Australian Government
Department of Infrastructure, Transport,
Regional Development, Communications and the Arts

Transport and Infrastructure Net Zero Consultation Roadmap

May 2024 / INFRASTRUCTURE 2024

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Acknowledgement of Country

We acknowledge the Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past and present.

We thank First Nations people for their continuing custodianship of, and care for, the Country that we live and work within today. It is fitting to reflect on the thousands of generations of traditional knowledge First Nations people hold, and generously share, as we look to decarbonise how we move people and goods across Australia.

We acknowledge the diversity of First Nations cultures, languages and practices across the country and the resilience of First Nations people in keeping these alive. We recognise the importance of listening to the voices of local First Nations people and responding to the uniqueness of each place.

We are committed to working in partnership with First Nations people in meeting current and future challenges and achieving opportunities, including through the net zero sectoral plans.

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Ministers' foreword

Transport shapes our cities and regions. It supports economic and social development and determines how we can engage with the communities around us. Today, the transport sector emits about a fifth of Australia's 465 million tonnes of annual carbon dioxide equivalent gas emissions. Ensuring the transport sector is fit for our net zero future is essential.

If we do not act, transport emissions are on track to be the largest source of greenhouse gas emissions in Australia by 2030, with almost 60% of these emissions coming from the light vehicle sector. A failure to act would also be a missed opportunity to increase the productivity and resilience of our transport sector, the infrastructure which it underpins and the job creation which will come from the sector's Net Zero transition.

The Australian Government is working to decarbonise Australia's transport system but a clear pathway forward across all transport modes and enabling systems is needed to guide the collective effort across our economy.

The Transport and Infrastructure Net Zero Roadmap and Action Plan is one of the six sectoral plans the Australian Government is developing to build our Net Zero 2050 plan, to ensure Australia maximises the benefits of the global transition to net zero and provides long-term policy certainty to drive investment in low emissions and renewable technologies.

There are exciting opportunities for positive change and innovation that will come with decarbonising our transport and infrastructure sectors. Achieving our goals will involve making careful decisions, and we must navigate the path ahead with care so that we create a cleaner future that is economically responsible, socially inclusive, creates jobs and eases the cost of living.

The Roadmap and Action Plan is an opportunity to establish a policy direction that benefits all Australians. It will build on initiatives introduced by the Australian Government to reduce emissions in the transport and infrastructure sectors. These initiatives include: increasing the uptake of electric vehicles through the National Electric Vehicle Strategy and an Australian New Vehicle Efficiency Standard; as part of our Future Made in Australia plan, fast-tracking support for a low-carbon liquid fuel industry, with an initial focus on sustainable aviation fuel and renewable diesel to support emissions reduction in the aviation, heavy vehicle, rail and maritime sectors; establishing the Australian Jet Zero Council; developing a Maritime Emissions Reduction National Action Plan; the National Rail Manufacturing Plan and establishing the High Speed Rail Authority; supporting zero emissions travel with the Active Transport Fund; embedding sustainability as a key strategic theme in the Infrastructure Policy Statement; and working with the states and territories through the Infrastructure and Transport Ministers' Meeting to reduce transport and transport infrastructure emissions.

This Consultation Roadmap sets out decarbonisation pathways for transport and transport infrastructure across our transport systems, all transport modes and the enabling inputs and policies. There is considerable complexity to decarbonising our transport system and we are committed to getting it right. That is why we have set out key questions in this Consultation Roadmap and will work with stakeholders on identifying and implementing the actions necessary to reduce our transport and infrastructure emissions in a way that is right for Australia. We seek the views of all interested Australians, and wish to engage with industry, the climate movement, experts, unions, the community and with all levels of government to develop this sectoral plan, ensuring it is robust, ambitious and achievable.

The Hon Catherine King MP
Minister for Infrastructure, Transport, Regional Development and Local Government

The Hon Chris Bowen MP
Minister for Climate Change and Energy

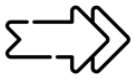
Executive summary

This Consultation Roadmap seeks feedback on potential pathways for transport and transport infrastructure to support economy-wide net zero as well as the actions or policies the Australian Government will need to take to support these potential pathways.

The Consultation Roadmap sets out the challenge in chapter 1 and considers opportunities to decarbonise the movement of people and goods in chapter 2, before analysing each transport mode in chapter 3. The enabling systems, including transport infrastructure and transport's energy needs, are outlined in chapter 4. The final chapter describes how the Australian Government will work collaboratively to reduce transport and transport infrastructure emissions.

The responses to the questions asked throughout the Consultation Roadmap will inform the pathways, actions and policies that the Australian Government will commit to in the final Transport and Infrastructure Net Zero Roadmap and Action Plan that will be released later this year.

Consultation Roadmap



Final Roadmap and Action Plan (transport sector plan)

Feedback from communities, industry, experts and unions on the potential decarbonisation pathways and the actions/policies that need to be taken to support these potential pathways

Chapter 1 – Introduction

The Consultation Roadmap begins by bringing together evidence to illustrate the challenge to reduce transport emissions. The Australian Government has an ambitious climate agenda, legislating to reduce national emissions by 43% on 2005 levels by 2030 and net zero by 2050 in line with the global goal to keep warming to well below 2°C and pursue efforts to keep it to 1.5°C. In addition, the government is developing a Net Zero Plan to help Australia maximise the benefits of the global transition to net zero. It will provide certainty through long-term policy and help drive investments in low emissions and renewable technologies. To support the Net Zero Plan, the government is developing six sectoral plans.

The Transport and Infrastructure Net Zero Roadmap and Action Plan will be the net zero sectoral plan for the transport and transport infrastructure sectors. It is being developed in two stages. The first stage is this Consultation Roadmap, which seeks your views on potential pathways to net zero for transport and transport infrastructure as well as the actions or policies taken by governments to support these potential pathways. What we hear from you will inform the pathways, actions and policies that the government will commit to in the second stage of development, the final Transport and Infrastructure Net Zero Roadmap and Action Plan.

Transport connects Australians to each other and to the rest of the world. It is essential for our economy and wellbeing. Transport is also the third-largest source of greenhouse gas emissions in Australia, amounting to 21% of Australia's greenhouse gas emissions in 2023. Since 2005, transport emissions have increased by 19%. Without further action, transport will be the largest source of emissions in Australia by 2030. We have an opportunity to decarbonise transport and support Australia's goal of reaching net zero by 2050.

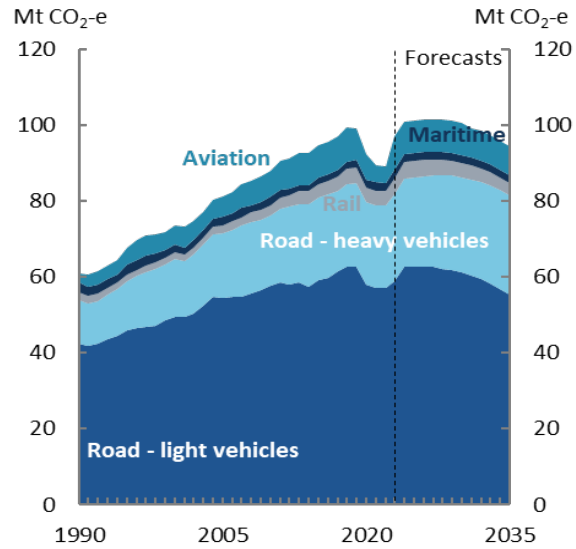
Transport activity's total contribution to the economy in 2020-21 was $164.4 billion or 7.9% of GDP. Transport was the second largest sector of the economy, behind the mining sector.

Total employment across all transport activity was 1.25 million people in 2020-21. A further 85,400 people were employed in the delivery of public roads, highways and subdivisions, bridges, railways and harbours.

Road transport is the main source of transport emissions (at around 83%), with emissions from light vehicles alone (passenger cars, motorcycles and light commercial vehicles) responsible for almost 60% of the sector's emissions. Heavy vehicle emissions account for 23% of all transport emissions. After light vehicles, heavy vehicles present the largest abatement opportunity for the transport sector. Emissions from domestic aviation are 9% of transport emissions, rail roughly 4% and domestic maritime roughly 2%. It is estimated that the embodied emissions in transport infrastructure accounts for approximately 3% of Australia's total emissions.

Road vehicles are responsible for the majority of transport emissions

Emission trends from the transport sector projected to 2035



Source: DCCEEW, Australia's emissions projections 2023, Australian Government, 2023.

Transport activity is also expected to continue to increase to 2050 in line with population and economic growth. The challenge is that, at the same time transport activity is projected to increase, we need to be reducing transport emissions. The projected emissions associated with our growing transport task are outlined in detail in chapter 1.2 of this Consultation Roadmap.

The government has a range of policy roles that can steer Australia to net zero: *leadership*, *investment* and *regulation*. Several key principles will guide how the government exercises these roles in developing the final Action Plan. We will seek to *maximise emissions reduction* and *economic opportunities* by providing *value for money* in an *inclusive and equitable* way that is *evidence-based*.

We will also *build on existing effort and knowledge*, acknowledging a range of actions have already been taken by governments, industry and communities to address climate change. As action on climate change is a shared responsibility, we will continue to *work in partnership* to reach net zero, especially with state and territory governments, industry, communities and international organisations. It is also necessary to work across *multiple timeframes*, considering actions that can be achieved in the short (2024-2030), medium (2030-2040) and long term (2040-2050). We will also look to embed resilience to current and future climate change in developing the final Action Plan.

Across these multiple timeframes it is necessary to consider abatement opportunities throughout our transport systems (chapter 2 looks at how people and goods move around our vast country), all four transport modes (chapter 3 breaks down the opportunities for road, rail, maritime and aviation) and the enabling inputs and policies (chapter 4 considers transport infrastructure and transport's energy use).

Chapter 2 – Rethinking our transport networks and systems

Chapter 2 outlines how our transport networks and systems can support decarbonisation. There are opportunities to reduce emissions by promoting better planning and increased use of digital communication technologies. Transport systems and networks can also be designed to encourage a shift to sustainable, low emissions ways of moving people and goods, such as active and public transport for moving people. Chapter 2.1 considers the movement of people and chapter 2.2 looks at the movement of goods.

Active and public transport can ease congestion, reduce harmful pollution, reduce heat and noise, decrease household transport costs and provide health benefits from increased physical activity levels. Achieving higher rates of active and public travel will require investment in electrified public transport and improvements in the safety, connectivity and convenience of walking and cycling infrastructure. All levels of government, especially state and local governments, will need to continue to work together on the planning, design and delivery of this transport and infrastructure investment. The Australian Government's $100 million investment in a new Active Transport Fund open to states and territories will ensure people who want to walk and cycle in their local community can do so.

A *shift* to sustainable, low emissions ways of moving goods also necessitates an end-to-end consideration of our freight and supply chains. *Improving* efficiency by adopting low or zero emission technologies across the freight sector must consider the cost impacts on commercial operators and consumers. Increasing access to intermodal facilities, and the share of goods moved on rail, as well as rolling out the required energy and transport infrastructure to enable low and zero emission freight transport modes will be essential to the transition.

The Australian Government is investing in nationally significant transport infrastructure consistent with the *Infrastructure Policy Statement*, which sets out three strategic themes to guide investment decisions. One of those themes is Sustainability, which is focused on reducing transport and infrastructure emissions through decarbonising transport operations, reducing emissions in the design, construction and operation of transport infrastructure, and investing in projects that encourage and enable more integrated and sustainable approaches to land use planning.

Chapter 3 – Net zero pathways for each transport mode

The pathway to net zero will be different for each transport mode. The approach for each transport mode will require a mix of technologies, policies and planning, based on evidence, market readiness and science. Chapter 3 outlines each transport mode and opportunities to *improve* the technology or efficiency of that mode.

Road – light vehicles (chapter 3.1): Road transport presents the largest emissions reduction opportunity. The decarbonisation pathway for light vehicles is fuel efficiency and electrification. That is why the government is taking action through an *Australian New Vehicle Efficiency Standard* and the *National Electric Vehicle Strategy*.

The introduction of an Australian New Vehicle Efficiency Standard will increase the availability of new cleaner, cheaper-to-run vehicles and contribute to a cleaner, greener and more sustainable transport sector over time. It will also encourage supply of hybrid vehicles and zero-emissions vehicles, such as electric vehicles (EVs), to the Australian market. The National Electric Vehicle Strategy is implementing a number of policy initiatives to accelerate the uptake of EVs. Through this Consultation Roadmap, the government welcomes ideas to reduce emissions in the existing light vehicle fleet.

Road – heavy vehicles (chapter 3.2): The pathway for heavy vehicles is not as clear as it is for light vehicles. Battery electric trucks may be limited to shorter distances with lighter payloads until battery technology and charging infrastructure improves. Hydrogen or low carbon liquid fuels may be required for larger payloads and distances.

The government is currently working with the states and territories to remove regulatory barriers (width and mass limits) to support Euro VI standards. Introducing Euro VI will mean manufacturers must add the advanced safety and fuel-saving technologies to Australian models that other countries already have. This will help improve safety outcomes and contribute to our emissions reduction targets. However, the reforms to mass limits to support Euro VI will not, by themselves, be enough to overcome the productivity penalty that zero emission trucks face as a result of their heavy batteries. Australia's steer axle mass limit, currently at 6.5 tonnes, will continue to limit the deployment of larger battery electric truck models. Although battery technology may become lighter over time, further reforms to mass limits will be necessary to remove this productivity penalty and increase the range of zero emission trucks available in Australia.

The high upfront cost of switching to low and zero emission heavy vehicles, together with the potential impact heavier vehicles would have on our road pavements, will remain challenging, even after regulatory barriers have been removed. Through this Consultation Roadmap, the government welcomes ideas to support the supply, uptake and operation of low and zero emission heavy vehicles.

Rail (chapter 3.3): Rail is a low-emissions mode of transport when compared to other modes. An efficient and integrated rail system that supports Australia's passenger and freight tasks is also crucial to our wellbeing and economic outcomes. Where feasible, increasing the share of freight moved on rail will also contribute to reducing overall freight emissions.

The decarbonisation of our rail sector will require the roll-out of infrastructure to support hydrogen and battery-electric trains, and consideration of policy settings to shift demand away from diesel locomotives. Low carbon liquid fuels could be required for larger payloads and distances until the supporting infrastructure for electrification is in place. Through this Consultation Roadmap, the government welcomes ideas to support rail decarbonisation.

Maritime (chapter 3.4): Maritime is a hard-to-electrify sector; it is unable to be completely electrified in the foreseeable future. Low carbon liquid fuels, hydrogen-derived fuels (such as green hydrogen, green ammonia and e-methanol), electrification and energy efficiency and optimisation improvements will all likely be needed to decarbonise maritime transport.

The *Maritime Emissions Reduction National Action Plan (MERNAP)* will set the strategic direction and recommend actions to decarbonise our domestic maritime transport sector, as well as our contribution to international shipping emissions. Australia's reliance on international vessels for coastal shipping services means international decisions will have great influence on decarbonising maritime transport. Australia will need to accommodate multiple energy sources and technologies, especially for international bunkering.

Aviation (chapter 3.5): As a hard-to-electrify sector, sustainable aviation fuel (SAF) will be the primary technology to reduce aviation emissions in the short-to-medium term. SAF is available as a drop-in fuel now. There are opportunities to encourage the development and deployment of SAF and other low carbon liquid fuels (LCLFs). Reducing the carbon intensity of liquid fuels with certification that verifies emissions abatement would ensure genuine emissions reduction in the aviation sector. Other technologies such as battery electric and hydrogen-powered aircraft are promising and will be trialled in Australia by regional domestic airlines.

The government is working with industry stakeholders, including through the *Australian Jet Zero Council*, to maximise aviation's contribution to achieving net zero through SAF and emerging technologies. The *Aviation White Paper* will set the long-term policies to guide the next generation of growth and innovation in the aviation sector, including how to maximise the aviation sector's contribution to achieving net zero carbon emissions.

Building on consultation undertaken through the *Aviation White Paper*, the government will be undertaking targeted consultation to identify options for production incentives to support the establishment of a made in Australia LCLF industry, including through the release of a LCLF consultation paper.

Australia also supports initiatives from the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) to reduce maritime and aviation emissions.

Chapter 4 – Supporting transport's net zero pathways

Chapter 4 looks at the enabling systems. There are several key inputs and enabling policies that are essential to transport achieving net zero, including appropriate and decarbonised transport infrastructure and the availability of low emissions energy (electricity and low carbon liquid fuels).

Transport infrastructure (chapter 4.1): Decisions around where and what infrastructure we build influences the greenhouse gases emitted by the transport sector; for example, the building of roads could increase the emissions from light and heavy vehicles by enabling this transport mode. The Sustainability theme in the *Infrastructure Policy Statement* ensures that infrastructure's role in enabling low and zero emission transport modes is considered in transport network planning and project selection frameworks.

However, the building, operation and decommissioning of transport infrastructure (roads, railways, ports and airports) also produces emissions. These emissions mostly come from the production of construction materials, such as cement, aluminium and steel. To decarbonise transport infrastructure, the main emissions reduction pathways will be through materials (low-carbon input materials such as green steel, concrete/cement, asphalt, aluminium and low-carbon recycled materials) and design (circular economy principles such as no-build situations, better maintenance, refurbishment or using more efficient planning, design and building techniques). Through this Consultation Roadmap, the government welcomes ideas on how to support transport

infrastructure decarbonisation through materials and design, as well as the role of infrastructure in enabling low and zero emission transport modes.

Energy – electricity and low carbon liquid fuels (chapter 4.2): All of the varied decarbonisation opportunities across Australia's transport sector will require a shift away from fossil fuels. Transport currently makes up 75% of Australia's liquid fuel demand. The primary method for reducing transport emissions will be through electrification, which is dependent on the decarbonisation of the electricity grid.

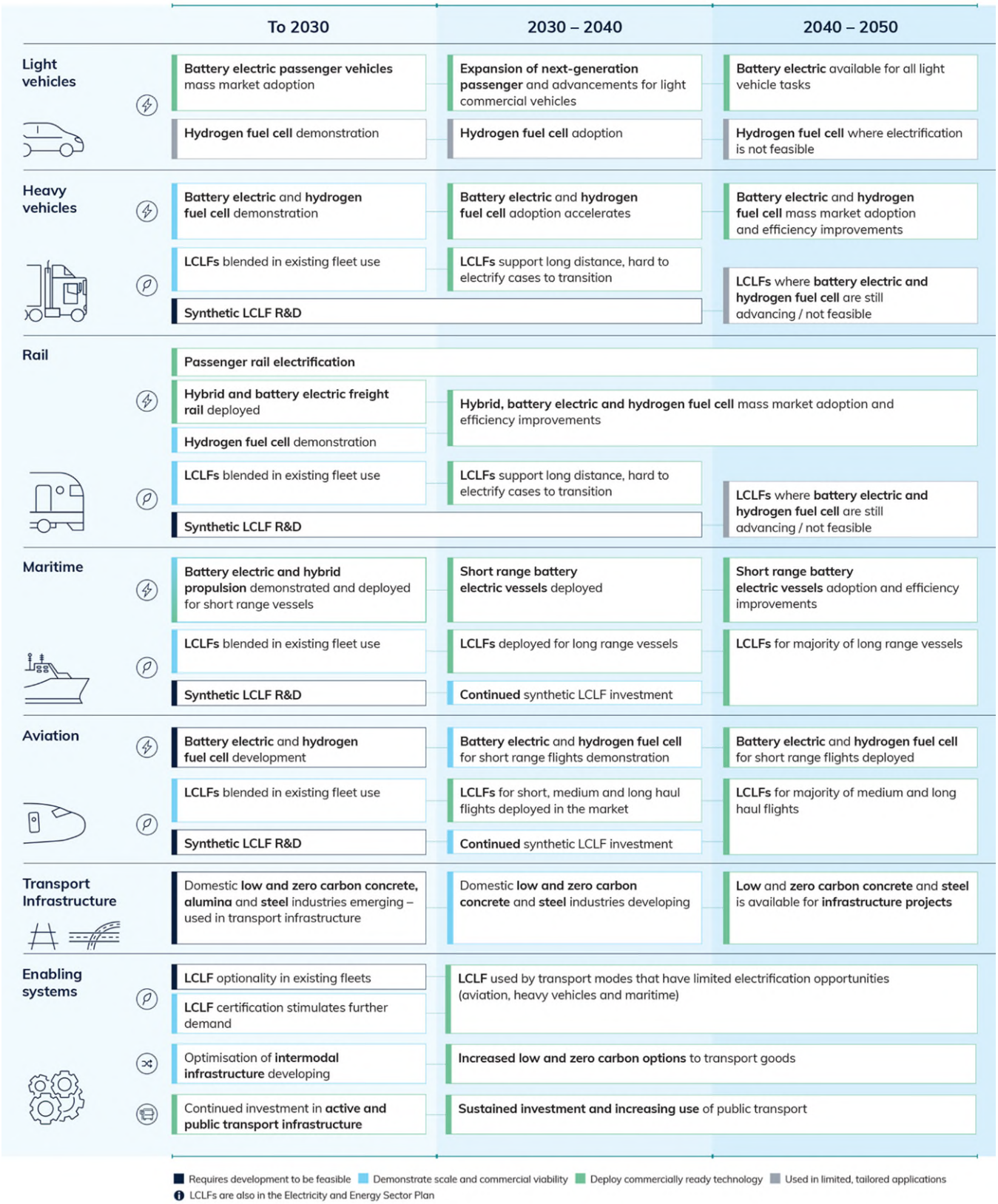
As part of the Future Made in Australia plan, the government will fast-track support for a LCLF industry, with an initial focus on sustainable aviation fuel and renewable diesel to support emissions reduction in the aviation, heavy vehicle, rail and maritime sectors. This will require local settings to develop the supply and use of LCLFs in Australia, as well as a regulatory system based on those used internationally to certify and accurately measure the lifecycle emissions of LCLFs. This is necessary so that government and industry are confident that the emissions benefits associated with displacing fossil fuel use are not being undermined by increasing carbon emissions elsewhere. Domestic production of LCLFs could provide opportunities for regional development and new jobs as well as liquid fuel security benefits.

The government will be undertaking targeted consultation to identify options for production incentives to support the establishment of a made in Australia LCLF industry, including through the release of a LCLF consultation paper.

Chapter 5 – Achieving net zero together

Collective action is needed for transport and transport infrastructure to reach net zero. That is why chapter 5 discusses how the government will continue to work collaboratively with states and territories, industry, unions, experts and local communities, as well as internationally, to develop the final Roadmap and Action Plan. What we hear from you on this Consultation Roadmap and the potential pathways to net zero will guide the development of the actions and policies the government will commit to in the final Transport and Infrastructure Net Zero Roadmap and Action Plan. These potential pathways are summarised on the next page.

Timeline of transport decarbonisation technology pathways



1. Introduction

Transport connects Australians to each other and to the rest of the world. It is critical to our economy and wellbeing. However, the transport sector is the third largest source of greenhouse gas emissions in Australia, amounting to 21% of Australia's greenhouse gas emissions in 2023. Since 2005, transport emissions have increased by 19%. Without further action, transport will be the largest source of emissions in Australia by 2030. This Consultation Roadmap sets out potential pathways to net zero by 2050 for transport and transport infrastructure consistent with Australia's targets and international commitments. The final Transport and Infrastructure Net Zero Roadmap and Action Plan will provide a clear strategy to reduce emissions across transport and transport infrastructure.

1.1 Why a Roadmap and Action Plan?

Key points

- The Australian Government has set an ambitious climate agenda, legislating Australia's targets to reduce emissions by 43% on 2005 levels by 2030 and net zero by 2050 in line with the global goal to keep warming to well below 2°C and pursue efforts to keep it to 1.5°C.
- The Australian Government is developing a Net Zero 2050 plan to establish pathways for our transition to a net zero economy. To support the Net Zero Plan, the government will lead the development of six sectoral plans.
- The Transport and Infrastructure Net Zero Roadmap and Action Plan will be the net zero sectoral plan for the transport and transport infrastructure sectors. It will provide a clear strategy to reduce emissions across the transport sector. It will cover all transport modes and consider cross cutting issues including low carbon fuels, freight and supply chains, and transport infrastructure.
- The Transport and Infrastructure Net Zero Roadmap and Action Plan is being developed in two stages. The first stage is this Consultation Roadmap that sets out potential pathways for transport and transport infrastructure to contribute to net zero by 2050. It does not set out the actions or policies that will be taken by government to support these potential pathways. The actions or policies to be taken by government will form the basis of the final Action Plan, which is the second stage of developing the final Roadmap and Action Plan.
- We are now seeking your views on the identified pathways and the actions or policies government will need to take to decarbonise transport and transport infrastructure.

Australia's path to Net Zero

Australia is already feeling the effects of climate change. Australia's leading scientific and climate institutions have concluded that Australia's land temperature has warmed on average by about 1.47°C since national records began in 1910, and that Australia is highly vulnerable to climate impacts.[1] Climate change poses significant risks to Australia's economy, workforce, communities and the natural environment.[2]

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[1] Bureau of Meteorology (BOM) and Commonwealth Scientific and Industrial Research Organisation (CSIRO), *State of the Climate 2022*, BOM, CSIRO, Australian Government, 2022; Australian Academy of Science, *The risks to Australia of a 3°C warmer world*, *Australian Academy of Science*, 2021.

[2] The Treasury, *Intergenerational Report 2023*, Australian Government, 2023.

Australia is playing its part in the global challenge to reduce greenhouse gas emissions. Australia is party to the Paris Agreement. The Paris Agreement came into force in 2016 and was a major step forward in international efforts to address climate change.

The Paris Agreement aims to strengthen the global response to the threat of climate change by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit temperature increase to 1.5°C.

In 2022, the government legislated these commitments to reduce economy-wide net greenhouse gas emissions to 43% below 2005 levels by 2030, and to net zero by 2050. 'Net zero emissions' refers to achieving an overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere. Across the economy, Australia emitted about 465 megatonnes (Mt) of carbon dioxide equivalent gases (CO_2-e) in the past year.[3]

This is why the government is developing a Net Zero 2050 Plan. The Plan will ensure Australia maximises the benefits of the global transition to net zero and provides long-term policy certainty to drive investment in low emissions and renewable technologies. To support the Plan, the government is developing six sectoral plans. These plans cover the following sectors: electricity and energy; industry; resources; the built environment; agriculture and land; and transport. Emissions from the waste sector, as well as synthetic greenhouse gas emissions, will be considered in the industry sector plan. A focus on the circular economy and energy performance will be a cross-cutting issue for all sectors.

The Transport and Infrastructure Net Zero Roadmap and Action Plan will be the transport sectoral plan.

The purpose of this Consultation Roadmap

The final Roadmap and Action Plan, to be released later this year, will set out a pathway to reduce greenhouse gas emissions across our transport systems as a whole and all four major transport modes – road (light vehicles and heavy vehicles), rail, maritime and aviation – when moving people and goods across our vast nation. It will also consider the critical role of transport infrastructure in reducing emissions. The construction, maintenance and operation of transport infrastructure creates emissions but it also has an important role in enabling a shift to low emission transport modes.

The Roadmap and Action Plan is being developed in two stages. This Consultation Roadmap is the first stage. In this Consultation Roadmap, we set out potential pathways for transport and transport infrastructure to contribute to net zero for the whole economy by 2050. We have framed our analysis across our transport systems, all four transport modes and the enabling inputs and policies. Across each of these elements we set out the relevant emissions profile, decarbonisation technologies, existing government policies, challenges and opportunities and a potential pathway to 2050. Each potential pathway sets out where the market needs to be at key intervals (short, medium and long term) for transport and transport infrastructure to contribute to the whole economy reaching net zero by 2050.

The scope and structure of the Consultation Roadmap is set out in Figure 1.

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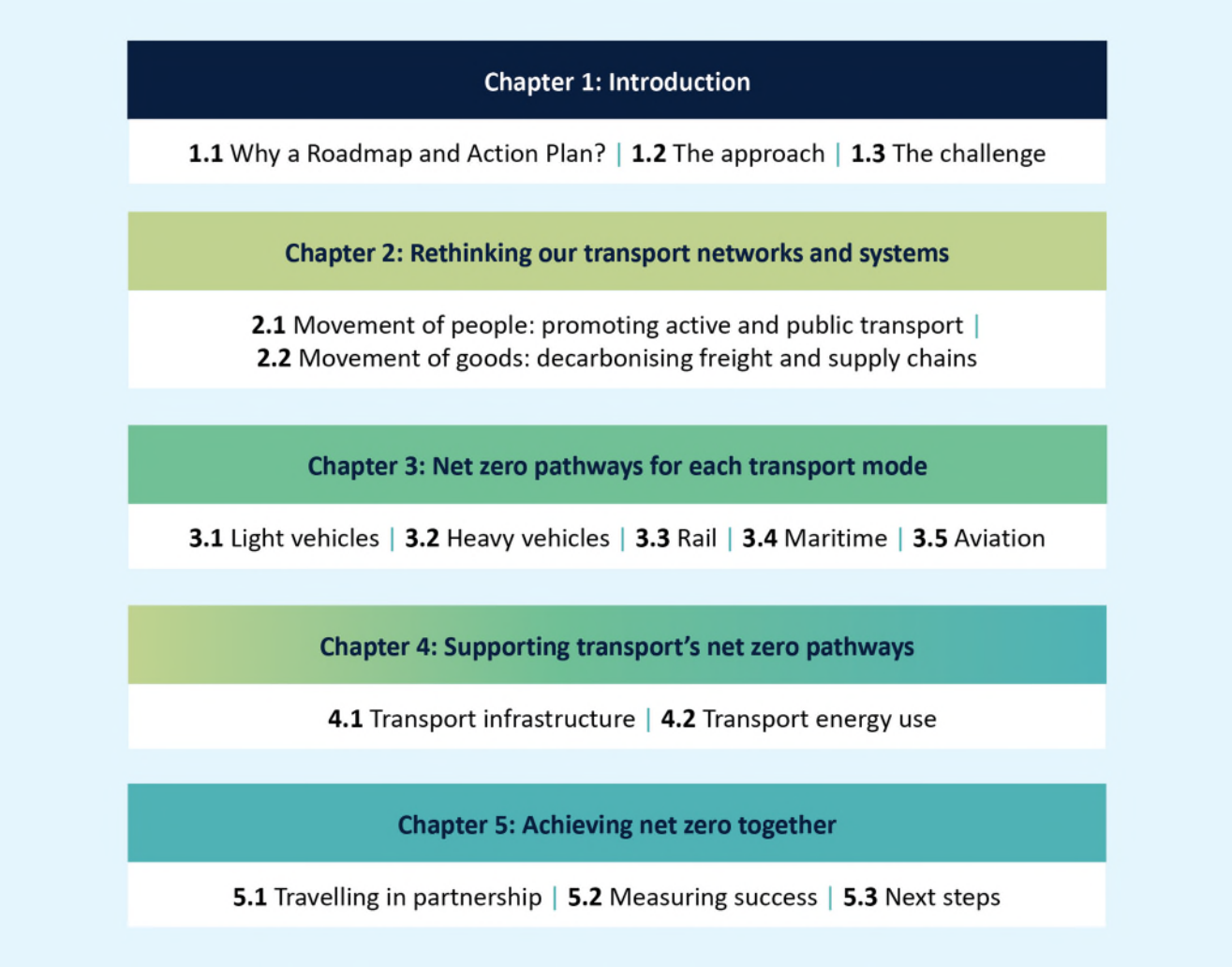
[3] Department of Climate Change, Environment, Energy and Water (DCCEEW), *National Greenhouse Gas Inventory Quarterly Update: June 2023,* DCCEEW, Australian Government, 2023.

Figure 1: Scope and structure of the Consultation Roadmap



This Consultation Roadmap focuses on the role of the Australian Government in decarbonising transport and transport infrastructure. However, Chapter 5 focuses on how we achieve net zero in partnership, especially with states and territories and with industry.

This Consultation Roadmap does not set out the actions or policies to be taken by government to support these potential pathways. The actions or policies to be taken by government will form the basis of the final Action Plan, which is the second stage of developing the final Roadmap and Action Plan.

The purpose of publishing this Consultation Roadmap is to receive feedback from communities, industry, experts and unions on the potential pathways as well as the actions or policies that may need to be taken by government to support these potential pathways. What we hear through this consultation and engagement will guide the development of the actions and policies that the government will commit to in the final Transport and Infrastructure Net Zero Roadmap and Action Plan.

Have Your Say

Throughout this Consultation Roadmap, we will be seeking your views on the pathways and actions to inform the Transport and Infrastructure Net Zero Roadmap and Action Plan to ensure it provides a clear strategy to 2050 that will reduce emissions, support Australia's international commitments, maximise economic and productivity opportunities, provide investors with future investment certainty and deliver a nationally consolidated approach to decarbonisation for the transport sector. Your feedback will ensure our plan is robust, ambitious, achievable and accepted by the community.

There are questions posed throughout this Consultation Roadmap to help guide stakeholder discussion. Questions follow each relevant chapter of this Consultation Roadmap. Broad comments and views are also welcome.

We invite you to write a submission or complete the survey at the Have Your Say portal on the website of the Department of Infrastructure, Transport, Regional Development, Communications and the Arts or the Department of Climate Change, Energy, the Environment and Water.

We recognise the considerable value and meaning of First Nations knowledge, culture and expertise in land management. First Nations experiences and insights on all aspects of this Consultation Roadmap and the questions that follow are particularly welcomed.

Please note that the government has recently engaged in consultation on aspects of transport decarbonisation through the 2023 review of National Freight and Supply Chain Strategy, the development of the Australian New Vehicle Efficiency Standard, the Maritime Emissions Reduction National Action Plan and the Aviation White Paper. Those consultations will also inform the final Transport and Infrastructure Net Zero Roadmap and Action Plan.

Interactions with other sectoral plans

As the transport sector plan, the Transport and Infrastructure Net Zero Roadmap and Action Plan will interact with the other five sectoral plans in the following ways:

Table 1: How the transport sectoral plan connects with the other five sectoral plans

Energy & Electricity	Built Environment	Industry	Resources	Agriculture & Land
EV charging stations and infrastructure	Transport networks	Freight transport beyond the facility boundary		
Energy use by transport modes (electricity, liquid fuels, hydrogen)	Infrastructure (roads, bridges, tunnels, ports, airports)	Waste collection	-	-

These interactions demonstrate that the sectoral plans are related and highlight opportunities for shared work between the transport sector plan and the other plans, as well as opportunities to leverage these interactions to reduce emissions.

1.2 The approach

Key points

- This Consultation Roadmap has been informed by the best available research, data and analysis.
- Our key policy principles are: maximise emissions reduction; value for money; maximise economic opportunity; inclusive and equitable; and evidence-based.
- The Australian Government has a range of policy and regulatory roles that can steer Australia to net zero while continuing to improve living standards: leadership; investment; and regulation.

How this Consultation Roadmap was developed

The potential pathways to net zero set out in this Consultation Roadmap are informed by research and consultation. The Department of Infrastructure, Transport, Regional Development, Communications and the Arts began with extensive desktop research on all forms of transport, low carbon liquid fuels (LCLFs), new technologies and transport infrastructure. We analysed over 130 transport emission reduction strategies from all over Australia and the world and reviewed submissions from previous government consultation processes on transport decarbonisation policy. We were also guided by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6). **Appendix A** summarises the key themes from the AR6.

We engaged directly with experts and stakeholders to inform the development of this Consultation Roadmap. The focus of these engagements was to understand views on the barriers to decarbonisation, the role of governments, industry and consumers, and examples of good practice taken here or overseas that we can build on.

On the department's website we invited any interested stakeholders to raise initial ideas submitted to an online portal. These have been considered in the development of this Consultation Roadmap – as have themes from previous government consultation processes. This is not the first time the government has consulted on decarbonisation policies and so we sought to understand the key themes relating to decarbonisation from consultations on the National Electric Vehicle Strategy (NEVS), the New Vehicle Efficiency Standard (NVES), the Aviation White Paper and the Maritime Emissions Reduction National Action Plan (MERNAP).

We also consulted across governments. To consult across the Australian Government, an Interdepartmental Committee (IDC) attended by 11 Commonwealth departments and statutory bodies was established: Department of Infrastructure, Transport, Regional Development, Communications and the Arts; Department of Agriculture, Fisheries and Forestry; Department of Climate Change, Energy, the Environment and Water; Department of Defence; Department of Finance; Department of Foreign Affairs and Trade; Department of Industry, Science and Resources; Department of the Prime Minister and Cabinet; Austrade; Treasury; and the Climate Change Authority. Consultation with the states and territories occurred through the Infrastructure and Transport Ministers' Meeting Decarbonisation of Transport Working Group and Senior Officials Group.

Finally, the potential pathways set out in this Consultation Roadmap were also guided by the government's second Annual Climate Change Statement, which was informed by independent advice from the Climate Change Authority, as well as the CSIRO's report *Pathways to Net Zero: Rapid decarbonisation pathways for Australia*.[4]

How we will develop the final Roadmap and Action Plan

The feedback we receive on this Consultation Roadmap will inform the actions and policies that will be set out in the final Roadmap and Action Plan.

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[4] DCCEEW, *Annual Climate Change Statement 2023*, DCCEEW, Australian Government, 2023; CSIRO, *Pathways to Net Zero Emissions: An Australian Perspective on Rapid Decarbonisation*, report prepared by Brinsmead et al., CSIRO, Australian Government, 2023.

It is proposed that the following five **guiding principles** will be used to guide the development of the final Roadmap and Action Plan:

1. Maximise emissions reduction

- Emissions reduction is at the centre of the government's net zero plan. We will identify and implement effective policies at the earliest opportunity that will result in the largest reductions in emissions, consistent with achieving the government's targets.

2. Value for money

- We will promote cost-effective measures to achieve the maximum abatement potential. We will consider the costs and benefits of various options and identify and implement measures that achieve the largest reductions in emissions for the lowest cost to the community. This includes incentivising the private sector to leverage their capital, innovation and effort to achieve net zero.

3. Maximise economic opportunity

- The global transformation to a net zero economy is a source of economic opportunity for Australia, its regions, industries and workers. Australia's regions and communities can take advantage of the decarbonisation of the transport sector and create new job opportunities that workers in emissions-intensive industries can be supported to transition into.

4. Inclusive and equitable

- No-one should be left behind on the journey to net zero. Inclusivity and equity, including intergenerational equity, will underpin our policy mix. By addressing the needs of a diverse range of communities and demographic groups, all Australians can benefit from decarbonisation. In particular, government support, training and close collaboration with industry will be necessary to ensure Australia has a workforce ready for net zero. Actions to decarbonise can also support liveability, health and other outcomes.

5. Evidence-based

- We will draw on expert analysis and experience to develop a Roadmap and Action Plan that acknowledges that no one pathway or technology will suit every transport mode. The outcome will be a mix of technologies, policies and planning, based on evidence and market readiness.

Consistent with these principles, we will consider the following elements to produce a comprehensive and clearly defined final Roadmap and Action Plan.

Building on existing effort and knowledge

A range of actions have already been taken by governments, industry and communities to address climate change. We will seek to build upon all of the existing government policies that are already accelerating the transition to net zero for the transport sector.

Existing Australian Government policy

- Active Transport Fund
- Australian Design Rules regulation reform
- Australian Jet Zero Council
- Australian New Vehicle Efficiency Standard
- Aviation White Paper*
- Critical Minerals Strategy
- Driving the Nation Fund
- Engagement at the International Maritime Organization and International Civil Aviation Organization
- Future Made in Australia*
- Green Vehicle Guide
- National Energy Performance Strategy
- National Freight and Supply Chain Strategy
- National Hydrogen Strategy
- National Partnership Agreement on Land Transport (to become a Federation Funding Agreement)
- National Rail Manufacturing plan
- National Reconstruction Fund
- National Urban Policy*
- National Housing Accord
- Noxious emissions standards for heavy and light vehicles

- Guarantee of Origin Scheme
- Infrastructure Policy Statement (IPS)
- Heavy vehicle road user charge trial
- Maritime Emissions Reduction National Action Plan*
- National Adaptation Plan
- National Battery Strategy
- Net Zero in Government Operations Strategy
- National Circular Economy Framework
- National Electric Vehicle Strategy
- Rail interoperability agenda
- Real World Testing Program for vehicle emissions
- Regional Investment Framework
- Renewable Energy Superpower
- Rewiring the Nation
- Safeguard Mechanism
- Sustainable Finance Strategy and Green Bonds Framework

*Currently under development

A Future Made in Australia

The 2024-25 Budget invests $22.7 billion over the next decade to build a Future Made in Australia. This plan is about maximising the economic and industrial benefits of the move to net zero and securing Australia's place in a changing global economic and strategic landscape.

Funding will catalyse clean energy supply chains and support Australia to become a renewable energy superpower. Funding includes support for renewable hydrogen and to develop a low carbon liquid fuels (LCLFs) industry in Australia, which will deliver the future energy needs for the transport sector, including:

- $1.7 billion over ten years from 2024-25 for the Future Made in Australia Innovation Fund, to be administered by the Australian Renewable Energy Agency, to support innovation, commercialisation, pilot and demonstration projects and early stage development in priority sectors, including LCLFs
- $20.9 million over four years from 2024–25 (and $1.2 million per year ongoing) to undertake further consultation on incentives to support the production of, and demand for, LCLFs, as well as the development of a LCLFs certification scheme through the Guarantee of Origin Scheme.

Working in partnership

Action on climate change is a shared responsibility between governments, industry and communities. We will continue to work in partnership to reach net zero by 2050, acknowledging the key role the national government has in reducing transport emissions to lead by example, seeking to facilitate an orderly and positive transition for all. In Chapter 5 of this Consultation Roadmap, we talk about how we work in partnership, building on the work already underway by state and territory governments, industry, communities and international organisations.

Key actions by state and territory governments to decarbonise transport

Australian Capital Territory: ACT Climate Change Strategy 2019-2025; Zero-emission Transition Plan for Transport Canberra 2020 (zero government emissions by 2040); Infrastructure Plan.

New South Wales: NSW Electric Vehicle Strategy; Towards Net Zero Emissions Freight Policy; Transport for NSW Net Zero and Climate Change Policy; NSW Hydrogen Strategy; NSW Zero Emission Bus Plan; NSW Active Transport Strategy; NSW Decarbonising Infrastructure Delivery Policy; Net Zero Plan Stage 1 (2020-2030).

Northern Territory: NT Electric Vehicle Strategy and Implementation Plan 2021-26; NT Renewable Hydrogen Strategy; NT Planning Scheme and the Darwin Regional Transport Plan; heavy vehicle open access and higher vehicle mass limit regime and Innovative Vehicles Scheme; NT Infrastructure Framework 2022-2030.

Queensland: Reducing Government Infrastructure Emissions Roadmap; Queensland Biofutures 10-Year Roadmap and Action Plan; Climate Positive Brisbane 2032 commitments; State Infrastructure Strategy; Queensland Freight Strategy; Queensland Zero Emission Vehicle Strategy; Zero Emission Bus Program; Queensland Walking Strategy; Queensland Cycling Strategy.

South Australia: South Australia – Responding to Climate Change; South Australian Climate Change Actions; initiatives supporting zero emission public transport, heavy vehicle decarbonisation and procurement to accelerate the uptake of zero emission vehicles; Way2Go travel behaviour change program; 20-year State Infrastructure Strategy.

Tasmania: Developing an Emissions Reduction and Resilience Plan for Tasmania's transport sector. Public consultation closed 29 November 2023.

Victoria: Victoria's Climate Change Strategy; Victoria's infrastructure strategy 2021-2051; developing a freight decarbonisation strategy; Zero Emissions Bus Trial; targets (e.g. 50% of new light vehicle sales being zero emission vehicles by 2030; 25% trips by active transport by 2030).

Western Australia: State Infrastructure Strategy 2023; strategy for decarbonisation of road freight in the South West Integrated System; investments to enhance the productivity of regional freight railways and decarbonise public transport; Active Transport Infrastructure Policy.

Avoid-shift-improve

We propose to use the avoid-shift-improve framework to identify all opportunities for abatement.

- *Avoid* refers to removing travel which people would prefer not to undertake. By improving the efficiency of the transport system through integrated land-use planning, transport demand management and telecommuting, the need to travel and the length of some travel may be reduced or avoided.
- *Shift* refers to decarbonising travel by shifting to more sustainable transport modes like active and public transport, or to low emission freight transport modes instead of diesel vehicles.
- *Improve* refers to improving the technology or efficiency of transport modes, such as through electrification.

Transport infrastructure is critical across all three domains.

Avoid and shift inform the chapter on rethinking the planning of our transport networks and systems for both the movement of people and the movement of goods (see Chapter 2). Improve is considered in the chapter on each specific transport mode (see Chapter 3).

Multiple timeframes

We will consider actions that can be achieved in the short (2024-2030), medium (2030-2040) and long term (2040-2050). This will enable us to adopt new technologies when it is cost-effective to do so. We will balance immediate abatement potential with investing in transformation to support long-term transport decarbonisation. We will also consider the cumulative impacts of various policies.

Embed resilience to current and future climate change

Despite strong global action, the impacts of climate change will continue to increase over the coming decades. We will seek to embed resilience to current and future climate change in our Roadmap and Action Plan.

Our toolkit

The government has a range of policy roles it can use to steer Australia to net zero (see Table 2: Government role in decarbonisation). Each of these tools could create opportunities and potential risks, and will require consideration of these trade-offs. Together the toolkit provides the elements of a comprehensive Roadmap and Action Plan.

Table 2: Government role in decarbonisation

Government's role	Tools	Example
Leadership 	**Government action**: Public sector activity, including delivering services.	Australian Public Service Net Zero Emissions by 2030
	Advocacy: Raising awareness or promoting particular actions by educating or persuading.	Green Vehicle Guide
	Coordination: Leveraging relationships, convening national forums, coordinating within and across government and with external partnership bodies (domestic and international) to develop and implement desired goals and behaviours.	National Freight and Supply Chain Strategy
Investment 	**Taxation/spending and investment**: Using taxation or spending powers to shape activity, including financing, local content incentives, grants, tax rebates or co-investment. Set clear incentives and priorities to de-risk, incentivise and encourage innovation. Provide financial disincentives to influence activity.	Infrastructure Investment Program Electric Car Discount
Regulation 	**Law, regulation and standards**: Using legislative power to require or restrict activity.	Safeguard Mechanism

When exercising these different roles, the government may intervene with direct policies that lead to measurable reductions in emissions or with enabling policies to facilitate an environment for decarbonisation and change. The government will consider policies that create supply for new technologies and policies that support demand for new technologies. The policy mix will depend on the capability and capacity of the market and transport mode.

For the Transport and Infrastructure Net Zero Roadmap and Action Plan to succeed, all Government roles will need to be considered. However, it may not be appropriate or responsible to use every tool for every policy or even every transport mode.

Throughout this Consultation Roadmap we will seek your views on the most appropriate mix of policy roles and tools to be used to decarbonise transport in Australia to 2050.

Have Your Say

1. Do you agree with the proposed guiding principles?

    1.1. Please add details to your response.

2. Do you support the use of the avoid-shift-improve framework as a tool to identify opportunities for abatement?

    2.1. Please add details to your response.

1.3 The challenge

Key points

- With Australia's population and economy expected to grow, transport activity is also expected to continue to increase to 2050. The challenge is that at the same time transport activity is projected to increase, we need to be reducing transport emissions.
- The transport sector is currently the third largest source of greenhouse gas emissions in Australia, and without further action is projected to be Australia's highest emitting sector by 2030.
- In 2023 transport emissions increased by 8.7% from 2022, reflecting the ongoing recovery from COVID-19 related travel restrictions. Since 2005, transport emissions have increased by 19%.
- Road transport – cars and trucks – is the main source of transport emissions (at around 83%). Emissions from light vehicles (passenger cars, motorcycles and light commercial vehicles) are the single biggest source of emissions in the transport sector at around 60% of Australia's transport emissions.

The transport sector is critical to all Australians and our economy

Transport enables our way of life by connecting us to jobs, essential services, economic opportunities and each other. These connections facilitate trade, commerce and communication that are essential to our economic prosperity and overall wellbeing.

The size and significance of transport in Australia[5]

- Transport activity's total contribution to the economy in 2020-21 was $164.4 billion or 7.9% of Gross Domestic Product. Transport was the second largest sector of the economy, behind the Mining sector.[6]
- Total employment across all transport activity numbered 1.25 million persons in 2020-21.[7] A further 85,400 individuals were employed in the delivery of public roads, highways and subdivisions, bridges, railways and harbours.[8]
- 9.2% of Australia's GDP was accounted for by Australia's major infrastructure industries in 2022–23.
- There were an estimated 32,756 route kilometres of open railway in Australia as at October 2023.
- Australia's total estimated paved road length was 427,000 kilometres in 2022.
- In 2022–23, there were an estimated 241.8 billion tonne kilometres of freight moved by road, 445.3 billion tonne kilometres of freight moved by rail, 91.3 billion tonne kilometres of freight moved by coastal shipping and 0.2 billion moved by air freight.

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[5] Unless separately referenced, facts and figures taken from Bureau of Infrastructure and Transport Research Economics (BITRE), *Australian Infrastructure and Transport Statistics: Yearbook 2023*, BITRE, Australian Government, 2023.

[6] BITRE, *Economic Contribution of Transport in Australia, 2020-21*, BITRE, Australian Government, 2023.

[7] BITRE, *Economic Contribution of Transport in Australia, 2020-21*, BITRE, Australian Government, 2023.

[8] Infrastructure Australia (IA), *Infrastructure workforce and skills supply: A report from Infrastructure Australia's Market Capacity Program*, IA, Australian Government, 2021.

- In 2022–23, 158.3 billion passenger kilometres were travelled by car, and 10.5 billion passenger kilometres were travelled on heavy rail networks in Australian capital cities.
- In metropolitan areas there were 328 million heavy rail passenger movements in 2021–22, down from 754 million in 2018–19.
- $20.6 billion was spent by the public sector on road construction in 2022–23.
- In 2022, there were 1,105 fatal road crashes and 23 fatal aviation accidents.
- 812 DC Fast and Ultrafast public charging sites were available for Australians to charge their electric vehicles at the end 2023.[9]
- There were 55.3 million revenue passengers on domestic flights in Australia in 2022–23, up from 30.4 million the year before.

Transport moves people and goods across our geographically large and diverse nation. The majority of goods, especially bulk freight, are moved by rail (Figure 2) and people move largely in cars (Figure 3).

Figure 2: Most domestic freight is moved by rail…

Annual freight task in 2022-23 by mode, measured in billion tonne-kilometres.

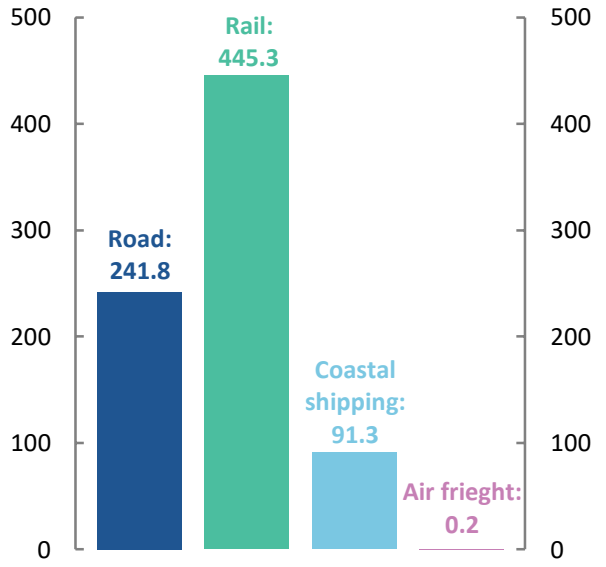
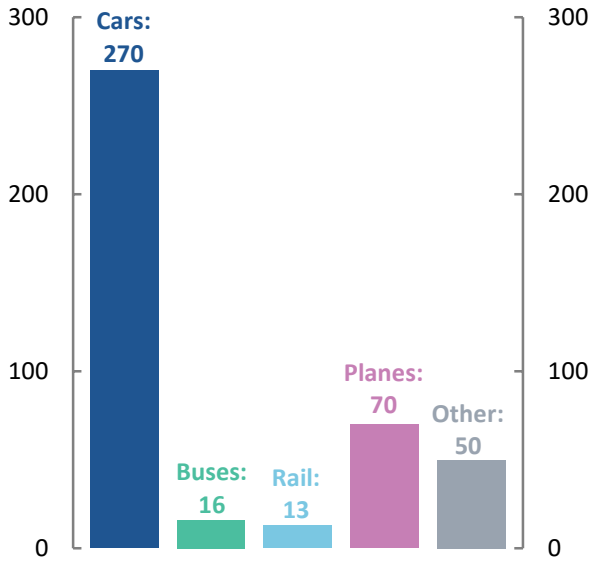


Figure 3: and most passenger travel is done in cars.

Annual passenger travel in 2022-23 by mode, measured in billion passenger kilometres.



Source: BITRE 2023 Yearbook

Transport activity is heavily influenced by trends in population, economic growth, and settlement patterns. With Australia's population and economy expected to grow, transport activity can be expected to continue to increase to 2050. Even with reduced growth in bulk mineral exports, Australia's freight volumes are projected to continue to grow (Figure 4). Further, with Australia having the ambition to become a renewable energy superpower, transport will be critical if we are to grasp the economic opportunities arising from the energy transition.

The challenge is that at the same time transport activity is projected to increase, we need to be reducing transport emissions. Responding to this challenge requires consideration of the varying emissions intensity of different transport modes. The emissions intensity of freight is often measured in grams of CO_2 emitted per

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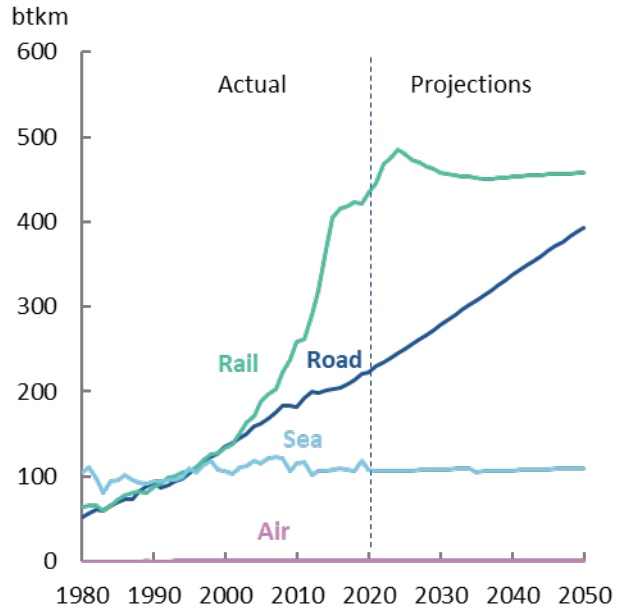
[9] Electric Vehicle Council, *Australian Electric Vehicle Industry Recap 2023*, EVC, March 2024.

tonne kilometre travelled. This measure provides a simple way to compare the emissions intensity of moving freight with different modes (Figure 5).

Figure 4: Australia's freight task has been rising for decades and is projected to keep growing…

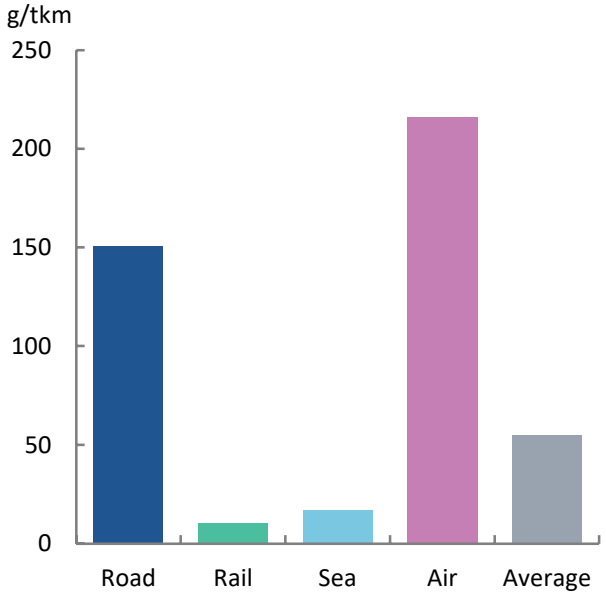
Projected freight growth to 2050 by mode in Australia.



1: BITRE/National Freight and Supply Chain Strategy

Figure 5: ... and the emissions intensity of moving goods on different modes varies widely.

Full fuel cycle greenhouse gas (CO_2-e) emissions intensity of the freight task, by transport mode, measured in grams CO_2-e per tonne-kilometre.



2: DITRDCA estimates using BITRE Australian Infrastructure and Transport Statistics - Yearbook 2023

Without further action, transport will be the highest emitting sector in 2030 and 2035

The transport sector is currently the third largest source of greenhouse gas emissions in Australia, with direct emissions amounting for 21% of Australia's greenhouse gas emissions (Figure 6).[10] Transport emissions increased by 8.7% from 2022, reflecting the ongoing recovery from COVID-19 related travel restrictions. Since 2005, transport emissions have increased by 19%.

On 30 November 2023, the Department of Climate Change, Energy, the Environment and Water released Australia's Emissions Projections 2023.[11] In the baseline scenario (policies already implemented or well progressed) transport emissions are projected to peak at 103 Mt CO_2-e in 2027, before declining to 95 Mt CO_2-e in 2035.

However, when coupled with falling emissions in other sectors, transport's contribution to Australia's total emissions is projected to be 26% of all direct emissions without further action by 2030. This would result in transport being Australia's highest emitting sector by 2030 (Figure 7). When the projections include the 'with additional measures' scenario (including announced policies where design and consultation are ongoing), transport will be Australia's second highest emitting sector by 2030, 1 percentage point behind stationary energy. Potential reductions from the introduction of the Australian New Vehicle Efficiency Standard is included in the 'with additional measures' scenario.

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[10] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.
[11] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.

Figure 6: In 2023, transport was the third largest emitting sector of the Australian economy...

Sector shares in 2023, as % of Australia's emissions

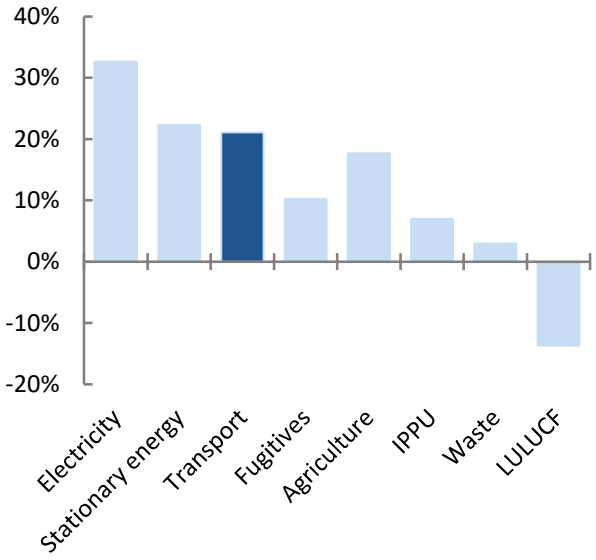
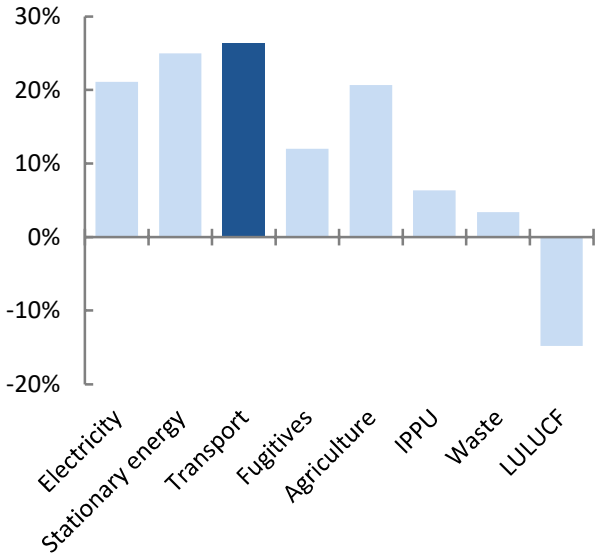


Figure 7: …and without further action, transport will be the largest source of emissions in 2030.

Sector shares in 2030 baseline scenario, as % of Australia's emissions



Source: DCCEEW, *Australia's emissions projections 2023*, Australian Government, 2023.

Road transport – cars and trucks – is the main source of transport emissions (at around 83%). Of this, light vehicles (passenger cars, motorcycles and light commercial vehicles) are the single biggest source of emissions, contributing around 60% of Australia's transport emissions.

In 2022-23, emissions from domestic aviation were 9% of transport emissions, rail roughly 4% and domestic maritime roughly 2% (Figure 8).[12] International aviation and international shipping are not included in Australia's total emissions (in line with international greenhouse gas reporting guidelines). However, international flights departing from Australia in 2019 produced emissions equivalent to 14% of our total transport emissions, and ships carrying our sea freight (irrespective of flag) contribute about 4% of global international shipping CO_2 emissions.[13]

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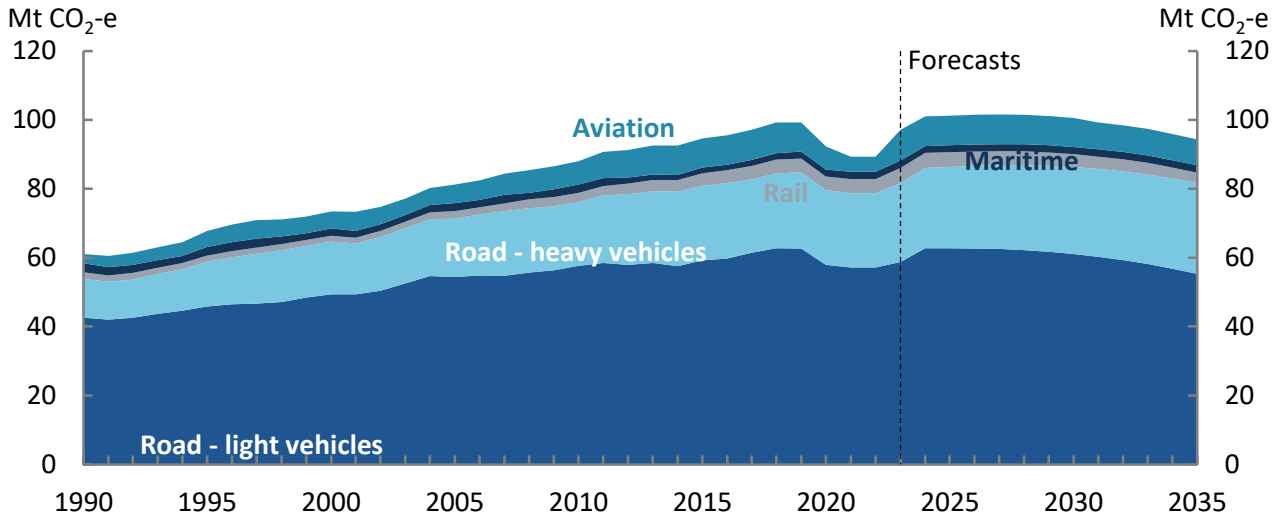
[12] BITRE, *Australian Infrastructure and Transport Statistics Yearbook 2023,* BITRE, Australian Government, 2023.

[13] Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA), *Economic Analysis of Global Shipping Carbon Price Impacts on Australia's International Shipping Costs and Maritime-Dependent Trade*, report prepared by BMT Defence and Security Australia Pty Ltd, DITRDCA, Australian Government, unpublished, 2022; DITRDCA, *Australia's State Action Plan – International Civil Aviation Organization (ICAO) Assembly Resolution A37-19 on Climate Change*, DITRDCA, Australian Government, 2022.

Figure 8: Road vehicles are responsible for the majority of transport emissions

Emission trends from the transport sector projected to 2035



Source: DCCEEW, *Australia's emissions projections 2023*, Australian Government, 2023.

Transport emissions reported under the National Greenhouse and Energy Reporting (NGER) Scheme are all direct emissions. Direct emissions are also referred to as scope 1 emissions. See Appendix A for more information on scope 1, 2 and 3 emissions.

2. Rethinking our transport networks and systems

Transport moves people and goods across our large and geographically diverse country. To support decarbonisation, there may be opportunities to *avoid* unnecessary travel over the long term through better planning and increased use of digital communication technologies. Transport systems and networks can also be designed to encourage a *shift* to sustainable, low emissions ways of moving people and goods. This includes promoting active and public transport. It also requires an end-to-end consideration of our freight and supply chains to *improve* efficiency and support the adoption of low or near zero emission technologies and fuels across the freight sector, while considering any cost impacts on commercial operators and consumers. This chapter looks at how we can rethink our transport networks and systems for both the movement of people (chapter 2.1) and the movement of goods (chapter 2.2).

2.1 Movement of people: promoting active and public transport

Key points

- Active and public transport can make a significant contribution to reducing road transport emissions, generating lower emissions per passenger, per kilometre compared to private car use.
- Active and public transport can support decarbonisation efforts while easing congestion and household transport costs, increasing physical activity levels and reducing harmful pollution, heat and noise.
- Achieving higher rates of active and public travel requires investment in electrified public transport and improvements in the safety, connectivity, and convenience of walking and cycling infrastructure. This will require all levels of government, especially state and local governments, to continue to work together on the planning, design and delivery of this infrastructure investment.
- The Australian Government recently announced a new Active Transport Fund for the construction and upgrade of bicycle and walking paths to encourage the use of active transport across Australia.

Improving the efficiency of our transport systems

Over the long term, improving the efficiency of our transport systems for the movement of people will reduce the need to travel, the length of travel and the emissions intensity of travel. There are several ways this could be realised:

- Better planning of our cities through integrated land-use planning, including high-density and mixed land use developments, could reduce trip lengths and support mode shift.
- Greater use of digital communication technologies may allow some people to work from home more or to travel for work less. There will be many industries, including in the transport and infrastructure sectors, where this will not be possible.
- Intelligent transport systems (ITS) and Cooperative-ITS (C-ITS), including dynamic pricing of different modes of transport, could help make networks operate more efficiently as well as encouraging and supporting behaviour change.
- Connected and automated vehicles (CAVs) should be able to operate more efficiently than human operated vehicles and will present opportunities to change the way vehicles are owned and used.
- New sharing economy businesses (ride sharing and car sharing) could also help, especially when coupled with enhanced active and public transport options.

- Multilingual educational materials and technology applications could encourage international tourists to use public transport to move about our cities.

Greater active and public transport use can contribute to improved wellbeing and lower cost of living

Active transport modes like walking, biking, skating and scooting (and electric micromobility such as e-bikes and e-scooters) produce a much smaller amount of greenhouse gases per person, per kilometre compared to driving. The same goes for public transport modes such as buses, trains, trams and ferries. Both alternatives are cheaper, better for our health, and better for our planet.[14] Increasing their mode share will help us reach net zero. Active and public transport modes should also be accessible, safe, convenient, reliable and efficient to encourage greater uptake.

While the focus on active transport often centres on urban areas, some regional towns are pushing ahead to provide their residents with safe, healthy and low carbon options for moving around. Wagga Wagga, in inland New South Wales, sought to overcome barriers to bike riding and bolster active transport with their Active Travel Plan.

Wagga Wagga's Active Travel Plan

Wagga Wagga is home to one of Australia's largest regional cycleways, with 50.7 km of the planned 56-kilometre active travel pathway now complete, linking all areas of the town with the CBD. The project is supported by the NSW State Government, and when completed it will crisscross the town and provide residents with a safe, alternative travel option for commuting. The network of shared paths aims to improve health outcomes, reduce reliance on cars, and enhance the liveability of the town.

The benefits of the shared paths are not limited to people who ride bikes; they offer a safe, accessible option to everyone in the community to move around the town, regardless of ability. For example, people using motorised scooters and wheelchairs have the opportunity to safely navigate the town, enabling them to access recreational spaces and the outdoors. The paths also provide a safe alternative for children to travel to and from school with minimal interaction with traffic, in addition to reducing traffic congestion and emissions.

Current infrastructure investments support public and active transport networks

State and territory governments primarily manage and fund public transport networks. State, territory and local governments support active transport by developing walking and cycling strategies, investing in active transport infrastructure, and developing active transport mode share targets.

While the design, project deployment and funding of biking and walking infrastructure is primarily a matter for state, territory and local governments, the Australian Government's investment in infrastructure includes, in relevant projects, the building of new active transport infrastructure as part of the overall project (where identified by project proponents).

The government's role as an investor has been strengthened through the new **Infrastructure Policy Statement** (IPS), which will guide the Commonwealth's funding of infrastructure to help unlock a range of significant economic, social and environmental objectives. The IPS defines and commits the government to delivering nationally significant infrastructure, and sets out three strategic

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[14] V Brown et al., Better transport accessibility, better health: a health economic impact assessment study for Melbourne, Australia, *International Journal of Behavioural Nutrition and Physical Activity*, 2019, 16-89, doi:10.1186/s12966-019-0853-y; T Xia et al., Cobenefits of replacing car trips with alternative transportation: a review of evidence and methodological issues. *Journal of Environmental and Public Health*, 2013, doi:10.1155/2013/797312.

themes that will guide future investment decisions: Productivity and Resilience; Liveability; and Sustainability. All three strategic themes support investments in active and public transport infrastructure:

- Productivity encompasses investing in projects that improve the ability of Australians to move around their cities, towns and regions, including prioritising investments that increase the role of mass transit in the urban commuter task to help develop more productive central business districts and precincts. Through targeted investment in infrastructure, we can ensure that our growing population is able to move faster and more safely to their destination.
- Liveability includes equity and connectivity, as well as safety. The government will seek to invest in land transport projects that advance equity for Indigenous Australians and vulnerable communities, and improve the prosperity, accessibility and liveability of our communities. This includes through projects which better connect people to where they live and work, while also providing better opportunities in lower socioeconomic areas.
- Sustainability is focused on reducing transport and infrastructure emissions, including decarbonising transport operations, reducing emissions in the design, construction and operation of transport infrastructure, and investing in projects that encourage and enable more integrated and sustainable approaches to land use planning. This will support further investments in active and public transport infrastructure.

Active Transport Fund

The Australian Government has recently committed $100 million over four years from 2025-26 to fund bicycle and walking paths to encourage the use of active transport across Australia. Well-designed and planned active transport infrastructure, such as bicycle and walking paths, supports regional development, road safety, reduced greenhouse gas emissions and improved productivity, health and community amenity.

The government is also demonstrating national leadership through the development of the **National Urban Policy.** The Australian Government has the reach, the resources and the responsibility to be engaged in cities policy. In July 2023 the Cities and Suburbs Unit was established within the Department of Infrastructure, Transport, Regional Development, Communications and the Arts, restoring national leadership to facilitate more sustainable urban development and settlement. The Unit leads implementation of the government's vision for cities, including delivery of the first National Urban Policy in more than a decade, and a State of Australian Cities report. The Unit also facilitates engagement with key stakeholders to inform development of these products, including the Urban Policy Forum, the Urban Policy Network, First Nations communities, and state, territory and local governments. The National Urban Policy will present a shared government vision for cities which are more productive, equitable, resilient, sustainable and liveable. Future active and public transport infrastructure planning may be guided by the National Urban Policy, noting the different roles and responsibilities of each level of government.

The **National Health and Climate Strategy** also seeks to promote active transport. Action 6.11 states that the Australian Government will seek to engage relevant agencies across all levels of government to promote active travel. This will support and complement implementation of the National Preventive Health Strategy 2021-2030. The National Health and Climate Strategy acknowledges that improving transport options with an emphasis on public and active transport will tend to boost average fitness levels, while reducing air and noise pollution and overall rates of motor vehicle accidents, with considerable population health benefits, especially in reducing rates of chronic disease.

The Australian Government will need to work closely with state, territory and local governments to rethink the planning of our cities, transport networks and systems to support active and public transport infrastructure.

Challenges and opportunities

The main barriers to active and public transport adoption are linked to safety, accessibility, comfort, geography and population density. Inadequate and poorly maintained infrastructure, as well as poor integration between transport modes, hampers the safety and accessibility of public and active transport. Low-density urban sprawl leads to increased distances between residential areas and essential services, employment opportunities, and public transport. Limited active and public transport infrastructure will lead people to opt for private vehicles. In this environment, car dependency is reinforced, leading to higher transport emissions and poorer health outcomes. However, there is also a significant cost to governments in investing in public and active transport infrastructure.

Regional communities face unique challenges related to the adoption of active and public transport. Regional areas have lower population densities and smaller local government budgets than big cities, making it challenging to establish efficient and cost-effective public transport routes. In regional areas transport poverty, which is the unaffordability or absence of transport options, is more common. Regional areas also often lack the necessary infrastructure to support active transport. Greater distances between services in regional areas can discourage people from cycling or walking to commute or access amenities. Regional roads may feel less safe for bike riders and pedestrians due to higher speeds and limited dedicated infrastructure.

Active and public transport can make a significant contribution to reducing transport emissions, while easing congestion, improving health, and reducing pollution, heat, and noise. We need to continue to improve the safety, connectivity, convenience and accessibility of active and public transport infrastructure to achieve higher rates of active and public travel. Investing in micro infrastructure projects to roll out active and public transport corridors, along with incentivising low-cost transport alternatives such as e-bikes, and developing policies to reflect the impact each mode and technology has on our shared environment and health would reduce emissions and increase the liveability and connectivity of our towns and cities.

It is important to understand the challenges associated with increasing the mode share of active and public transport. The benefits of active and public transport have long been well understood but it has been a challenge for governments to drive their uptake. We need to acknowledge that decades of past planning decisions, along with geography, weather, and accessibility will be significant barriers in large parts of the country. Behaviour change is also difficult for governments to bring about, especially when seeking to overcome concerns around safety and comfort. Notwithstanding these challenges, increased use of active and public transport will be part of reaching net zero.

How Seville built a bikeable city

The city of Seville, Spain has a population of a little less than 700,000 and is unique for its success in promoting cycling as an integral part of its urban mobility in only five years (2006-2011), through the implementation of a well-designed, safe and comfortable network of cycle paths covering the city.

Seville's bike path network was planned and built from 2006 to 2010 with a budget of €32 million, having begun with a plan for 80km in 18 months. By 2010 the network was 120 km long and covered all the populated areas of the municipality with bidirectional, continuous, homogeneous and comfortable cycling infrastructure.

The 80km has grown to 180km and is still expanding. The number of cycling trips on a working day increased from approximately 13,000 to a peak of 72,000 in just three years.[15] A new master plan approved in 2017 aims to improve intermodality, safe parking options and the quality of the network. The aim is to increase total mobility - pedestrians excluded - from the current 9% modal share (67,000 trips a day) to 15% (115,000 daily trips).

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[15] Calvo M and Marqués R, How Seville Became a City of Cyclists, *C40 Knowledge Hub*, 2020.

Alongside the bike network, Seville has a public bicycle location system - around 2600 bikes and some 260 stations – that serves roughly 23% of the daily cycling trips. In addition, the city's university rents out 400 bikes on an annual basis, while the Metropolitan Transport Consortium has 250 bikes which can be used free of charge for a whole day by people who have made a trip by metropolitan bus.

A net zero pathway for active and public transport

A net zero transport pathway will require a substantial increase in the use of active and public transport. All levels of government could actively support this shift by implementing a comprehensive national policy framework for active and public transport that includes infrastructure development, public engagement, legislative reform and technological advancement. This framework could consist of a combination of the following elements, focusing on the role of government as a leader and investor.

Government as a leader:

- **Establishing mode share and investment targets for active and public transport.** The government could lead by setting national goals to achieve higher rates of active and public transport. Any such targets would need to complement the existing targets in some states and territories.
- **Urban planning and zoning reform.** Urban planning policies could be revised to prioritise active transport and public transport networks. Government leadership at the state and territory level could support more mixed-use neighbourhoods with amenities and employment opportunities close together to create more walkable and bike-friendly communities, which increases the safety, accessibility and connectivity for all members of the community. This is already happening in many states and territories.
- **Road pricing reforms.** The government is working with states and territories on long-term options for zero emission vehicle road user charging.
- **Technological innovations in active transport.** The government could support technological advancements in active transport, especially electric micromobility. Initiatives like this could result in e-bikes and e-scooters gaining popularity in personal transport and urban last-mile delivery, expanding the potential for active transport to reduce overall car emissions. Innovations in mobile applications and data analytics will provide real-time information on active transport routes, allowing individuals to plan their journeys more efficiently.
- **Public awareness and education.** The government could play an advocacy role to deliver public awareness campaigns to promote active transport and highlight the benefits of shifting to active and public transport. This could include educational programs that provide information on responsible e-scooter use, bike education and training, traffic safety, and pedestrian/bike rider rights. These programs will empower individuals with the knowledge and skills necessary for safe and enjoyable active commuting.

Government as an investor:

- **Expansion of public transport services.** Governments could invest in modernising and expanding the public transport network, increasing the frequency and coverage of services in urban, suburban and regional areas. Governments will also need to prioritise public transport accessibility for vulnerable populations, including people with disability and the elderly.
- **Electrification of public transport.** Australia is already transitioning its public transport fleet towards electrification. Electric buses and ferries need to be prevalent across the country, powered by renewable electricity, alongside existing electric trains and trams. The Australian Government could accelerate the electrification of the public transport fleet by investing in the delivery of charging infrastructure in strategic locations. The transition to electrified public transport could drive local manufacturing, create new jobs and stimulate economic growth. Improved public transport connectivity will reduce the need for private car travel, reducing emissions.
- **Active transport infrastructure improvements.** The government could collaborate with state, territory and local governments to deliver additional safe and accessible cycling lanes, pedestrian walkways, and shared paths in urban, suburban, and regional areas. Investing in infrastructure improvements could provide

seamless connections between major hubs, employment centres, and public transport nodes, encouraging more Australians to use active transport for their daily trips. Green spaces, shading and parks would continue to be incorporated into urban design to enhance the pedestrian experience and reduce the impacts of urban heat.

- **Integration of active transport with public transport.** Governments could strengthen intermodal connectivity, allowing smooth transitions between active and public transport. Last-mile connectivity could be supported through investing in improved footpaths, secure bike parking facilities and end of trip amenities. Governments could also promote transit-oriented development to ensure that residential and commercial areas are in close proximity to public transport nodes and active transport infrastructure.
- **Incentives for public and active transport.** The government works with state, territory and local governments to introduce incentives to encourage individuals to select active and public transport options. This includes state and territory governments developing more efficient public transport fare settings, as recommended by the Productivity Commission.[16] Incentives and improved public transport fare settings will allow individuals to save money on transport costs, reducing the economic burden associated with motorised transport and its associated externalities.

Have Your Say

3. Do you agree the development of a national policy framework for active and public transport will support emissions reduction?

    3.1. Please add details to your response.

4. What should be included in a national policy framework for active and public transport and how should it be developed?

5. What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to ensure the movement of people contributes to transport emissions reduction?

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[16] Productivity Commission, *5-year Productivity Inquiry: Advancing Prosperity: Recommendation 3.6*, Productivity Commission, Australian Government, 2023.

2.2 Movement of goods: decarbonising freight and supply chains

Key points

- Freight transport plays a major role in Australia's economy and is critical to ensuring we have access to essential goods.
- Australia's freight task is projected to grow by 26% to 2050, with urban freight forecast to increase by nearly 60% to 2040.[17]
- It is increasingly important for freight and supply chains to reduce emissions in order to contribute to Australia's net zero targets and meet customer expectations.
- The interconnected nature of global supply chains highlights the need for end-to-end freight movements to be considered across multiple transport modes along with infrastructure requirements and opportunities to decarbonise other aspects of supply chains.
- Improving access to intermodal facilities and increasing the share of goods moved on rail, as well as rolling out the required infrastructure to enable low and zero emission freight transport modes could help shift demand away from fossil fuel powered vehicles.

Australia's freight task is projected to grow to 2050

The domestic freight and logistics sector is critical to every supply chain into, across, and out of Australia. The movement of goods is fundamental to our economic and social wellbeing. We depend on supply chains to get fuel to the service station, fresh foods to supermarket shelves, household waste to the tip, construction materials on site and essential pharmaceuticals to our hospitals. They also connect our agricultural regions and resource basins to cities and ports, delivering Australian produce and minerals to international markets.

Freight is transported across all four transport modes. Most supply chains rely on multiple modes of transport, with the transfer between modes taking place at ports, airports, intermodal terminals, rail freight interchanges, and warehouses where freight is consolidated for onward transport or disaggregated for distribution. Table 3 provides a summary of how the different transport modes are used for freight.

Overall Australia's freight task is projected to grow by 26% to 2050.[18] The projected increase is driven by population growth – expected to reach around 40 million by 2060 – and growth in consumer demand. This growth is currently expected to be met by a major increase in road freight, with a smaller increase in rail freight. Coastal and air freight are expected to remain steady.[19] These projections are consistent with recent trends that have seen a reduction in the share of non-bulk freight (including manufactured goods, produce, post, foods and drinks) transported by rail. Recent research released by the Australasian Railway Association (ARA) and Freight on Rail Group, found that rail's share of non-bulk freight is only 17% and just 11% across the eastern seaboard.[20]

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[17] BITRE, *Road and Rail Supply Chain Resilience Review – Phase 1*, BITRE, Australian Government, 2023; BITRE, *Australian aggregate freight forecasts 2022 update (summary)*, BITRE, Australian Government, 2022.
[18] BITRE, *Australian aggregate freight forecasts 2022 update (summary)*, BITRE, Australian Government, 2022.
[19] K Schott, *The Delivery of Inland Rail: An Independent Review*, DITRDCA website, 2023.
[20] Australasian Railway Association (ARA) and Freight on Rail Group, *The future of freight*, ARA website, 2023.

Table 3: Freight transport modes: Percentage of domestic freight task 2022-23

Mode	Freight use case
Road (31.05%)	The main mode of transport for urban, inter-urban and regional freight, and part of most import supply chains. The only segments of the domestic freight task where road freight plays a minor role are in Australia's large bulk mineral transport supply chains – iron ore, coal, bauxite/aluminium and crude oil and condensate – where rail and coastal shipping predominate. Road freight is projected to grow by 77% between 2020 and 2050.
Rail (57.19%)	Rail is well suited to moving freight in large volumes over long distances. Rail moves almost three quarters of Australia's bulk commodities (such as agricultural and mining products, especially iron ore and coal) but accounts for just 17% of non-bulk freight. Rail freight is projected to grow by 6% between 2020 and 2050, even as the share of coal freight is projected to decline.
Aviation (0.03%)	Domestic air freight is carried in the cargo holds of passenger aircraft and by a small fleet of dedicated freight aircraft. Air is generally used for high-value, low-density freight, such as mail, small parcels and perishables. Forecasts predict that domestic air freight will increase by around 3% per annum to 2050.
Maritime (11.72%)	Australian coastal shipping is important for several major export commodities and domestic industries, including aluminium, steel, and petroleum. Coastal shipping is also crucial for transporting primary production or extraction products to domestic locations for further processing. Coastal shipping is the primary mode of transport between Tasmania and the mainland, and carries small volumes of freight between capital cities. The coastal freight task is projected to remain steady to 2050, with growth rates varying for different commodity and market segments. Ships transport over 99% of Australia's international trade by weight.

Source: BITRE, Australian Infrastructure and Transport Statistics: Yearbook 2023, 2023; National Freight Data Hub, Navigating Australia's Freight Future, 2023; BITRE, *Australian sea freight 2020-21*, BITRE, 2023.

The overwhelming majority of freight emissions are from road transport

With Australia's growing freight task dependent on road transport, projections indicate that emissions from articulated and rigid trucks will increase in the next decade, producing 24 Mt CO_2-e in 2030, an 8 Mt CO_2-e increase from 2005 levels.[21] Articulated and rigid trucks currently account for 21% of transport emissions.[22] In contrast, rail is a low-emissions mode of transport. Despite moving 58% of national freight by weight and 4% of passenger traffic, Australia's rail network accounts for only 4% of transport emissions.[23] A 2020 report prepared by Deloitte Access Economics for the Australasian Railways Association concluded that a 1% shift in freight moved from road to rail would result in a reduction in emissions nationally of 330,150 tonnes of CO_2-e, with an

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[21] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.
[22] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.
[23] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.

average of $71.9 million saved annually in terms of environmental damage, road conditions and pollution-related health outcomes.[24]

Decreasing our reliance on road freight would have potential decongestion and safety benefits, in addition to a reduction in emissions. For example, heavy use of road freight on Australia's north-south eastern seaboard corridor (between Melbourne and Brisbane) increases the safety risk to passenger transport, which also shares this corridor. The annual cost of road accidents to the Australian economy was an estimated $30 billion in 2021, with heavy vehicle crashes contributing $1.5 billion of this cost.[25] There are around 1,200 fatalities each year on our roads, and almost 40,000 serious injuries. In addition to decreasing the emissions intensity of the goods we move, increasing the modal share of rail freight could yield economic gains in the avoidance costs associated with collisions and other accidents.

High-value freight and parcel delivery is driven by online shopping and an increasingly competitive retail environment, which has led to a significant growth in small freight movements in higher-density areas.[26] As a proportion of total vehicle kilometres travelled, light commercial vehicle use has grown from 36.28 billion vehicle kilometres travelled in 2005-06 to 57.93 billion vehicle kilometres travelled in 2022-23, contributing to an increase in emissions and traffic congestion.[27] Route optimisation and low carbon modes of last kilometre delivery provide opportunities to decrease congestion and noise and air pollution along with carbon emissions. Low carbon modes of last kilometre delivery could include light commercial electric vehicles and electric cargo bikes, as well as emerging technologies like drones or automated electric delivery buggies in denser urban areas.

Existing policies to reduce freight emissions

The Australian Government is exercising national leadership across a range of initiatives to reduce emissions from freight transport. The **National Freight and Supply Chain Strategy** has the support of all levels of government and provides the framework to meet Australia's growing freight task. The 2023 Review of that Strategy acknowledges that supply chains also have an important role to play in helping Australia achieve net zero by 2050.[28] The **National Urban Freight Planning Principles** have been designed to guide land use decision-making across all levels of government to improve planning for freight in Australia's metropolitan areas. The government has launched the **National Freight Data Hub**, to improve the efficiency, safety, productivity and resilience of the freight sector through capturing, improving, standardising and sharing freight data.

National Freight and Supply Chain Strategy

The National Freight and Supply Chain Strategy is a national framework which outlines a coordinated approach to increase the safety, productivity and resilience of freight and supply chains. It sets an agenda for government and industry action across all freight modes to 2040 and beyond. It is accompanied by a National Action Plan which identifies key focus areas.

A review of the Strategy was announced by Minister Catherine King in August 2023 with support from state and territory infrastructure and transport ministers. Under the Terms of Reference, the review assessed if there are gaps in the Strategy's goals, identified priorities for the next five-year National Action Plan and proposed a number of key performance indicators.

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[24] ARA, *Value of Rail 2020,* ARA, report prepared by Deloitte Access Economics, 2020.
[25] DITRDCA, *Reducing Heavy Vehicle Lane Departure Crashes*, DITRDCA, Australian Government, 2022.
[26] IA, *Australian Infrastructure Audit 2019: Freight transport*, IA, 2020.
[27] BITRE, *Australian Infrastructure and Transport Statistics: Yearbook 2023,* Australian Government, 2023.
[28] DITRDCA, *Review of the National Freight and Supply Chain Strategy - Terms of Reference*, DITRDCA, Australian Government 2023.

More information on the 2023 Review of the National Freight and Supply Chain Strategy is available online.[29]

The **Rail Freight Productivity Review**, which was led by the Australasian Centre for Rail Innovation (ACRI), with input from the Australasian Railway Association (ARA) and Freight on Rail Group (FORG), and supported by the Department of Infrastructure, Transport, Regional Development, Communications and the Arts, identifies the barriers and provides solutions to increasing rail's mode share of freight. The Review sets out the policy changes and investments needed to improve rail freight productivity. It identifies practical steps industry and government can take together to deliver a more reliable, efficient and sustainable rail freight network to meet growing demand.

The government is also coordinating with states and territories through the **Infrastructure and Transport Ministers' Meetings (ITMM)** Decarbonisation of Transport Working Group, which is developing shared principles for national transport decarbonisation and a national transport decarbonisation work plan.

The **Safer Freight Vehicles** package includes increasing the overall width limit for new trucks that are fitted with a number of safety features. Allowing for wider trucks on our roads will also reduce total road freight trips, saving money, reducing environmental impacts and benefitting the economy, as well as allowing for a greater range of low emission vehicles to operate on our roads.

The Australian Government is also investing in nationally significant transport infrastructure consistent with the **Infrastructure Policy Statement** (IPS). In addition to the Sustainability theme focused on reducing transport and infrastructure emissions, the first theme of Productivity and Resilience provides that the government will seek to invest in infrastructure proposals that improve national productivity.

The Government's investment in **Inland Rail** will enhance national freight and supply chain capabilities, connecting existing freight routes through rail, roads and ports. Delivering Inland Rail will help shift more goods onto rail, meaning faster, more reliable freight; safer, less congested roads; and fewer emissions.

Challenges and opportunities

Decarbonising our freight and supply chains will involve avoiding emissions as a result of productivity and efficiency improvements, a shift of some freight tasks from road to rail, and the adoption of new technologies. The range of emerging technologies across all transport modes that could reduce freight emissions will be considered later in this Consultation Roadmap.

Access to supply chains and markets are hindered by **inconsistent regulation** between jurisdictions and levels of government.[30] Regulations controlling access to Australia's freight network can be fragmented, inefficient and confusing for transport operators.[31] The variable standards to which roads are constructed and maintained place restrictions on the weight, height, width and axle configuration of vehicles that can be used on different roads. The heavy batteries in electric trucks cause them to be heavier than trucks powered by fossil fuels, which has added safety implications and means electric trucks can't access as many roads as fossil fuelled trucks carrying the same sized load. In the rail sector there are a range of interoperability issues, including different gauges for different rail networks, that add time and cost to rail freight.

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[29] DITRDCA, *2023 Review of the National Freight and Supply Chain Strategy*, DITRDCA, Australian Government, 2023.
[30] IA, *Australian Infrastructure Audit 2019: Freight transport*, IA, 2020.
[31] IA, *Australian Infrastructure Audit 2019: Freight transport*, IA, 2020.

The **quality of our regional supply chains** varies widely and the varying standards of **land transport infrastructure in remote and regional areas** can constrain operations and access to markets. Australia's large mining supply chains are world-leading, while agricultural supply chains often struggle with bottlenecks and poorly maintained infrastructure. Grain railways and local roads have lower technical specifications than state-significant and interstate routes. These railways lack the capacity to carry goods to market in bumper harvest years.[32] All regions need resilient, quality infrastructure to ensure no parts of the goods and services network, nor segments of society, are left out of the transition. Continuing to build and maintain this infrastructure also provides highly localised jobs in rural regions.

Australia's urban supply chains can struggle with **congestion**, which hinders access to markets and causes productivity losses. In Sydney and Melbourne, delays on access routes to key facilities such as ports, intermodal terminals and airports are common. There are opportunities to ease congestion with strategic planning in collaboration with states and territories. Incentives and targets which encourage the shift from road to rail at ports and on key routes will not only lower the emissions intensity of the goods we move, but also lower congestion in our cities and increase safety on regional and remote roads.

As the energy landscape changes, **large-scale renewable energy projects** will continue to be built as fossil fuel infrastructure is decommissioned. Construction of these projects will involve the transport of oversized freight, and place-based planning will need to occur to minimise impacts to transport infrastructure and disruptions to regions, individuals and the projects themselves. New transport infrastructure may also need to be built quickly to support these projects.

Policies that address these productivity and efficiency barriers need to be considered as we seek to decarbonise freight. There are exciting opportunities to leverage **green energy hubs at ports** and **intermodal terminals** to demonstrate low emission freight solutions. These changes will provide opportunities to provide incentives to retain and upskill new entrants to the workforce, including women.

Technological interventions that seek to improve vehicle efficiency and reduce emissions, including the role of low carbon liquid fuels (LCLFs), will be explored in the next chapter on a mode-by-mode basis.

A net zero pathway for freight

A net zero pathway for freight will likely see an increase in the share of freight transported by rail. The interconnected nature of supply chains will also require national leadership alongside strategic planning with the states and territories on intermodal innovation and optimisation, and urban freight consolidation. All levels of government are committed to actively supporting this transition, including investing in transport infrastructure that improves the productivity and sustainability of freight transport.

A net zero pathway for freight could involve a combination of the following elements, with the Australian Government playing a key role as leader and investor.

Government as a leader:

- **Mode shift from road to rail.** The growing freight task will need to be met with increases in both road and rail freight. In response to concerns around congestion and emissions from increased road freight, especially in urban environments, governments could consider the commercial incentives facing transporters as well as targets for freight mode shift from road to rail at ports and on intra- and inter-state routes. Rail is particularly well suited for the movement of non-time sensitive goods.
- **Urban planning.** As industry and governments consider longer term investments in strategic supply chain infrastructure, urban planning systems need to consider protecting future freight corridors.

Government as an investor:

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[32] IA, *Australian Infrastructure Audit 2019: Freight transport*, IA, 2020.

- **Intermodal innovation and optimisation.** Intermodal terminals play a significant role in the consolidation, storage and transfer of freight between rail and road at the beginning and end of each rail journey. They provide connectivity to ports, regional networks and other capital cities and locations. Investing in efficient intermodal terminals can also increase flexibility for freight operators and decrease the overall cost in a supply chain.[33]
- **Rail resilience**. Improving the reliability and resilience of the rail network would contribute to making rail a more attractive mode of freight transport
- **Urban freight consolidation centres.** Urban freight transport covers short distances, involves many trips and small loads. Globally, these movements represent approximately 3% of total freight activity but are very carbon intensive and inefficient.[34] Investing in urban freight consolidation centres have the potential to reduce emissions, by decreasing the number of freight vehicles and the distances they travel in urban areas.
- **Improvements to last kilometre delivery**. The last kilometre of freight distribution is the last link of the supply chain. This last kilometre is used to transport a wide variety of goods over relatively short distances in congested urban settings with a high frequency of delivery.[35] For freight operators, delivery from the depot to the door is the most complex, accounting for 53% of the delivery cost.[36] Government support for micromobility freight options, including electric cargo-bikes, drones and automated delivery buggies could play an important role in reducing the emissions from urban goods movements.
- **Incentives for fleet owners to invest in emission reduction technologies.** Governments and industry could consider offering incentives for fleet owners to adopt low or zero emission vehicles by including efficiency and reporting requirements in project tender criteria.

A net zero pathway for freight will also rely on decarbonising freight transport modes, especially heavy vehicles. The next chapter in this Consultation Roadmap considers the net zero pathways for each transport mode.

Have Your Say

6. The Australian Government has already engaged in consultation on the 2023 review of the National Freight and Supply Chain Strategy and those consultations will also inform the final Roadmap and Action Plan.

6.1. What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to ensure that the movement of goods contributes to transport emissions reduction?

6.2. How would these actions address the identified challenges and opportunities for emissions reduction in the movement of goods?

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[33] DITRDCA, *Intermodal terminals, Inland Rail*, DITRDCA, Australian Government, unpublished, 2023.

[34] International Transport Forum (ITF), *Transport Outlook 2021 Chapter 5: Freight Transport*, ITF, OECD iLibrary website, 2021

[35] Suksri et al., *'Towards sustainable urban freight distribution: a proposed evaluation framework'* [conference paper], Australasian Transport Research Forum, 2012.

[36] S Snood and G Pointer, *Future of delivery: Unleashing the potential of micromobility for the last mile*, WSP, 2022.

3. Net zero pathways for each transport mode

The pathway to net zero will be different for each transport mode. The approach for each transport mode will require a mix of technologies, policies and planning, based on evidence, market readiness and science. There are opportunities within each mode to *improve* the technology or efficiency of that mode. This chapter considers these opportunities for each transport mode.

3.1 Road – light vehicles

Key points

- In 2023 light vehicle emissions were almost 60 Mt CO_2-e. Light vehicle emissions account for almost 60% of all transport emissions, which is just over 12% of Australia's total emissions.
- Light vehicles present the largest emissions saving potential for transport and can be decarbonised with electrification.
- The Australian Government is taking action through the National Electric Vehicle Strategy and an Australian New Vehicle Efficiency Standard.
- The introduction of an Australian New Vehicle Efficiency Standard will increase the availability of new cleaner, cheaper-to-run vehicles and contribute to a cleaner, greener and more sustainable transport sector over time. It will also encourage supply of more low and zero-emissions vehicles, such as battery electric vehicles and plug-in hybrid electric vehicles, to the Australian market.
- There are other policy initiatives that could be considered to accelerate the uptake of EVs and other zero emissions technologies and phase out the existing fleet. This includes the roll out and support of public and private EV infrastructure; supply-side regulatory reforms; consumer education; technology innovation trials and demonstration projects; circular economy initiatives; and changes to financial policies to promote uptake.

Light vehicles make up almost 60% of Australia's transport emissions

Australia is a car-dependent society with 21.2 million registered vehicles on our roads as at 31 January 2023 – an increase of approximately 2.3% since the end of January 2022.[37] Just over 90% of those registered vehicles are considered to be light vehicles.[38] Light vehicles are four-wheeled vehicles with a mass of less than 3.5-4.5 tonnes. They include passenger cars with a sedan or hatchback body, sports utility vehicles (SUVs) and light commercial vehicles such as utes and vans.

Light vehicles contribute almost 60% of Australia's transport emissions and over 12% of Australia's total emissions.[39] As Australia's population continues to grow, more and more light vehicles are expected to be on our roads. Sales of bigger and heavier cars such as SUVs are the fastest growing vehicle segment[40]. These trends have the potential to offset any reduction in emissions we may see from fuel efficiency improvements and the increased adoption of electric vehicles (EVs).

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[37] BITRE, *Road Vehicles, Australia, January 2023*, BITRE, 2023.
[38] BITRE, *Road Vehicles, Australia, January 2023*, BITRE, 2023.
[39] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.
[40] National Transport Commission (NTC) *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles 2022*, NTC, Australia Government, 2023.

Electrification is the clear technology to decarbonise light vehicles

The main technology pathway to reduce light vehicle emissions will be electrification. This relies on a renewable electricity grid. EVs have zero tailpipe emissions, but still have emissions associated with them. Electric vehicles have lower lifecycle emissions than petrol and diesel internal combustion engine (ICE) vehicles, but higher emissions in the production phase due to their large batteries. The manufacturing emissions of EVs depend directly on the location of battery cell production and material refining. Currently, carbon dioxide emissions from battery manufacturing in China are around 60% to 85% higher than those in Europe and the U.S.[41] Over the whole lifecycle, EVs have much lower emissions than ICE vehicles including 66–69% lower in Europe, 60–69% lower in the United States and 37–45% lower in China.[42] In Australia, an EV charged from renewably-sourced electricity (e.g. home solar) will offset those emissions after about one year, and if charged from the grid (using a mix of electricity generation sources), two years.[43]

Secondary emissions (scope 2 emissions) of charging an EV from the electricity grid are already lower than emissions from equivalent ICE vehicles and will reduce further as our electricity grid decarbonises.[44] Many emerging public charging infrastructure providers in Australia have committed to using renewable energy. The emissions associated with an EV charged with electricity from the grid is directly linked to the emissions intensity of the grid. As our electricity system decarbonises, the lifecycle emissions of EVs will continue to decrease.[45]

EVs also offer substantially lower operating costs – the average EV consumes around $400 worth of electricity per year.[46]

Advancements in battery technology are reducing the price of vehicles, contributing to the increasing market share of EVs, with expectations that globally EVs will reach sticker price parity with ICE vehicles sometime between 2025 and 2029.[47]

Demand for EVs in Australia has grown significantly in the past year. 2023 saw EVs overtake sales of conventional hybrid vehicles in Australia.[48] This mirrors global momentum, where EV sales accounted for around 14% of the global car market in 2022, up from 9% in 2021, and in spite of globally contracting markets. EV sales in 2022 were 23% of car sales in the UK, 21% in the EU and 8% in the US.[49]

Although EVs will be the prevailing technology for reducing light vehicle emissions, there are several other technologies that will also contribute to reducing light vehicle emissions, especially in the short term:

Hydrogen fuel cell electric	FCEVs convert compressed hydrogen into electricity to power an electric motor and, like battery electric vehicles (BEVs), have zero tailpipe emissions. FCEVs can play a role in

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[41] Bloomberg New Energy Finance (BNEF), *The Lifecycle Emissions of Electric Vehicles*, BNEF, 2021.
[42] International Council on Clean Energy Transportation (ICCT), *A Global Comparison of The Life-Cycle Greenhouse Gas Emissions of Combustion Engine and Electric Passenger Cars*, ICCT, 2021.
[43] BITRE, Impact Analysis for Fuel Efficiency Standards, BITRE, Australia Government, unpublished, 2023.
[44] International Energy Agency (IEA), *Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle*, IEA website, 2021.
[45] R Smit and DW Kennedy, *Greenhouse Gas Emissions Performance of Electric and Fossil-Fueled Passenger Vehicles with Uncertainty Estimates Using a Probabilistic Life-Cycle Assessment*, *Sustainability,* 2022, doi:10.3390/su14063444.
[46] Electric Vehicle Council (EVC), *Insights into electric vehicle ownership: a survey of Tesla Owners Club Australia members in partnership with the Electric Vehicle Council* [PDF, 1,387 KB], EVC website, 2022.
[47] BNEF, *'Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh'*, BNEF website, 2020.
[48] J Dowling, 'VFACTS April 2023: Electric cars now outsell hybrids in Australia', *DRIVE*, 2023.
[49] IEA, *Global EV Outlook 2023: Catching up with climate ambitions*, IEA, 2023.

vehicles (FCEVs) 	decarbonising light vehicles, especially when the hydrogen is produced from renewable energy. The production of FCEVs is currently significantly lower globally than EVs. The demand for FCEVs in Australia is also limited with just over 50 light FCEVs sold since 2021, mainly through fleet trials. Hydrogen also has the benefit of increased range compared to EVs. However, hydrogen may not be a competitive long-term light vehicle decarbonisation solution due to its relatively low energy efficiency and the need to establish new refuelling infrastructure to support it.
Hybrid vehicles 	Hybrid vehicles can run on both petrol/diesel and electric power. They use an electric motor powered by a battery as the primary or supplementary power to improve vehicle fuel efficiency in addition to an ICE. The battery is re-charged onboard by residual braking technology (conventional hybrid) or by an external EV charger (plug-in hybrid). In 2023, conventional hybrid vehicles made up 8.45% of sales in Australia, with plug-in hybrid vehicles being 1% of sales.[50] Hybrid vehicles offer some benefits in terms of reduced emissions compared to traditional ICE vehicles and will be important for decarbonising light vehicles in the short-term. For longer trips or frequent highway driving, both conventional and plug-in hybrids operate primarily on fossil fuels, leading to higher emissions than EVs.
Efficiency improvements	Efficiency improvements in ICE and hybrid vehicles will mean less fuel is consumed, resulting in cost savings to owners and reduced emissions. Improvements in fuel efficiency will contribute to transport decarbonisation in the short- to medium-term alone but will not result in zero emissions.

The road transport technology landscape more broadly is also changing rapidly. Advances in sensor technology, automation, machine learning, connectivity, and data processing and analysis are being applied to road vehicles, infrastructure, and road management systems. Road vehicles are becoming increasingly connected, electric and automated. Enabling new technologies allows consumers to access the latest vehicles that are safer and have lower emissions. The draft National Road Transport Technology Strategy sets out the role of governments in technology rollout, and principles to help governments decide how to best support new road transport technologies. Future innovation in bidirectional charging, which will allow EVs to both receive and discharge energy, will enable more EV models to contribute electricity to power homes and the grid in the future. The draft strategy also complements the National Electric Vehicle Strategy and state and territory EV initiatives that aim to increase uptake.

The government is already targeting light vehicles but more work is required

The **National Electric Vehicle Strategy** sets out a nationally consistent framework to increase the uptake of EVs to reduce emissions and improve the wellbeing of Australians. The Strategy sets out 3 key objectives:

1. increase the supply of affordable and accessible EVs
2. establish the resources, systems and infrastructure to enable rapid EV uptake
3. encourage increased EV demand.

Implementing initiatives under the objectives will help us deliver the following outcomes:

- expand EV availability and choice

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[50] Federal Chamber of Automotive Industries (FCAI), *Australia breaks all-time new vehicle sales in 2023*, FCAI, 2024.

- reduce road transport emissions
- make it easy to charge EVs across Australia
- increase local manufacturing and recycling
- make EVs more affordable
- reduce the cost to Australians of running their vehicles.

At the centre of the Strategy is the introduction of an **Australian New Vehicle Efficiency Standard**, to encourage supply of more efficient light vehicles. This regulation will provide a clear direction for vehicle suppliers, and has public support from the community, motoring clubs, climate groups, businesses, unions and vehicle manufacturers.

An Australian New Vehicle Efficiency Standard to promote cleaner cars

The government is introducing an Australian New Vehicle Efficiency Standard to save Australians money at the fuel bowser, bring cleaner cars to Australia and give more choice of cars to buy and drive. It will also help reduce greenhouse gases and other pollution from cars to improve the air that you and your family breathe.

Most advanced economies have fuel efficiency standards. Even New Zealand, which is a smaller and more remote market than Australia, has introduced a fuel efficiency standard.

Fuel efficiency standards set an average CO_2 emissions target for cars sold by each vehicle supplier. They only apply to new cars, not cars that are already in the market or being used on the road.

Over time, suppliers need to meet the CO_2 target and this means the cars they sell need to have lower emissions. The target is applied on average across the entire fleet a supplier provides. This means that suppliers can still sell any vehicle they like (including ICE and hybrid vehicles), but will need to sell more clean cars to offset the higher emission cars they sell.

If suppliers sell more fuel efficient cars than the target, they get credits. If they sell more polluting cars than the target, they need to either use credits they have banked in previous years, buy credits from a different supplier or receive a penalty.

Final policy settings on the New Vehicle Efficiency Standard have been announced, following extensive consultation.

New Vehicle Efficiency Standard Implementation

The Australian Government will provide $154.5 million over six years from 2023–24 (and $12.6 million per year ongoing) to implement a New Vehicle Efficiency Standard to support greater choice of fuel-efficient vehicles that will reduce motoring costs and transport emissions. Funding includes:

- $84.5 million over five years from 2024–25 (and $12.6 million per year ongoing) to establish a regulator to administer the New Vehicle Efficiency Standard, including to capture emissions data, establish a credit trading platform and undertake monitoring and compliance activities, and to undertake further work to bring Australian vehicle standards into line with those of our peers
- $60.0 million over four years from 2024–25 to support the installation of electric vehicle charging infrastructure at automotive businesses to support the transition to selling and servicing electric vehicles
- $10.0 million in 2023–24 for a national communications campaign to raise awareness of the New Vehicle Efficiency Standard, with funding already provided for by the government.

Challenges and opportunities from the EV transition

The National Electric Vehicle Strategy has kick-started Australia's transition to a decarbonised transport system, with light vehicles as the first priority. The Strategy will expand and increase the **current supply of affordable and accessible EVs**, with the New Vehicle Efficiency Standard being a strong driver for the supply of cleaner, cheaper cars.

Australia is dependent on international manufacturers for vehicle supply. The absence of a light vehicle fuel efficiency standard to date has hindered the supply of fuel-efficient vehicles to Australia, as manufacturers prioritise sending their most efficient models to countries that regulate fuel efficiency. The introduction of an Australian New Vehicle Efficiency Standard will help to address this challenge by increasing the availability and affordability of fuel-efficient vehicles, and reducing the supply of high emitting vehicles.

A potential challenge to decarbonising light vehicles is that **Australians increasingly prefer heavy passenger vehicles** like SUVs and utes. More than 50% of new vehicles sold in the country last year were SUVs, a proportion that has almost doubled over the past decade, despite higher registration fees for heavier vehicles.[51] This has coincided with a doubling of the advertising spend for SUVs and light commercial vehicles (which includes four-wheel drive utes).[52] These vehicles consume more energy and fuel per kilometre than smaller vehicles, resulting in higher emissions and effectively cancelling out the savings made by higher EV sales. The New Vehicle Efficiency Standard will be critical to improving consumer choice. Fuel efficiency standards internationally have encouraged suppliers to develop low and zero emissions cars that meet consumer needs. While there are already electric SUVs and utes being manufactured, a fuel efficiency standard will encourage manufacturers to supply the next generation of electric SUVs and utes for the Australian market.

A further option to encourage the uptake of EVs is through **road pricing reforms**. The government is currently working with states and territories on long-term options for zero emission vehicles user charging.

Currently EVs generally have **higher upfront costs compared** to equivalent ICE vehicles. The upfront cost of EVs will decrease as battery technology improves and becomes more cost-effective, and as manufacturers start to target a wide range of consumers beyond early adopters. State government subsidies and Commonwealth tax incentives such as the Electric Car Discount, which includes a tariff reduction and fringe benefits tax (FBT) exemption, are helping to offset this price differential in the short to medium term. EVs are expected to reach price parity with ICE vehicles by the end of the decade.

The widespread adoption of EVs will need to be matched by increased **availability and reliability of charging infrastructure**, particularly in regional and remote areas, and for people living in multi-residential buildings. All levels of government are currently implementing measures to establish, expand and support charging infrastructure, complimented by commercial investment.

The National Electric Vehicle Strategy outlines a range of work being undertaken to address these challenges. However, there may be opportunities for additional support to accelerate grid upgrades and the roll out of charging infrastructure, as well as to assist low income earners to overcome the higher upfront costs of purchasing an EV. This may be especially necessary for rural and regional Australians who are more likely to experience **transport inequality** compared to their urban counterparts due to limited public transport, longer driving distances, higher fuel costs and lower average incomes.[53]

Providing transitional support for rural, regional, and remote communities will ensure that the decarbonisation of light vehicles is inclusive and equitable. The deployment of charging infrastructure in regional and remote areas can support the adoption of EVs in these communities.

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[51] E Visontay, 'Carmakers double spending on ads in Australia for SUVs and utes', *The Guardian*, 2023.
[52] E Visontay, 'Carmakers double spending on ads in Australia for SUVs and utes', *The Guardian*, 2023.
[53] ACCC, *Fuel prices in regional locations*, ACCC website, Australian Government, 2023

There are also **significant economic opportunities** for Australia as a result of the EV transition. Critical minerals are vital to international decarbonisation efforts as they are the foundation for many of the technologies which underpin the renewable transition, including EVs and batteries. We also have the capability and capacity to develop manufacturing opportunities to support EV supply, including in component parts and batteries.

Of course, it will also be important to repurpose and recycle these batteries at the end of useful life, where possible. Supporting a **circular economy** will be important to help mitigate the environmental impacts of EV production and EV waste, and reduce the strain on battery supply chains. The National Battery Strategy will consider potential battery repurposing and recycling initiatives.

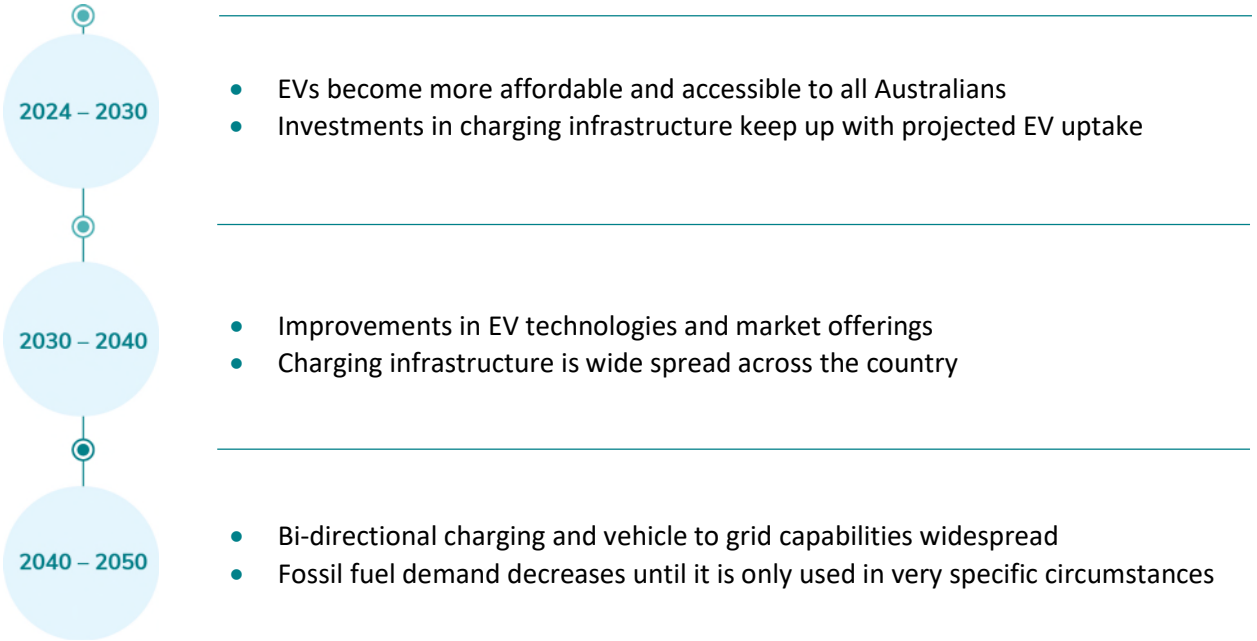
A net zero pathway for light vehicles

EVs are the key net zero pathway for light vehicles. In the short-term, this transition could be supported by incentives from the government for purchasing EVs, along with the Australian New Vehicle Efficiency Standard, regulation and consistent national charging requirements. These actions, together with advancements in battery technology, would make EVs more affordable and accessible to all Australians.

In the medium-term, charging infrastructure investment will be needed to enable all Australians to access charging when they need. Government will also support and help coordinate continued investment, including from the commercial sector, and increases in renewable energy and network grid capacity. EV technology will continue to improve, and their costs will decrease to reach upfront parity with ICE vehicles. Government could also ensure that new technology innovations (e.g. conversions or range extenders) are supported with clear regulatory guidelines to scale up.

In the long-term, regulation should evolve to support bi-directional charging and vehicle to grid capabilities, supporting grid stability and demand flexibility. As the light vehicle fleet continues to electrify, fossil fuel demand will continue to decrease until it is only used in light vehicles in very specific circumstances. Government will have a role to play in ensuring all Australians have opportunities to transition their vehicles, while maintaining transport access.

Figure 9: A net zero pathway for light vehicles



Have Your Say

7. Do you agree with the proposed net zero pathway for light road vehicles?

7.1. Please add details to your response.

8. The Australian Government is currently developing an Australian New Vehicle Efficiency Standard and has already begun to implement actions in the National Electric Vehicle Strategy.

8.1 What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to reduce light vehicle emissions?

8.2. How would these actions address the identified challenges and opportunities to reduce light vehicle emissions?

3.2 Road – heavy vehicles

Key points

- In 2023 heavy vehicle emissions were 23 Mt CO_2-e. Heavy vehicle emissions account for 23% of all transport emissions. After light vehicles, heavy vehicles present the largest abatement opportunity for the transport sector.
- There is a range of technologies emerging for decarbonisation of heavy vehicles. Battery electric trucks may be limited to shorter distances with lighter payloads until battery technology and charging infrastructure improves. Hydrogen or low carbon liquid fuels (LCLFs), like renewable diesel, may be required for larger payloads and distances.
- The Australian Government is currently working with the states and territories to remove regulatory barriers (width and mass limits) to support Euro VI standards. These reforms will ensure Australia has access to the fuel-efficient engines being supplied in other markets that are required to reduce CO_2 and noxious emissions concurrently. Further reforms to mass limits will be necessary to overcome the productivity penalty that zero emission trucks face as a result of their heavy batteries and to increase the supply of low and zero emission trucks in Australia.
- Charging infrastructure is being rolled out across the country, although much more will be needed to support battery electric trucks, especially in regional and rural Australia.
- The high upfront cost of switching to low and zero emission trucks, together with the potential impact these heavier trucks will have on our road pavements, will remain challenging, even after the regulatory barriers have been removed. Improving the availability of charging infrastructure and appropriate financing mechanisms to address up-front costs will be important.
- There are opportunities to support the uptake of low and zero emission trucks through trials, subsidies or loans. There is also potential for local heavy vehicle manufacturing using Australian made batteries.

Heavy vehicles make up almost a quarter of Australia's transport emissions

Heavy vehicles transport essential goods all over the country, especially in and out of regional and rural Australia. Earlier in this Consultation Roadmap, we talked about the need to rethink the way we move goods, considering the end-to-end aspects of freight movement. This chapter focuses solely on heavy vehicles, which will always be an important part of Australia's freight and supply chain, especially as the transport task is going to continue to grow to 2050.

There are a variety of ways to define or categorise heavy vehicles. In this part of the Consultation Roadmap, we consider heavy vehicles to be rigid trucks, articulated trucks and buses over 4.5 tonnes gross vehicle mass. Light commercial vehicles, which have an important role to play in last kilometre delivery of goods, were considered in the previous chapter on light vehicles.

Old trucks make up a large share of the fleet, with the average Australian age of trucks on the road in 2019 being 14.4 years,[54] significantly higher than in other countries such as six years in Austria and nine years in France, Germany and the Netherlands (noting the EU is a very different heavy vehicle market compared to

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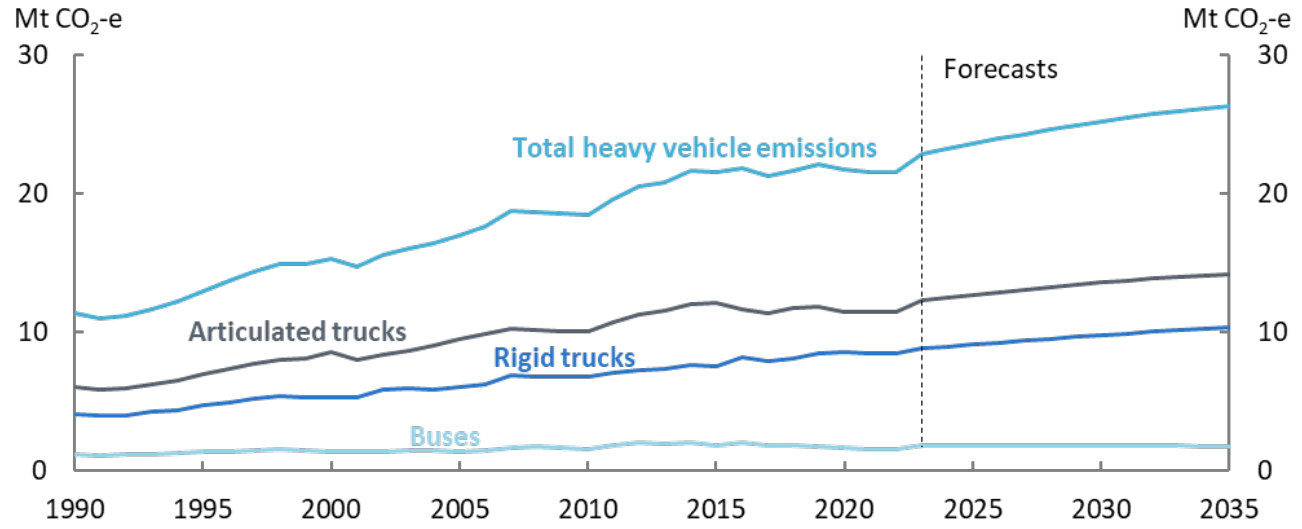
[54] Truck Industry Council (TIC), *Modernising the Australian Truck Fleet: Budget Submission 2019/20*, TIC, 2019.

Australia).[55] The comparatively old age of the Australian truck fleet means older, higher emission vehicles are staying on our roads longer.

Without intervention, projections indicate that emissions from articulated and rigid trucks will increase by 15% in the next decade as our population and GDP grows, producing 23 Mt CO_2-e by 2030 (Figure 10:).[56]

Figure 10: Heavy vehicle emissions



Source: DCCEEW, *Australia's emissions projections 2023*, Australian Government, 2023.

A combination of low emission technology and fuels will likely be required to decarbonise heavy vehicles

While battery electric technologies have a developing market presence and supply chains, battery electric trucks are currently unable to carry all loads across the country. Hydrogen and LCLFs may be more suitable for larger payloads and distances but will face different challenges that could impact prices. Hydrogen requires vehicle adjustments, the development of an industry and the establishment of supply. LCLFs can be available in the short term, and use existing fuel systems in vehicles, however higher costs of production remain. The cost to productivity and margins will likely determine the preferred technologies and fuels for heavy vehicles. Financial and regulatory incentives could play a significant role in reducing the upfront cost burden of the transition to an electric truck where appropriate.

The various technologies and fuels that could contribute to decarbonising heavy vehicles include the following:

Battery electric vehicles (BEVs)	Battery electric truck technology is already an option for rigid trucks operating in urban areas and following set routes, since they can recharge frequently at a central location. Battery electric truck supply is increasing.[57] By 2030 the total cost of ownership of light rigid electric trucks should approach, and in some cases undercut, that of equivalent diesel trucks.[58] The weight of batteries has a significant impact on BEVs, especially for trucks that operate over long distances and/or at a higher gross combination mass.

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[55] Electric Vehicle Council (EVC) and Australian Trucking Association (ATA), *Electric trucks: Keeping shelves stocked in a net zero world*, EVC and ATA, 2022.

[56] EVC and ATA, *Electric trucks: Keeping shelves stocked in a net zero world*, EVC and ATA, 2022.

[57] EVC and ATA, *Electric trucks: Keeping shelves stocked in a net zero world*, EVC and ATA, 2022.

[58] J Dudley-Nicholson, 'Electric trucks are driving closer to price parity with diesel, and are cheaper to run', *The Driven*, 2023.

	Electric buses are already economically viable and operating on a large scale internationally.
Hydrogen fuel cell electric vehicles (FCEVs) 	The hydrogen truck market is even less advanced than the market for electric trucks. This is mainly because FCEVs require extensive infrastructure to produce and distribute hydrogen. This rollout of infrastructure is less advanced than the infrastructure for electric charging. Hydrogen trucks are under development but there are limited options available in Australia. This makes it challenging for Australian transport companies to assess the actual costs and benefits in terms of efficiency and range, and to verify the operating and maintenance cost assumptions for FCEVs. FCEVs may play a role in road freight transport in the long-term where electrification is less feasible (due to EV battery range or the long charging times).
Battery swapping and range extending technologies 	Battery swapping heavy vehicles are popular in some other countries, especially China. These heavy vehicles are designed for batteries to be quickly removed and replaced, allowing drivers to replace depleted batteries with recharged ones. The advantage of this technology is its short charging times. However, increased adoption of battery swapping trucks also has barriers, including the lack of uniform standards for battery design and increased charging service fees making battery swapping less economical.
Low carbon liquid fuels (LCLFs) 	Drop-in LCLFs offer abatement potential and could act as a short to medium-term transition solution as it allows industry to continue using their existing diesel fleet, while lowering emissions. Drop-in fuels are LCLFs that can be used as direct replacements for traditional fossil fuels, without the need for any modifications to the existing fuel infrastructure or engine technology. These fuels are designed to have the same chemical composition and properties as traditional fuels. In Chapter 4 we discuss the role LCLFs could play in supporting the transition. LCLFs will play a role in decarbonising a range of transport modes, but there are competing and limited feedstock options. Feedstock will need to be weighted toward highest decarbonisation value products.
Efficiency improvements	Efficiency improvements in ICE trucks will mean less fuel is consumed, resulting in cost savings to owners and reduced emissions. Improvements in fuel efficiency will contribute to transport decarbonisation in the short- to medium-term but will not result in zero emissions.

Current Government policies are removing regulatory barriers and establishing the necessary infrastructure

The government is pursuing a range of measures focused on addressing barriers and providing incentives to enable the uptake of low emissions heavy vehicles. The government is not pursuing a New Vehicle Efficiency Standard for heavy vehicles.[59]

Removing regulatory barriers will enable the supply of electrified heavy vehicles.

Australia's **Heavy Vehicle National Law** (HVNL) regulates the use of heavy vehicles that have a gross vehicle mass of more than 4.5 tonnes. It applies nationally, except for Western Australia and the Northern Territory. The HVNL aims to enhance public safety, industry productivity and efficiency, innovative and safe business practice, and manage the impact of heavy vehicles. The HVNL has prescriptive key provisions on vehicle

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[59] DCCEEW, *Annual Climate Change Statement 2023*, DCCEEW, Australian Government, 2023

operations, vehicle mass, dimension and loading, fatigue management, access, performance-based standards, and enforcement.

The HVNL includes limits on the width and mass of heavy vehicles. These limits have acted as a barrier to the availability of both battery electric and hydrogen trucks in Australia, as zero-emissions trucks currently available overseas are both wider and heavier on the steer axle than similar diesel trucks. Due to Australia's comparatively small vehicle market, it has not been commercially viable to redesign or reengineer these vehicles specifically for our market.

The government is implementing several reforms in the recently announced **Safer Freight Vehicles** package, to increase the overall width limit from 2.5 to 2.55 metres for new trucks that are fitted with a number of safety features. This will increase the supply of zero-emission trucks available in Australia.

The National Heavy Vehicle Regulator and National Transport Commission are also working with government and industry stakeholders to progress **reforms to mass limits** to ensure trucks with advanced safety and emissions do not risk a productivity penalty. This will be necessary to support the uptake of **Euro VI** heavy vehicles which will apply to new trucks from 1 November 2024 through **Australian Design Rule (ADR 80/04)**. These standards will reduce noxious emissions from trucks (such as oxides of nitrogen and particulates) that affect the quality of the air we breathe.

Truck and bus suppliers advise that their latest Euro VI engines are up to 10% more fuel efficient than previous Euro V models.[60] This improved fuel efficiency comes by ensuring Australia has access to the fuel-efficient engines being supplied in other markets that are required to reduce CO_2 and noxious emissions concurrently. Some noxious emissions, such as nitrous oxide, are also more potent greenhouse gases than CO_2. The introduction of Euro VI will also help reduce these greenhouse gas emissions.

However, the reforms to mass limits to support Euro VI will not, by themselves, be enough to overcome the productivity penalty that zero emission trucks face as a result of the heavy batteries. Australia's steer axle mass limit, currently at 6.5 tonnes, will continue to limit the deployment of larger battery electric truck models. Although battery technology may become lighter over time, further reforms to mass limits may be necessary to remove this productivity penalty and increase the range of zero emission trucks available in Australia.

The government is also progressing work to implement **vehicle safety standards** for EV safety and hydrogen fuel cell vehicle safety. This includes updates to the **Australian Design Rules** with two new rules to provide protection and set minimum standards for EV and hydrogen fuel cell vehicles. These standards will increase consumer confidence in these new technologies, as well as industry confidence in supplying vehicles to Australia without requiring redesign to meet local standards.

Additionally, the **Guarantee of Origin** (GO) is a world-class assurance scheme being designed to track and verify emissions associated with hydrogen, renewable electricity and potentially other products made in Australia. The GO scheme will show where a product has come from, how it was made, and its lifecycle carbon intensity.

Australia's GO scheme will inform choice. Consumers and investors will be able to choose what kind of product they buy and sellers will be able to prove the integrity of their product. See chapter 4.2 for more information on transport energy use and low carbon liquid fuels.

To de-risk and support the transition for long-distance freight transport, the government has established the hydrogen highways initiative, under the Driving the Nation Fund, to co-invest up to $10 million per jurisdiction on a matched basis to support the development of hydrogen refuelling networks along key freight routes. This investment recognises the opportunity to grow Australia's hydrogen industry and the potential benefits for long-distance freight transport.

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[60] M Terrill et al., *The Grattan truck plan: Practical policies for cleaner freight*, Grattan Institute, 2022.

The government is also shaping the transition through financing via the **Australian Renewable Energy Agency (ARENA)** and the **Clean Energy Finance Corporation (CEFC).** For example, ARENA and the CEFC have supported ARK Energy Corporation to operate five purpose-built hydrogen fuel cell heavy trucks to transport zinc ore from Townsville Port in Queensland to the Sun Metals Refinery, where they will refuel with green hydrogen produced on site, before taking zinc ingots back to the port in a 30 km clean energy round trip.

The Australian Government committed $125 million of funding, matched by the WA government, to deliver a $250 million **electric bus manufacturing facility and bus depot** in Perth. This initiative has already saved over 230 tonnes of CO_2 emissions.[61]

Zero Emission Buses – Macquarie Park Depot

The Australian Government has recently committed $115 million to construct a new purpose-built electric bus depot in Macquarie Park to house Zero Emission Buses that will support the Australians Government's commitment to achieve Net Zero by 2050.

The project is part of the first stage of the New South Wales Government's plan to upgrade 11 existing bus depots and construct a new bus depot in Macquarie Park supporting zero emissions technology. The new depot will house 165 busses and will be the first purpose-built electric bus depot. The depot will include charging bays, maintenance and wash bays, a multilevel administration block, below ground car parking and fire and storm water facilities.

Challenges and opportunities arising from the transition to zero emission heavy vehicles

Once the heavy vehicle **regulatory** barriers are removed, the government will continue to seek opportunities to support the uptake of low and zero emission heavy vehicles, especially in the short to medium term.

Electrification may be limited to **shorter distances with lighter loads** until battery technology and charging infrastructure improve. Currently available battery electric trucks in Australia have a **limited range** between 100km and 500km and a battery size between 70 and 265 kWh.[62] There will also be opportunities for battery electric self-driving connected and automated (CAV) trucks.[63]

Electrification presents Australia's manufacturing industry with an opportunity to leverage the domestic **manufacturing and industrial component** of the net zero transition if the right signals are set. Multiple manufacturers currently operating in Australia are moving towards producing low or zero emission buses and trucks. The bus and coach industry started decarbonising earlier than the trucking industry, however there are encouraging examples of both industries investing strongly in low and zero emissions vehicles and technologies.

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[61] Government of Western Australia, *'Bus fleet goes electric with a $125 million State investment'*, Government of Western Australia website, 2023.
[62] Driving Insights, Electric trucks charging into Australia, *Driving Insights*, n.d.
[63] Transurban, *A smart move: Australia's first live-traffic automated truck trial*, Transurban website, 2022.

Australian-made electric trucks – SEA Electric

SEA Electric launched its first proprietary electric power-system technology for urban delivery and distribution fleets in 2017 and has since released multiple medium and commercial EV models with applications including delivery trucks, garbage trucks, tipper trucks, school and shuttle buses and cargo and passenger vans.[64]

Founded in Australia in 2012, SEA Electric is now headquartered in Los Angeles, serving markets in the United States, Canada, Australia, New Zealand, Asia and the EU, with numerous ongoing collaborations with leading OEMs and business fleets.

SEA Electric's Australian facility has commenced 100% Australian production of electric trucks supported by a national SEA Electric dealer network. Employing 50 staff, they have the capacity to manufacture 500 electric trucks a year.

The **lack of charging and refuelling infrastructure**, especially in rural and regional areas, limited reliable electricity infrastructure networks, and **long charging times** all remain barriers to the uptake of zero-emissions vehicles. Diesel trucks can refuel quickly at petrol stations, but publicly accessible hydrogen refuelling stations and charging stations remain sparse.[65] Battery electric trucks can also be slow to recharge, eating into the time a truck can spend on the road, making scheduling and rostering harder. This can have a significant impact on the productivity of a trucking business.[66] The limited range and long charging times for battery electric trucks mean that drop-in renewable diesel will likely be required for larger payloads and distances in the medium term. In the long term, hydrogen may be an option but will require the roll out of its own dedicated refuelling network.

The current **high upfront cost** of switching to a zero-emission truck is another barrier that suggests renewable diesel is likely to be needed as a transition fuel. This is because renewable diesel is a drop-in fuel that does not require the purchase of a new vehicle. The heavy vehicle industry works on tight margins. Pre-pandemic research puts the industry's median profit margin at just over 2%, with the bottom quartile of the industry either experiencing negative, flat or very tight profit margins.[67] This makes it challenging for the industry to invest in battery electric trucks, where the upfront cost can be twice that of a diesel equivalent. With the high price of heavy vehicles, this can represent an additional $200,000. As such, there may be opportunities to encourage business and single vehicle owners to adopt zero emission trucks through trials, subsidies, loans or other incentives.

The physical road infrastructure may need to support **increased mass on road pavements**. If reforms to mass limits are introduced to enable a wider range of low and zero emission trucks to operate without a productivity penalty, this will increase wear on roads and associated infrastructure, meaning road pavement upgrades and increased maintenance may be needed. This is likely to be especially critical given the potential for increased truck movements associated with the transition to net zero – construction of new infrastructure to support new renewable energy projects, critical mineral mines and factories, public transport projects and more – and rebuilding from floods, fires, storms and climate impacts.

A net zero pathway for heavy vehicles

To contribute to a net zero pathway, heavy vehicles will require a supply of low and zero-emission technologies and fuels, enabling infrastructure and incentives to shift demand away from diesel vehicles.

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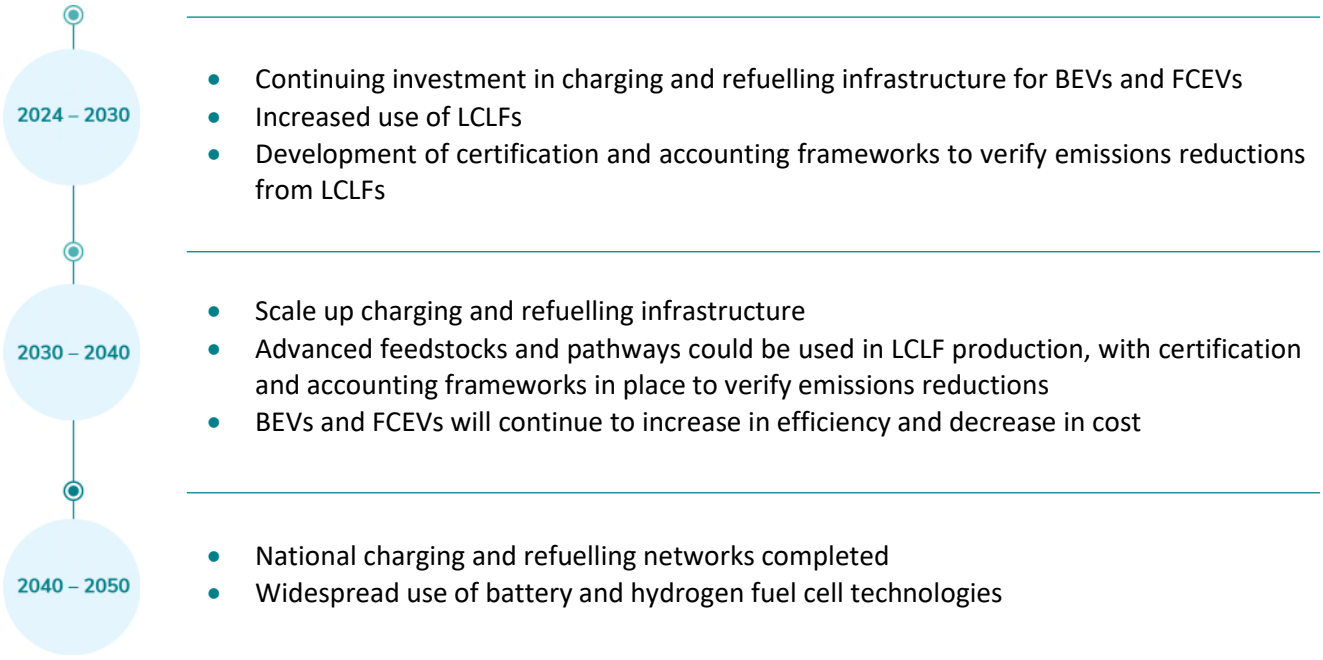
[64] SEA Electric, *About Sea Electric*, Sea Electric website, 2022.
[65] J Dowling, 'Australia's third hydrogen-car refuelling station to open within months, in Brisbane', *Drive*, 2021
[66] EVC and ATA, *Electric trucks: Keeping shelves stocked in a net zero world*, EVC and ATA, 2022.
[67] ATA, *Trucking Australia: The report* [PDF 4.0 MB], ATA, 2023.

In the short-term, Government will play a role in coordinating and providing clarity to the industry on transition aspirations and milestones, which can unlock investment certainty. Investment in the rollout of charging infrastructure needed for BEVs should begin in metropolitan areas, with consistent national regulatory requirements established. LCLFs will be blended in small volumes in conventional engines. The development of certification and accounting frameworks to verify LCLFs will also be necessary.

In the medium-term, establishment of advanced feedstocks and pathways could be used in LCLF production, with certification and accounting frameworks in place to verify emissions reductions. The transition will accelerate for early movers as infrastructure for BEVs continues to scale, along with increases in technology efficiency and decreases in cost. Guidance on the role of FCEVs and associated refuelling infrastructure will need to be established.

The long-term net zero future will require a completed national charging and refuelling infrastructure network. As industry adopts wide scale use of battery and hydrogen fuel cell technologies, industry reliance on liquid fuels will have peaked and will decrease. Government guidance and support for the last to transition could support improved safety and productivity outcomes for the industry.

Figure 11: A net zero pathway for heavy vehicles



Have Your Say

9. Do you agree with the proposed net zero pathway for heavy road vehicles?

    9.1. Please add details to your response.

10. The proposed pathway for heavy road vehicles relies on a mix of battery electric, hydrogen fuel cell and low carbon liquid fuels. Rank from 1 to 3 the order in which these should be prioritised for emissions reduction.

    10.1. Please add details to your response. Why did you rank them in that order?

11. What role should low carbon liquid fuels play in heavy vehicle decarbonisation?

12. What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to reduce heavy vehicle emissions?

    12.1. How would these actions address the identified challenges and opportunities to reduce heavy vehicle emissions?

3.3 Rail

Key points

- In 2023 rail emissions were 4 Mt CO_2-e.
- Rail is a low emissions mode of transport. Despite moving 57% of national freight and 4% of passenger traffic, Australia's rail network accounted for only 4% of transport emissions in 2023.
- An efficient and integrated rail system that supports Australia's passenger and freight tasks is crucial to our wellbeing and economic outcomes.
- The decarbonisation of our rail sector requires the roll-out of infrastructure to support hydrogen and battery-electric trains, and strong economic incentives to shift demand away from diesel locomotives. Low carbon liquid fuels (LCLFs), like renewable diesel, may be deployed for larger payloads and distances until the supporting infrastructure for electrification and hydrogen is in place.
- Increasing the share of freight moved on rail can also contribute to reducing freight emissions.

Australia's rail industry generates almost $30 billion in economic activity each year, and supports 165,000 direct and indirect Australian jobs.[68] The rail network operates across several passenger and freight markets, as discussed in Chapter 2.2, Movement of goods: decarbonising freight and supply chains. The freight task is generally split into bulk freight and non-bulk freight. Bulk freight involves large quantities of homogenous product, typically liquid or crushed solid material, transported en masse and without packaging. Non-bulk freight is any containerised or other unitised freight, such as pallets, motor vehicles and trailers, and uncrated live animals.

Passenger services are also split into two categories. Light rail refers to trams, streetcars, or other usually electrified methods of conveyance, whose rails are primarily on surface streets that are shared with other forms of transportation. Heavy passenger rail includes urban rail services, that enable the mass movement of passengers to, from and around capital city centres, as well as non-urban passenger services that include long distance connections between cities and regional centres, heritage railway travel for nostalgia and leisure purposes and tourist-focused services.

Rail plays an important role in alleviating transport congestion on urban transport networks. Weekday commuting around city areas is a key role for passenger rail. Across Australia's capital cities, rail carries 68% of the mass transport passenger kilometres.[69]

Since 2010, the demand for passenger rail had steadily increased by around 2% per year.[70] However, the COVID-19 pandemic saw a drop in patronage and a change in the travelling behaviour of public transport users. As more working from home arrangements are now in place, it is not yet clear how this trend will continue.[71]

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[68] NTC, *'Rail interoperability'*, NTC website, Australian Government, 2023.
[69] Engineers Australia, *Future of Rail: A Transport Australia Society Discussion Paper*, Engineers Australia, 2022.
[70] ARA, Value of Rail 2020, ARA, 2020.
[71] HS Munawar et al., Insight into the Impact of COVID-19 on Australian Transportation Sector: An Economic and Community-Based Perspective, 2021, *Sustainability*, doi.org/10.3390/su13031276.

Rail is a low emissions mode of transport – despite moving 57% of national freight and 4% of passenger traffic, Australia's rail network accounted for only 4% of transport emissions.[72] Research indicates one automated train in the Pilbara carries the equivalent of 631 B-Double trucks.[73] Rail handles most of our domestic freight task (Figure 12) but this is largely bulk freight, especially iron ore and coal, which represent over 75% of Australia's total rail freight volume by weight.[74] Rail also has the lowest emissions intensity of all freight modes (Figure 13).

Figure 12: Rail handles most of our domestic freight task…

Goods moved (in billion tonne-kilometres) across road and rail.

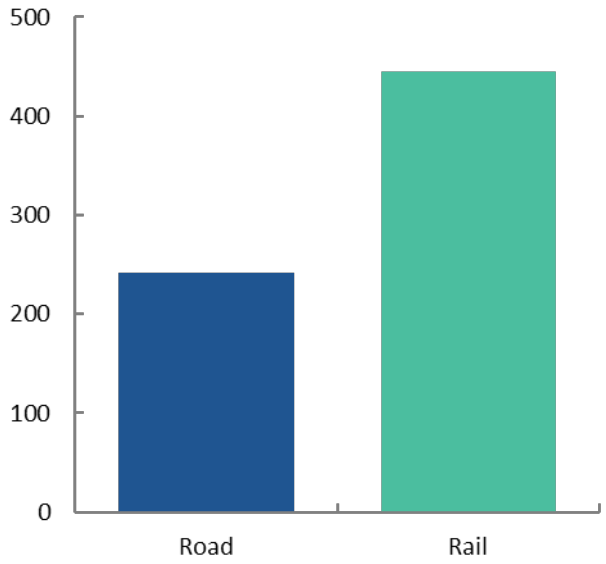
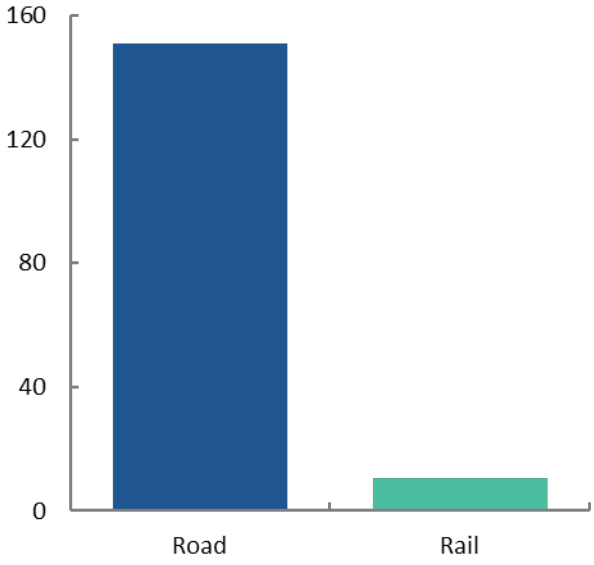


Figure 13: …and has the lowest emissions intensity of all freight modes.

Full fuel cycle (CO_2-e) emissions intensity of freight moved across road and rail measured in grams of CO_2-e per tonne-kilometre.



DITRDCA estimates using BITRE Australian Infrastructure and Transport Statistics - Yearbook 2023

Technologies to decarbonise rail transport

Electrification of the rail network is a mature and readily available solution. However, electrifying rail track infrastructure can be expensive, requiring high traffic use and shorter distances for financial viability. As such, the decarbonisation of our rail network will likely require some mix of these technologies:

Track Electrification 	Electrification is achieved through the construction of overhead lines or a third rail to connect electricity to an electric motor. Currently, 11% of operational railway in Australia is electrified, with the majority used for passenger transport. The rest of the operational railway relies on diesel. Electrified locomotives can take advantage of the rise of renewable energy in the electricity mix. However, investment in rail electrification is expensive and

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[72] Rail Industry Safety and Standards Board (RISSB), *National Rail Carbon Footprint Study*, RISSB, 2022; DCCEEW, *Australia's Emissions Projections 2022*, DCCEEW, Australian Government, 2022.

[73] ARA, Value of Rail 2020, ARA, 2020.

[74] BITRE, *Australian aggregate freight forecasts 2022 update (summary),* BITRE, Australian Government, 2022.

	requires high traffic use for financial viability. There are likely to only be limited opportunities for track electrification.
Hydrogen fuel cell 	Hydrogen fuel cell locomotives can play a role in decarbonising rail, provided the hydrogen is produced with low or zero emissions. Research, pilots, trials and demonstrations along the supply chain are occurring and will need to continue to provide social license and scale-up requirements for long-term development. Hydrogen can be stored in large quantities for long periods of time and is able to be released without contributing to atmospheric or water pollution.[75] There are also health benefits of not releasing noxious emissions.
Battery electric technologies 	Switching from diesel-electric locomotives to battery electric locomotives is a promising solution, although the range of a battery electric locomotive is much less than a diesel-electric locomotive. The technology has undergone substantial advances over recent years and will continue to develop.[76] Battery electric locomotives are being trialled internationally and BHP is conducting trials of four battery electric locomotives at its Western Australia Iron Ore rail network.[77] Due to the long asset life of locomotives, retrofitting the diesel engine with a battery in an existing locomotive is less expensive, and aligns with circular economy principles. In addition to battery electric locomotives, battery electric or hydrogen fuel cell electric tenders (additional vehicles carrying the fuel or power needed) could be used.
Low carbon liquid fuels (LCLFs) 	LCLFs, like renewable diesel, could be a potential short to medium term solution, which will allow the industry to use their existing diesel fleet while lowering emissions. LCLFs are considered later in this Roadmap in chapter 4. Low and zero CO_2-e ammonia could also be viable for rail transport. Compared to hydrogen, ammonia is easier to transport and store as it requires less cooling to liquify. Requirements for its safe production, storage and use are also well established. However, it is not a drop-in fuel, which means diesel engines need to be retrofitted to be compatible with the addition of ammonia to diesel. Using ammonia would require carrying three times the volume when compared to diesel to cover the same distance due to reduced energy density.[78]
Energy efficiency and optimisation 	Improved rollingstock design and optimised logistics can enhance overall efficiency, thereby reducing emissions. This could include regenerative braking; aerodynamic train bodies that reduce drag and fuel use; anti-idling technology such as stop-start systems; double stacking containers to increase carrying capacity; lubricating wheels to reduce friction; and retrofitting locomotives to emit fewer pollutants. While these technologies improve overall rail efficiency, they are limited in their capacity to decarbonise the sector if they still involve the use of fossil fuels. Regenerative braking, in particular, can lead to substantial CO_2 emission reductions when applied to full stop service commuter trains (8-17% emissions reduction), very dense suburban network trains (approximately 30%) and freight trains (21-55%).[79]

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[75] RISSB, *National Rail Carbon Footprint Study*, RISSB, 2022.

[76] R Knibbe, et al., Application and limitations of batteries and hydrogen in heavy haul rail using Australian case studies, *Journal of Energy Storage*, 2022, doi:10.1016/j.est.2022.105813.

[77] BHP, *BHP orders four battery-electric locomotives for WAIO rail network* [media release], BHP, 17 January 2022.

[78] Association of European Rail Rolling stock Lessors (AERRL) and RISSB, *Study on alternatives to fossil diesel use in railways: Presenting a roadmap for near-term decarbonisation* together, AERRL and RISSB, 2022

[79] United Nations Climate Technology Centre and Network (CTCN), *Regenerative braking in trains*, CTCN, United Nations, n.d.

Existing policies to reduce rail emissions

The Australian Government is improving the productivity and resilience of the national rail network. This will contribute to lower emissions and increase the attractiveness of moving freight on rail. Some rail freight operators are also captured by the Safeguard Mechanism.

The **National Rail Action Plan** aims to create a more seamless, productive and safe national rail network through the interoperable use of technologies, a national approach to skills and training and by harmonising standards of key rail interfaces so train control and signalling systems from different networks can talk to each other.

The government is investing over $15 billion in major rail projects from 2023-24 to 2032-33, such as **Inland Rail** and **High Speed Rail**. The **National Rail Manufacturing Plan** will focus on helping to grow a more globally competitive rail manufacturing sector that lifts productivity, improves social and environmental outcomes, and creates economic value.

Other investment funding and strategies will impact on the rail sector's decarbonisation pathway. The **$15 billion National Reconstruction Fund** will provide project finance to support, diversify and transform Australia's industry and economy. Existing and new clean energy industries will also be developed through the **$1.9 billion Powering the Regions Fund**. The **National Battery Strategy** will help create a globally competitive Australian battery industry, and Australia's **National Hydrogen Strategy** aims to position the industry as a major global player by 2030. Hydrogen and batteries will play a role in getting the rail sector to zero emissions.

Regulation, through **the Safeguard Mechanism**, sets legislated limits on the greenhouse gas emissions of Australia's largest industrial facilities, with a declining trajectory consistent with achieving Australia's emissions reduction targets. The policy currently captures a larger portion of the rail freight sector than road freight, which could disproportionately impact freight on rail despite it being a low-emissions mode. There are currently seven rail freight operators and two road freight operators covered by the Safeguard Mechanism.

Challenges and opportunities

Even though rail is a low emissions mode of transport, there are challenges limiting its further decarbonisation, as well as making it an attractive alternative to other modes of transport. Simply improving the reliability and resilience of the rail network could go a long way to making rail a more attractive mode of transport.

The long asset lives of rollingstock and rail infrastructure means the fleet takes a long time to change, although there are opportunities to retrofit freight rail with batteries. Promptly identifying the technology pathways will provide industry with policy certainty for decision-making. **Developing the supporting infrastructure is resource and investment intensive**. Rail infrastructure installation in regional Australia presents an opportunity to provide highly localised jobs in rural regions to install and maintain infrastructure, and support rollingstock.

In addition, the Australian rail network has historically been made up of a number of smaller, fragmented rail markets, as opposed to one central, national market.[80] The current network is operated and owned by separate state-based networks and private systems, consisting of 29 networks, three different railway gauges and 11 separate signalling systems. There is **varying interoperability of the network** across the country, imposing an administrative burden on operators, and an impediment to reform.

Inefficiencies associated with manufacturing railway products to different standards and specifications also acts as a deterrent to investment in innovation and larger scale manufacturing. The **National Rail Manufacturing Plan** seeks to address these

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[80] NTC, *National Rail Action Plan*, NTC, report prepared for the Transport and Infrastructure Council, 2022.

challenges by growing local manufacturing of passenger and freight rollingstock, and components that will meet Australian requirements.

The energy density of LCLFs and battery electric solutions are lower than diesel, meaning there would be a trade-off between range and capacity. The **high costs** of these technologies may also deter widespread adoption, which makes their deployment challenging. The rail sector will face competition from the aviation and maritime sector for LCLFs. Scaling up production is being addressed through the **Hydrogen Headstart Program, Hydrogen Hub funding** and other sources of assistance.

Increasing the share of freight moved on rail would decrease the emissions intensity of the freight task. The rail sector's ability to generate Australian Carbon Credit Units (ACCUs), as well as other policy options to incentivise mode shift should be explored. Mode shift from road to rail was also discussed in chapter 2.2, Movement of goods – decarbonising freight and supply chains.

A net zero pathway for rail transport

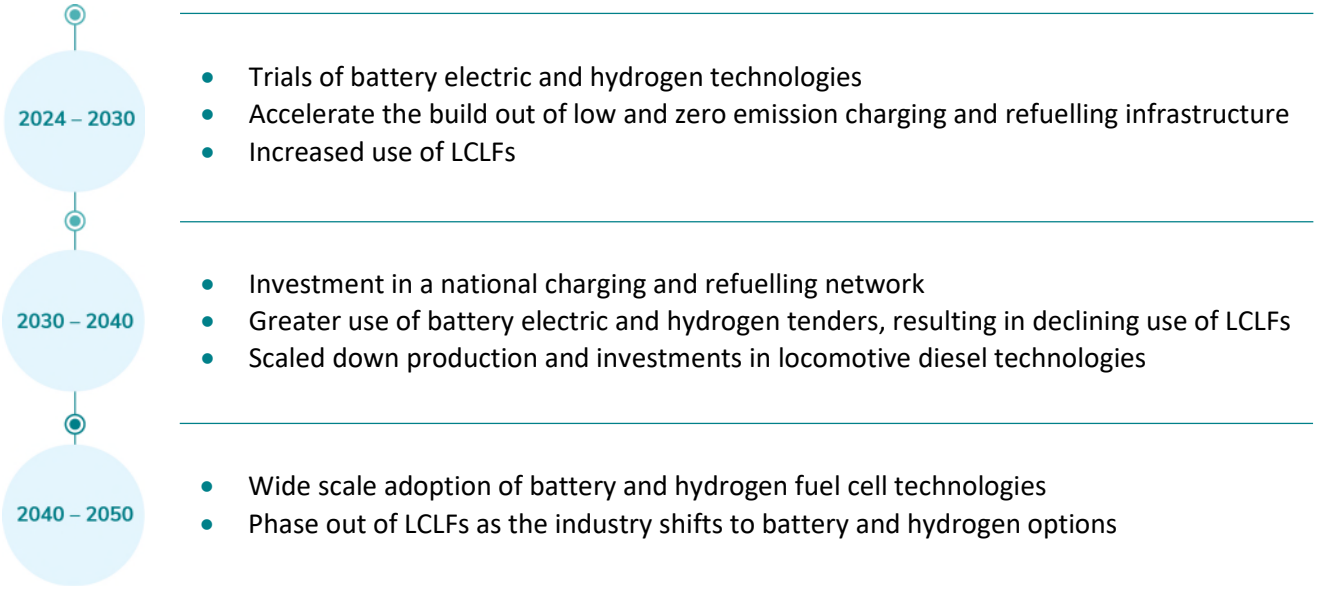
The decarbonisation of rail transport will require a supply of zero-emission technologies and the roll-out of enabling infrastructure as well as economic incentives to shift demand away from diesel locomotives. The rail sector will likely require a combination of technology improvements and pilot projects in the short-term to determine the pathway to the medium- and long-term solutions.

In the short-term, Government will play an important leadership role to test and establish future net zero pathways. Co-design of technology pathways and the enabling infrastructure investments, regulatory requirements and rolling stock standards will be needed. LCLFs could be used where alternative emissions reduction technology is not yet viable, while battery and hydrogen technology trials should begin to establish which use-cases they suit best. Investment and regulatory requirements for low and zero emission charging infrastructure should begin across the rail network.

In the medium-term, LCLFs should begin to decrease as battery and hydrogen technology expands. Where LCLFs are used, certification and accounting frameworks to verify emissions will be necessary. As domestic production capacity of battery and hydrogen technologies grows, investment will occur in a national refuelling and charging network, including hydrogen refuelling infrastructure.

The long-term net zero future will require a complete reduction in fossil fuels as industry adopts wide scale use of battery and hydrogen fuel cell technologies. A completed charging and refuelling network will support this.

Figure 14: A net zero pathway for rail



Have Your Say

13. Do you agree with the proposed net zero pathway for rail?

    13.1. Please add details to your response.

14. The proposed pathway for rail relies on a mix of battery electric, hydrogen fuel cell and low carbon liquid fuels. Rank from 1 to 3 the order in which these should be prioritised for emissions reduction.

    14.1. Please add details to your response. Why did you rank them in that order?

15. What role should low carbon liquid fuels play in rail decarbonisation?

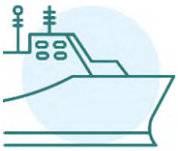
16. What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to reduce rail emissions?

    16.1. How would these actions address the identified challenges and opportunities to reduce rail emissions?

3.4 Maritime

Key points

- In 2023 domestic maritime emissions were 2 Mt CO_2-e. Domestic maritime emissions account for 2% of transport emissions. Consistent with international guidelines, emissions from international shipping are not included in Australia's domestic maritime emissions.
- The economic prosperity of Australia is deeply tied to international shipping, both in terms of exports and imports.
- Australia's reliance on international vessels for shipping services means international decisions, including through the work of the International Maritime Organization that Australia contributes to, will have great influence on decarbonising maritime transport. Australia will need to accommodate multiple energy sources and technologies, especially for international vessels refuelling at Australian ports.
- Maritime is a hard-to-electrify sector; it is unable to be completely electrified in the foreseeable future. Hydrogen-derived low and zero carbon fuels (such as green hydrogen, green ammonia, and e-methanol), low carbon liquid fuels (LCLFs), electrification, and energy efficiency and optimisation improvements will all likely be needed to decarbonise maritime transport.
- The Australian Government is taking action through the Maritime Emissions Reduction National Action Plan (MERNAP). The MERNAP will set the strategic direction and recommend actions to decarbonise our maritime transport sector, as well as contribute towards reducing international shipping emissions. The plan will seek to identify opportunities and future-proof the domestic maritime industry, ensuring Australia benefits from the global net zero maritime transition.
- The MERNAP will also help tie together a broad range of existing decarbonisation initiatives from government, ports and industry, providing a proactive strategy that seeks to effectively guide future investments.



Domestic maritime emissions are a small share of Australia's transport emissions

Maritime transport plays a vital role in trade and commerce, carrying approximately 80% of global trade by volume.[81] Maritime transport refers to the movement of goods and passengers over bodies of water using various types of vessels. Maritime activities include shipping, fishing, marine research, tourism (including cruise ships) and leisure activities.

As an island continent, Australia relies heavily on maritime transport for international trade. Ships transport over 99% of Australia's international trade by weight and around 87% by value.[82] Each year more than 6,000 cargo ships make over 30,000 port calls in Australia, across both coastal and international voyages.[83]

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[81] United Nations Conference on Trade and Development (UNCTAD), *Review of Maritime Transport 2021*, UNCTAD, United Nations, 2021.

[82] BITRE, *Ports: Job generation in the context of regional development*, BITRE, Australian Government, 2014; BITRE, *Australian Sea Freight 2020-21*, BITRE, Australian Government, 2023.

[83] BITRE, *Australian Sea Freight 2020-21*, BITRE, Australian Government, 2023.

For 2023, domestic maritime transport contributed around 2 Mt CO_2-e or 2% of transport emissions and around 0.4% of Australia's total emissions.[84]

Australia's share of global sea freight is 14%, but ships carrying our sea freight (irrespective of flag) contribute a lower share of 4% of global international shipping CO_2 emissions.[85] The lower emissions on average is because:

- a majority of Australia's trade commodities is dry bulk cargo, and large bulk carriers are generally more energy efficient compared to other vessel types
- the sailing distances between Australia and its main trading partners are relatively short – 92% of Australia's trade is with Asia (excluding South Asia).

International maritime emissions have been rising due to increased global trade and expanding maritime activities. The International Maritime Organization (IMO) projects that international shipping emissions will increase from about 90% of 2008 emissions in 2018 to up to 130% of 2008 emissions by 2050.[86]

Australia's reliance on international vessels for domestic shipping means international commercial decisions will have great influence on decarbonising our maritime transport.

Most maritime transport emissions are generated by the use of heavy fuel oils (HFO), which provide 79% of the energy associated with international shipping.[87] The remaining energy sources consist predominantly of other fossil fuel derived energy sources, mainly marine diesel oil (MDO) and liquified natural gas (LNG).

A range of technologies will likely be needed to decarbonise maritime transport

As a result of the diversity of the maritime transport sector both in Australia and internationally, a range of decarbonisation technologies will be required:

Hydrogen and hydrogen-derived fuels 	Hydrogen and hydrogen-derived fuels with low or no CO_2-e emissions, such as green hydrogen, green ammonia, and e-methanol will play a role in the decarbonisation of long-distance shipping. Currently, global production of these fuels relies heavily on coal and natural gas, but hydrogen-derived fuels can be made from renewable electricity and water and/or captured CO_2. Investment is being made in scaling up production of hydrogen-derived fuels and presents new commercial opportunities for domestic industry.
Electrification 	Battery electric technology may be suited for use in smaller vessels and other domestic maritime applications with shorter voyages. Battery electric technology will be highly limited by vessel size and voyage length. E-vessels, such as battery electric boats, sailing yachts, tug boats, ferries and smaller cargo ships, are already available and in use in other countries. Although advancements in battery technology are improving the feasibility and range of electric vessels, it is unlikely to be suitable for international shipping given the large vessels and distances involved.

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[84] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.

[85] DITRDCA, *Economic Analysis of Global Shipping Carbon Price Impacts on Australia's International Shipping Costs and Maritime-Dependent Trade*, report prepared by BMT Defence and Security Australia Pty Ltd, DITRDCA, Australian Government, unpublished, 2022.

[86] International Maritime Organization (IMO), *Fourth Greenhouse Gas Study 2020,* IMO, 2020.

[87] DCCEEW, Australian Energy Update 2023, DCCEEW, Australian Government, 2023.

Low carbon liquid fuels (LCLFs) 	LCLFs emit less emissions than conventional marine fuels, depending on the feedstock and production process.[88] LCLFs have the advantage of being a 'drop-in' fuel that does not require additional capital investment for vessel owners, which is relevant given the sector's typical long asset lives. The widespread adoption of LCLFs is limited by the availability of sustainable feedstocks. The use of LCLFs requires the application of strict sustainability criteria to prevent the use of biofuels that have high lifecycle emissions.
Energy efficiency and optimisation 	Improved ship design and optimised vessel operations can enhance overall efficiency, thereby reducing emissions. This can include hull optimisation, waste heat recovery, advanced monitoring systems, slow steaming and just-in-time port scheduling. Wind-assisted and solar-assisted propulsion can also reduce fuel consumption and emissions, but are unlikely to meet the full power requirements of large shipping vessels.

The Maritime Emissions Reduction National Action Plan will set the strategic direction and recommend actions to decarbonise our maritime transport

In the May 2023 Budget, the government committed to develop the **Maritime Emissions Reduction National Action Plan (MERNAP)** in FY2023-24. Informed by an industry co-design approach, the MERNAP will set the strategic direction, support national emissions reduction targets and signal to global trading partners Australia's practical pathway to zero emission shipping in our waters and ports. The plan will seek to identify opportunities and future-proof the domestic maritime industry, ensuring it is not left behind in the global zero emissions transition.


The MERNAP will tie together a broad range of existing decarbonisation initiatives, providing a proactive strategy that seeks to effectively guide future investments. Current actions to reduce maritime emissions include:

- investing in the development of **clean hydrogen industrial hubs near ports** to produce renewable hydrogen-derived fuels for domestic use and export (including for fuelling ships)
- reviewing and developing **responsive regulatory frameworks to accommodate technological advancements in the clean energy space**, including developing a domestic **Guarantee of Origin** (GO) certification scheme to track and certify emissions from locally-produced hydrogen
- engaging in **international partnerships** to establish hydrogen value chains and accelerate the deployment of low and zero carbon maritime technologies
- establishing **green shipping corridors** to support decarbonisation of shipping along defined routes
- working to sustainably manage 100% of our national waters, guided by a national **Sustainable Ocean Plan**, by 2025
- developing a **Maritime Single Window** to improve port efficiency and reduce emissions.

Further information about the MERNAP is available online.[89]

The government is also actively engaging with the IMO to reduce maritime emissions, including supporting the adoption of the 2023 IMO GHG strategy to reach net zero emissions by or close to 2050, with the interim checkpoints of reducing total annual emissions from international shipping by at least 20% striving for 30% by 2030, and 70% striving for 80% by 2040, compared to 2008 levels.[90]

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[88] USEPA (United States Environmental Protection Agency), *Economics of Biofuels*, USEPA, Federal Government of the United States, 2023.

[89] DITRDCA, *Charting Australia's Maritime Emissions Reductions*, DITRDCA, Australian Government, 2023.

[90] IMO, *2023 IMO Strategy on Reduction of GHG Emissions from Ships*, IMO, 2023.

Green shipping corridors

Green shipping corridors (GSCs) are practical, collaborative mechanisms to demonstrate low and zero emission vessels and fuel supply chains – accelerating their uptake. To support green shipping corridors, Australia is a signatory to the Clydebank Declaration for Green Shipping Corridors, which was launched at COP26 in November 2021. The Clydebank Declaration seeks to establish at least six green shipping corridors by the middle of the decade. At present, 24 countries have committed to the Clydebank Declaration.

Global interest and engagement in investigating and developing green shipping corridors is growing rapidly, with many new international value chain partnerships being established to support the fuels, technology, finance and capacity building necessary for shipping's energy transition.

In October 2022 Australia entered a new bilateral trade agreement with Singapore (the GEA) that includes measures to implement green shipping corridors using technology to decarbonise the maritime sector. A Memorandum of Understanding (MoU) on a Green and Digital Shipping Corridor was signed between the two Transport Ministers in March 2024. Under the MoU, both countries will work with interested partners to explore opportunities to develop zero or near-zero GHG emission fuel supply chains for the maritime industry, including building necessary infrastructure, formalising standards, and developing and implementing the training requirements.

At COP27 in November 2022, Australia joined other countries and industry in signing up to the Green Shipping Challenge, announced by the Norwegian and US governments in May 2022. The Challenge focuses on zero-emissions fuels and renewable energy infrastructure in the maritime industry.

Ports and industry have also committed to a broad range of decarbonisation initiatives. The MERNAP will seek to identify the roles that the government and industry can jointly play in decarbonising the domestic maritime sector. The plan will identify and support current government and industry initiatives, identify critical gaps and chart a vision for how Australia can contribute to, and benefit from, a decarbonised global maritime industry.

Challenges and opportunities

While progress has been made, barriers persist in Australia's maritime transport decarbonisation efforts. A significant challenge is that current low carbon technologies are in the early stages of technological development and deployment. **LCLFs have lower energy densities** compared to conventional marine fuels, meaning there also needs to be a trade-off between range and capacity for larger storage volumes of fuel and more frequent refuelling will be necessary, impacting productivity.

Adopting low carbon maritime energy sources and technologies entails **significant upfront and ongoing costs** for vessel owners and operators, which can deter widespread adoption, especially considering the industry's slim profit margins and market uncertainties. There is currently a large price gap between drop-in LCLFs and conventional fuels. There are further costs associated with **infrastructure development**. Building the necessary bunkering and recharging infrastructure for hydrogen-derived fuels and battery electric vessels is time-consuming, expensive and technically complex. Many ports are also located in areas where there is limited land available for the development of this infrastructure. Shore power will also need to be implemented as an emissions control measure in ports that provides ships with a connection to the local land-side power grid, rather than utilising the ship's engines when at berth.

An additional challenge is **the long asset lives of vessels.** This means it takes longer for new, more efficient technologies to be introduced into fleets. However, retrofitting will be possible for many ships and technologies.

Finally, the **global nature of maritime transport** means that the decarbonisation of international shipping requires coordination across multiple jurisdictions; for example, in developing appropriate bunkering facilities along deep-sea shipping routes, and consistent global regulatory frameworks. Reaching consensus and implementing effective global regulations through the IMO is a complex undertaking. Australia has a role in pushing for ambitious measures in the IMO to help decarbonise the international fleet.

Policies need to be targeted at addressing these barriers. At the same time, the decarbonisation of the maritime sector provides significant opportunities for Australia. Support for hydrogen and LCLF supply chains can de-risk and service multiple sub-sectors at ports, regional centres and hydrogen hubs (servicing road and rail) which can support employment growth in regional Australia. There are also **employment opportunities** for domestic manufacturing to support the production of low emissions domestic public transport vessels. Australia also has an opportunity to become a **green bunkering hub**, decarbonise our supply chains more efficiently than our trading competitors and create new workforce opportunities.

A net zero pathway for maritime transport

To contribute to a net zero pathway, the maritime transport sector will likely require a combination of technology improvements and pilot projects in the short-term to determine the pathway to the medium- and long-term solutions. The pilot projects should prioritise low and zero carbon propulsion technologies on short routes and coastal shipping operations. Government is already initiating this work with a national strategy to coordinate and set guidance for industry.

In the medium-term, it is expected that Government and industry investment priorities and transition milestones will be possible, based on evidence from trials and pilot projects. Widespread adoption of electric vessels for short route tasks, and hydrogen-derived low and zero carbon fuels will be more widely used, supported by the expansion of shore power and refuelling infrastructure connected to a low carbon electricity grid.

The long-term net zero future will require delivery of zero-emissions port and vessel infrastructure and removal of regulatory barriers to see a significant increase in national electric short haul vessels and vessels powered by hydrogen-derived low and zero carbon fuels.

Figure 15: A net zero pathway for maritime

- Pilot projects of low and zero carbon propulsion technologies on short routes and coastal shipping operations
- Vessel new-builds and retrofits prioritise low and zero carbon propulsion technologies
- Improved battery technology extends the range and efficiency of small electric vessels
- LCLFs are used in some small vessels
- Development of certification and accounting frameworks to verify LCLFs

- Widespread adoption of electric vessels for short routes, including public transport
- Greater use of hydrogen and hydrogen-derived fuels
- Expansion of shore power infrastructure

- Significant increase in vessels powered by hydrogen and hydrogen-derived fuels
- Zero-emission ports
- National electric short haul vessel charging network

Have Your Say

17. Do you agree with the proposed net zero pathway for maritime?

    17.1. Please add details to your response.

18. The Australian Government is engaging in consultation as part of the development of the Maritime Emissions Reduction National Action Plan and those consultations will also inform the final Roadmap and Action Plan.

    18.1. What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to reduce maritime emissions?

    18.2. How would these actions address the identified challenges and opportunities to reduce maritime emissions?

3.5 Aviation

Key points

- In 2023, domestic aviation emissions were 9 Mt CO_2-e. Domestic aviation emissions account for 9% of transport emissions. Although emissions from international aviation are not included in Australia's domestic aviation emissions, international flights departing from Australia in 2019 produced 14 Mt CO_2-e.
- Sustainable aviation fuels (SAF) are a key technology for reducing emissions in the aviation sector. There is an opportunity to encourage the development and deployment of SAF and other low carbon liquid fuels. Reducing the carbon intensity of liquid fuels with certification that verifies emissions abatement would ensure genuine emissions reduction in the aviation sector. Other technologies such as battery electric and hydrogen powered aircraft are promising and will be trialled in Australia by regional domestic airlines.
- The Australian Government is working with industry stakeholders, including through the Australian Jet Zero Council, to examine issues related to the Australian aviation industry's transition to net zero emissions, and is developing the Aviation White Paper that will look at how to maximise aviation's contribution to achieving net zero carbon emissions through SAF and emerging technologies.
- Australia is supporting International Civil Aviation Organization (ICAO)-led initiatives to reduce emissions from international aviation while still facilitating growth in the industry. ICAO has agreed the long-term aspirational goal of net zero carbon emissions for international aviation by 2050.

Aviation underpins our national and international supply chains, people-to-people links and trade, including our tourism, manufacturing, resources and higher education sectors. Tourism is particularly dependent on aviation, along with high value, low volume freight.

Prior to COVID-19, the aviation sector annually contributed around $20 billion to the economy, employed around 90,000 people and transported 42.1 million international and 61 million domestic passengers.[91]

Emissions from domestic aviation were 8 Mt CO_2-e in 2019, or 8% of total transport emissions.[92] After dipping to 4 Mt CO_2-e in 2021 at the height of the COVID-19 pandemic, activity has increased from pre-COVID-19 levels (to 9 Mt CO_2-e) in 2023.[93]

Emissions are projected to grow steadily in line with population growth, increasing the demand for domestic flights. Emissions are projected to peak in 2027, after which they are expected to decline to 8 Mt CO_2-e in 2035. Emissions from domestic aviation are from flying only and do not include emissions from airports and ancillary services.

International flights departing from Australia in 2019 produced 14 Mt CO_2-e.[94] For both international and domestic flights, Australia has one of the highest per capita CO_2-e emissions (495 and 267 kg respectively in 2018).[95] This is due to our geographic isolation (meaning Australians fly longer on average) and high propensity to travel.

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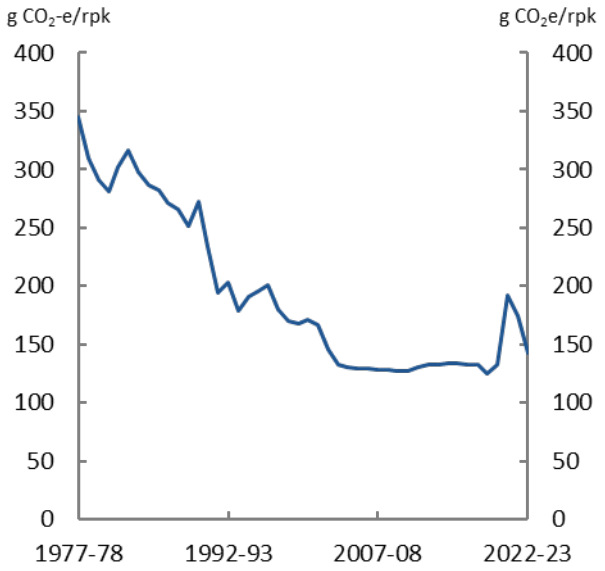
[91] Australian National Audit Office (ANAO), *COVID-19 Support to the Aviation Sector*, ANAO, Australian Government, 2022.
[92] DCCEEW, *Australia's emissions projections 2023*, DCCEEW, Australian Government, 2023.
[93] BITRE, *Australian Infrastructure and Transport Statistics - Yearbook 2023*, BITRE, Australian Government, 2023.
[94] DITRDCA, *Australia's State Action Plan – International Civil Aviation Organization (ICAO) Assembly Resolution A37-19 on Climate Change*, DITRDCA, Australian Government, 2022.
[95] H Ritchie, *'Where in the world do people have the highest CO_2 emissions from flying?'*, Our World in Data, 2020.

As a sector with limited electrification opportunities except for on short, regional routes due to propulsion, weight and energy density limitations, aviation faces unique challenges in reaching its decarbonisation goals. That is why sustainable aviation fuels (SAF) will be critical for the aviation sector.

Figure 16: Despite the falling emissions intensity of aviation...

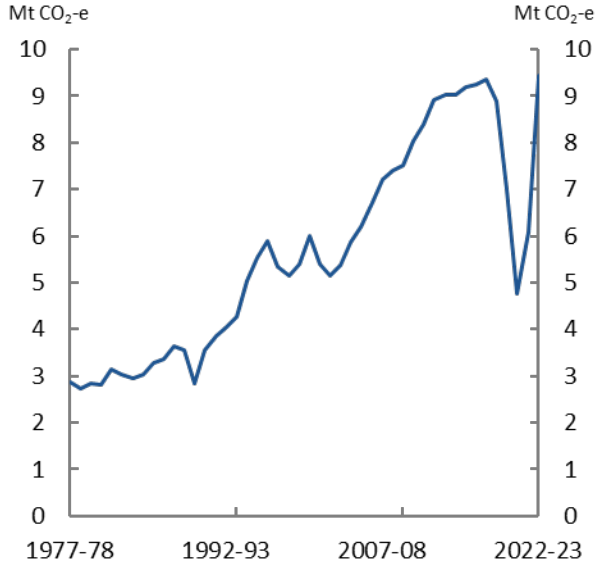
Emissions intensity per revenue passenger kilometre travelled, measured in grams of CO_2-e per revenue passenger kilometre.



Source: DITRDCA estimates using BITRE 2023 Yearbook data

Figure 17: …aviation emissions are rising due to the increased volume of air travel.

Domestic aviation emissions (including general aviation) measured in megatonnes of CO_2-e.



Source: BITRE 2023 Yearbook

Sustainable Aviation Fuel is the primary pathway to decarbonise aviation

SAF is a low carbon liquid fuel (LCLF) that is an umbrella term for aviation fuels derived from non-fossil sources or 'feedstocks'. It is a 'drop-in' fuel that can be directly substituted for jet fuel using existing aircraft and airport refuelling infrastructure, and can be blended with conventional jet fuel. Potential feedstocks include canola seeds, municipal solid wastes and tallow. SAF procured from these biogenic feedstocks can reduce 17-94% of carbon emissions over the fuel's lifecycle compared to traditional jet fuel (with reductions determined by the feedstocks used, production methods and supply chains).[96]

In the longer term, third and fourth generation biofuels as well as synthetic SAF will get closer to a 100% reduction in lifecycle emissions. The outlook for SAF in the short, medium and long term can be found in Appendix A.

Australia could develop a local SAF industry; it is estimated that domestic feedstocks are potentially sufficient to produce up to 60% of Australia's current jet fuel demand, with a value of roughly $10 billion.[97] A SAF industry could also produce by-products such as renewable diesel, naphtha and gasoline lubricants and lighter hydrocarbons, allowing other local industries to access low-carbon alternatives.

Building on consultation undertaken through the Aviation White Paper, the Australian Government will be undertaking targeted consultation to identify options for production incentives to support the establishment of

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[96] BNEF, *Sustainable Aviation Fuel: Pathways to Production,* BNEF, 2021.
[97] CSIRO, Sustainable Aviation Fuel Roadmap, CSIRO, Australian Government, 2023.

a made in Australia low carbon liquid fuel industry, including through the release of a Low Carbon Liquid Fuels consultation paper. Feedback heard through this process will also inform development of the final Transport and Infrastructure Net Zero Roadmap and Action Plan.

Several studies are underway in Australia looking at the feasibility of an Australian SAF industry.[98] Key issues identified in these studies include the reliability of feedstock sources; the cost of production and final cost of SAF to potential users; supply chain, transport and infrastructure storage requirements; and the markets which Australian SAF producers would be looking to cater for, including Australia's domestic, regional and general aviation operations, international airline operations out of Australia and export markets overseas.

Although SAF will be the primary decarbonisation pathway for jet aircraft, there are several opportunities to reduce aviation emissions in conjunction with the use of SAF:

Battery powered aircraft 	Battery-powered aircraft may be able to increase services to regional Australia in the future. In the short-term, this technology is likely to be restricted to smaller aircraft with propellers operating over shorter distances with low payloads, whether that be for flight training, short-haul passenger and freight services or regional and agricultural work. In the intermediate term emerging advanced air mobility services, so-called 'air taxi' operations, are expected to start service in a small number of cities overseas from around 2025. These will provide 2-4-person commuter flights to avoid road traffic congestion. The major barriers to this technology lie in the range and payload (passengers or freight) due to the weight of the batteries and their energy density.
Hydrogen 	Hydrogen shows some promise for replacing short- and medium-haul flights, as well as in general aviation, where the low energy density of hydrogen is less problematic. Hydrogen fuel cell powered aircraft may also be particularly well suited to Australia's regional aviation needs, where smaller aircraft are required. Using new fuels such as hydrogen for longer-haul flights would face significant technological and supply chain challenges, such as developing onboard hydrogen storage and establishing large-scale domestic green hydrogen production and distribution. Creating refuelling and recharging infrastructure and large-scale manufacturing capabilities will require time and investment, and costs are currently unclear.
Flight alternatives 	Modal shift towards alternative transportation methods like low emission road transport, high-speed rail and increased use of videoconferencing could reduce domestic demand for flights, consequently leading to emissions reduction. However, our dispersed population and geographical isolation from the rest of the world limit alternatives to flights.
Operational and efficiency gains 	Engine and aerodynamic efficiency gains are reducing greenhouse gas emissions from aviation. New technology step changes will further improve the fuel efficiency of aircraft. This is achieved through aerodynamic improvements to aircraft to reduce drag or to increase the fuel burn efficiency of engines. Each new generation of planes has been estimated to reduce fuel use, and therefore emissions, by 15-20%.[99] Both Qantas and Virgin Australia are renewing fleets, and while they are deriving benefits through efficiency measures, these aircraft are likely to be in operation for many decades.

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[98] J Simons, *IFM Investors & Graincorp announce renewable fuels initiative*, GrainCorp, 2023.

[99] International Air Transport Association (IATA), *Net zero 2050: new aircraft*, IATA 2023.

High-quality carbon offsets 	Carbon offsets are widely used in aviation, especially for international aviation as part of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Offsets are generated by projects that reduce, remove, or capture atmospheric greenhouse gas emissions. Offsets are a measure to achieve net emissions reductions, rather than a measure to decarbonise aviation. These projects, such as reforestation, cancel out some or all CO_2 emissions from flights. Technological advancements have increased the carbon accounting legitimacy of offset projects and demand has grown with net zero targets. Offset projects in Australia are registered under the Australian Carbon Credit Unit Scheme, administered by the Clean Energy Regulator. Offsets will play a role in the near-term as other technologies scale and in the long-term to address residual CO_2 emissions. Under the Safeguard Mechanism reforms, facilities using offsets for more than 30% of their requirements must submit a statement to the Clean Energy Regulator setting out why onsite abatement hasn't been undertaken. This may drive uptake of SAF and other decarbonisation measures where available.
Airport operations 	Ongoing efficient air traffic management by Airservices Australia can reduce unnecessary time spent by aircraft in the air or in taxi, avoiding additional emissions. Airports can also prioritise reduction of their operational emissions through the electrification of ground vehicles and facilities.

The aviation industry is committed to decarbonisation. For example, both Virgin Australia and Qantas have committed to net zero by 2050. Qantas is aiming to operate on a fuel mix that includes 10% SAF by 2030. Qantas has also established a $400 million Climate Fund to direct investment in solutions that will help it to achieve its climate ambitions. The fund incorporates a partnership with Airbus to invest in SAF and feedstock initiatives to accelerate the establishment of a SAF industry in Australia. Virgin Australia is going through a process to renew its fleet, and has ordered 33 new aircraft with significantly better fuel efficiency compared to its existing fleet. In addition, Regional Express Airlines has entered a strategic partnership with Dovetail Electric Aviation to investigate the conversion of conventional turbine aircraft to electric propulsion systems. Flight testing is expected in 2024.

Existing policies to decarbonise aviation

The Australian Government is approaching aviation decarbonisation from multiple angles including domestic and international leadership opportunities, investment in development of a SAF industry and ensuring that an effective regulatory environment is ready to support aviation decarbonisation.

The **Safeguard Mechanism** is the government's policy for reducing emissions at Australia's largest emitting facilities. Qantas and Virgin Australia make up 95% of Australia's domestic aviation market share and, under the Safeguard Mechanism, will be required to limit the net greenhouse gases they emit, declining predictably and gradually on a trajectory consistent with Australia's emission reduction targets. As such, the impact of the Safeguard Mechanism on the sector is significant.

The **Guarantee of Origin Scheme** is a world-class assurance scheme being designed to track and verify emissions associated with hydrogen, renewable electricity and potentially other products made in Australia. Over time, it could expand to include a range of fuels, including SAF.

The government established the **Australian Jet Zero Council** in 2023 to bring together a cross-section of stakeholders from across the aviation sector and provide advice to Government on industry's transition to net zero emissions. The **Aviation White Paper**, expected to be released in mid-2024, will outline the government's policy to maximise the aviation sector's contribution to

achieving net zero carbon emissions, including through SAF and emerging technologies. Further information about the Aviation White Paper is available online.[100]

The **CSIRO Sustainable Aviation Fuel Roadmap** highlights the potential opportunities for Australia to build a SAF industry, including opportunities to produce and scale production using Australian feedstocks.

A range of funding for aviation decarbonisation exists, including the Australian Renewable Energy Agency (ARENA) **Sustainable Aviation Fuel Funding Initiative**, which will provide up to $30 million in grants to support development of a SAF industry. ARENA is also deploying the $2 billion **Hydrogen Headstart** program to commercialise renewable hydrogen, which could contribute to aviation decarbonisation. The $1.9 billion **Powering the Regions Fund** will support decarbonisation of existing and creation of new industries. The $15 billion **National Reconstruction Fund** will provide finance for projects that diversify Australia's industry and economy, with transport included as a priority funding area.

On the global stage, Australia is supporting **International Civil Aviation Organization (ICAO)-led initiatives to reduce emissions from international aviation** while still facilitating growth in the industry. ICAO has agreed to a long-term aspirational goal of net zero carbon emissions for international aviation by 2050.

Australia has been participating in the ICAO's **Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)** since it commenced in 2019, with the support of our international airlines. The scheme requires international airlines to monitor and report their emissions and to offset emissions that exceed a global baseline. Under CORSIA, airlines can reduce their offsetting requirements through the use of certified SAF or other lower carbon aviation fuels.

Challenges and opportunities

The aviation sector faces several challenges on its path to decarbonise both domestically and internationally.

Continued fleet renewal will be required to reduce emissions. However, modern aircraft have useful lives of about 20-30 years which means the choices airlines make to renew fleets today will have an emissions impact well into the future. There is also some uncertainty on the **commercial viability of hydrogen and electric propulsion aircraft**. Although these technologies are promising and may replace short haul and regional flights in the future, further research and development into these options could provide a better range of options to decarbonise aviation. Trials of both electric propulsion and hydrogen fuel cell technology supported by regional airlines will occur in Australia in 2024.[101] Although SAF is a drop-in fuel and doesn't require new aircraft, there are still difficulties with SAF as the primary pathway to decarbonising aviation.

A major challenge is the **current cost of SAF**, which can range from being two to four times more expensive than traditional jet fuel. As fuel is a significant part of airline operating costs, bringing the relative cost of SAF down from current levels will be an important element of future work in the global production of SAF. There are also challenges around the reliability of feedstocks and the development of markets for Australian SAF producers.

SAF is only produced in a few countries with barriers to international production including the high costs of initial investment, first mover financial risks and commercial uncertainty associated with obtaining finance and longer-term feedstock supplies. Strong Guarantee of Origin certification mechanisms will be needed to ensure production of feedstocks for SAF does not impact on use of arable land for food crops.[102]

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[100] DITRDCA, *Aviation White Paper*, DITRDCA, Australian Government, 2023.
[101] S Green, Rex Airlines announces plan to retrofit existing fleet with electric-propulsion engines in regional trial, *ABC News*, 27 July 2022.
[102] CSIRO, *Sustainable aviation fuel opportunities for Australia*, CSIRO, Australian Government, 2023.

Another key challenge is the significant number of potential sources of SAF, which provide different levels of life cycle reductions in carbon emissions. Not all SAF is created equal and lifecycle emissions should be accounted for. Depending on the feedstock used in the production process, emissions can be higher than that of fossil jet fuel. The absence of certification and accounting frameworks **to verify and measure emissions reductions claims** could lead to SAF use that doesn't reduce emissions.

However, these challenges can produce opportunities for Australia. In particular, **a new Australian SAF producing industry** could provide SAF for domestic aviation, international airlines operating in Australia and for export to other countries in the region. Such an industry could provide employment opportunities, including regional areas, as well as providing sovereign fuel security to the Australian industry.

There is also the opportunity to create a **local manufacturing industry** to support electric and hydrogen aircraft. This would diversify Australia's economy and also complement existing manufacturing in clean energy technology (batteries, electric engines, light-weight composite fibres, and hydrogen fuel cells). There is a social expectation that aviation will reach net zero. Industry investment and commitment to net zero highlights the sentiment of shareholders and customers wanting greater action to decarbonise.

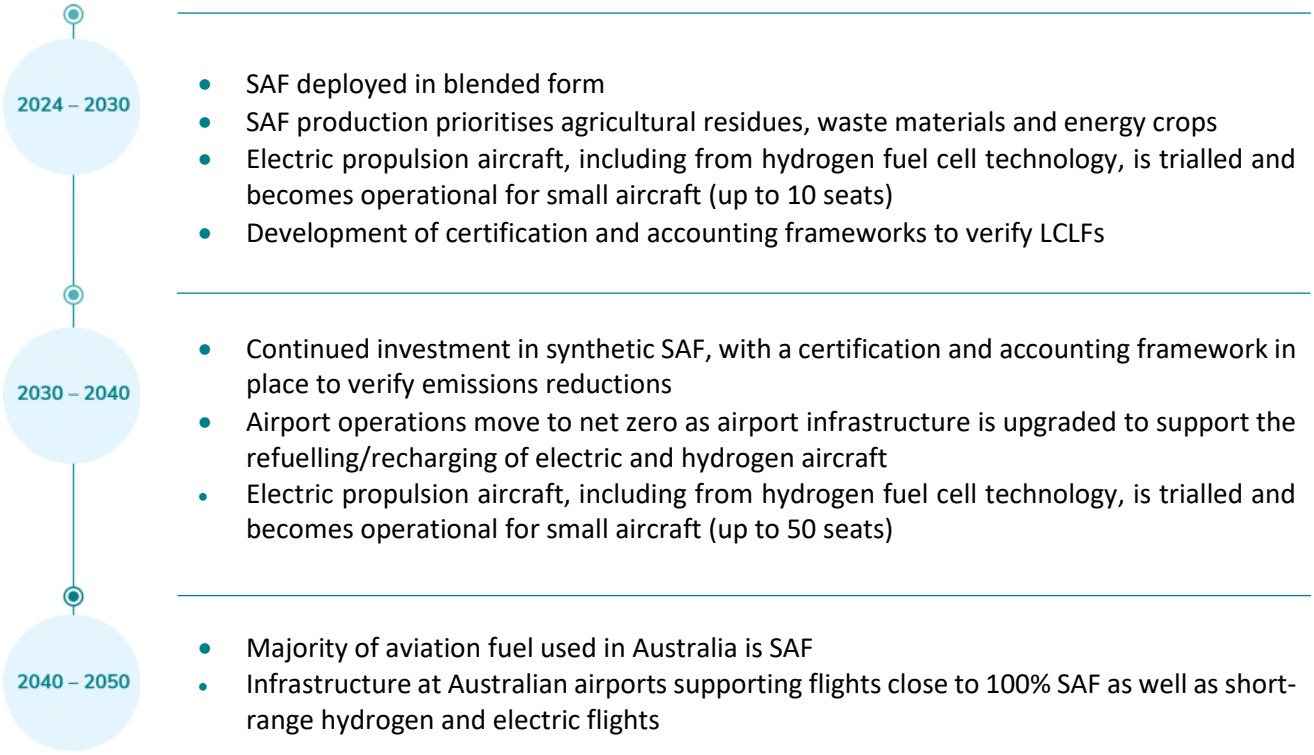
A net zero pathway for aviation

To contribute to a net zero pathway, the aviation sector will rely heavily on SAF. In the short-term, SAF will be deployed in blended form, using conventional aircraft engine technology, while investment supports scaling up of electric and hydrogen-powered technology pilots. Airport operations should begin to electrify, powered by on-site renewable energy where available. Investment into a domestic SAF industry could also support other local industries to access low-carbon alternatives such as renewable diesel, naphtha and gasoline lubricants and lighter hydrocarbons. Australia will need to establish certification and accounting frameworks to verify emissions reduction for SAF production.

In the medium-term, investment in domestic SAF production will have evolved to advanced feedstocks and pathways. Airport infrastructure should continue to be upgraded, as hydrogen and electric propulsion flights move from demonstration pilots to small aircraft use-cases.

In the long-term, the majority of aviation fuel used in Australia will be SAF. A domestic SAF industry could continue to develop. Infrastructure at Australian airports will support short-range hydrogen and electric flights.

Figure 18: A net zero pathway for aviation



Have Your Say

19. Do you agree with the proposed net zero pathway for aviation?

    19.1. Please add details to your response.

20. The Australian Government has already engaged in consultation on aviation decarbonisation through the development of the Aviation White Paper and those consultations will also inform final Roadmap and Action Plan.

    20.1. What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to reduce aviation emissions?

    20.2. How would these actions address the identified challenges and opportunities to reduce aviation emissions?

4. Supporting transport's net zero pathways

There are several key inputs and enabling policies that are essential to transport achieving net zero, including appropriate and decarbonised transport infrastructure, availability of low emissions energy (electricity and low carbon liquid fuels) and the operation of carbon markets. This chapter considers transport infrastructure and transport's energy use.

4.1 Transport infrastructure

Key points

- Decarbonisation of transport infrastructure is important to achieving Australia's net zero goals. Transport infrastructure is estimated to account for 3% of Australia's total emissions.
- Transport infrastructure (such as road, rail, ports and airports) produces greenhouse gas emissions from building, operating and decommissioning infrastructure. Infrastructure consumes more than half of the world's materials produced annually. Emissions are mostly produced through the production of construction materials, such as cement, aluminium, and steel.
- Infrastructure also enables various sectors. Decisions around what infrastructure to build where influences the emissions emitted by certain transport sectors; for example, the building of roads will increase the emissions from light and heavy vehicles by enabling this transport mode.
- To decarbonise transport infrastructure, the main emission reduction pathways are through materials (to use low-carbon input materials such as green steel, concrete/cement, asphalt, aluminium and low carbon recycled materials), or by design (through circular economy principles such as no-build situations, better maintenance, refurbishment, or using more efficient planning, design, and building techniques). This requires better data on the embodied emissions in infrastructure materials.
- Focus should also be given to infrastructure's role in enabling other forms of transport, particularly low carbon transport modes, as well as transport network planning and project selection frameworks (for increased efficiency in the movement of goods and people). This will require further consideration of investment priorities by all levels of government.
- Through the Infrastructure Policy Statement, the government is setting decarbonisation as a priority outcome for its transport infrastructure investments, to set the standard throughout the transport infrastructure industry. One of the three strategic themes guiding Commonwealth investment in land transport infrastructure projects is sustainability, which includes reducing transport infrastructure emissions.

Infrastructure, across the energy, transport, water, waste, digital communications and building sectors, is related to 79% of all greenhouse gas emissions globally.[103] Key building resources, such as cement, steel and aluminium, are high in emissions intensity and their decarbonisation poses challenges. Globally, infrastructure consumes more than half of the world's produced materials each year, with G20 countries responsible for around 70% of this

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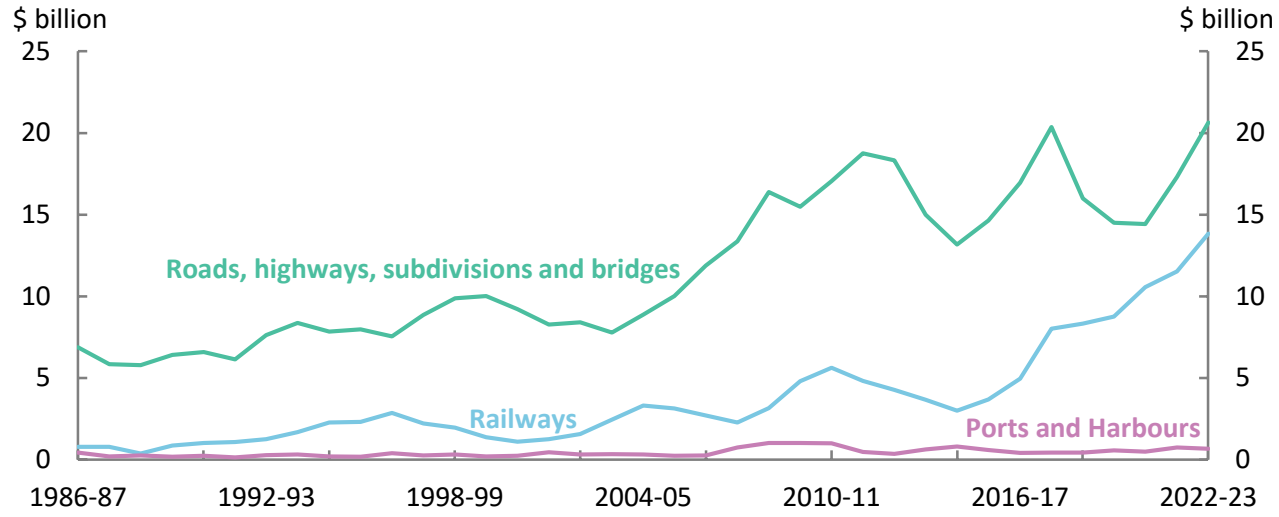
[103] UNOPS (United Nations Office for Project Services), *Infrastructure for Climate Action*, UNOPS, United Nations, 2021.

consumption.[104] Worldwide material consumption is expected to increase in the infrastructure sector by 68% by 2060 compared to today.[105]

Transport infrastructure includes roads, railways, ports and airports. It refers to all types of built, public infrastructure used by vehicles. Figure 19 shows the investment from governments in different types of transport infrastructure.

Figure 19: Most of Australia's transport infrastructure investment is in roads

Total value of public sector transport infrastructure engineering and construction work done (by the private sector for the public sector and by the public sector), adjusted by chain volume index, 2022-23 prices.



Source: BITRE Australian Infrastructure and Transport Statistics - Yearbook 2023

Transport infrastructure planning and building is guided by Commonwealth, state, territory and local government investment and planning, as well as private investment. Operation, maintenance and decommissioning of infrastructure assets is also spread across various public and private stakeholders, depending on the ownership of the transport asset and transport network.

While governments and industry are progressing various initiatives to reduce emissions from the construction of infrastructure, there is a need for greater coordination and a national approach to ensure consistent decarbonisation. The choices made for transport infrastructure projects and network planning will have a major impact on the emissions, productivity and effectiveness of our transport networks into the future, as well as our cities and regions.

As acknowledged in the State of Australia's Regions Report 2024, land transport infrastructure is a fundamental enabler of productive, connected and inclusive communities and economies. It connects people, places and services, while facilitating the distribution of significant quantities of goods – across agriculture, resources and manufacturing – throughout Australia and around the world. Different infrastructure will also be needed in different places, depending on local priorities such as economic opportunities, the landscape, and climate. For some regions, the focus will be on infrastructure investment to help drive economic growth, for example investment in port and rail facilities to unlock export opportunities in emerging sectors. Australia's national energy transformation investment through Rewiring the Nation, the National Hydrogen Strategy and other investments to unlock Australia's potential as a renewable energy superpower will need to be supported by low emissions transport infrastructure.

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[104] Global Infrastructure Hub (GIHub), *Infrastructure consumes more than half the world's materials - it will be key to advancing sustainable production and consumption*, GIHub, 2021.

[105] Global Infrastructure Hub (GIHub), *Infrastructure consumes more than half the world's materials - it will be key to advancing sustainable production and consumption*, GIHub, 2021.

In other regions, new or upgraded roads may be required to respond to extreme weather events, ease traffic congestion resulting from strong population growth, increase the resilience of supply chains, or improve safety for road users and local residents. In particular, transport infrastructure also faces significant resilience and adaptation challenges from the changing climate. For example, bushfires across Australia have highlighted the fact that roads and associated infrastructure are critical enablers of bushfire prevention, preparation, response and recovery activities, while also highlighting the vulnerability of road infrastructure and transport networks for people and goods during and after a bushfire. Flooding has resulted in the closure of railways (for example, the Trans-Australian Railway in early 2022), prompting the prevention of goods from reaching markets, causing shortages and economic losses. Increased natural disasters, rising temperatures, and rising sea levels will require infrastructure to be built with improved resilience and forward-planning to withstand such challenges and cater for the changes these cause to the movement of people and goods on Australia's transport network.

One challenge for road infrastructure that was considered earlier in this Consultation Roadmap is that low and zero emission trucks are currently heavier than the existing truck fleet. The increased mass of these trucks is expected to result in increased road wear. Although the extent of increased wear is unknown – as are the costs associated with repairing any damaged roads – governments will need to consider the impact of heavier vehicles on our roads, including cases where road pavement upgrades may be needed to accommodate the increased mass of these vehicles.

Transport infrastructure will also have to respond to other economic and social challenges, such as population growth and urbanisation straining existing networks, as well as challenges associated with delivering transport infrastructure in parts of regional and remote Australia. In responding to these challenges, there will be employment opportunities from transitioning our transport infrastructure.

Three categories of emissions from transport infrastructure

Greenhouse gas emissions from transport infrastructure can be considered in three categories:

- **Enabled emissions** — from the use of infrastructure (for example, cars on roads).
- **Operating emissions** — from the energy use of the asset during the use stage (for example, electricity used at train stations).
- **Embodied emissions** — from construction activity and materials.

Cumulatively, these are known as whole-life emissions. They account for all the emissions released during the entire lifecycle (project scoping, selection, design, construction, operation, and decommissioning) of a transport asset.

Operating and embodied emissions in transport infrastructure are not included as a standalone item in Australia's National Greenhouse Gas Inventory, however estimates suggest that in 2018 operating emissions were equivalent to 4% of transport infrastructure-related emissions and embodied emissions were equivalent to almost 18% of transport emissions, or about 3% of Australia's total emissions.[106]

Existing policies and actions to support reducing emissions in transport infrastructure

Infrastructure decarbonisation will require a concerted effort from all levels of government and across industry. The government will need to work with states and territories to develop policies to decarbonise transport infrastructure. Many state, territory and local governments have their own infrastructure strategies which focus on sustainability and decarbonisation. There is also work to develop low emission building materials and practices from construction companies and material producers.

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[106] Clean Energy Finance Corporation (CEFC), *Issues Paper: Reshaping Infrastructure for a Net Zero Emissions Future,* CEFC, 2020.


As discussed in chapter 2, the recently released **Infrastructure Policy Statement** now guides Commonwealth funding of properly planned and targeted infrastructure to help unlock a range of significant economic, social and environmental objectives.

There are three priorities for the Commonwealth's investment: productivity, liveability and sustainability. It means cutting congestion, ensuring supply chains are resilient, building equity into the heart of where we live, improving prosperity, reducing our emissions and encouraging more sustainable ways to travel.

The Commonwealth is committed to working in partnership with the states and territories, who are our primary infrastructure delivery partners, on priorities for Australian Government co-investment.

The third theme of **sustainability** is especially critical for the net zero agenda. The Statement acknowledges that achieving the government's commitment to cut emissions by 43% by 2030 and achieve Net Zero by 2050 will require reduced emissions across our national transport task and will require a concerted effort to decarbonise. This includes reducing emissions through decarbonising transport operations, as well as in the design, construction and operation of transport infrastructure.

The government expects project procurement practices to encourage sustainable resource management and support the circular economy. States and territories should aim to maximise, where appropriate, the proportion of recycled materials used in project design and construction, as well as potentially recycling or reusing materials during the project's lifecycle. State, territory and local governments have already taken important steps to support infrastructure decarbonisation.

NSW Sustainable Infrastructure Program

The New South Wales (NSW) Sustainable Infrastructure Program provides a Roadmap for NSW to deliver infrastructure with net zero outcomes and transition infrastructure delivery to a circular asset model between 2023 to 2026. The objective of the program is to streamline and simplify decarbonisation and circular economy practices for project teams and industry partners through:

- embracing digitisation to update systems and processes to capture carbon reduction measures
- a clear and consistent approach to carbon management to deliver carbon reduction targets
- informing decision making by linking circular economy outcomes and decarbonisation.

A further key investment initiative is through **funding partnerships with states and territories**. The government is developing the next five-year Federation Funding Agreement Schedule (FFAS) on land transport infrastructure with the states. Negotiations have commenced and the new FFAS provides an opportunity to further pursue the delivery of wider socioeconomic benefits through infrastructure investment, including decarbonisation, greater use of recycled materials and the transition to a more circular economy, supporting Australian industry and training new skilled workers and apprentices.

The government has also made various investments to support the commercialisation of **low and zero emission building materials**, such as investments in green concrete from the SmartCrete Cooperative Research Centre and the Clean Energy Finance Corporation, and investments in green steel from the Australian Renewable Energy Agency. The government has also committed $15 billion to finance projects in priority areas to leverage Australia's natural and competitive strengths through the National Reconstruction Fund. $1 billion of this funding has been ear-marked for advancing manufacturing and $3 billion for renewables and low emissions technologies.

The Commonwealth is also providing national leadership to support transport infrastructure decarbonisation in the following ways:

- **ITMM decarbonisation of infrastructure workstream.** Through the Transport and Infrastructure Minister's Meeting (ITMM), a decarbonisation of infrastructure work program has

been established. The Australian Government is collaborating with states and territories to establish nationally consistent means of measuring and valuing embodied emissions for inclusion in project proposals for transport infrastructure, as well as exploring additional policy levers governments may use to further drive transport infrastructure decarbonisation. In December 2023, ITMM approved a nationally consistent set of carbon values for use in transport infrastructure project decision making. These values were developed by Infrastructure Australia in consultation with key stakeholders across the Australian, state and territory governments, Treasury, CSIRO, and Australian National University.[107] The values, which are based on modelling of the least-cost approach to achieve Australia's legislated emissions reductions targets, are a tool to be used to measure the social impacts of carbon emissions in infrastructure proposals.

- **Infrastructure Australia.** Infrastructure Australia advises governments, industry and the community on the investments and reforms needed to deliver better infrastructure for all Australians. Following the *Climate Change (Consequential Amendments) Act 2022*, Infrastructure Australia is required to consider Australia's emissions reduction targets in its advice to government, and in its plans, audits and evaluations. Infrastructure Australia is currently developing guidance to include embodied emissions within business cases.
- **Supporting industry decarbonisation.** Industry groups working to support the transition of the infrastructure sector to net zero in a cost-effective and efficient way, such as the Infrastructure Net Zero Initiative Green Star Ratings and the Infrastructure Sustainability Ratings also function to encourage greenhouse gas reduction in infrastructure emissions compared to business as usual. These are effective strategies to reduce emissions, but they do not target absolute decarbonisation.
- **Circular Economy Ministerial Advisory Group.** The government is working to guide Australia to a more circular economy by 2030. This includes looking at the potential for circular economy practices in the built environment through the Circular Economy Ministerial Advisory Group. This group will examine the role of circular economy in the built environment, including transport infrastructure, and provide advice to Ministers.
- **Government Business Enterprises.** A number of Government Business Enterprises are working to reduce embodied emissions. Western Sydney Airport Co Ltd requires the optimisation of recycled content in materials to reduce embodied emissions and is aiming for 'carbon neutral' under the Airport Carbon Accreditation Scheme. In 2020, the Moorebank Intermodal Terminal and Inland Rail both received 'excellent' Infrastructure Sustainability Ratings for their use of sustainable construction materials, reducing embodied emissions. The Australian Rail Track Corporation (ARTC) is also a participant in the NSW Low Emission Building Material initiative.

The government is also establishing regulatory frameworks to support industry decarbonisation through carbon markets and green bonds:

- **Carbon markets.** A carbon market refers to a market in which carbon units, representing emissions reductions or removals, are traded within a defined framework. Carbon markets are created by governments for policy compliance or by governments and business for voluntary emissions reductions. They allow the purchase or trading of emissions units or equivalents. Carbon trading is considered to be either domestic – where the abatement, trade and cancelling of the credit occurs within Australia and is captured by our national carbon accounts (e.g. programs like the Australian Carbon Credit Units (ACCUs) scheme) or international – where the abatement occurs overseas but the credits are purchased and used in another country to offset emissions there, generally for voluntary offsetting purposes. Carbon markets are already playing a key role in helping Australia reach its net zero targets. With sufficient demand for carbon credits, carbon markets can spur investment in low carbon technologies and projects that generate credits.
- **Green Bond Program**. The Green Bond Program will enable investors to back public projects that drive Australia's transition to net zero by 2050 and support environmental objectives. It will boost the scale and credibility of Australia's green finance market and attract more green capital to Australia by increasing

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[107] Infrastructure Australia (IA), *Valuing emissions for economic analysis*, IA, 2024.

transparency around climate outcomes and the volume of green investments available. An amount equal to the total net proceeds of any green bonds issued will be allocated to finance and/or refinance, in whole or in part, Eligible Green Expenditures that meet the Green Bond Criteria set out in the Australian Government Green Bond Framework. This includes supporting infrastructure, such as construction of core electric transport infrastructure and EV charging infrastructure.

Challenges and opportunities for low or zero emission transport infrastructure

Reducing the transport emissions that infrastructure **enables** will require **whole of system planning**. In Chapter 2 of this Consultation Roadmap we discussed the importance of continuing to invest in transport infrastructure that enables low carbon forms of travel.

Reducing the **embodied** and **operational** emissions of transport infrastructure will require national leadership to address the following barriers:

- **Commercial feasibility of input materials.** Over half of the embodied emissions from a typical infrastructure project comes from the use of cement, asphalt and steel.[108] Traditional construction materials are emissions intensive but green construction materials need to have sufficient supply and commercial potential to supersede conventional materials. Currently there is a limited supply of low carbon materials and they can be more expensive than traditional input materials.
- **Limited data.** The measurement of emissions from transport infrastructure projects is currently limited. There is no nationally consistent means to measure the emissions from infrastructure projects and no central body where emissions are reported to, to track and compare emissions across projects and jurisdictions. National standards should be set on data collection, measurement and reporting, in order to enable a fair comparison and assessment of emissions from transport infrastructure.
- **Limited assessment of emissions.** Greenhouse gas emissions should be considered at all stages of the infrastructure lifecycle. For transport infrastructure in Australia, the costs of operating emissions are already included in infrastructure business cases under the Australian Transport Assessment and Planning (ATAP) Guidelines. However, the costs associated with embodied emissions are generally not included. The consistent measurement and inclusion of embodied emissions in infrastructure business cases would allow the Australian Government to encourage or require low emission designs and circular economy considerations as a condition of infrastructure funding.
- **Limited application of circular economy practices.** Infrastructure practices have often had a 'build new' mentality, rather than the refurbishment or reuse of existing assets. Recycled building materials are not always used in current industry practice, and encouraging circular economy planning principles could significantly reduce emissions. For example, use of recycled materials could replace 27% of the 200 million tonnes of virgin materials needed for 998 planned road projects throughout Australia between 2015-2031.[109]
- **Greater harmonisation of approaches.** ATAP, Austroads, the National Transport Research Organisation (NTRO) and other national and state-based organisations have been developing standards and guidelines to support infrastructure decarbonisation. However, there is a need for greater national consistency to encourage industry and delivery partners to commence low emission infrastructure practices immediately. A nationally harmonised approach across sectors and jurisdictions would help provide industry with clarity and reduce costs.

At the same time, the changing climate and the severity and unpredictability of weather events also requires infrastructure to be built with improved resilience and forward-planning to withstand these challenges.

Regional and remote communities face unique challenges related to transport infrastructure. Regional and remote areas need to factor in additional costs and emissions for transport of goods and people to these

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[108] CEFC, *Australian buildings and infrastructure: opportunities for cutting embodied carbon,* CEFC, 2021.

[109] IA, *Replacement Materials: Understanding the market for replacement materials across major infrastructure road projects*, IA, 2022.

locations, often due to a lack of locally produced materials, particularly low or zero emissions materials, as well as higher fuel costs. There are also substantial opportunities for some regional, rural and remote communities as central supply hub routes with associated infrastructure, or where they are closely connected to major urban areas. This will be especially critical to support Australia becoming a renewable energy superpower. Net Zero Australia modelling projects a 7 to 8.5 times increase in the size of Australia's energy sector workforce by 2050, most of which is projected to occur in regional centres and remote locations.[110]

A net zero pathway for transport infrastructure

State, territory and local governments are primarily responsible for transport infrastructure through their ownership, operation and maintenance of assets, and as co-investors, driving the planning, identification and delivery of infrastructure projects. Although the Australian Government relies on state procurement decisions, it does have some influence over transport infrastructure emissions through decision-making during all stages of the project lifecycle. This includes through leveraging Australia's public infrastructure investment pipeline to develop a national approach to transport infrastructure decarbonisation, encourage low emission building practices, efficient and less polluting transport networks for goods and people, support enabling industries (such as low emission materials demand), and establish the right market settings for private industry. The Australian Government can provide national leadership and consistency for infrastructure decarbonisation, providing investment certainty and efficiencies to industry supply chains, drive more sustainable growth and drive decarbonisation.

Infrastructure also enables projects which may help or hinder decarbonisation. For example, key transition facilities, such as renewable energy hubs and green hydrogen facilities, are enabled by transport infrastructure. Through infrastructure project selection that is mindful of our energy transition objectives, infrastructure funding can achieve complementary policy objectives.

Decarbonising infrastructure must be considered throughout all stages of the infrastructure lifecycle – the earlier the consideration, the greater the influence on whole of life emissions.

To contribute to a net zero pathway in the short-term, reducing embodied emissions in infrastructure will be a key priority. This approach will require establishing markets, building governance architecture, prioritising low or zero emissions procurement, and working to fill the knowledge and skills gap. National standards on data collection, measurement and reporting of embodied emissions will be required in order to enable a fair comparison and assessment of emissions from transport infrastructure. This will require national leadership and coordination. There will also need to be increased investment in low and zero carbon materials (steel, cement and aluminium).

In the medium term, operational emissions should be close to net zero, with a significant reduction in embodied emissions. At this stage, the focus should be on achieving absolute emissions reductions (as opposed to emissions reductions against a business as usual scenario) and a reduction of enabled emissions.

In the long term, low and zero carbon concrete and steel will be price-competitive and available for infrastructure projects.

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[110] D Davis et al., '*Modelling Summary Report*', Net Zero Australia, 2023.

Figure 20: A net zero pathway for transport infrastructure

- National standards for data collection, measurement and reporting of embodied emissions, in order to enable a fair comparison and assessment of emissions from transport infrastructure
- Increased investment in low and zero carbon materials (steel, cement & aluminium)

- Operational emissions are net zero, with a significant reduction in embodied emissions
- Low and zero carbon concrete and steel is prioritised by industry

- Low and zero carbon concrete and steel is price competitive and available for infrastructure projects

Have Your Say

21. Do you agree with the proposed net zero pathway for transport infrastructure?

    21.1. Please add details to your response.

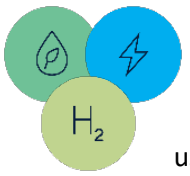
22. What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to reduce transport infrastructure emissions and ensure that transport infrastructure is ready for and enables low-emission transport modes?

    22.1. How would these actions address the identified challenges and opportunities to reduce transport infrastructure emissions?

4.2 Transport energy use

Key points

- The transport system in Australia is currently heavily reliant on direct combustion of fossil fuels.
- Transport makes up 75% of Australia's total liquid fuel demand.
- The primary method for reducing emissions in the transport sector will be through electrification.
- Where electrification is not feasible low carbon liquid fuel (LCLF) substitutions will be required to reduce emissions. Aircraft and maritime vessels, as well as some heavy road freight vehicles and rail, will need to rely on LCLFs where electrification is not viable.
- As part of the Future Made in Australia plan, the government will fast-track support for a LCLF industry, with an initial focus on sustainable aviation fuel and renewable diesel to support emissions reduction in the aviation, heavy vehicle, rail and maritime sectors.



This Consultation Roadmap has highlighted that the decarbonisation opportunities are varied for Australia's transport sector. Light vehicles will likely decarbonise through electrification, but other modes are hard to electrify and have fewer alternatives to replace the use of liquid fuels. Low carbon liquid fuels (LCLFs) will enable those transport modes to use energy dense hydrocarbons as a fuel, produced in a way that minimises emissions.

The government is developing a separate sectoral plan for electricity and energy that will consider energy use more broadly. This Consultation Roadmap considers only transport energy use.

Electrification will decarbonise much of the transport sector

Electrification is the clear decarbonisation pathway for much of the transport sector. However, this outcome relies on the decarbonisation of the electricity grid. The **$20 billion Rewiring the Nation commitment** and **Capacity Investment Scheme** will modernise Australia's electricity grid and infrastructure, and increase renewable energy capacity to meet the government's renewable energy targets and lower energy costs.

Further work will also be necessary to ensure Australia's electricity system is ready for the rapid electrification of most of Australia's transport sector. It will be necessary to ensure a positive experience for consumers using electric charging infrastructure. It will also be necessary to maintain the social licence to support the network infrastructure to support an increasingly electrified transport sector.

Commonwealth, state and territory Energy Ministers have agreed to undertake further work in priority areas for reform to ensure Australia's electricity system is ready for the rapid adoption of EVs.

This work will include:

- delivering nationally consistent and, where possible, internationally aligned standards and communications protocols for EV supply equipment (EVSE), cybersecurity, and smart functionality in Australia
- establishing a common mechanism for EVSE data sharing
- aligning Service and Installation Rules nationally
- streamlining network connection processes for consumer energy resources, including EVSE.

Through the National Electric Vehicle Strategy, the Commonwealth, state and territory governments have agreed to work together to align reporting and sharing of vehicle and infrastructure related data across Australia and collaborate on nationally consistent standards. Cooperating on implementation pathways that are

nationally consistent, and where possible, internationally aligned, will ensure Australia's electricity grid remains secure, reliable, equitable and affordable for all Australians, not just for those who own an EV.[111]

Some EVs can also provide energy storage for houses and the electricity grid. EVs could play a key role in storing and later dispatching excess power generated from solar photovoltaic (PV) and other renewable energy systems, and potentially assist in electricity grid management.[112]

The **National Energy Performance Strategy** sets out the Australian Government's approach to improve energy performance across the economy, lifting the role of the demand-side of the energy system to support the government's objectives to deliver net zero emissions, energy affordability and reliability. The Strategy is underpinned by close collaboration and coordination with state and territory governments through the National Energy Transformation Partnership to build on, support and leverage governments' energy and climate action.

Low carbon liquid fuels will be required to reduce emissions for some modes

Transport accounts for the largest share of Australian energy consumption and is almost entirely dependent on refined liquid fuels. About three quarters of Australia's total liquid fuel demand is consumed by the transport sector, with over half of this (54%) consumed by road transport – more than four times the consumption of the aviation sector.[113] Liquid fuels account for around half of Australia's final energy consumption and around 90% of the fuel we consume is derived from imports (based on imports of refined products and domestic production based on imported crude). [114]

Australia's heavy vehicle, rail, maritime and aviation sectors will continue to rely on liquid fuels in the short and medium term. This reliance on liquid fuels requires a fuel substitute that generates significantly lower emissions.

Low carbon liquid fuels (LCLFs) are fuels produced from certain feedstocks that emit low to zero lifecycle CO_2 emissions during their production and in their use, compared to the fuels they are displacing. LCLFs are produced sustainably from some waste materials, biomass, or combining hydrogen from low or zero carbon feedstocks with captured CO_2. LCLFs like SAF and renewable diesel will be important to enabling net zero for the transport sector.

For all LCLFs it will be important that government and industry are confident that carbon emissions benefits associated with displacing fossil fuel use are not being undermined by increasing carbon emissions elsewhere, such as through soil carbon depletion, forest carbon depletion or land use change.

How LCLFs could contribute to a net zero pathway

LCLFs will be an important tool to decarbonise hard-to-electrify transport modes. However, Australia is competing with international markets and there is a risk that local supply of feedstocks will be locked up for international use. Other jurisdictions, such as the European Union, United Kingdom, Canada and the states of California, Oregon and Washington already have a range of policies aimed to reduce the carbon intensity of motor vehicle fuels over time and to set a long-term growth plan that provides certainty for suppliers, by supporting demand for these more highly valued fuels. Domestic production of LCLFs could provide opportunities for regional development and new jobs as well as liquid fuel security benefits.

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[111] DCCEEW, *National Electric Vehicle Strategy*, DCCEEW, Australian Government, 2023.
[112] AEMO *(Australian Energy Market Operator), 2022 Integrated System Plan: June 2022*, AEMO website, 2022.
[113] DCCEEW, *Australian Energy Update 2023*, DCCEEW, Australian Government, 2023.
[114] DCCEEW, *Australian Petroleum Statistics*, DCCEEW, Australian Government, 2023.

A Future Made in Australia

As part of the Future Made in Australia plan, the government will fast-track support for a LCLF industry, with an initial focus on SAF and renewable diesel to support emissions reduction in the aviation, heavy vehicle, rail and maritime sectors.

This investment will help move our transport sector towards net zero and create new jobs and industry across Australia, and includes:

- $18.5 million over four years from 2024-25 to develop a certification scheme for LCLFs, including SAF and renewable diesel, in the transport sector by expanding the Guarantee of Origin scheme
- $1.5 million over two years from 2024-25 to undertake a regulatory impact analysis of the costs and benefits of introducing mandates or other demand-side measures for LCLFs
- investing $1.7 billion over the next decade in the Future Made in Australia Innovation Fund, to support the Australian Renewable Energy Agency to commercialise net zero innovations including low-carbon liquid fuels.

The government will be undertaking targeted consultation to identify options for production incentives to support the establishment of a made in Australia low carbon liquid fuel industry, including through the release of a LCLF consultation paper.

This feedback will build on consultation undertaken through the Aviation Green Paper and Electricity and Energy Sector Plan processes by further consulting stakeholders on supporting production and accelerating Australia's emerging low carbon liquid fuels industry. The consultation will seek views on the optimal policy mix, including the design of production incentives and demand-side options and the interaction of these measures; detailed production costs and market insights to support policy design; and other barriers or issues slowing the growth of an Australian LCLF industry, at least cost to the taxpayer while minimising price impacts and promoting competition.

Feedback on the LCLF consultation paper will also inform development of the final Transport and Infrastructure Net Zero Roadmap and Action Plan.

In the short-term to 2030, Australia will need local policy settings to develop the supply and use of LCLFs in Australia. As an important first step for LCLFs, the government is developing a renewable diesel fuel quality standard. An Australian fuel quality standard will reduce barriers for suppliers and provide a market signal. The standard will ensure consistent fuel quality so that users can have confidence to replace mineral diesel with a low carbon substitute. We also need to develop a system based on those used internationally to certify and accurately measure LCLF lifecycle emissions.

A comprehensive set of policies complementing one another will be needed to promote the production of LCLFs now, to achieve a sustainable industry in the longer term. LCLF policy needs to consider broader energy, environmental and economic implications as the industry will integrate with the existing fuel infrastructure and will need to operate within the liquid fuel market. Policies need to be synchronised with fuel transition plans of the existing market and the government's fuel security actions.

In the medium term to 2040, LCLFs should be produced from non-food competing and synthetic carbon feedstocks. Low and zero carbon hydrogen production would be used as an energy carrier in the production for LCLFs. Hydrogen derived fuels will have increased use in the maritime sector.

In the long term to 2050, all LCLFs should be produced using directly captured carbon and 100% renewable electricity. Third or fourth generation biofuels as well as synthetic LCLFs would be reserved for transport modes that have no electrification alternative. As zero carbon hydrogen is used as an energy carrier in the production of synthetic LCLFs, the synthetic LCLF value chain is zero carbon.

Have Your Say

23. The Australian Government invited views on aspects of the energy transformation that represent the most material challenges and opportunities for the electricity and energy sector. Submissions closed on Friday 12 April 2024 (AEDT). This feedback will be used to inform the development of the Electricity and Energy Sector Plan and Net Zero Plan.

The Australian Government will be undertaking targeted consultation to identify options for production incentives to support the establishment of a made in Australia low carbon liquid fuel industry, including through the release of a low carbon liquid fuels consultation paper.

Feedback heard through this process will also inform development of the final Transport and Infrastructure Net Zero Roadmap and Action Plan.

What additional actions by governments, communities, industry and other stakeholders need to be taken now and in the future to ensure the energy mix is ready to support transport emissions reduction?

24. How should the use of low carbon liquid fuels be prioritised across different transport modes over time to achieve maximum abatement?

5. Achieving net zero together

Action on climate change is a shared responsibility between industry, business, governments and communities. This chapter describes how the government will work collaboratively to reduce transport and infrastructure emissions.

5.1 Travelling in partnership

Key points

- Collective action is needed to reduce transport emissions. The Australian Government will continue to work collaboratively with all levels of government, the community and industry to reach net zero.
- The Australian Government will build on the success of national collaboration through the National Electric Vehicle Strategy in other transport modes.
- Industry is a key decarbonisation partner. The Australian Jet Zero Council and the Maritime Emissions Reduction National Action Plan co-design process are good examples of the government working collaboratively with industry to reduce emissions.
- Australia will continue to be actively engaged in international fora to reduce emissions and look to establish international partnerships to advance low emission technologies.

The Transport and Infrastructure Net Zero Roadmap and Action Plan will require close collaboration with industry and the states and territories if it is to succeed in reaching net zero by 2050. Fortunately, industry and the states and territories already have, or are currently establishing, their own net zero strategies to support the transition. The Roadmap and Action Plan is an opportunity to build on the actions that are already well underway across Australia.

In order to do this, we will seek to align our goals nationally and consistently with our international commitments. We will work together to help communities and industry to transition. What this looks like will depend on the transport mode, the actions already underway and the capacity and capability of the market.

Working with the states and territories

All of the states and territories have set a target of net zero emissions by 2050 or earlier. The Commonwealth, NSW, the ACT, Tasmania and Victoria have legislated these targets, with South Australia (SA) and Western Australia (WA) progressing legislation of their targets currently. All jurisdictions also have renewable energy targets, supporting electrification as the logical place to start in reducing transport emissions (noting that some transport modes are hard to electrify).

There are a range of policies and actions to reduce emissions that constitutionally are only able to be taken by the states and territories. That makes it especially important for all levels of government to coordinate with each other to drive the maximum possible abatement. Taking collective responsibility will also provide industry with greater certainty on the pathways to net zero, allowing them to invest with confidence.

The Commonwealth will continue to work with the states and territories to deliver infrastructure that shifts how people and goods move across Australia. We will also work collaboratively to deliver coordinated policies that reduce emissions. This will build on the approach taken to deliver the **National Electric Vehicle Strategy (NEVS)**, where all states and territories agreed to the NEVS framework and key areas for national collaboration to ensure a national approach to EVs. The **Transport and Infrastructure Ministers' Meeting (ITMM)** has identified decarbonisation as a national priority and has set up two decarbonisation working groups to take

forward this collaboration. ITMM has also approved a set of shared principles for national transport decarbonisation.

Working with industry

Collaborating with industry is crucial to leverage the technological expertise and resources at the necessary scale to significantly reduce emissions. By fostering partnerships, we can enhance transport efficiency and address the complex challenges associated with achieving net zero emissions. Collaborative action can make the transition to net zero faster and at a lower cost. In order to maximise these benefits, collaboration in these sectors needs to be inclusive and well-coordinated.

The Commonwealth is already bringing together industry to decarbonise transport. The Australian Jet Zero Council and Maritime Emissions Reduction National Action Plan (MERNAP) co-design process will enable the government and industry to work together to reduce emissions.

Australian Jet Zero Council

The Australian Government established the Australian Jet Zero Council on 21 June 2023.

Convened by the department, the council brings together a cross-section of stakeholders from across the aviation sector and its supply chains. Members include airlines (Qantas Airways, Regional Express Airlines and Virgin Australia), airports (Brisbane Airport Corporation), aviation fuel (Australian Institute of Petroleum and the Sustainable Aviation Fuel Alliance of Australia and New Zealand), major SAF projects (bp), manufacturers (Airbus and Boeing), research and development (CSIRO), finance and investment (the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC)), regional aviation (Regional Aviation Association of Australia) and defence (Department of Defence).

The council will lead efforts to deliver net zero aviation in Australia by coordinating across the sector to provide advice to Government on issues related to the aviation industry's transition to net zero emissions.

Co-designing a plan with the maritime industry

The MERNAP is being developed by the department, with a strong emphasis on co-designing the plan in collaboration with the maritime industry through the involvement of a Consultative Group and broader industry and public consultation. The Consultative Group consists of key representatives from the government, maritime industry and academia, ensuring diverse perspectives and expertise.

Primary areas of focus for the MERNAP have been determined collaboratively, such as decarbonisation technologies, low carbon liquid fuels (LCLFs), energy efficiency, green ports and policy development. Both government and industry partners are undertaking research and analysis to identify best practices, emerging technologies, and innovative approaches for reducing maritime emissions, with the department preparing issues papers on the identified focus areas and integrating insights from the research and analysis phase. The Consultative Group meets regularly to discuss, provide feedback, and iterate on the issues papers, refining the plan's components and strategies.

The department is testing the issues papers and MERNAP components with a wider range of stakeholders, including public consultations, to gather feedback and ensure the plan addresses the needs and concerns of various interest groups. Feedback from the Consultative Group and broader stakeholder consultations will be integrated into the MERNAP, ensuring that the plan, which is due to be submitted to government for decision in mid-2024, is comprehensive, actionable, and well-supported by both the government and the maritime industry.

It is also critical that the government's policy settings attract industry investment and support the environmental, social and governance (ESG) outcomes of businesses. The CEFC is investing in solutions for renewable energy, energy efficiency and low emissions opportunities. In particular, the CEFC is working across the economy to accelerate investment in measures to reduce transport-related emissions, including mode switching from road to rail, the electrification of urban transport, charging infrastructure and finance for fleet and residential electric vehicles.

Working with local communities

The government will continue to work with local communities and local governments across the country, especially regional, rural and remote Australia, including through the development of Australia's **First Nations Clean Energy Strategy**.

The transformation to a net zero economy is a significant source of opportunity for Australia, its regions, and workers as new industries emerge. The Australian Government established the **Net Zero Economy Agency**, a precursor to the establishment of a legislated Net Zero Economy Authority, which will occur following established Parliamentary processes. The Net Zero Economy Agency will seize the opportunities of the net zero transition by coordinating effort, brokering investments that create jobs in regions, and supporting workers through change. Together with the **Net Zero Economy Agency**, we will work closely with **communities, regional bodies, local government and First Nations groups** to manage this transformation and ensure the benefits of the net zero economy are realised and shared.

The government will also support the decarbonisation of existing industries and creation of new clean energy industries through the **$1.9 billion Powering the Regions Fund**.

As discussed throughout this Roadmap, regional Australia will face unique challenges transitioning to net zero. This is especially true for Northern Australia because of its relatively small and dispersed population, as well as its reliance on Fly-In, Fly-Out (FIFO) workers. However, the electrification of transport presents other potential benefits and opportunities for Northern Australia.

Electrification and Northern Australia

The electrification of transport modes present opportunities to reduce energy costs while improving convenience for communities in remote Australia. Electrification can also build resilience to supply chain shocks for regional and remote Australia. For example, with no refineries in Northern Australia, the use of petrol and diesel is dependent on long supply chains vulnerable to disruption and often requiring regular delivery or travel to secure. Therefore, increasing electrification in the fleet-mix will improve community and freight sector resilience to supply chain disruption, where batteries and solar-generation can be housed on-site where land is typically abundant (compared to urban settings).

Support is available for private sector enterprise looking to increase electrification and renewable generation in the north. The **Northern Australia Infrastructure Facility (NAIF)** is a $7 billion development financier, with the experience, expertise, and broad investment mandate to support transformative growth in the north – be it through investment in manufacturing, mining, transport or other common user infrastructure, or social infrastructure. This could include projects that increase renewable and/or energy storage, installation of charging facilities, or potentially even fleet upgrades.

Working internationally

Australia will continue to be an active participant in international initiatives to reduce emissions.

Australia supports **International Civil Aviation Organization (ICAO)** initiatives to reduce greenhouse gas emissions from international aviation while still facilitating growth in the industry. In October last year at the

41st ICAO Assembly, Australia supported the establishment of ICAO's long-term aspirational goal (LTAG) of net zero carbon emissions by 2050.

A key global market-based measure that will help the sector reach this goal is the ICAO's Carbon Offsetting Reduction Scheme for International Aviation (CORSIA), which aims to hold carbon emissions from international aviation at an agreed baseline. Australia's international airlines have participated in the CORSIA since 2019, and Australia continues to be involved in ensuring it is a robust and effective scheme.

Reducing emissions from international aviation

At the 3rd ICAO Conference on Aviation and Alternative Fuels (CAAF/3) agreement was reached on a global framework to facilitate scaling up the development and deployment of SAF, lower carbon aviation fuels and other cleaner energy sources. The framework includes four major building blocks covering: policy and planning, the regulatory framework, implementation support, and financing.

The framework will facilitate international capacity building, technology transfer, establishment of regulation, and future access to public and private finance, which is particularly important for developing countries.

To support the LTAG for international aviation of next zero carbon emissions by 2050, ICAO and member states agreed to strive to achieve a collective global aspirational vision to reduce CO_2 emissions in international aviation by 5% by 2030 through the use of SAF, low carbon aviation fuels (LCAFs) and other aviation cleaner energies (compared to zero cleaner energy use).

Additional initiatives agreed at the Conference include:

- the establishment of ICAO's 'Finvest Hub', a facilitation platform connecting aviation decarbonisation projects with potential investors;
- the use of the existing CORSIA framework and sustainability criteria as the accepted basis for the eligibility of SAF, LCAF and other cleaner energies in international aviation; and
- ICAO undertaking a study to better understand fuel accounting systems including 'book and claim' and ICAO's potential role in supporting these systems.

Australia also supports a range of initiatives from the International Maritime Organization (IMO) to reduce emissions from international shipping. Member states of the IMO recently adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships, with enhanced targets to tackle harmful emissions. The revised IMO GHG Strategy includes an enhanced common ambition to reach net-zero GHG emissions from international shipping by or around, i.e. close to, 2050, with indicative check-points for 2030 and 2040, as well as a commitment to ensure a 5%, striving for 10%, uptake of alternative zero and near-zero emission fuels by 2030.

The Australian Government is working closely with international partners to advance practical action on climate change and build new clean energy industries, particularly for green hydrogen and its derivatives.

International partnerships on low emission technologies

Australia – Germany Hydrogen Accord: Australia and Germany are committing $50 million each to deliver the German-Australian Hydrogen Innovation and Technology Incubator (HyGATE) to support real-world projects along the hydrogen supply chain.

Australia – Japan Partnership on Decarbonisation through Technology: Advancing cooperation in clean hydrogen and ammonia, carbon capture, use and storage (CCUS), and low emissions steel and iron ore, including strong cooperation through the Hydrogen Energy Supply Chain (HESC) project.

Australia – Republic of Korea Low and Zero Emissions Technology Partnership: Collaboration across low and zero emissions technologies, including clean hydrogen and ammonia supply, hydrogen power generation, hydrogen fuel cell electric vehicles, CCUS and low emissions steel and iron ore.

Australia-United States Net Zero Technology Acceleration Partnership: Practical cooperation on energy storage, digital electricity grids, hydrogen, and CO_2 removal, including direct air capture.

Australia – United Kingdom Partnership on Low Emissions Solutions: Collaboration on making low emissions technologies commercially viable, with a focus on clean hydrogen, CCUS, small modular reactors, low emissions material like green steel, and soil carbon measurement.

Australia – Singapore Initiative on Low Emission Technologies for Maritime and Port Operations: $30 million initiative to accelerate the deployment of clean hydrogen and ammonia fuels and technologies specifically in maritime and port operations.

Australia – India Low Emissions Technology Partnership: Australia and India have committed to working together to reduce the cost of clean hydrogen and solar technologies, including through an Australia-India Green Hydrogen Taskforce.

Australia-Netherlands Memorandum of Understanding on Cooperation in the Field of Hydrogen: To develop a renewable hydrogen supply chain from Australia to Europe covering hydrogen trade policy, regulations, port infrastructure and supply chains, and hydrogen technologies, including for shipping.

Have Your Say

25. What are the best ways for the Australian Government to work collaboratively with industry, business, governments and communities to implement the proposed pathways?

25.1. What are good domestic or international examples of partnership and collaboration on transport and transport infrastructure emissions reduction that could inform the final Roadmap and Action Plan?

25.2. What opportunities can the government leverage to show leadership in Australia and internationally?

5.2 Measuring success

Key points

- The success of the Roadmap and Action Plan will ultimately be judged by the contribution of the transport sector to Australia's overall decarbonisation progress.
- In a rapidly evolving landscape, it will be important to regularly review the Transport and Infrastructure Net Zero Roadmap and Action Plan to measure success and inform future government actions.

The success of the final Roadmap and Action Plan will primarily be guided by the emissions reductions achieved by the transport sector as it contributes to Australia's overall decarbonisation targets.

We will also structure the future evaluation of the final Roadmap and Action Plan with a range of indicators, linked to the guiding principles and based on available data sources. We will consider additional metrics as data becomes available.

The final suite of success measures and metrics can only be determined after feedback on the Consultation Roadmap is used to update the mix of actions, priorities and opportunities. We have identified some potential options in Table 4.

Table 4: Potential success measures to explore

Guiding principle	Success measures	Data sources
Maximise emissions reduction	Percentage reduction in CO_2 emissions from Australia's transport sector. Coordinated with other net zero sector plans. Availability and uptake of zero or low emission technologies. Availability of charging and refuelling infrastructure	• National Greenhouse Gas Inventory and Australia's emissions projections • BITRE and ABS data sources • Distance travelled by modes • EV sales data (future analysis from Cleaner Cars Regulator)
Effective investment (value for money and maximise economic opportunity)	Consider impact on the Australian budget. Leverage higher impact through partnerships. Consider trade-offs with other policy work. Cost to government of zero or low emission technologies.	• Leverages existing regulatory frameworks, touch points and opportunities with government • Monitor electricity demand impact on prices • Employment data
Inclusive and equitable	Ensure that all Australians have access to transport to meet their needs, which does not create disadvantage but creates improved opportunities and outcomes. Cost to consumers of zero or low emission technologies.	• Quantified statistics on access to public or active transport options, fuel efficient vehicles – before and after interventions • Climate risk in decision making ensures future transport assets/access is not compromised • Improved health outcomes, reduced congestion, etc.
Credible evidence	Pathways development is evidence-based. Consultation is broad and	• Consultation evaluated based on number of responses, and a

Guiding principle	Success measures	Data sources
	includes all key stakeholders. Ongoing opportunity for feedback and adjustments through clear and transparent processes.	comparison of responses received during previous consultation phases • Ongoing feedback based on correspondence received post-implementation • Public awareness of the Roadmap and Action Plan

Reviews

It is proposed that progress against the Roadmap and Action Plan will be reported via annual updates, including in existing Commonwealth reports and statements, such as Australia's annual emissions projections and the Minister for Climate Change and Energy's Annual Climate Change Statement to parliament. A comprehensive and in-depth review will be undertaken every three to five years.

Have Your Say

26. What measures and metrics should be used to evaluate the final Transport and Infrastructure Net Zero Roadmap and Action Plan?

    26.1. What other data and evidence could governments use and how could this offer further insights on the pace, scale and location of transport emissions reduction pathways?

27. Do you have any feedback on the proposed review process?

28. Do you have any further feedback on the Consultation Roadmap and proposed pathways?

    28.1. Is there anything missing? Are the sections appropriately integrated? Is the Roadmap appropriately ambitious?

29. Is there any further information or documentation that you wish to be considered with your submission?

5.3 Next steps

Key points

- What we hear through this consultation and engagement will guide the development of the actions and policies that the government will commit to in the final Transport and Infrastructure Net Zero Roadmap and Action Plan.
- We encourage you to have your say at https://infrastructure.gov.au/netzeroroadmap.

The purpose of publishing this Consultation Roadmap is to receive feedback from communities, industry, experts and unions on the potential pathways as well as the actions or policies that may need to be taken by government to support these potential pathways. What we hear through this consultation and engagement will guide the development of the actions and policies that the government will commit to in the final Transport and Infrastructure Net Zero Roadmap and Action Plan.

Public consultation on this Roadmap will occur over the next two months and will close on 26 July 2024. For information on how to have your say please go to https://infrastructure.gov.au/netzeroroadmap.

The feedback you provide may also be used to inform the development of the other five sectoral plans.

Appendix A: Background information

Appendix A.1 – IPPC Sixth Assessment Report: Climate Change 2023

The Synthesis Report of the IPCC Sixth Assessment Report (AR6) summarises the state of knowledge of climate change, its widespread impacts and risks, and climate change mitigation and adaptation. The Report states that transport emissions can be reduced by demand-side options and low emission technologies.

Key findings include:

- Changes in urban form, reallocation of street space for cycling and walking, digitalisation (such as teleworking) and programs that encourage changes in consumer behaviour (such as transport pricing) can reduce demand for transport services and support the shift to more energy efficient transport modes.
- EVs offer the largest decarbonisation potential for land-based transport. The costs of EVs are decreasing and their adoption is accelerating, but they require continued investments in supporting infrastructure to increase the scale of deployment.
- Advances in battery technologies could facilitate the electrification of heavy-duty trucks and complement conventional electric rail systems.
- Sustainable biofuels can offer additional mitigation benefits in land-based transport in the short and medium term.
- Sustainable biofuels, low-emissions hydrogen, and derivatives (including synthetic fuels) can support mitigation of CO_2 emissions from shipping, aviation, and heavy-duty land transport but require production process improvements and cost reductions.

Appendix A.2 – What are scope 1, 2 and 3 emissions?

Scope 1, 2 and 3 emissions categorise an entity's greenhouse gas emissions.

Scope 1 emissions are the direct emissions from an owned or controlled source. In the context of transport, scope 1 emissions would account for tailpipe emissions from burning fuel in an ICE vehicle.

Scope 2 emissions cover the indirect emissions from purchased electricity, such as the grid emissions associated with charging an EV.

Scope 3 emissions are the broader, indirect emissions in the supply chain. These can come from how cars are manufactured (what is often referred to as a vehicle's embodied emissions) as well as the emissions associated with extracting, refining and delivering fuel to the bowser for ICE vehicles.

On a transport infrastructure build, scope 1 involves direct sources of emissions like combustion of fuel in the diesel-powered vehicles and equipment used for construction activities.

Scope 2 involves the indirect emissions associated with the electricity consumed by the build, such as electricity used in on-site facilities that are powered by the grid.

Scope 3 covers a broader spectrum and considers the entire supply chain. It includes emissions from the extraction, manufacturing and transport of construction materials (the embodied emissions of input materials) as well as ongoing maintenance activities, including the end of life decommissioning that may be needed.

Appendix A.3 – SAF outlook in the short, medium and long term

	Benefits	Challenges
Short term outlook	Near term SAF capacity will be supplied by fuels produced from used cooking oil and beef tallow, known as hydro-processed esters and fatty acids (HEFA) fuels, which are already available for use in aircraft. Other SAF production pathways such as Alcohol-to-Jet (AtJ) will further help scale SAF development locally.	Little SAF is expected to be available in Australia. With competition from other transportation sectors that can also use HEFA fuels, ensuring a sufficient volume of HEFA fuels for aviation may be difficult. The key to greater acceptance and deployment of SAF is the reduction in its cost to airlines, which will require investment in advanced technologies to process feedstocks more efficiently at a larger scale. Consideration should also be given to using feedstocks that have a low emissions output when converted into SAF.
Medium term outlook	Opportunities with advanced LCLFs which are derived from agriculture and forestry wastes are expected to become more common in the medium-term. Agriculture residues and municipal solid waste are expected to be the key feedstock sources in Australia.	With numerous feedstocks and technologies to choose from, Australia will have to identify what its most suitable SAF production options are to help develop sovereign SAF capability.[115] Competition with other LCLFs may outcompete the production of SAF, as industry seeks to maximise the yield of refineries.
Long term outlook	SAFs in the long-term are likely to be produced either synthetically, using renewable energy sources other than biomass or using advanced feedstocks like algae. These fuels are currently in developmental phases. Further support for research, development and demonstration of synthetic fuels as well as algae is needed to improve conversion efficiencies and reduce costs.	Uncertainty remains on carbon capture technology pathways needed for synthetic SAF production. Synthetic SAF is also reliant on cheap renewable energy used in the production process to ensure attractive economics.

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[115] CSIRO, *Sustainable aviation fuel opportunities for Australia*, CSIRO, Australian Government, 2023.

List of abbreviations

ACCUs: Australian Carbon Credit Units

ACT: Australian Capital Territory

ADR: Australian Design Rule

ARENA: Australian Renewable Energy Agency

ATAP: Australian Transport Assessment and Planning

BETs: Battery electric trucks

BEVS: Battery electric vehicles

BITRE: Bureau of Infrastructure and Transport Research Economics

CCUS: Carbon capture, use and storage

CEFC: Clean Energy Finance Corporation

CO_2: Carbon dioxide

CO_2-e: Carbon dioxide equivalent

CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation

DAFF: Department of Agriculture, Fisheries and Forestry

DCCEEW: Department of Climate Change, Energy, the Environment and Water

DFAT: Department of Foreign Affairs and Trade

DISR: Department of Industry, Science and Resources

DITRDCA: Department of Infrastructure, Transport, Regional Development, Communications and the Arts

EVs: Electric vehicles

EVSE: EV supply equipment

FBT: Fringe benefit tax

FCETs: Hydrogen fuel cell electric trucks

FCEVs: Hydrogen fuel cell vehicles

FES: Fuel Efficiency Standard

GA: General aviation

GDP: Gross Domestic Product

GEA: Green Economy Agreement

GO: Guarantee of Origin

GSC: Green Shipping Corridor

HEFA: Hydro-processed esters and fatty acids

HFOs: Heavy fuel oils

HVNL: Heavy Vehicle National Law

ICAO: International Civil Aviation Organisation

ICE vehicles: Internal combustion engine vehicles

IDC: Interdepartmental Committee

IIP: Infrastructure Investment Program

IMO: International Maritime Organization

IPS: Infrastructure Policy Statement

ITMM: Infrastructure and Transport Ministers' Meeting

kWh: Kilowatt-hour

LCLFs: Low carbon liquid fuels

LNG: Liquified natural gas

MECLA: Materials and Embodied Carbon Leaders' Alliance

MERNAP: Maritime Emissions Reduction National Action Plan

Mt CO_2-e: Million tonnes of carbon dioxide equivalent

NDC: Nationally Determined Contribution

NEVS: National Electric Vehicle Strategy

NVES: New Vehicle Efficiency Standard

NGER Scheme: National Greenhouse and Energy Reporting Scheme

NHVR: National Heavy Vehicle Regulator

NRF: National Reconstruction Fund

NTC: National Transport Commission

PMC: Department of the Prime Minister and Cabinet

SAF: Sustainable aviation fuel

SUV: Sports utility vehicle

TDWG: Transport Decarbonisation Working Group

UNFCCC: United Nations Framework Convention on Climate Change

WA: Western Australia

Glossary

Abatement: Stopping the increase of greenhouse gases in the atmosphere. Abatement includes mitigation (preventing emissions) and sequestration (capturing and storing emissions).

Adaptation: Actions to build resilience and protect communities, economies, and the environment from the impacts of climate change.

Ammonia: Ammonia is a useful source of fertiliser, fuel and heat. Ammonia is traditionally produced by stripping hydrogen from natural gas using steam, which produces CO_2 as a by-product. Low-carbon ammonia can be produced using hydrogen from renewable energy. See ***green ammonia***.

Avoid-shift-improve hierarchy: The avoid-shift-improve hierarchy emphasises first *avoiding* unnecessary trips through telecommuting or better urban planning, then *shifting* to more sustainable transport modes like active and public transport, and finally *improving* the technology or efficiency of the transport mode, such as through electrification.

Battery electric vehicle (BEV): An electric vehicle that exclusively uses chemical energy stored in rechargeable battery packs to power at least one electric motor with no secondary source of propulsion.

Carbon dioxide equivalent (CO_2-e): A description of, for a given mixture and amount of greenhouse gases, the amount of CO_2 that would have the same global warming ability when measured over a specified time period.

Carbon dioxide (CO_2): Carbon dioxide is a colourless, non-flammable gas at room temperature and pressure. It is also a greenhouse gas which contributes to climate change. See also ***greenhouse gas.***

Carbon offset: A type of carbon credit that represents a reduction in emissions – whether prevented from entering the atmosphere or removed from the atmosphere – that is used to compensate for emissions that occur elsewhere.

Circular economy: The circular economy is a system where materials are reused rather than being wasted. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling and composting.

Climate change: Climate change refers to long-term shifts in temperatures and weather patterns. These shifts can be natural, but, since the 1800s, human activities have been the main driver of climate change, primary due to the burning of fossil fuels (coal, oil and gas).

Critical minerals: A metallic or non-metallic element that is essential for the functioning of modern technologies, economies or national security, and with a risk that its supply chains could be disrupted.

Decarbonise: To stop or reduce carbon gases, especially carbon dioxide, being released into the atmosphere as the result of a process, like the burning of fossil fuels.

Direct emissions: See ***scope 1 emissions***.

Electric vehicles (EVs): Plug-in vehicles powered solely by electricity. Excludes hybrid vehicles, which are powered by electricity and fossil fuels.

Electrification: The process of replacing technologies or processes that use fossil fuels, like internal combustion engines and gas boilers, with electrically powered equivalents, such as electric vehicles or heat pumps.

Embodied emissions: Emissions generated during the production and transportation of goods, from the extraction of raw materials to the manufacturing process and final delivery to the consumer. For infrastructure, embodied emissions come from the emissions embodied in the input materials, as well as the emissions generated during the construction and installation processes.

E-methanol: Chemically identical to fossil fuel-based methanol, produced by combining green hydrogen and captured carbon dioxide.

Emissions intensity: A measure of the amount of emissions associated with a unit of output – for example, emissions per unit of GDP, electricity production, or kilometre travelled.

Emissions: A quantity of greenhouse gases released into the atmosphere.

Enabled emissions: Emissions resulting from the use of infrastructure, such as from the cars on the roads.

Equitable transition: See ***just transition***.

Euro VI standards: The Euro VI standards reduce the maximum permitted emissions of nitrogen oxides by up to 80 % and the maximum permitted emissions of particulates by up to 66 %.

Externality: The cost or benefit caused by a producer that is not financially incurred or received by that producer.

Feedstock: Raw material that can be directly used as a fuel or converted to another form of fuel or energy product.

Fossil fuels: Fossil fuels include coal, petroleum, natural gas, oil shales, bitumens, tar sands, and heavy oils. All contain carbon and were formed as a result of geologic processes acting on the remains of organic matter produced by photosynthesis, a process that began in the Archean Eon (4.0 billion to 2.5 billion years ago).

Fringe benefit tax (FBT): A fringe benefit is a payment made to an employee which is not their salary or wages. These benefits are subject to a fringe benefits tax which is separate to income tax and calculated on the taxable value of the fringe benefit.

Global warming: The long-term heating of the earth's surface observed since the pre-industrial period due to human activities, primarily fossil fuel burning (coal, oil and gas), which increases heat-trapping greenhouse gas levels in earth's atmosphere.

Global warming potential: A measure of how much infrared thermal radiation a greenhouse gas added to the atmosphere would absorb over a given time frame, in essence, how strong of a **greenhouse effect** a **greenhouse gas** will have in the atmosphere.

Green ammonia: See ***ammonia***. Ammonia can be made synthetically by combining nitrogen with hydrogen in a process called ammonia synthesis. When this process is completed using renewable energy sources such as wind, solar, hydropower and geothermal energy, the process does not emit carbon dioxide, and the result is green ammonia.

Green hydrogen: Hydrogen is produced using electricity to separate the hydrogen from the oxygen in water. Green hydrogen is produced from electricity obtained from renewable sources and the use of this energy does not emit carbon dioxide into the atmosphere.

Green Shipping Challenge: Led by the United States and Norway, the Green Shipping Challenge is intended to encourage countries, ports, companies and other actors in the shipping value chain to come forward with concrete announcements at COP28 that will help put the shipping sector on a pathway this decade that is aligned with the goal of limited global temperature rise to 1.5°C.

Greenhouse effect: Some gases in the earth's atmosphere act like the glass in a greenhouse, trapping the sun's heat and stopping it from leaking back into space. The greenhouse effect is the cause of global warming.

Greenhouse gas: Any gas (natural or produced by human activities) that absorbs infrared radiation in the atmosphere, including carbon dioxide, water vapour, nitrous oxide, methane and ozone.

Heavy vehicles (road): Vehicles that have a gross vehicle mass or aggregate trailer mass of more than 4.5 tonnes. The gross vehicle mass is the maximum it can weigh when fully loaded, as specified by the manufacturer. In this Roadmap, we consider heavy vehicles to be rigid trucks, articulated trucks and buses.

High-Speed Rail: A type of rail transport network, using trains that run significantly faster than traditional rail and an integrated system of specialised rollingstock and dedicated tracks. A High-Speed Rail network in Australia would allow passengers to travel between major cities and regional centres at speeds exceeding 250 km per hour.

Hybrid vehicle: Hybrid vehicles use an electric motor powered by a battery as a primary or supplementary power to improve vehicle fuel efficiency, in addition to an internal combustion engine. The battery is either re-charged onboard by residual braking technology (conventional hybrid) or by an external EV charger (plug-in hybrid).

Hydrogen fuel cell electric vehicle (FCEV): An electric vehicle that uses electricity from a fuel cell powered by compressed hydrogen, rather than electricity from batteries.

Hydrogen Headstart: The Hydrogen Headstart Program will provide up to $2 billion of revenue to support large-scale renewable hydrogen production projects.

Hydrogen Highway: The Hydrogen Highway describes roads equipped with hydrogen refuelling stations, allowing the use of hydrogen fuel cell vehicles.

Import duty: Generally, all goods imported into Australia are liable for duties and taxes unless an exemption or concession applies.

Indirect (secondary) emissions: See ***scope 2 emissions***.

Intergenerational equity: The embodiment of care for future generations. It is the idea of fairness or justice between generations.

Intermodal terminal: Intermodal terminals play a significant role in the consolidation, storage and transfer of freight between rail and road at the beginning and end of each rail journey. Intermodal terminals provide connectivity to ports, regional networks and other capital cities and locations.

Internal combustion engine (ICE) vehicles: A conventional vehicle is a vehicle with only an internal combustion engine system – that is, a conventional vehicle powered by fossil fuel.

Just transition: Involves maximising the social and economic opportunities of climate action, while minimising and carefully managing any challenges.

Last-mile connectivity: In supply chain management and transportation planning, the last mile is the last leg of a journey comprising the movement of passengers and goods from a transport hub to a final destination. It is also the term used for the gap between public transport to the destination.

Lifecycle emissions: Emissions produced during a vehicle or product's production, operation and disposal.

Low carbon liquid fuels (LCLFs): Low carbon liquids fuels are liquid fuels from non-fossil origin, with low or no net CO_2 emissions from production and combustion.

Micro infrastructure: Smaller scale capital construction projects, programs and services that are needed to improve connectivity and accessibility to public transport, and thus increase public transport use within the suburban context.

Micromobility: Forms of transport using small, lightweight vehicles operating at speeds typically below 25 km per hour and driven by their users personally such as electric bikes (e-bikes) and electric scooters (e-scooters).

Mode shift: The shift from one mode of transport to another, for example from private vehicles to public and active transport, or from road freight to lower emissions modes such as rail.

National Greenhouse and Energy Reporting (NGER) scheme: The NGER scheme is a single national framework for reporting and disseminating company information about greenhouse gas emissions, energy production, energy consumption and other information specified under NGER legislation. The objectives of the NGER scheme are to inform government policy and the Australian public, and help meet Australia's international reporting obligations.

National Greenhouse Gas Inventory: Australia's National Greenhouse Gas Accounts fulfils Australia's international treaty obligations by submitting National Inventory Reports to the UNFCCC.

Net zero: An overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere.

Nitrous oxide: Nitrous oxide (N_2O) is an odourless, colourless, non-flammable gas. Nitrous oxide is a greenhouse gas, and molecules stay in the atmosphere for an average of 121 years before being removed by a sink or through chemical reactions. The global warming potential of nitrous oxide is 265 times that of carbon dioxide. Globally, 40% of total nitrous oxide emissions come from human activities.

Offsets: See ***carbon offset***.

Operating emissions: Emissions from the energy use of an infrastructure asset during its use stage, for example from the energy used to operate a train station.

Paris Agreement: The Paris Agreement came into effect in 2016 and was a major step forward in international efforts to address climate change. It aims to strengthen the global response to the threat of climate change by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit temperature increase to 1.5°C.

Particulate emissions: Emissions of particulate matter, which is a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, smoke or soot, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using a microscope. Particulate matter can be inhaled and can cause serious health problems.

Passenger kilometre: A passenger kilometre is the unit of measurement representing the transport of one passenger by a defined mode of transport over one kilometre.

Plug-in hybrid: A hybrid vehicle whose battery can be recharged by plugging it into an external source of electric power, as well as by its on-board internal combustion engine.

Pre-industrial: Pre-industrial, as defined in the Intergovernmental Panel on Climate Change, refers to the period 1850–1900.

Renewable diesel: An advanced biofuel made from a range of waste and purpose-grown biomass sources. Unlike first-generation biodiesel which requires blending with conventional fuels or modification of vehicle engines to run 100% biodiesel, renewable diesel can directly substitute conventional diesel and does not require blending.

Renewable energy: Energy from a source that is not depleted when used, such as wind or solar power.

Resilience: The capacity of people, communities and assets to cope with a hazardous event, trend or disturbance, responding to or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.

Rollingstock: Referring to railway vehicles, including both powered and unpowered vehicles – for example, locomotives, freight and passenger cars, and non-revenue cars.

Safeguard Mechanism: A legislated obligation on Australia's largest greenhouse gas emitters, or 'Safeguard facilities', to keep their net emissions below an emissions limit (a baseline).

Scope 1 emissions: The release of greenhouse gases into the atmosphere as a direct result of activities occurring within a responsible entity's control or geographic boundary.

Scope 2 emissions: The indirect release of greenhouse gases into the atmosphere from the consumption of purchased electricity, heating, cooling or steam that is generated outside of a responsible entity's control or geographic boundary.

Scope 3 emissions: All indirect emissions (not included in scope 2) that occur in the value chain of the reporting entity, including both upstream and downstream emissions.

Supply chain: The network of all the individuals, organisations, resources, activities, processes and technologies involved in the creation and sale of a product.

Sustainable aviation fuel (SAF): A liquid fuel which has the potential to reduce CO_2 emissions by up to 80% compared to traditional aviation fuel. It can be produced from a number of feedstocks, including waste oil and fats, green and municipal waste and non-food crops.

Tailpipe emissions: The product of fuel burning in an internal combustion engine, released through an engine exhaust. Tailpipe emissions include a number of pollutants such as carbon dioxide, carbon monoxide and nitrogen oxides.

Tonne kilometre: A unit of measurement of freight transport which represents the transport of one tonne of goods over the distance of one kilometre.

Transport inequality: Unequal distribution of travel between social groups, related to transport resources, including car ownership, access to public transport, and other modes of transport more generally.

Transport infrastructure: The fixed installations, structures and networks that enable the movement of people and goods.

Transport poverty: A lack of adequate transport services necessary to access general services and work, or the inability to pay for these transport services.

Whole-life emissions: See ***lifecycle emissions***.