepted methodology of lifecycle carbon emissions (similar to carbon credits) that are auditable across each stage of its lifecycle (production, transport, storage and use) including coming from a verified feedstock.

Importantly for aviation, Australia's methodology and recognition needs to align and be recognised internationally so that our domestic and internal operators, operating out of Australia can benefit. For example, the European Union is determining whether to recognise Sustainable Aviation Fuel (SAF) produced from arable crops due to lessons learned with palm oil, which led to deforestation and its negative impact on climate change. As Australia has domestic and international operators using local fuel, Australia needs to have our SAF recognisable so that our LCLS is more competitive (increase in demand). Furthermore, we need to learn the lessons from others, e.g. the unintended consequence of policies and production that led to the palm oil issues.

Question 2.10: What lessons can Australia learn from other jurisdictions that have already implemented LCLF production support measures?

See response to Question 2.9.

Question 3 - Fuel Production

Question 3.1: Considering the objective below, what production pathways should be focused on or prioritised?

Question 3.1a: Should priority be given to projects that use more-established production pathways (e.g. HEFA and HVO) than nascent production pathways that may present a higher level of technology risk?

Australia needs both. However, not all LCLFs are created equal and so priority needs to consider Carbon Intensity (CI) across the lifecycle. For example, HEFA from Canola can have a 83% CI compared with HEFA from UCO and Tallow with CI of 15% and 25% CL respectively. (See CSIRO's SAF Roadmap p23 Figure 9).

Prioritisation will change over time (as discussed above regarding bracketed incentives) across CI, Technology Readiness levels (TRL, which is a known method for measuring technology risk) and volumes required. For example, aviation requires 11GL of Sustainable Aviation Fuel with a weighted average CI of 15% 2050 to offset 42% of its emissions compared. If the weighted average CI is 30%, the maximum carbon offset will reduce to around 36%. Alternatively, if only 6GL is available at 30% CI, the maximum carbon offset reduces to 20%.

Question 3.1b: How can nascent production pathways compete with more-established production pathways (e.g. HEFA and HVO)?

By having brackets that factors in lifecycle Carbon Intensity this will incentivise cleaner local production. It is noted that some HEFA, e.g. from Tallow feedstock, will be highly competitive if available in the right volumes (CSIRO's SAF Roadmap Figure 9 p23).

However, to get to the volumes required and the weighted average CI as low as practicable new/emerging technologies will be required. By having a bracketed system that factors in volume required and gets regularly reviewed, e.g. every 5 years, this can easily be set-up to promote emerging technologies that are novel but promising, e.g. Power to Liquid (PtL). It is noted that PtL is essential for our future to achieve the volumes required but is current a low TRL. (see SAF Roadmap Figure 4 p8)

Alternatively, targeted grants can be provided to explore and or import promising technologies, such as PtL, that are at lower TRLs to speed up the adoption and implementation.

Question 3.1c: What minimum stage of project development (and evidence) should be expected by projects under the program?

By having a bracket system, the government could have a program that allows lower TRLs for lower CI so it is not a one size fits all system. For example, to achieve the future volume required at a certain of weighted average Carbon Intensity brackets could promote various projects, e.g. projects with a CI less than 15% may represent TRL3-4, whereas projects with a CI above 50% may be TRL7-8.

Question 3.2: Should there be a minimum facility size to be eligible?

Yes. For higher carbon intensive technologies/projects but only up to a certain volume across the market due to the need to achieve a weighted average Carbon Intensity. For lower TRL/CI technologies this may be more on the ability to scale the technology based on the feedstock, additional inputs limitation and efficiencies involved.

Question 3.3: Should LCLF be required to meet a carbon intensity threshold (% carbon intensity reduction compared to fossil equivalent) to be eligible for the program? If yes, what would be a reasonable threshold, and how should that threshold be calculated and verified? If not, why not?
Question 3.3a: If the production incentive is based on carbon emissions reduced, rather than volume of LCLF produced (see Question 2.3), is a minimum carbon intensity threshold still needed as part of the eligibility criteria?
Yes. However, by having a bracketed system that is reviewed every 5 years, this will assist in how this threshold to develop over time. 50% may be suitable initially but by 2050 Australia needs to be aiming for 15-30% across all production. Starting at 50% will allow the market to develop/grow initially but this will drag the weighted average CI of the market down at a later date.

This can be easily modelled through the ANU work to predict the impacts of a bracketed system on aviation to see what is optimal in terms of growth and future weighted average. The ANU model could be expanded to cover other sectors (e.g. maritime and road) to include the impacts (individually and collectively) from the various sectors and the ability to achieve carbon reductions. For example, aviation will rely on hydrogen and other technologies in 15 years but until then SAF is likely the key technology and will remain so out to 2050.

Question 3.3b: Should Indirect Land Use Change be included in the method for determining carbon intensity, for the purpose of the Program?
Absolutely., LCLF needs feedstock (crops, waste). Using prime farmland for fuel crops competes with food/feed, so the EU mandates safeguards, focusing on waste/residues first, but also permits crops from less productive land .See EU Clean Aviation (https://transport.ec.europa.eu/transport-modes/air/environment/refueleu-aviation/faq-refueleu-aviation_en). However, there is uncertainty of how far this will reach as the European Commission is actively assessing "Book & Claim" as part of its Clean Industrial Deal. A key factor is the lessons learned from Palm Oil increasing the arable land but led to mass deforestation , which had a negative impact on the climate.

Question 3.3c: Should any feedstocks be prioritised or otherwise considered out of scope?
Lower Carbon Intensity feedstock that can scale for volume needs to be prioritised. For example, forestry and agricultural residues; whereas Canola/HEFA should be de-prioritised and left for domestic-home use. (See CSIRO SAF Roadmap Figures 4 and 9

Question 3.4: Other than carbon intensity, should any other sustainability criteria be included?
Yes. A Systems of Systems (SoS) approach could be undertaken to look at the input and output of the various sources to determine critical areas. An approach, such as model based systems engineering, could be used to factor in the various inputs and outputs to look at what is possible. Initial consideration could factor in water/electricity (inputs) and pollutants/biproducts (outputs) as there will be critical limitations across each technology that will lead to higher level trade-offs and true impacts.

A SoS approach is very achievable to look at the unintended consequences of achieving LCLF at the volumes required.

QUESTION 3.5: WHICH INTERNATIONAL AND DOMESTIC SUSTAINABILITY SCHEMES SHOULD BE ALLOWED TO VERIFY SUSTAINABILITY CLAIMS?

For aviation, the more importantly is to identify which schemes Australia needs to be recognised by international? Aviation LCLF will need to be recognised by ICAO and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Otherwise, Australian aircraft operators may not have their flights recognised under sustainability and international operators may charge more to come to Australia as they won't be able to recognise our SAF.

See https://www.icao.int/CORSIA -CORSIA allows aircraft operators to reduce its offsetting requirements through the use of CORSIA eligible fuels. Related Standards are defined in Annex 16, Volume IV at sections 2.2.4 (Monitoring of CORSIA eligible fuels claims), 2.3.3 (Reporting of CORSIA eligible fuels), 2.4.3 (Verification of CORSIA eligible fuels) and 3.3 (Emissions reductions from the use of CORSIA eligible fuels).

Question 4 Other policy considerations

QUESTION 4.1: WHAT ARE YOUR VIEWS ON THE FOLLOWING FACTORS AFFECTING THE MERIT OF A PROPOSAL?
The factors identified in the Cleaner Fuels Program, Policy Design and Engagement Paper are a great start but need to be expanded to factor in location (proximity to the end user) and how to minimises the supply chains footprint on the end user to minimise the life cycle emissions to be minimised. In aviation this is referred to as "well to wake" emissions. There is minimal point in creating LCLF its carbon intensity is exploded through transport footprints to the end user. For example, importing clean SAF to Australia by dirty means.

QUESTION 4.2: RECIPIENTS UNDER THE PROGRAM WILL NEED TO DELIVER BENEFITS ACCORDING TO THE COMMUNITY BENEFIT PRINCIPLES UNDER THE FUTURE MADE IN AUSTRALIA ACT (SEE APPENDIX D OF THE POLICY DESIGN AND ENGAGEMENT PAPER). HOW DO YOU CONSIDER THE COMMUNITY BENEFIT PRINCIPLES IN RELATION TO LCLF PROJECTS? ARE THERE SPECIFIC COMMUNITY BENEFIT PRINCIPLES THAT ARE MORE OR LESS RELEVANT?
No Response

QUESTION 4.3: HOW WILL OVERSEAS POLICY DEVELOPMENTS INTERACT WITH DOMESTIC POLICY SETTINGS TO SUPPORT PROJECTS REACHING FINAL INVESTMENT DECISIONS? FOR EXAMPLE, LCLF DEMAND-SIDE TARGETS OR MANDATES, AND INTERNATIONAL FRAMEWORKS SUCH AS THE INTERNATIONAL CIVIL AVIATION ORGANISATION LONG-TERM GLOBAL ASPIRATIONAL GOAL FOR INTERNATIONAL AVIATION (LTAG) OF NET-ZERO CARBON EMISSIONS BY 2050.
Overseas policy developed are already driving the need for certain levels of LCLF in various sectors. For example, the EU and ICAO will set minimum levels. This is important for larger aircraft (narrow body and wide body aircraft) that will be hard to transition to other technologies, such as electric and hydrogen powered.

The Australian National University Sustainable Aviation Model (the underlying model to Engineers Australia's policy advice paper) accounts for this in how much fuel is required for sustainable aviation fuel. Whilst smaller aircraft will be more likely to be able to transition, the larger aircraft are the larger consumers of SAF. Moreover, these large aircraft dominate Australia's domestic carbon emissions as we are a large island nation.

QUESTION 4.4: IN ADDITION TO PRODUCTION SUPPORT, WHAT OTHER MEASURES ARE CONSIDERED CRITICAL TO ACHIEVE FINAL INVESTMENT DECISIONS FOR PROJECTS? WHAT ARE THEIR KEY FEATURES?
No Response

QUESTION 4.5: WHAT ARE THE INTERSECTING POLICIES YOU EXPECT NEED TO BE CONSIDERED TO UNLOCK A DOMESTIC LCLF PRODUCTION INDUSTRY?
Electricity demand, specifically green electricity, to enable Power to Liquid (PtL) technologies. There is a massive growth in electricity demand (e.g. Artificial Intelligence, electric cars and green hydrogen) and so whilst PtL could have a very low Carbon Intensity (CI), this is on the assumption that it has a (green) electricity power supply.

The laws of thermodynamics will mean that all LCLF conversions and refinements will have a given level of efficiency and electricity (and potentially water availability) will be critical factors in producing enough LCLFL at the right CI.

Hydrogen and Electrical Transition of Aircraft. Note hydrogen transition will have up to about a third of the effect of SAF in terms of carbon reduction, and electrical transition about 2%. The ability to fund the associated regulators (CASA and Airservices) to adopt new technology earlier will reduce the volume requirements of SAF. A similar consideration is expected for the transition of maritime and road transport to other fuel sources (e.g. electrical and ammonia fuel sources).

QUESTION 4.6: IS THERE ANY OTHER FEEDBACK YOU WOULD LIKE TO PROVIDE THAT ISN'T COVERED BY QUESTIONS ABOVE?

A data driven and systems of systems engineering approach is recommended to model the impacts of volume, carbon intensity, production locations, production inputs and production outputs in order to truly understand the impacts of LCLF in achieving carbon reductions (benefits) but also understanding the negative consequences.

The Australian National University model has been developed to understand the key levers for the aviation ecosystem and could easily be expanded to incorporate bracket systems to achieve the volumes required at a suitable weighted (volume) average carbon intensity. This also could be expanded to factor in other sectors such as maritime and aviation.

See the Engineers Australia Policy Advice Paper provides the underlying paper to the analysis and identifies are other trade-offs that could be leveraged by government to minimise the LCLF requirements for a sustainable Australian aviation sector. To date the ANU model has concentrated on how to make the current aviation system more towards net zero; however, having an appropriate model allows trade-offs to be made to understand what options the government has to move more holistically to net zero.

Towards net zero: Supporting Australia’s aviation transformation

Policy Advice Paper

November 2025

This paper has been developed through Engineers Australia’s member-delivered policy and advocacy by the Joint Board for Aerospace Engineering of Engineers Australia and the Royal Aeronautical Society – Australian Division.

Contents

About the Authors

Engineers Australia

Engineering is the essential link between thinking and doing. Between idea, and implementation. It's our means for positive, sustainable change, with an influence on every aspect of modern society. Engineers are the enablers of productivity because they convert smart ideas into new products, processes and services.

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A mission-based, not-for-profit professional association, Engineers Australia is constituted by Royal Charter to advance the science and practice of engineering for the benefit of the community. We back today's problem-solvers, so they can shape a better tomorrow.

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- a sustainable future;
- a skilled future; and
- an innovative future.

Royal Aeronautical Society Australia Division

Aerospace Engineering is complex, multi-disciplinary engineering for the aeronautical and space domains, and includes land-based infrastructure support systems.

The Royal Aeronautical Society Australia Division (RAeSAD) works collaboratively with other organisations and performs the function of a technical society of Engineers Australia. The Society is the Australian arm of world's oldest global Aerospace Society and is a prominent, independent, authoritative body that has influence on issues confronting today's aerospace community.

RAeSAD fosters expertise and professionalism through education, consultation, networking and recognition, by participating in government and industry body forums, conducting professional conferences and seminars, through industry promotion and measured advocacy and by briefing the media. The Society plays an important role in raising the profile of, and connecting the participants across, the aerospace community.

RAeSAD is a home for all aerospace and aviation professionals, regardless of their field of work – military or civil, general aviation or commercial air transport, operations or manufacturing. The Society's membership profile is drawn from all aerospace and aviation disciplines, including engineering, aircrew, aviation medicine, air traffic control, law and procurement.

This Policy Advice Paper was led by Honorary Associate Professor Jonathan Couldrick in his position on the Joint Board for Aerospace Engineering, with assistance from policy advisors from Engineers Australia and review by members of both organisations over 2024 and 2025.

Purpose

This paper is structured to inform our members and aviation decision makers of the key issues that will impact the future of Australian aviation's response to transitioning to a low-carbon economy and the future physical impacts of a changing climate. This paper presents five key recommendations to tackle these challenges.

This paper has been developed by the Joint Board for Aerospace Engineering (JBAeroEng), which manages the activities and relationship between Engineers Australia (EA) and the Royal Aeronautical Society Australia Division (RAeSAD).

The purpose of this paper is to engage members of EA and RAeSAD, as well as associated communities, about the future of sustainable aviation in Australia. Feedback will be used to inform later papers and future work to tackle aviation's sustainability challenges, which will be a multi-decadal endeavour.

Although this paper discusses government action, it acknowledges that "government" is made up of many stakeholders at both the Commonwealth, and state and territory levels. This includes many organisations: regulators, e.g. the Civil Aviation Security Authority (CASA); government-owned statutory authorities, e.g. Airservices Australia;, government business enterprises, e.g. Western Sydney Airport; and government departments, e.g. the Department of Infrastructure, Transport, Regional Development, Communications, Sport and the Arts (DITRDCSA) and Department of Climate Change, Energy, the Environment and Water (DCCEEW). This paper aims to synthesise a variety of perspectives to allow meaningful discussion on how many varied stakeholders can contribute to decarbonising Australia's aviation ecosystem.

Contact

We welcome feedback on this policy advice paper to help inform future work. To provide feedback or engage in further discussion, please email policy@engineersaustralia.org.au.

Summary of Recommendations

1. Promote sustainable modes of transport across land, water and air to ensure they are attractive and accessible.
2. Support Australia's adoption of sustainable aviation fuel (SAF) and hydrogen in aviation.
3. Establish a Chief Engineer position in the Australian Government to champion engineering in the public service and advise on a low-carbon aviation future.
4. Support the investigation of emissions reduction opportunities for non-carbon greenhouse gases.
5. Ensure that Australia's aviation infrastructure is ready for the future physical impacts of climate change.

Introduction

Aviation activities contribute 2.5 per cent of total global warming.[1] Since 2005, Australian aviation's CO_2-e emissions have grown 53-70 per cent.[2] If aviation does not address its greenhouse gas (GHG) emissions, the sector's predicted contribution to the remaining global carbon budget could account for as much as 25 per cent by 2050.[3] As other sectors reduce their GHG emissions, there will be increasing pressure on aviation to restrict its activities over the next 25 years so that Australian can reach net zero by 2050 across all sectors.

The Australian Government has legislated to reduce national emissions by 43 per cent on 2005 levels by 2030 and net zero by 2050[4] in line with the global goal to keep warming to below 2°C and pursue efforts to keep it to 1.5°C. In September 2025, the Australian Government announced its 2035 target of a 62-70 per cent reduction of CO_2 emissions from 2005 levels.[5] The target is supported by the Net Zero Plan and six sector plans, which set out how Australia can achieve a fair, orderly and efficient transition to net zero. The Transport and Infrastructure Net Zero Roadmap and Action Plan (Transport Sector Plan)[6] is one such sector plan and contains the decarbonisation planning relevant to aviation. The Australian Government has also committed $1.1 billion to support the production of low carbon liquid fuels (LCLF) in Australia via the 10-year Cleaner Fuels Program.[7]

Australian aviation is a complex ecosystem that contributes significantly to the Australian way of life. Commercial aviation is one of the safest,[8] and sometimes the only means of meeting the transport needs of Australia's highly dispersed and internationally mobile population. It underpins Australia's national and international supply chains, as well as people-to-people connections and trade, including our tourism, manufacturing, resources, and higher education sectors. Before the COVID-19 pandemic, the aviation sector annually contributed around $20 billion to the Australian economy, employed around 90,000 people and transported 42.1 million international and 61 million domestic passengers.[9] It is projected that the Australian aviation sector activities will overtake the scale of activities pre-COVID-19 and continue to grow until 2050.[10]

Further to the sector's economic contributions, aviation also performs an important social function, connecting families and friends worldwide. As societies become more globalised and people move

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[1] Intergovernmental Panel on Climate Change (IPCC), "Sixth Assessment Report", Figure 6.16, 2021. https://www.ipcc.ch/report/ar6/wg1/figures/chapter-6/figure-6-16/. See Also https://archive.ipcc.ch/ipccreports/sres/aviation/index.php?idp=71.

[2] See DCCEEW, Australian Petroleum Statistics (June 2024). https://www.energy.gov.au/energy-data/australian-petroleum-statistics. 70 per cent represents the increase in equivalent CO_2 from total aviation fuel usage by both domestic and international operators refuelling only in Australia; however, 53 per cent is the growth in domestic fuel use, See Table F of the Australian Energy Statistics 2025 Energy Update Report, "Australian Energy Update 2025," https://www.energy.gov.au/publications/ australian-energy-update-2025.

[3] Deloitte, Aviation's Ticket to Decarbonisation - How business can help sustainable aviation fuel take flight, Report, 2024 https://www.deloitte.com/global/en/issues/climate/aviation-ticket-to-decarbonisation.html.

[4] Climate Change Act 2022, s10 (1).

[5] See https://www.infrastructure.gov.au/infrastructure-transport-vehicles/towards-net-zero-transport-and-infrastructure, Accessed 18 September 2025.

[6] Australian Government, DITRDCA, "Transport and Infrastructure Net Zero Roadmap and Action Plan" published in 2025 and consulted on across 2023-24 via the roadmap and net zero position paper.

[7] Australian Government, 17 September 2025 [media release], "Joint media release: Fuelling the future: $1.1 billion to power cleaner Aussie fuel production,"
see: https://minister.dcceew.gov.au/bowen/media-releases/joint-media-release-fuelling-future-11-billion-power-cleaner-aussie-fuel-production.

[8] DITRDCA, Australian Infrastructure and Transport Statistics Yearbook 2023 December 2023. Table 10.3a (fatality rates) and 10.3b injury rates normalised per billion passenger km travelled.

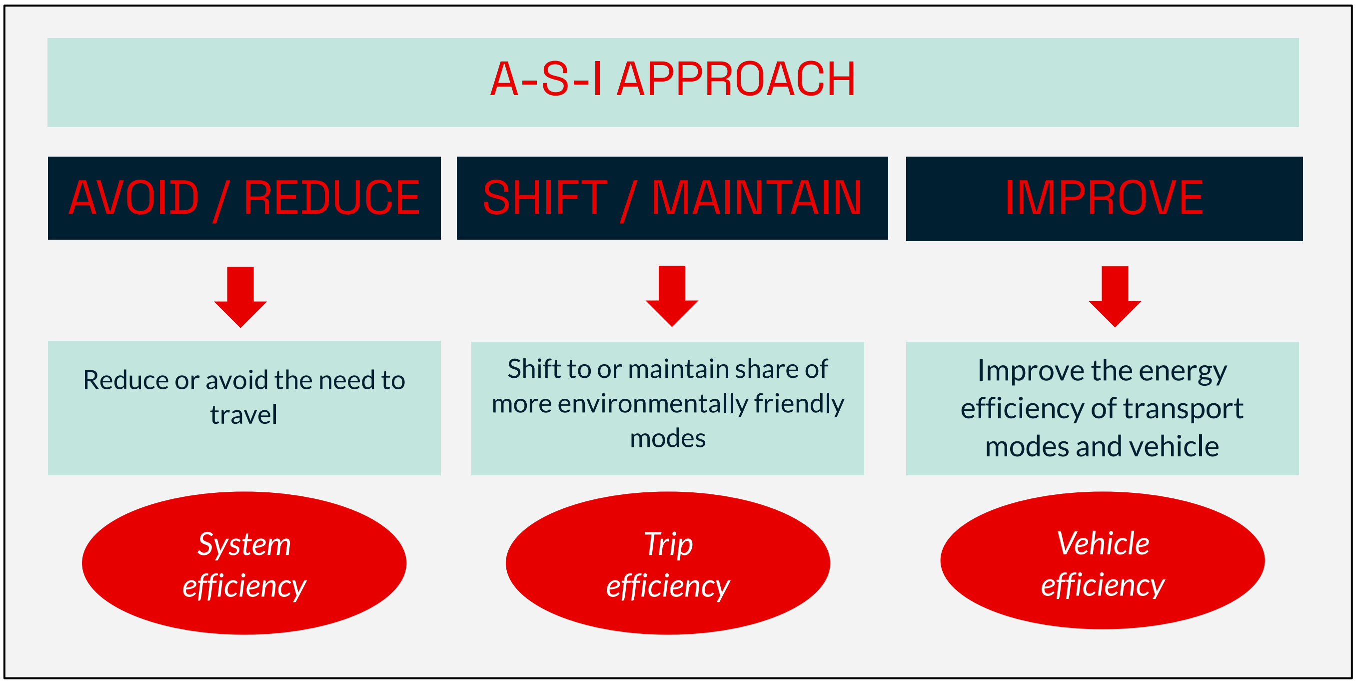
[9] Australian National Audit Office (ANAO), COVID-19 Support to the Aviation Sector, ANAO, Australian Government, 2022. https://www.anao.gov.au/work/performance-audit/covid-19-support-to-the-aviation-sector.

[10] Australian Government, Department of Infrastructure, Transport, Cities, Regional Development, Communications and the Arts, Bureau of Infrastructure and Transport Research Economics (BITRE), "Australian aviation forecasts – 2024 to 2050: Research Report 157", May 2024, https://www.bitre.gov.au/publications/2024/australian-aviation-forecasts-2024-2050.

further away from their hometowns, aviation allows people to stay physically connected.[11] Current forecasts for future aviation demand in Australia range from 3.5 to 5.0 per cent annual growth out to 2050.[12] Australia's mobile, multicultural society will continue to drive the demand for domestic and international passenger travel.

Due to the scale of Australia's aviation sector and its social, environmental and economic impacts, a thorough understanding of the impacts on various stakeholders is required before policies and targets are set. Examples of existing consultation and planning can be seen in the Australian Government's Aviation White Paper[13] and the Transport Sector Plan[14] – EA and RAeS AD encourage these consultative planning approaches.[15] However, discussions in Australia have so far focused mainly on "improve" measures within the Avoid–Shift–Improve framework (see Figure 1). In contrast, significant work is underway internationally to optimise the broader system of systems that is aviation. Australia should draw on these global efforts and adapt relevant approaches to suit the local context.

Figure 1: Sustainable Transport: Avoid-Shift-Improve Framework[16]



Aviation is a system-of-systems, with aircraft, airports, support systems, supply chains and air traffic management systems interacting to achieve a single mode of transport. Aviation also sits within a transport network comprising road, rail, maritime and other active methods (walking, cycling,

[11] Australian Bureau of Statistics, 2022 (https://www.abs.gov.au/media-centre/media-releases/2021-census-nearly-half-australians-have-parent-born-overseas).
[12] SAF Roadmap from CSIRO predicts ~5 per cent growth for Australian activities compared with: a similar rate predicted by BITRE "Australian aviation forecasts – 2024 to 2050 May 2024"; and global international airline activity growth is predicted to be 5.3 per cent (see International Air Transport Association "Global Outlook for Air Transport: Deep Change" June 2024), which is expected to be driven by developing nations.
[13] Australian Government, DITRDCA "Aviation White Paper" https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/aviation-white-paper.
[14] Australian Government, DITRDCA, "Transport and Infrastructure Net Zero Roadmap and Action Plan" published in 2025 and consulted on across 2023-24 via the roadmap and net zero position paper.
[15] See Engineers Australia's submissions to the Transport and Infrastructure Net Zero Roadmap Consultation (submission) and the Aviation Green Paper (submission).
[16] Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) Gmbh, "Sustainable Urban Transport: Avoid-Shift-Improve (A-S-I)", Division 44, Water, Energy, Transport. See also Engineers Australia, "Climate Change and Transport – Transport Australia Society Discussion Paper", October 2020, p.6.

e-mobility, etc.). Each mode of transport has its benefits and limitations, with distinct mechanisms for meeting the requirements of local, national, and international conveyance of people and goods.

This paper presents five recommendations to position Australian aviation to achieve its net zero target by 2050 and to build resilience to the physical impacts of climate change. While 2050 may seem distant, reaching net zero within the next 25 years is an ambitious challenge, particularly for the aviation sector. The paper highlights the urgency of early action, noting that some opportunities will be easier and more cost-effective to plan and implement in the coming years, whereas delaying action could significantly increase costs and jeopardise Australia's ability to meet its net zero goal.

If aviation fails to achieve its reductions in emissions and continues to grow as a share of global GHGs, the sector could face pressure to limit flights to reduce the sector's climate impact. EA and RAeS AD believe that any consideration of imposing future restrictions on aviation must be carefully balanced against the sector's highly significant socio-economic value. Early investment in emissions reduction can help avoid the need for any cuts to Australian air travel in the future. Aviation faces a once-in-a-generation imperative as competition evolves, climate initiatives are implemented, and disruptive technologies are introduced – the industry stands at a critical crossroads in its evolution.

Recommendation 1: Promote sustainable modes of transport across land, water and air to ensure they are attractive and accessible.

The Australian Government's Transport Sector Plan considers aviation as one component within a larger transport system, all of which requires significant effort to decarbonise. A key action within the Transport Sector Plan promotes voluntary flight alternatives to shift to transport modes with lower emissions impacts.[17] This contrasts with overseas approaches that have included bans[18] or increased taxes on short-haul flights.[19]

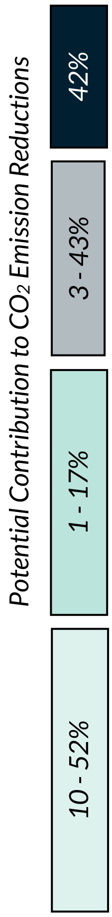
EA and RAeSAD support the Australian Government's proactive planning approach and recommend that future modes of transport (shifting use from one mode to another) consider more than the time and economics of a particular mode. Future considerations need to be broadened to include:

- Broader societal needs, including equitable access, safety, and sustainability.
- A shift from focusing solely on short-term trade-offs between time and cost to also considering the long-term needs of current and future generations.
- Integration of coordinated transport networks to enable seamless connections between different modes.
- Inclusion of full life-cycle assessments for each transport mode to capture total climate impacts, including infrastructure requirements.
- Policies that promote more sustainable ways of achieving the same outcomes, ranging from encouraging alternative modes of transport to reducing the need for travel altogether (for example, through remote meetings where feasible).

[17] See Note 2, p34.
[18] BBC, 2023, "France bans short-haul flights to cut carbon emissions", [online], accessed 14 October 2025, https://www.bbc.com/news/world-europe-65687665.
[19] Bernardo, V., Fageda, X. and Teixidó, J., 2024. Flight ticket taxes in Europe: Environmental and economic impact. *Transportation Research Part A: Policy and Practice*, *179*, p.103892.

Recommendation 2: Support Australia's adoption of sustainable aviation fuel and hydrogen in aviation.

To project aviation's emissions out to 2050, we have undertaken research to identify possible emissions sources and their scale within the Australian context (see Appendix 1). This analysis assumed that Australian aviation activity will continue to grow at a 3.6 per cent per annum out to 2050.[20] Based on this level of growth, emissions reductions can be grouped into:



- **Technical and operational efficiencies**: The aviation industry has typically achieved an annual 2 per cent efficiency dividend as conventional (tube and wing) flight has evolved over the last 25 years. These efficiencies will be realised through fleet renewals, new aircraft types and new air traffic management and operational practices.
- **Low carbon liquid fuels (LCLFs)**: Also referred to as biofuels and Sustainable Aviation Fuel (SAF), LCLFs are a promising technology for Australia with the potential to have a large impact on aviation's carbon footprint, but only if available in sufficient quantity and at the right locations. Australia will need approximately 6 Gigalitres (GL) and 11 GL of SAF to be available by 2035 and 2050 respectively, to achieve the higher end of the potential CO_2 savings.
- **Electrification and hydrogen fuel switching**: Whilst SAF has the potential to have a bigger impact on CO_2 emission reductions (potentially up to 43 per cent), transition to electrical- and hydrogen-fuelled aircraft will still have a significant effect on Australia's CO_2 emissions (potentially up to 17 per cent). Whilst most of this reduction will come from hydrogen (of the 17 per cent, up to 15 per cent will be from hydrogen), their impact will be limited in the short term by the fact that long- and medium-haul aircraft are currently Australia's largest CO_2 emitters and the hardest to transition.
- **Market-based measures (MBMs)**: This includes behavioural incentives and deterrents such as emissions trading schemes (ETS), carbon taxes and carbon offset markets, as well as stricter regulatory intervention that shape the aviation market, such as route caps or bans. Importantly, there were no scenarios out to 2050 for aviation to reach net zero in isolation, meaning these measures will play an essential role in aviation's decarbonisation, as carbon removals may be easier elsewhere in the economy. The mutual recognition of these emissions units across borders is an immediate action for consideration by the Australian Government.

Appendix 1 outlines the projected contribution of each area to overall emissions reductions. The exact scale of these contributions will depend on how quickly and successfully Australia adopts new technologies and practices. Achieving this will require coordinated and sustained action across industry, government, and peak body stakeholders.

A corollary of the MBM calculations is that these measures can be used to predict the expected change in CO_2 emissions by Australia's aviation flight activities. Based on mid-point MBMs of 65 per cent and 31 per cent in 2035 and 2050, respectively (see Table 3 in Appendix 1), and combined with the a 53 per cent growth in CO_2 emissions between 2005 and 2023, it is expected that the CO_2 emissions from Australian aviation flight activity will continue to grow out to 2050 above 2023 levels unless significant and urgent work is undertaken now (see Table 1).

CO_2 emissions reductions are highly dependent on the successful integration of all the elements of the Australian Government's Net Zero Roadmap, which will require concerted effort over the next 25 years.

[20] See footnote 11.

Our analysis shows that under a successful implementation of the roadmap, the carbon footprint of Australian aviation in 2035 is expected to increase by 52 per cent in 2035 and 23 per cent in 2050 compared to 2005 levels. "Successful" is the mid-range of all scenarios using a multivariable model of SAF availability (10-90 per cent), SAF Carbon Intensity (30-15 percent) and fleet transition to electrical or hydrogen powered, dependent on the category of aircraft (See Table 2 and Table 4 of Appendix 1 for more details). As such, concerted effort on multiple fronts is required to see a net reduction in aviation's footprint – otherwise aviation will be pressured to reduce its activities.

Table 1: Potential Australian aviation CO_2 emissions footprint from domestic and international flying activities of the Australian civil registered fleet compared with 2005 levels

Level of implementation of the Australian Government's Net Zero Roadmap	Aviation CO_2 emissions footprint compared with 2005 levels			
	2005	**2023**	**2035**	**2050**
Highly successful	100%	153%	129%	40%
Successful	100%	153%	152%	123%
Unsuccessful	100%	153%	176%	207%

Urgent adoption and scaling of current and novel technologies and behaviours are required to achieve a full implementation of the Australian Government's Transport Sector Plan. This will likely require:

- **Increasing the appetite for innovation adoption:** Australian Government agencies (such as CASA and Airservices Australia) and infrastructure owners and operators must be positioned to adopt novel technologies as early as practicable, which will likely change how aviation operates and manages risk.
- **Increasing the availability and market fungibility of LCLFs:** LCLFs must be available to aviation in sufficient quantities. This requires the consideration of global competition for the associated feedstock and supply, and domestic competition from other transportation methods (e.g. heavy road vehicles and maritime). An Australian framework is required that recognises international LCLFs supplies for domestic import, and for Australia to be able to trade our LCLFs (and associated emissions units/credits) internationally (if a domestic surplus occurs).
- **Accelerating infrastructure planning and construction:** Significant new Australian infrastructure will be required between 2035 and 2040[21] to support the integration of hydrogen and electrical charging infrastructure into the aviation supply chain. To achieve this, modelling and planning across 2025-2030 is essential to allow infrastructure owners and other stakeholders to prepare and understand the impacts through the subsequent design phases (2030-2035).
- **Defining Australia's aviation footprint:** Clarity is needed from the Australian Government's engagement with international bodies on the scope of responsibility (e.g. whether it covers all Australian-registered flights worldwide, or all flights operating within/departing Australia). This definition will inform additional roadmap actions to reduce aviation's carbon impact. In the short term, Australian universities, research organisations and industry are well placed to deliver holistic modelling, enabling medium-term readiness and minimising aviation's long-term impact.

[21] The Air Transport Action Group projects 2030-2035 as the early adoption of hydrogen for regional and short-haul aircraft with medium-haul by 2040 (see footnote 29); however, groups such as Airbus have delayed hydrogen activities, citing hydrogen infrastructure concerns (see https://theicct.org/zero-emission-planes-hit-turbulence-what-do-recent-delays-mean-for-net-zero-aviation-by-2050-may25/).

Recommendation 3: Establish a Chief Engineer position in the Australian Government to advise on achieving a low-carbon aviation future.

Achieving net zero emissions in aviation by 2050 will depend on the coordinated implementation of the measures outlined in the Australian Government's Transport Sector Plan. This includes integrating a range of decarbonisation pathways, such as sustainable aviation fuels, hydrogen, electrification, operational efficiency and behaviour change, while ensuring the supporting infrastructure, regulatory settings, and workforce capabilities are in place.

The next decade will be decisive. Decisions made now about infrastructure, technology development and operational models will determine whether Australia locks in or reduces aviation emissions to 2050. Delivering this transition requires alignment across governments, airlines, airport operators, manufacturers, professional bodies and the research community. Advisory mechanisms such as the Australian Jet Zero Council play a valuable role in this coordination, but additional, targeted engineering leadership will be critical to ensure technical feasibility, safety, and system integration.

Establishing a Chief Engineer position within the Australian Government could provide this leadership. The Chief Engineer would ensure that policy, planning and investment decisions are informed by robust engineering insight, integrating technological, environmental and economic considerations across sectors. This role would help translate innovation into practical and scalable implementation by connecting technology development with real-world deployment, and by identifying dependencies and trade-offs across complex systems.

For example, the transition to hydrogen-powered aviation will require extensive planning to align technology readiness with infrastructure development. Early modelling and systems analysis are essential to estimate land requirements, infrastructure scale and supply chain needs. This will enable airports and policymakers to plan for hydrogen deployment in the 2030s while ensuring early action is taken to preserve future options.

A Chief Engineer could also oversee system-wide modelling to explore and optimise the many trade-offs involved in decarbonising aviation, such as:

- Adjusting the VH-fleet mix towards smaller aircraft that are better suited to alternative fuel types or electrification. Long-haul and medium-haul aircraft are expected to rely on LCLFs (likely beyond 2050) while smaller aircraft are likely to adopt a wider range of low-emission technologies. Although options for international flights remain limited, domestic routes could support earlier transitions, subject to trade-offs in airport infrastructure and operations.
- Assessing the economic and environmental implications of operating at different speeds, altitudes and passenger capacities. These factors are key determinants of fuel use per passenger kilometre, but any adjustments would have significant implications for airline business models and the economics of mass air transport in Australia.
- Exploring operational changes, such as adjusting flight departure times to take advantage of daily variations in temperature, pressure and humidity. This could help reduce contrail formation and associated climate impacts, although it would also influence the commercial and scheduling dynamics of flight operations.

By adopting a systems-of-systems perspective, a Chief Engineer would ensure that second- and third-order impacts are identified and managed before large-scale implementation. This would enable governments and industry to make informed and evidence-based decisions that maximise carbon reductions while maintaining safety, resilience and economic performance across Australia's aviation ecosystem.

Recommendation 4: Support the investigation of emissions reduction opportunities for non-carbon greenhouse gases.

While this paper focuses primarily on CO_2 emissions, other GHGs also contribute to aviation's overall climate impact. Although a global evidence base is emerging, further research, planning, consultation and analysis will be required to understand how this knowledge can be applied in the Australian context. Some effects may not be negative[22] and additional investigation is needed to assess their downstream implications.

Whilst current climate action discussions focus heavily on CO_2 emissions, the push to encompass the impacts of other GHGs will shift the mitigation dialogue in aviation. This can be seen in international actions, such as in the European Union (EU), which has mandated monitoring, reporting and verification of non-CO_2 emissions from 1 January 2025.[23] The EU's Clean Aviation initiative categorises the other emitting areas for aviation into contrails, water, nitrogen oxides (NO_X) and fuel production.

Non-carbon GHGs may collectively contribute as much as 69 per cent of aviation's global warming potential (GWP).[24] Non-carbon GHGs have varying atmospheric lifetimes (how long they remain in the atmosphere) and compounding potential (where molecules interact to form compounds with more potent warming potentials) – which is variable based on the altitude at which the GHGs are released.[25]

Although Australia can draw on international research on non-carbon GHGs, this information will need to be adapted to local conditions. For instance, dynamic air route management that accounts for water vapour at different altitudes may need to reflect Australia's unique atmospheric and climatic characteristics rather than the dissimilar conditions of Europe or North America.

In the near term, Australia's focus must be on planning and implementing CO_2 reduction measures. Over the coming decade, this will need to expand into a broader approach that captures the total GWP of all GHGs across the aviation system. Building this understanding will be essential for developing a comprehensive and effective strategy to manage aviation's full climate impact.

Recommendation 5: Ensure that Australia's aviation infrastructure is ready for the future physical impacts of climate change.

The physical impacts from a changing climate are already impacting aviation infrastructure, with both flights and airports expecting to face increasing hazards, such as changes in wind, turbulence, dust, smoke, hail, flooding and extreme temperatures.[26] Aviation systems will need to iteratively adapt over the coming decades with the emergence of new climate-related risk reporting requirements (that will

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[22] Whilst contrails at night lead to global warming by trapping in heat, contrails during the day can increase the Earth's albedo by reflecting solar energy. See Avila, D et al. "Reducing global warming by airline contrail avoidance: A case study of annual benefits for the contiguous United States," https://www.sciencedirect.com/journal/transportation-research-interdisciplinary-perspectives, Vol 2, September 209, https://doi.org/10.1016/j.trip.2019.100033.

[23] European Commission , "New monitoring rules agreed for the EU ETS, including non-CO_2 emissions from the aviation sector", https://climate.ec.europa.eu/news-your-voice/news/new-monitoring-rules-agreed-eu-ets-including-non-CO2-emissions-aviation-sector-2024-08-30_en, dated 30 Aug 24.

[24] See Note 1.

[25] See International Civil Aviation Organisation, "Report on the Feasibility of a Long-Term Aspirational Goal (LTAG) for International Civil Aviation $C0_2$ Emissions Reductions – Appendix S1 Climate Science Context", Table 2, p14, March 22 and D.S. Lee et al. "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018 ", Atmos Environ (1994). 2021 Jan 1; 244: 117834. Table 5 (10.1016/j.atmosenv.2020.117834) for 20-, 50- and 100-year timescales.

[26] Holmes, M.E., Ryley, T., Ward, A., Fein, E.C. and Martin, S., 2024. Australasian aviation climate change hazards: A systematic review. *Journal of Air Transport Management*, *121*, p.102670.

likely reveal new imperatives and opportunities for adaptation) and the increased provisioning of supporting infrastructure to meet increasingly severe climate impacts.

Some asset and infrastructure owners are already adapting to climate change – for example, Sydney Airport's flood and head modelling, and Brisbane Airport, which has already raised its runway elevations, built tidal channels and erected seawalls to manage flood risk from sea level rise.[27] Heathrow Airport is undertaking a risk-based approach where the likelihood of a consequence changes over time as confidence levels are better known.[28] Heathrow's adaptive planning approach allows new requirements to be incorporated into planning and to determine how existing infrastructure will need to change over the coming decades.

An adaptive approach will need to be considered for a variety of cases in Australia. For example, future extreme weather and rising temperatures may result in more frequent aircraft groundings, increased pressure on airport parking and flight routing, and the need for upgraded runways, taxiways and airport infrastructure to withstand higher heat conditions and maintain safe operations. In addition to adaptive planning for infrastructure, the aviation workforce will also have to be trained to recognise acute climate-related hazards to maintain the safety of travellers and the efficiency of travel as these hazards become more severe, more frequent, and appear in new locations.

Conclusion

Government, industry and academia must urgently work together to reduce aviation's GHG emissions and adapt to the physical impacts of a changing climate. With coordinated effort, aviation's emissions could be significantly reduced by 2050. Without it, based on a 3.6 per cent growth in aviation activities, emissions are likely to double (See Table 1 and Table 4 in Appendix 1), making aviation one of the largest global polluting sectors and threatening its continued social licence to operate. This paper makes five recommendations:

- Promote sustainable modes of transport across land, water and air to ensure they are attractive and accessible.
- Support Australia's adoption of sustainable aviation fuel and hydrogen in aviation.
- Establish a Chief Engineer position in the Australian Government to advise on achieving a low-carbon aviation future.
- Support the investigation of emissions reduction opportunities for non-carbon greenhouse gases.
- Ensure that Australia's aviation infrastructure is ready for the future physical impacts of climate change.

To enable the government to achieve its target of achieving net zero emissions by 2050 and reducing Australia's footprint by 62-70 per cent by 2035, Australia must be enabled to pursue full implementation of new technologies, SAF, and transition to electrical and hydrogen-powered aircraft as recommended in this paper.

[27] NCCARF, 2016: *Planning for Brisbane Airport's new runway: accounting for climate change. Snapshot for CoastAdapt*, National Climate Change Adaptation Research Facility, Gold Coast, available at: https://coastadapt.com.au/sites/default/files/case_studies/SS16_Brisbane_airports_new_runway.pdf.
[28] Heathrow Airport Ltd, "Climate Change Adaptation Report – Third Round Progress Report", January 2022.

Appendix 1 – Summary of Research into the Potential CO_2 Reductions across Australia's VH-Fleet

To project aviation emissions out to 2050, research has been undertaken to identify the scale of where emissions reductions might come from compared to Australia's aviation emissions in 2023. The research was led by Honorary Associate Professor Jonathan Couldrick of the Australian National University, based on the fundamental assumption that Australian aviation activity will continue to grow at 3.6 per cent per annum out to 2050.[29] The research models only the flying component of the aviation system (i.e. just the aircraft, which will be the hardest to abate) using 2023 ADS-B flight data across the global Australian (VH-) fleet,[30] cross-referenced with individual aircraft predicted fuel consumption and the Air Transport Action Group's projection of where low- and zero-carbon energy could be deployed.[31]

Table 2: Scenario Variables that might be achievable by 2050

Variable	Low Range	High Range
SAF Availability	10%	90%
SAF Carbon Intensity (Carbon composition of the SAF Supply Chain)	30%	15%
Fleet Saturation (Transition to Electric or Hydrogen)		
Commuter Category	65%	100%
Regional Category	40%	100%
Narrow-Body Category	0%	50%
Wide-Body Category	0%	0%

To create consistency between this and international research, different scenarios were modelled under a multivariable analysis.[32] The key variables are identified in Table 2 for what is likely achievable by 2050. SAF availability ranging from 10 to 90 per cent of aviation's need is taken from CSIRO's modelling of current planned SAF production to the maximum SAF achievable from Australian feedstock respectively.[33] Carbon Intensity (CI), which is the carbon equivalent emissions of SAF based on a Life

[29] 3.6 per cent is a conservative amount compared with the SAF Roadmap from CSIRO predicting ~5 per cent growth, which is similar to the BITRE rate "Australian aviation forecasts – 2024 to 2050 May 2024" and the international airline activity growth of 5.3 per cent (see International Air Transport Association "Global Outlook for Air Transport: Deep Change" June 2024), which is expected to be driven by developing nations. A rate closer to 5 per cent would further reduce our ability to achieve net zero. At the lower end, CSIRO's modelling predicts Australia's aviation energy use to grow between 0.3-1.6 per cent annually (" Modelling Sectoral Technology and Emissions Pathways to 2035 and Net Zero Emissions – Final Report", June 2025. See https://www.csiro.au/en/research/environmental-impacts/decarbonisation/sectoral-pathways-modelling). Accounting for the historical 2 percent aviation efficiency the CSIRO uses an equivalent 2.3-3.6 per cent growth in Australian domestic aviation activities from 2025.

[30] "VH-" refers to the Australian civil registered aircraft on the CASA aircraft register, see https://www.casa.gov.au/search-centre/aircraft-register.

[31] Air Transport Action Group, "*WAYPOINT 2050: Balancing Growth in Connectivity with a Comprehensive Global Air Transport Response to the Climate Emergency: A Vision of Net-Zero Aviation by Mid-Century*", 2nd Ed, September 2021, p54, < https://aviationbenefits.org/downloads/waypoint-2050/>.

[32] The same approach was taken by note 31 and other models (for example Boeing's Cascade model, see note 40), allowing comparison to international research and adapting it to Australia's context.

[33] CSIRO, Sustainable Aviation Fuel Roadmap, Report, August 2023, Figure 4, p8, https://www.csiro.au/en/news/all/articles/2023/august/sustainable-aviation-industry-Australia.

Cycle Analysis,[34] ranged from 30 to 15 per cent. This corresponds to the average CI of all SAF technologies and the average of all SAF technologies, less the more carbon intensive feedstock of canola and municipal solid waste (25% non-biogenic carbon) respectively,[35] as it is assumed that SAF will become cleaner over the next 25years. Fleet saturation balances ATAG's predicted transition across aircraft categories[36] against fleet renewal timeframes. For example, larger aircraft take longer to acquire and remain in service for longer, slowing down the transition of larger aircraft.[37]

The results are summarised in Table 3, which identifies the scale of carbon emission reduction from different areas, with the level of uncertainty principally being derived from how successful Australia will be in ramping up/adopting the various technologies and practices. It is noted that this will depend heavily on the concerted effort of numerous stakeholders and the ongoing need for bodies such as the Jet Zero Council of Australia to advocate for their adoption, to be coordinated by the relevant Australian Government departments.

Table 3: Potential CO_2 savings for the Australian aircraft fleet from different sources out to 2050 based on modelling of 2023 ADS-B flight data of the (combined domestic and international) VH-fleet

	Potential CO_2 savings	
	2035	**2050**
Technical & Operational Efficiencies	-22%	-42%
Sustainable Aviation Fuel	-13% ±10%	-23% ±20%
Electrical and Hydrogen Transition	-1% ±1%	-9% ±8%
Market-Based Measure	-65% ±10%	-31% ±21%

Emissions reduction technologies and practices are grouped into:

- **Technical & Operational Efficiencies** – The aviation industry has typically achieved an annual two per cent efficiency dividend as conventional flight has evolved over the last 25 years. Projecting forward, this will come from areas such as:
    - New aircraft designs such as the Blended Wing Body (BWB) or Transonic Truss Braced Wing (TTBW).
    - Evolution of the current tube and wing design with lighter and more efficient aircraft structures and systems (e.g. more efficient engines).
    - Operational efficiencies, such as more dynamic modelling of routes to reduce distance travelled and holding patterns; and more efficient operations to reduce turnaround times or direct routes, e.g. Qantas' project Sunrise, creating a direct route from Sydney to London.[38]
- **Low Carbon Liquid Fuel (LCLF)** – Also referred to as biofuels and Sustainable Aviation Fuel (SAF), LCLF is a very promising technology for Australia with the potential to have a large impact on aviation's carbon footprint, but only if available in sufficient quantity at the right locations. Modelling identifies that Australia will need approximately 6 GL and 11 GL of SAF to be available by 2035 and 2050 respectively, to achieve the higher end of the potential CO_2 savings identified in Table 3. This is slightly below CSIRO's projected total Australian SAF

[34] Also known as "Well to Wake" emissions.

[35] See Note 32, Figure 9, p23.

[36] See Note 31.

[37] Modelling did not factor in a complete disruption of the smaller aircraft market, that some are predicting from the introduction of electric vertical take-off and landing (eVTOL) and advanced air mobility (AAM). See Note 14.

[38] Qantas, "A350 Project Sunrise", https://www.qantas.com/au/en/about-us/our-company/fleet/new-fleet/project-sunrise.html, accessed 05 October 2025.

production capacity from all feedstock types;[39] however, it is expected that there will be significant competition for this feedstock from maritime, home use and restrictions on LCLFs being produced from urban land feedstock.

- **Electrical and Hydrogen Transition** – Whilst SAF has the potential to have a bigger impact, transition to electrical- and hydrogen-fuelled aircraft will still have a significant effect on Australia's CO_2 emissions. However, their impact will be limited in the short term by the fact that Long- and Medium-Haul aircraft are currently Australia's largest CO_2 emitters and the hardest to transition before 2050. As Australia will likely be a net consumer of electrical and hydrogen aircraft technology, we need to plan for their incorporation in the 2035 time frame to maximise their adoption. This planning is more about infrastructure, as such planning needs to happen now so that Australia is ready to incorporate them into the fleet as soon as possible – see below for further discussion.
- **Market Based Measures (MBM)** – These are the economic levers that the Australian Government can pull to allow carbon offsets to be recognised between entities, as there were no scenarios out to 2050 for aviation to reach net zero in isolation. This means that MBM will be required, with the only question being their magnitude. Depending on the success of the above technical/operational efficiencies, implementation of SAF and transition to new power sources, MBMs may need to offset up to half of aviation's carbon footprint from flying.

Figure 2: Potential CO_2 savings for the Australian aircraft fleet from different sources out to 2050 based on modelling of 2023 ADS-B flight data of the (combined domestic and international) VH-fleet

[39] See Note 33.

Figure 2 presents Table 3 pictorially and overlays predictions from Boeing's cascade model[40] for the scale of impact from operational efficiencies, new aircraft types and fleet renewals. The Cascade model was used to validate the findings, with the key difference coming from the use of the actual Australian fleet mix and baselining the data in 2023.

A corollary of MBMs is that they can be used to predict the expected change in CO_2 emissions by Australia's aviation sector's flight activities. As such, based on the mid-point MBMs of 65 per cent and 31 per cent (see Table 3), it is expected that the carbon footprint of Australian aviation flight activity in 2035 and 2050 is expected to decrease by 0.5 per cent and 19 per cent respectively compared to 2023 levels.[41] As shown in Table 4, this is highly dependent on the successful implementation of all elements of the roadmap coming together. A "Highly Successful" implementation of the Net Zero Roadmap is the optimal scenario equivalent of achieving all the high-range variable targets identified in Table 2, with "unsuccessful" equivalent to achieving the low range of all variables. "Successful" is the mid-range of all scenarios modelled, rather than the mid-range of the individual variables.

Table 4 – Potential Australian aviation carbon footprint from domestic and international flying activities of the VH-fleet compared to 2023 levels[42]

Level of implementation of the Australian Government's Net Zero Roadmap	Aviation Carbon Footprint compared to 2023 levels		
	2023	**2035**	**2050**
Highly Successful Implementation	100%	84.2%	26.0%
Successful Implementation	100%	99.5%	80.6%
Unsuccessful Implementation	100%	115%	135%

October 2025 – Domestic Only Addendum

In September 2025, the Australian Government announced its 2035 target of a 62-70 per cent reduction of $C0_2$ emissions from 2005 levels.[43] This was based on a transport sector plan[44] and advice from the Climate Change Authority.[45] The government target and roadmap factor in both international and domestic aviation activity; however, the underlying modelling by CSIRO only models the domestic use.[46] As such, an addendum has been provided to isolate domestic effects, compared to the previous research that combined domestic and international effects.

[40] https://cascade.boeing.com/.
[41] As such, the expected carbon footprint of Australian aviation in 2035 is expected to reduce by 0.5% (100% * (1+0.53) * (0.65)) in 2035 and 20% (100% * (1+1.6) * (0.31)) in 2035 and 2050 respectively under a successful implementation of the government's Transport and Infrastructure Net Zero Roadmap (see note 14) compared to 2023 levels. However, this will be a net increase of 52% and 23% respectively compared to 2005 levels after accounting for a 53% increase in fuel usage between 2005-2023. This would be higher still if fuel usage has increased 70% (the increase in aviation turbine fuel use in Australia across domestic and international operators).
[42] These numbers will be higher with a less conservative/higher rate of growth in aviation activities. See footnote 26
[43] See https://www.infrastructure.gov.au/infrastructure-transport-vehicles/towards-net-zero-transport-and-infrastructure, Accessed 18 September 2025.
[44] Department of Infrastructure, Infrastructure, Regional Development, Communications, Sport and the Arts, "Transport and Infrastructure Net Zero Roadmap and Action Plan Transport Sector Plan", September 2025, See https://www.infrastructure.gov.au/department/media/publications/transport-and-infrastructure-net-zero-roadmap-and-action-plan.
[45] Climate Change Authority, "2035 Targets Advice", https://www.climatechangeauthority.gov.au/2035-emissions-reduction-targets-advice.
[46] CSIRO," Modelling Sectoral Technology and Emissions Pathways to 2035 and Net Zero Emissions – Final Report", June 2025. See https://www.csiro.au/en/research/environmental-impacts/decarbonisation/sectoral-pathways-modelling.

Table 5: Potential CO_2 savings for the Australian aircraft fleet from different sources out to 2050 based on modelling of 2023 ADS-B flight data of the (Domestic Only) VH-fleet

	Potential CO_2 savings	
	2035	**2050**
Technical & Operational Efficiencies	-22%	-42%
Sustainable Aviation Fuel	-13% ±11%	-22% ±20%
Electrical and Hydrogen Transition	-2% ±1%	-16% ±13%
Market Based Measure	-64% ±11%	-29% ±22%

Table 3 and Table 4 have been replicated, showing domestic only data, see Table 5 and Table 6 respectively. Comparing Tables 2 and 4, the average potential $C0_2$ savings from SAF does not fundamentally change. However, the potential savings from transitioning to electrical and hydrogen fuel sources has almost doubled due to the increased ability to transition smaller domestic aircraft compared to the larger narrowbody and widebody international aircraft that will be highly reliant on SAF for the foreseeable future.

Domestic only flights are predicted to require 3.7GL and 4.5GL of SAF in 2035 and 2050 respectively to achieve its maximum effect. The modest increase in SAF between these two epochs, compared to the 6GL to 11GL for domestic and international combined, is due to international aircraft will not have as many options to transition to electricity or hydrogen power, compared to the smaller domestic fleet.

Importantly, the need for market-based measures has not fundamentally changed, comparing Table 4 against Table 2. However, the key difference is that for the best-case scenario, there is potential to reduce the domestic fleet's carbon footprint to 18.2 per cent by 2050 compared with 2023 levels (see Table 5), i.e. a reduction of nearly 82 per cent. This compares to reducing the combined international and domestic fleet's footprint to 26.0 per cent (Table 3), a reduction of 74 per cent from 2023 levels. Both cases will require a highly successful implementation of the government's roadmap. After factoring the 52.9 per cent growth in domestic aviation fuel usage between 2005 to 2023, the best-case scenario translates to a potential total Australian domestic footprint of 27.8 per cent, i.e. a CO_2 reduction of 72 per cent from 2005 levels.[47]

Table 6: Potential Australian aviation carbon footprint from domestic only flying activities of the VH-fleet compared to 2023 levels

Level of implementation of the Australian Government's Net Zero Roadmap	Aviation Carbon Footprint compared to 2023 levels		
	2023	**2035**	**2050**
Highly Successful Implementation	100%	81.1%	18.2%
Successful Implementation	100%	97.9%	75.4%
Unsuccessful Implementation	100%	115%	133%

Using a 9.1Mt CO_2-e domestic Australian aviation emissions in 2023,[48] this infers the government is relying on aviation having a highly successful implementation of the government's roadmap and action plan. Comparing Table 6 to the CSIRO model,[49] CSIRO's worst cases (A50/G2 and A40/G2)[50] predict

[47] Compared to the 40 per cent identified in Table 1, which is a 60 per cent reduction from 2005 levels.
[48] CSIRO are projecting 9.36Mt $C0_2$-e in 2025 (see note 46), which is aligned to this analysis. Reverse engineering implies CSIRO would have an equivalent 9.07 Mt $C0_2$-e in 2023.
[49] Figure 33 of note 46.
[50] Restricting global warming to 2°C and achieving net zero by 2040 or 2050.

that Australia must reduce its domestic aviation footprint to 12.7 per cent by 2050 compared to 2023 levels. Every other scenario required a lower emission target with some down to net zero for domestic aviation. **Therefore, to enable the government to achieve its target of achieving net zero emissions by 2050 and reducing Australia's footprint by 62-70 per cent by 2035, Australia must be enabled to pursue full implementation of new technologies, SAF, and transition to electrical and hydrogen powered aircraft as recommended in this paper.**