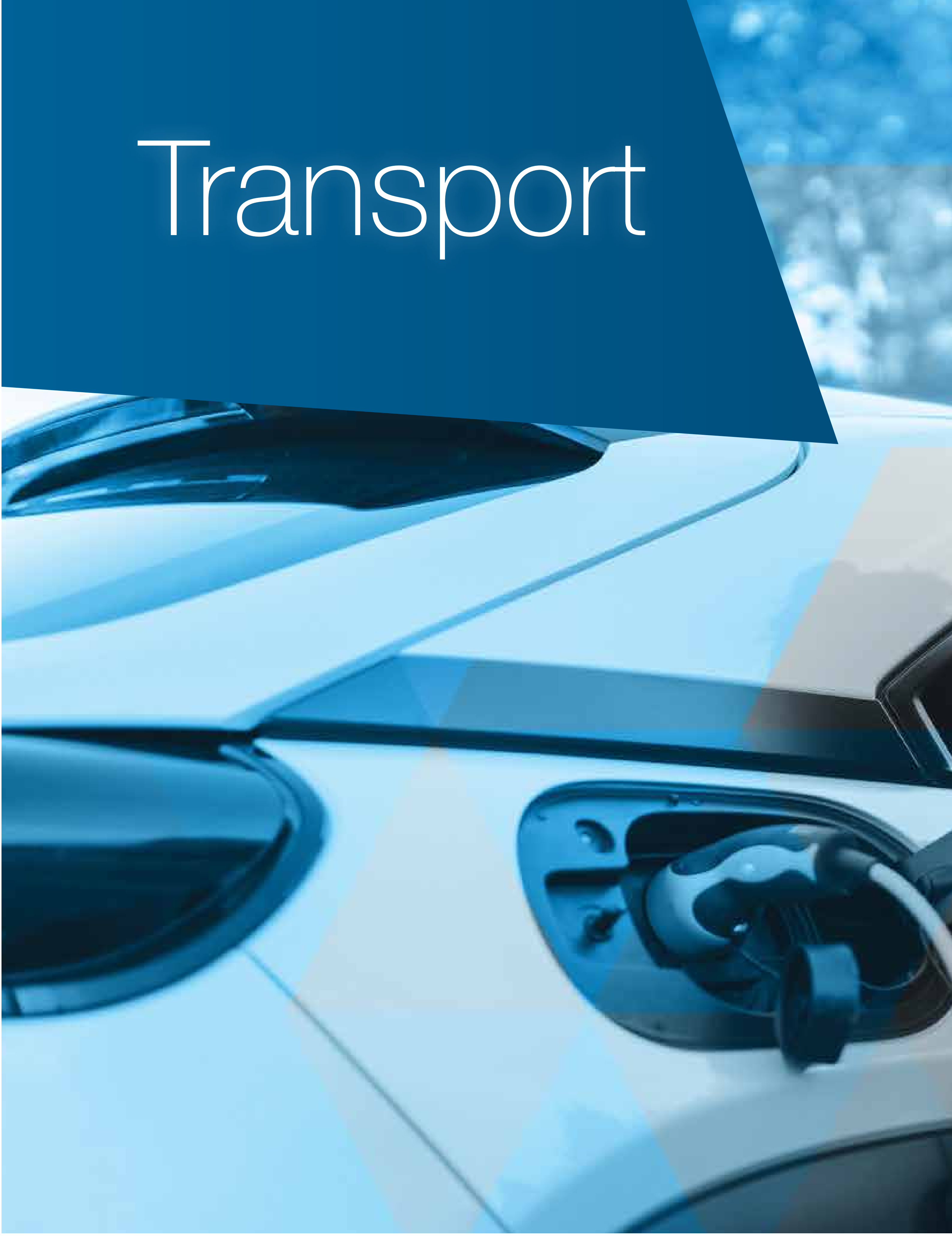
# Transport



TRANSPORT

# Sector summary

The transport sector is a significant and growing source of emissions in Australia. Deep and rapid reductions in these emissions are possible in the near term, but progress in some subsectors will depend on further developments in technology.

Transport was the source of 90 Mt $CO_2$-e of emissions in 2022 and is currently projected to be Australia's largest source of emissions by 2030. For this sector to best support Australia's transition to net zero by 2050, the deployment of existing technologies will need accelerate and developing technologies will need to be taken up quickly as they mature. This will require changes in the vehicles Australians purchase and the way Australians travel, electrification of other transport types where possible and new liquid fuels or hydrogen where it is not, and new supporting infrastructure.

Technologies are available now to reduce emissions from light vehicles in the form of battery electric vehicles and active and public transport options. Sales of new light vehicles reaching 100% electric ahead of 2040 can ensure there are minimal light vehicle emissions by 2050. Planning and roll-out of new and upgraded public and active transport networks will also support achieving emissions reduction goals.

Global manufacturers can supply the battery electric vehicles to decarbonise the passenger and light commercial vehicle fleet, which accounts for roughly half of Australia's transport emissions. The roll-out of charging infrastructure will need to lead electric vehicle sales for the current high rate in growth in these sales to be sustained.

Aviation, shipping, rail and heavy vehicle transport currently have immature and expensive low and zero emissions technology options. The pathway to minimise these emissions by 2050 will likely involve:

- accelerating take-up of battery electric technology in heavy vehicles and rail, which can occur from 2025 for mature vehicle types such as buses and light rigid trucks
- replacing existing diesel heavy vehicles and rail with hydrogen technology as soon as it matures, where battery electric is not suitable
- switching to renewable fuels where hydrogen and battery electric are not suitable or available, including sustainable aviation fuels in aviation, green ammonia and methanol in shipping, and potentially renewable diesel for remaining road and rail freight.

Challenges to transitioning to low and zero emissions technologies include high upfront costs, lack of supporting infrastructure and appropriate regulation. Technology maturity and long asset lives present further barriers for aviation, shipping, rail and heavy vehicles. There is also inadequate information on the supply and demand and future costs of renewable fuels to inform technology investment decisions. These challenges mean there will likely be some residual transport emissions in 2050.

## T.1 Sector state of play

The transport sector includes, for both passengers and freight, road transportation (cars, light commercial vehicles, heavy duty trucks, buses, motorcycles) and off-road transportation (domestic aviation, domestic shipping, rail).

### T.1.1 Economic contribution

The transport sector provides essential services for Australia's economy, moving goods to where they are needed and connecting people to families, jobs, education, communities and essential services. The transport sector contributed $125 billion Gross Value Added (GVA) in 2022-23, approximately 5% of Australia's total GDP (Appendix B, ABS (2023)). Road transport contributed 31%, rail contributed 57% and ships contributed 12% of domestic freight transport in 2022-23 (calculated from BITRE (2023a)).

### T.1.2 Emissions profile

Transport emissions were 90 Mt $CO_2$-e (21% of Australia's emissions) in 2022, with on-road vehicles accounting for 85% of the total emissions in the sector. All transport subsector emissions have grown since 2005, reflecting growth in population and the economy, and limited deployment of low emissions technologies.

Table T.1: Emissions in the transport sector, 2022

| Sub sector | Mt $CO_2$-e | Subsector share (%) |
|---|---|---|
| Cars[1] | 38 | 42 |
| Light Commercial Vehicles | 17 | 19 |
| Heavy-Duty Trucks and Buses | 22 | 24 |
| Motorcycles | 0.2 | 0.2 |
| Railways | 4 | 4 |
| Domestic aviation | 6 | 6 |
| Domestic shipping[2] | 2 | 3 |
| Mobile air-conditioning and transport refrigeration | 2 | 2 |
| Other transportation | <0.1 | <0.1 |
| Total | 90 | 100 |

Note: Mt $CO_2$ -e and subsector share (%) may not sum to the totals due to rounding.

Light vehicle road transport is the largest source of transport emissions (60% in 2022) and has mature abatement technology in the form of electric vehicles. However, electric vehicles currently make up less than 1% of Australia's light vehicle fleet (BITRE, 2023c). In 2022, there were approximately 19 million cars in the Australian light vehicle fleet (BITRE, 2023b). In 2021, 91% of households owned at least one vehicle and 55% owned two or more (ABS, 2022). Of vehicle owning households, around 75% have access to off-street parking where charging may be more easily accessed.

1 Including sport utility vehicles (SUVs).
2 "Domestic shipping" means the same as the Australian National Greenhouse Accounts Inventory category "domestic navigation".

Heavy vehicle transport is the second largest source of emissions in the transport sector (24% in 2022) and is made up of emissions from rigid trucks (8.7 Mt $CO_2$-e), articulated trucks (11.7 Mt $CO_2$e) and buses (1.6 Mt $CO_2$-e in 2022). Electric buses and small electric trucks are mature technologies (National Transport Commission, 2023; Electric Vehicle Council & Australian Trucking Association, 2022; Queensland Transport and Logistics Council, 2022) and are being deployed across Australia, but make up less than 1% of the heavy vehicle fleet (BITRE, 2023c). Alternative low emissions vehicles such as hydrogen powered trucks are still at the demonstration stage.

Domestic aviation and shipping are a smaller source of emissions (9%) and no direct abatement options have been deployed in Australia at commercial scale.

The authority considered small sources of emissions in this sector, such as refrigerant gas released from air-conditioning systems keeping passengers and freight cool, but these were not prioritised for deeper analysis. Motorcycle emissions are also not discussed, but there is potential for this technology to follow light vehicles and electrify. International shipping and aviation emissions are not considered within the scope of this review.

## T.2 Existing and prospective technologies

The following technologies and operational changes can address the major sources of transport emissions (Table T.2). A key challenge for all transport subsectors, which technological advancements should address over time, is the range that can be achieved by electric vehicles compared to vehicles with internal combustion engines.

Table T.2: Potential emissions reduction opportunities for transport

| Emissions subsector | Sector emissions share 2022 | Priority abatement lever(s) | Readiness | Barriers to adoption |
|---|---|---|---|---|
| Light vehicles | 60% | Electric vehicles | Commercial (competitive) | Capital cost, charging infrastructure, consumer choices |
| | | Mode shift to active and public transport | - | Capital cost, planning approvals and delays for new infrastructure, consumer choices |
| Heavy vehicles | 24% | Electric vehicles | Commercial (supported) | Regulation, long asset life, capital cost, charging infrastructure, supply |
| | | Hydrogen vehicles | Demonstration | Regulation, capital cost, refuelling infrastructure, hydrogen cost, tech maturity, hydrogen supply |
| Domestic aviation | 6% | Sustainable Aviation Fuel | Demonstration | Regulation, SAF cost, tech maturity, feedstock competition |
| Domestic shipping | 3% | Methanol | Demonstration | Regulation, long asset life, cost, tech maturity, refuelling infrastructure, long asset life |
| | | Ammonia | Research and Development | |
| Rail | 4% | Electric rail and hydrogen rail[3] | Overhead electric: Commercial (competitive)<br>Battery electric: Demonstration<br>Hydrogen rail: Demonstration | Capital cost, recharging/ refuelling infrastructure, long asset life |

3 Electric rail was included in the authority's Targets, Pathways and Progress issues paper, but the authority since has also considered hydrogen rail.

There are immediate opportunities to reduce emissions in the transport sector, particularly in relation to electrification of the light vehicle fleet (Figure T.1). Harder to electrify transport modes are dependent on developments in technology, availability of supply, and cost (Figure T.2). The transport sector will decarbonise by deploying electric technology first, hydrogen technology where electric is not suitable, and renewable fuels where neither electric or hydrogen are suitable or available.

Figure T.1: Prospective decarbonisation pathways for road transport using battery electric vehicles, mode shift and hydrogen vehicles

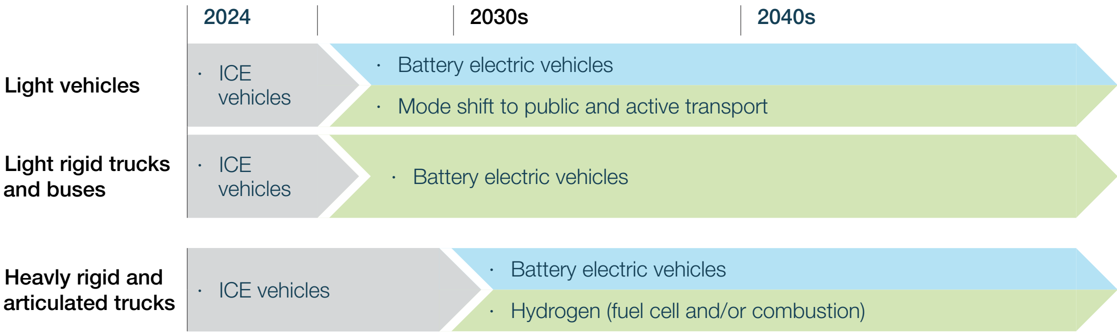
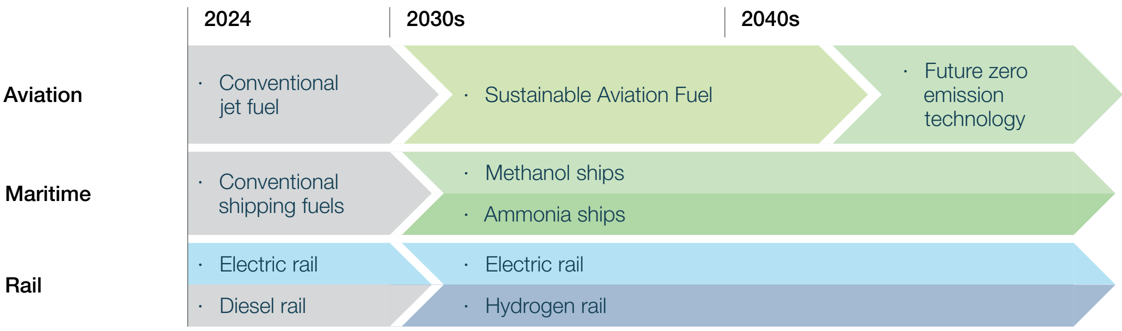



Figure T.2: Prospective decarbonisation pathways for non-road transport using renewable fuels, hydrogen and electric rail




## T.2.1 Decarbonising the light vehicle fleet

EVs have emerged as the most suitable technology to replace light internal combustion engine (ICE) vehicles. EVs can do most of the tasks currently performed by ICE vehicles and their share in new car sales is growing rapidly from a low base (CCA, 2023). EVs have no tailpipe emissions. When taking into account scope 2 electricity emissions, EVs charged with electricity at the current average generation mix of fossil and renewable sources across Australia's main grids are lower emitting than ICE vehicles (DCCEEW, 2023). Many EV models have a range of over 400 km before needing to be recharged (Green Vehicle Guide, 2024).

Achieving a high uptake of EVs is dependent on reaching price parity with ICE vehicles, availability of charging infrastructure, and EV model availability across the various market segments. There is evidence indicating that consumers' primary reasons for not purchasing EVs are price and lack of public charging (The Australia Institute, 2023) (see more in T.3 Barriers).

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EV model availability is improving for passenger cars but is lacking in light commercial segments. There were approximately 56 battery electric passenger car models available in Australia in 2023 (Electric Vehicle Council, 2024). However, there was only one electric utility vehicle available (Electric Vehicle Council, 2023). The National Farmers' Federation (2024) has expressed concerns over the lack of electric substitutes for the towing capacity and range of diesel utility vehicles, and it is expected to take time for more models to become available (Electric Vehicle Council, 2023).

### T.2.2 Mode shift to public and active transport

Travel by public and active transport is emissions intensive compared to private vehicle travel, is socially beneficial, and can reduce cost-of-living pressures (Centre for Urban Research, 2018; International Transport Forum, 2023; Rural and Regional Affairs and Transport References Committee, 2014). Travel by active transport can provide immediate emissions reduction not dependent on electricity decarbonisation.

> *Facilitating greater use of active, shared and public transport can cut climate pollution further and faster [than electrifying vehicles] - and do so this decade - because the effects are seen immediately through reduced use of private motor vehicle travel.*
>
> Living Streets Canberra submission, 2024

New approaches in infrastructure and city planning are key for developing functional public and active transport networks (Centre for Urban Research, 2018; International Transport Forum, 2023). Encouraging people to choose active and public transport requires adequate transport options, infrastructure and information to address safety, convenience, comfort, and accessibility concerns. For example, Glouias et al. (2002) found in Perth that 31% of private vehicle trips required system or infrastructure improvements to shift to alternative modes, and 34% of trips had subjective reasons against shifting to alternative modes such as lack of information. Through consultation, the authority heard from stakeholders that the key enablers to mode shifting include active and public transport infrastructure investment and appropriate land use planning to make cities more walkable such as improved precinct design.

There are long lead times in planning public investment into active and public transport infrastructure. For example, the first stage of Canberra's light rail project took 6 years to complete (Box T.1). Adelaide's Frome Street Bikeway has yet to be completed, 10 years after public consultation on the project was undertaken (City of Adelaide 2024; Adelaide City Council 2013).

### T.2.3 Decarbonising the heavy vehicle fleet

Heavy vehicles (trucks and buses) make up 24% (22 Mt $CO_2$-e) of transport emissions in Australia. Decarbonising the heavy vehicle fleet is likely to be a long-term task as the turnover of vehicles within the fleet is slow. Over 23% of all trucks and 14% of all buses on the road are older than 21 years in 2023 (BITRE, 2023c). The lack of availability of zero emissions heavy vehicles in the market and the inertia of asset replacement in this sector is a significant barrier to the uptake of new technologies to lower emissions in heavy vehicles and will require policy attention.

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The authority heard through consultation that battery electric options are currently suitable for a range of heavy vehicle applications, especially where low payloads are moved less than 300 km. The characteristics of mature battery electric technology makes it applicable to most 'return to depot' light rigid truck and bus operations (Global Commercial Vehicle Drive to Zero, 2023). These types of operations are typical of many rigid trucks and are the source of approximately 9 Mt $CO_2$-e of emissions each year in Australia (DCCEEW, 2022). Globally there have been improvements in the battery electric heavy vehicle market, with growth in model availability for heavy duty trucks in recent years, and the average range of these models has grown by over 10% between 2020 and 2023 (Global Commercial Vehicle Drive to Zero 2023).


## Box T.1: The ACT's light rail investments led to emissions reductions, but projects take a long time to complete

**The introduction of light rail has reduced the ACT's carbon emissions per capita and contributed to reducing the daily average number of motor vehicles counted at one intersection near the light rail corridor by 21% in 2019 and 18% in 2024 compared to 2016 (Transport Canberra, 2024). The light rail is an 100% emissions reduction compared to each car ride it replaces since the ACT has reached 100% renewable electricity. (Note: The ACT Government offsets its electricity emissions by retiring Large Generation Certificates (Point Advisory, 2023).**

**These projects require substantial time for planning, consultation, approvals, and construction. Stage 1 of the light rail project was completed in 2019, 6 years from feasibility studies to building completion (ACT Government, n.d.). Expansions of the network are expected to be complete in 2027 and 2033; with stage 2b taking 10 years from public consultation to completion (ACT Government, 2024).**

Hydrogen is a promising technology for decarbonising some articulated trucks, some heavy rigid trucks and long-haul buses (BITRE, 2019; NPROXX, 2024). Hydrogen has better energy density characteristics than current battery technology (Copenhagen Centre on Energy Efficiency, 2019), allowing hydrogen vehicles to carry heavier payloads without sacrificing as much range as a battery electric vehicle. Hydrogen is also much faster to refuel than battery electric is to recharge (BITRE, 2019). Hydrogen fuelled heavy vehicles are not yet a commercially mature technology, but this could occur in the 2030s (Hydrogen Council, 2021; Hydrogen Europe, 2024; McKinsey, 2023).

The authority heard through consultation that stakeholders are concerned about whether zero emissions vehicle technology can improve enough to do the longest and heaviest trucking tasks. Australian road freight can be up to 130 tonnes (including the truck weight) on articulated trucks (National Heavy Vehicle Regulator, 2016) which the authority heard through consultation is globally unique. To lower emissions, these uniquely long and heavy freight tasks could be undertaken by running conventional trucks on renewable diesel. However, competition for various renewable fuels from other parts of the economy may affect the affordability and availability of renewable diesel for road transport. Renewable diesel could also be used to reduce emissions in the short- to medium-term, while other low and zero emissions technologies for heavy vehicles mature, subject to fuel availability.

## Box T.2: Fossil fuel and infrastructure phaseout for road vehicles

The phase out of fossil fuels and relevant infrastructure needs to be managed carefully for users that could require access to liquid fuels into the future. The IEA projects that global road fuel demand is approaching its peak (IEA, 2024a). In a scenario of the light vehicles transport fleet modelled by CSIRO, 10 years after new light ICE vehicles were no longer available, light ICE commercial services decline rapidly or are no longer viable to operate (CSIRO, 2023a). This decline in the commercial viability of ICE fuel infrastructure may lead to a sparse liquid fuel network by 2050 (Boston Consulting Group, 2019).

The phase out of fossil fuels may also impact the commercial viability of Australia's remaining fuel refineries, noting there may be increasing demand for domestically manufactured renewable fuels such as sustainable aviation fuels.

### T.2.4 Decarbonising aviation

Sustainable Aviation Fuel (SAF) is the most promising technology for decarbonising aviation emissions. SAF is a drop-in fuel (i.e., can be used in existing aircraft engines) that can be used instead of conventional jet fuel, made from non-petroleum feedstocks. It can be made from synthetic or biogenic sources, such as biomass, waste products, natural oils and fats, other carbon sources and hydrogen. Other technologies (hydrogen and electric planes) are only at a nascent stage and will initially only be suitable for short and low payload routes which are a relatively small share of domestic aviation emissions (Mission Possible Partnership 2022; ICCT 2022).

The CSIRO found that Australia could play a key role as a source of feedstocks for international production and as a SAF producer, noting that Australia already produces significant quantities of feedstocks exported for biofuel production (for example, canola seed exported to the European Union) (CSIRO, 2023c).

### T.2.5 Decarbonising shipping

Green ammonia and methanol[4] are prospective technologies for decarbonising the largest shipping tasks (the largest share of domestic shipping emissions). However, both fuels are only in demonstration phase (ARENA, 2023). In comparison, smaller near-shore vessels may be replaced by or retrofitted to battery electric and hydrogen power (due to shorter distances travelled) (Energy Networks Australia, 2019; Interreg, 2020).

Green ammonia is zero emissions and methanol can reduce tailpipe emissions by 10% and lifecycle emissions by 51-94% compared to conventional fuels used in shipping (European Maritime Safety Agency, 2023; Methanol Institute, 2022). Consultation advice was that vessel asset life varies, but 20 to 30 years is common so this sector will likely decarbonise slowly in the absence of policy measures.

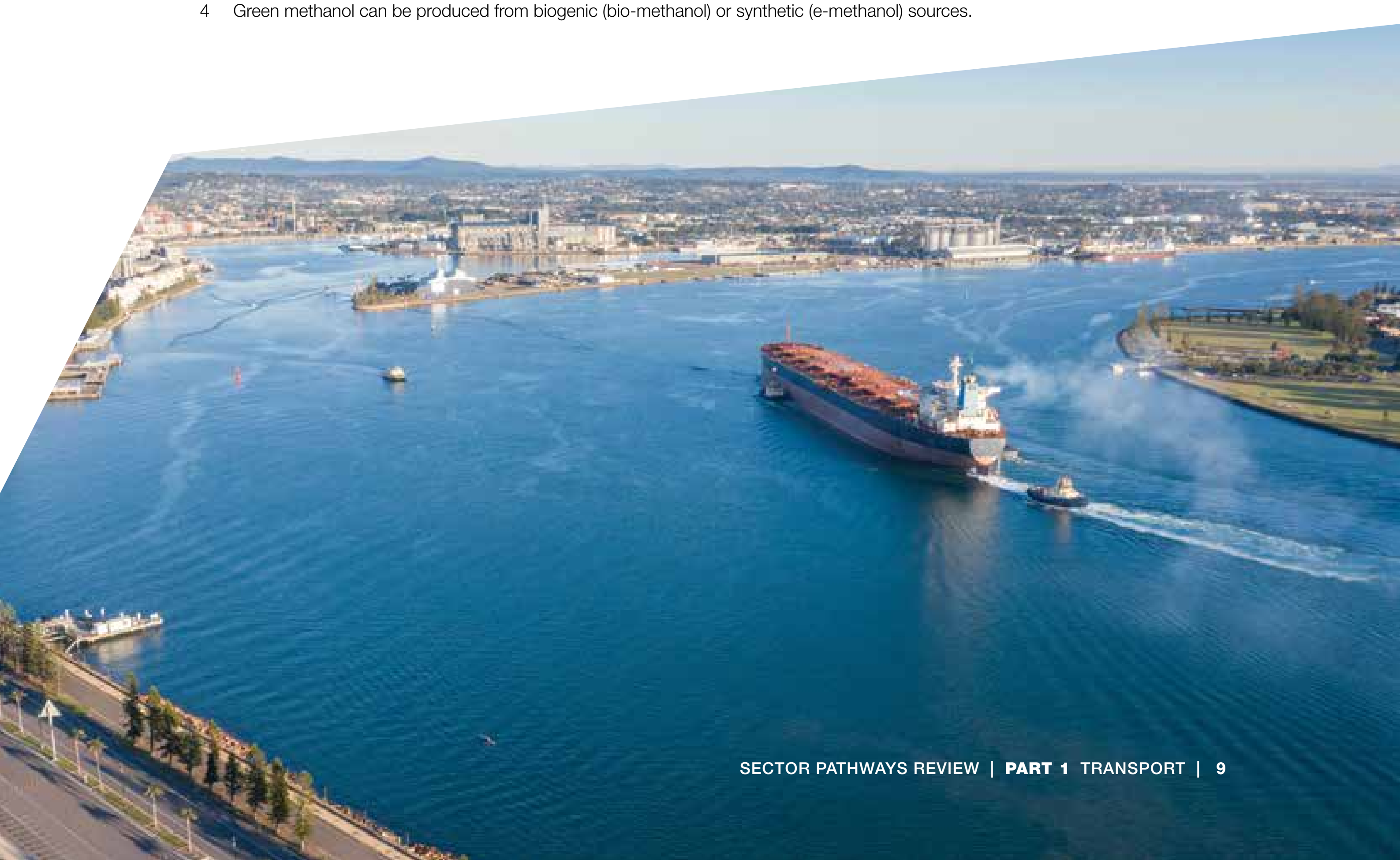
### T.2.6 Decarbonising rail

The most promising technologies to decarbonise rail are grid-connected electric, battery electric and hydrogen powered engines. Grid-connected electric rail is a mature technology. Battery electric is maturing now, while hydrogen rail is not expected to mature until the 2030s (CSIRO, 2018; Hydrogen Council, 2021). Renewable diesel presents an opportunity to reduce remaining emissions, but there are barriers to overcome (see below). Ensuring that existing rail locomotives are replaced with zero emissions alternatives, at least at end-of-asset-life, is critical due to their long-lived nature.

> *'Australian rollingstock has an average lifespan of about 25 - 30 years. It is anticipated that about half of the nation's fleet will be due for replacement in the next 8 to 13 years. The rollingstock procured during this period will therefore have an expected lifespan beyond 2050.'*
>
> Australasian Rail Association submission, 2024

Noting that zero emissions rail technology is still maturing, it is possible 20 - 50% of Australia's diesel rail could be transitioned to electric and hydrogen technology by 2050. The authority consulted with a major Australian rail operator who indicated that they were considering adopting battery electric technology in the near term due to its maturity and low running costs, and would consider hydrogen as it matures.

4 Green methanol can be produced from biogenic (bio-methanol) or synthetic (e-methanol) sources.



## Box T.3: Renewable fuels

Renewable fuels[5] include diesel, petrol or jet fuels made from biogenic or synthetic feedstocks. Depending on the feedstock and manufacturing pathway, they can be used as a complete replacement for fossil fuels in existing engines or may need to be blended with fossil fuels (NSW Government, 2023; Office of Energy Efficiency & Renewable Energy, n.d.; van Dyk, 2022). Australia imports approximately 90% of its liquid fuel (CSIRO, 2023c). Transitioning to electric drive trains and developing a domestic renewable fuel manufacturing capacity will enhance Australia's energy security.

Renewable fuels are likely to play an important role in decarbonising Australia's economy, particularly for sources of emissions that are difficult to electrify due to energy density requirements, access to infrastructure, or technology readiness. Examples include aviation, the military, remote power generation, shipping and machinery in industries such as construction, agriculture and forestry.

There is the potential for Australia to leverage its advanced farming practices, significant production base, established supply chains and renewable energy resources to develop a domestic renewable fuel industry.

However, there are challenges to overcome in scaling up the availability of affordable renewable fuels. Key inputs—land, water and renewable energy—are also needed for food, maintaining soil carbon and other environmental services, and land sector removals (Becken et al., 2023). Australian feedstocks such as canola and tallow are already being exported for renewable fuel production and this is likely to continue (CSIRO, 2023c). Constraints on the availability of the resources required for the production of renewable fuels means they are likely be in short supply (IEA, 2024b) and will need to be prioritised for industries that lack other options to decarbonise.

*'Biofuels may also play an important role for hard to decarbonise processes and applications, as well as in a transitional capacity. However, for biofuels to be competitive in Australia, the associated challenges of high capital and production costs, ability to reach efficient scales of production, and managing ongoing competition for feedstocks need to be overcome.'*

BHP submission, 2024

5 Renewable fuels are also referred to as 'sustainable fuels' and 'low carbon liquid fuels'. Some examples of these fuels are sustainable aviation fuel, renewable diesel, biodiesel, bioethanol, and e-fuels.

Renewable fuels typically emit similar tailpipe emissions as their fossil fuel equivalents (European Union Aviation Safety Agency, 2024). The carbon sequestered from the atmosphere to create a biogenic or synthetic feedstock is typically around the same quantity as the tailpipe emissions produced from using a renewable fuel and (Hanaki & Portugal-Pereira, 2018; US Energy Information Administration, 2024). This makes the fuel carbon neutral except for lifecycle emissions from the processing, refining and transporting of feedstocks, and in the case of biogenic feedstocks, land use change (Hanaki & Portugal-Pereira, 2018). Lifecycle emissions from renewable fuels can be up to 90% lower compared to fossil fuels, but can also be higher depending on the processes employed across their production, transport and use (Becken et al., 2023; Prussi et al., 2021).

Renewable fuels can be made from a wide range of biogenic sources such as corn, canola and animal fats (ETIP Bioenergy, 2024). Other biogenic sources such as algae, waste and agricultural residues are promising but production methods for these are immature (bp, 2023; FAO, 2010; IEA, 2024b; Wood Mackenzie, 2022). Renewable fuels can also be made synthetically using green hydrogen and a source of carbon (biogenic, manufactured or captured carbon). These fuels are also referred to as e-fuels due to their reliance on large volumes of renewable energy and are still maturing as a technology (efuel alliance, 2022; Wood Mackenzie, 2024). Government coordination will be needed to manage renewable fuel markets to ensure that sustainable land use is supported, that land use competition issues are managed and that finite fuels are available in sectors of the economy that most need them. As part of the 2024 Budget, the government announced a series of commitments to support a low-carbon-liquid fuels market in Australia. This included a commitment to consult on policy approaches to accelerate investment and incentivise efficient production of renewable fuels with a key initial focus on producing sustainable aviation fuel and renewable diesel.

The government also committed to undertake a regulatory impact analysis of the costs and benefits of introducing demand-side measures for renewable fuels.

A renewable fuels industry would aid in regional job creation in feedstock production, collection and transportation from regional areas to refineries and monetizing existing waste streams as part of a circular economy.

## T.3 Barriers, opportunities and enablers

### T.3.1 Green premium

New EVs are widely available for sale in Australia and sales are rapidly approaching 10% of the new vehicle market (CCA, 2023). EV sales have grown exponentially, making up less than 1% of the market in 2019. This rate of growth in the EV share of the new vehicle market needs to continue to decarbonise the light vehicle fleet ahead of 2050.

To sustain the rapid growth in new EV sales, it is likely that EVs will need to reach price parity with conventional ICE vehicles well before the end of the current decade. Consumers noted they would be more likely to buy an EV if there was a rebate available (Rosel, 2023). Purchase costs of electric vehicles are currently higher than ICE vehicles but are forecast to reach price parity between 2024 and 2033 in major markets (BNEF, 2023).

Adoption of EVs for passenger transport in Australia will require the installation of a wide-spread network of public EV charging infrastructure. The number of public EV charging locations has been growing in Australia. However, the rapid adoption of EVs that is required to reduce emissions means Australia will need a faster rollout of public chargers of various charging speeds in more locations. A lack of access may be exacerbated in regional areas where charging will be needed but overall use would be lower than in the city, impacting the economic case for regional and remote sites. Strategic investment by governments to ensure adequate coverage across the country can support consumers to choose electric vehicles in regional and remote areas.

The authority has been told that the installation of public charging infrastructure faces barriers in Australia.

> *'For Tesla, Australia is the most difficult country in the region to install direct current (DC) fast chargers, with transformer upgrades and grid connections often taking over 1 year for utilities to complete, compared to just 6-8 weeks in other countries.'*
>
> Tesla Motors submission, 2024

The majority of EV charging is expected to occur at home (Energetics, 2024), so access to home charging is essential. Around three-quarters of Australia households have access to off street parking such as a garage or carport (ABS, 2022).

Home charging is less accessible to homes without off street parking. The majority of apartments also have additional barriers to installing charging infrastructure which could delay EV purchases. Almost all older buildings in Australia will require electrical infrastructure upgrades to support EV charging (Strata Community Association, 2023), which will generally need to be paid equally across each owner in a strata building (Strata Community Association, 2023). Electrical upgrades require a vote, and those in the building who do not own an EV may not agree to installation. As the whole building requires upgrades, an owner cannot pay for their portion of the upgrades alone (Strata Community Association, 2023).

> *'Access to off-street charging is one of the most important enablers of EV adoption, and one of the key equity challenges of EVs, because Australians who are less socio-economically advantaged are less likely to own their homes, have off-street parking, or be able to access workplace charging.'*
>
> Tesla Motors submission, 2024

Over 90% of truck operators are small businesses with less than five staff and less than $2 million in revenue (ABS, 2023a, 2023b), and hence with limited capacity to afford trucks with the higher total cost of ownership (TCO) that is currently associated with zero emissions trucks due to their higher purchase prices (Electric Vehicle Council & Australian Trucking Association, 2022; Transport and Environment, 2020). The cost of hydrogen fuel also adds to the cost of ownership for hydrogen vehicles (Grattan Institute, 2023). The TCO for hydrogen trucks is not projected to meet parity with diesel trucks until the 2030s or later (CSIRO, 2022; Hydrogen Council, 2021; International Council on Clean Transportation, 2022).

Well-configured public finance and public finance policy mechanisms can address the price premium barriers that are holding back the greater uptake of low-carbon transport alternatives. The authority heard from stakeholders that the upfront cost of low carbon transport alternatives remains a significant barrier to uptake. For example, one stakeholder recommended public finance is necessary until 30% of the light vehicle sales are EVs (Electric Vehicle Council, 2023). The authority also heard from stakeholders that higher purchase costs for fuel alternatives such as green hydrogen, ammonia or sustainable aviation fuel for low carbon transport alternatives are a barrier to uptake for heavy vehicles, aviation, shipping and rail. Further, mechanisms are needed to ensure there are sufficient charging and refuelling networks, particularly where the charger is uneconomical and critical to network coverage.

Government has a role to play in supporting the infrastructure that assists low emissions choices of individuals and business. This includes investment in public infrastructure such as for active and public transport and electric vehicle chargers.

> *'The Government must increase investment in infrastructure to support walking and riding. The factors preventing mode shift are not technological, but they are deep and engrained in existing transport planning and decision-making culture.'*
>
> WalkSydney submission, 2024

> Well-configured public finance mechanisms can address the price premium barriers that are holding back the greater uptake of low-carbon transport alternatives.

## Box T.4: How financial incentives can drive uptake of low emissions technology

Since 1990, Norway has been providing incentives for the uptake of EVs, with the goal of having all new cars sold zero-emissions (electric or hydrogen) by 2025 (Norwegian Electric Vehicle Association, 2022). In March 2024 battery electric vehicles achieved a 90% market share, positioning Norway as the leader in global EV uptake (European Commission, 2024).

Incentives commenced in the 1990s, such as free municipal parking and no charges on toll roads for EVs. Most of these incentives continued for at least 20 years, while new ones have been added over that period.

| Incentive | Time period |
|---|---|
| All publicly procured cars need to be zero emissions (buses from 2025) | 2022-present |
| All apartment buildings must make charging points available for residents | 2017-present |
| 25% value-added tax exemption on leasing EVs | 2015-present |
| Discounted or no charge to take an EV on a ferry | 2009-present |
| 25% value-added tax exemption on EV purchases | 2001-2022 |
| No purchase or import tax on EVs | 1990-2022 |
| No annual road tax for EVs | 1996-2021 |
| 25-50% reduced company EV tax | 2000-2017 |
| Free municipal parking for EVs | 1999-2017 |
| No charges on toll roads for EVs | 1997-2017 |

*Source: Norwegian Electric Vehicle Association, 2022*

National target setting can support policy certainty for public and private stakeholders to invest in the green transition. For example, Norway has also set a target for all new trucks sold in the country to be electric or biogas by 2030. Through Enova – a national funding agency to support late-phase technology development and early market introduction of climate and energy solutions – the Norwegian government has supported the purchase of 420 electric trucks and 115 electric buses, and is investing in national charging infrastructure for heavy vehicles (Norwegian Government, 2023).

### T.3.2 Technical constraints

The allowed width of Australian vehicles limits the potential overseas supply of zero emissions heavy vehicles to Australia (Electric Vehicle Council & Australian Trucking Association, 2022). As Australia is a small right hand drive market, it is unlikely to be economical for overseas manufacturers to design a bespoke zero emissions truck to align with Australia's vehicle width regulations. The authority heard similar concerns regarding buses.

> *'The Bus Industry Confederation is seeking an Australian Design Rule Change that allows buses or coaches to be built to 2.55 m body and axle width (in conjunction with an ADR change to allow for the external addons such as cameras and sensors to go to 2.6 m) as part of a package that would not only ensure the ongoing high level of bus and coach safety, but also to address known operating mass issues...'*
>
> Bus Industry Confederation submission, 2024

The authority heard from a range of stakeholders that current axle weight limits are restricting use of low emissions vehicles (which are heavier due to the weight of batteries and hydrogen systems) on Australia's roads. Allowed axle weights are set by the owners of roads, state and territory governments and local councils (Australian Trucking Association, 2019). Queensland, New South Wales, South Australia and Victoria have announced weight regulation changes or are holding trials (NatRoad, 2024; Trucksales, 2024; VicRoads, 2023).

> *'Revising weight limitations to allow LZEHV[6]s on Australian roads is a key part of the transition. At present, there is a lack of consistency in approaches from the states and territories which acts as a barrier to the transition. Consistency in approach and in weight allowances is needed to encourage heavy vehicle operators to transition to LZEHVs.'*
>
> Heavy Vehicle Industry Australia submission, 2024

Heavy vehicles will require a comprehensive electric charging and/or hydrogen refuelling network. However, there is currently almost no dedicated heavy vehicle public charging available in and heavy vehicles often do not physically fit into light vehicle charging bays. There are few hydrogen refuelling stations in Australia (CSIRO, 2023b).

> *Electric vehicle charging stations/ hydrogen refuelling stations often only cater to passenger vehicles, or are not practically located to support existing high-volume freight routes.*
>
> Heavy Vehicle Industry Australia submission, 2024

Stakeholders have raised a range of barriers around the installation of charging infrastructure, including:

- there may not be sufficient energy capacity in the grid which may require expensive electrical upgrades such as getting a second electrical connection.
- electrical infrastructure upgrades are a financial risk for operators and owners in rented depots, where operators are uncertain on a future lease, and owners are uncertain if future tenants will require charging.

### T.3.3 Supply chain constraints

There may be global competition for renewable fuels and their feedstocks to decarbonise multiple sectors including transport, agriculture, and mining. This competition will exacerbate land and water use demand pressures (see AL.3 Barriers, opportunities and enablers under the agriculture and land sectoral pathway).

Some renewable fuel production methods are mature, but there is a limited supply of these feedstocks. In the SAF Roadmap, for example, mature SAF production methods[7] can only provide approximately 10% of Australia's 2050 jet fuel demand (CSIRO, 2023c).

Until all renewable fuels production methods mature, supply of renewable fuels will remain limited. Immature fuel production methods include:

- green ammonia as a shipping fuel (Argus, 2020)
- advanced biofuels from algae and agricultural residues (IRENA, 2019)
- synthetic fuels (e-fuels) (S&P Global, 2024)

Renewable fuels for aviation and shipping have significant price premiums compared to fossil fuels (Table T.3). With competition for feedstocks, it is not clear whether these price premiums could be overcome.

6 LZEHV refers to 'Low and zero emissions heavy vehicles'
7 HEFA

Table T.3: Price premium of renewable compared to fossil fuels

| Renewable fuel | Price premium compared to fossil fuel |
|---|---|
| E-methanol (using carbon capture) | 3.5-7 times higher |
| Green ammonia | 3.4-7 times higher |
| SAF | 1.6-4.5 times higher |
| Bio-methanol | 1.4-3.4 times higher |

*Sources: CSIRO, 2023c; European Maritime Safety Agency, 2023; IRENA (International Renewable Energy Agency), 2021.*

### T.3.4 Information and data gaps

Supporting an orderly transition to low emissions transport will require better data on Australia's current transport activities, as well as how this could change in the future, including on:

- **Supply and demand of fuels:** The use of bioenergy, including renewable diesel and SAF, requires integrated net zero planning across several sectors including transport, resources (mining haulage), agriculture (farm machinery) and industry (high temperature heat). Further work is needed to:
    1. Collect and publish comprehensive statistics on Australia's liquid renewable fuel use and their feedstocks in Australia. This includes annual quantities of:
        a) The production of renewable liquid fuels
        b) The consumption of renewable liquid fuels
        c) The import of renewable liquid fuels and feedstocks
        d) The export of renewable liquid fuels and feedstocks
    2. Based on these data and other sources analyse current capacity of Australia to produce renewable liquid fuels and develop a projection of how this could develop over time.
    3. Consult with the key industries on this analysis and develop a strategic plan for liquid renewable fuel availability in Australia, including the identification of priority uses for this fuel.
- **Unknown costs for operators:** Transport fleet operators raised concerns with the authority about adopting zero emissions vehicles due to unknown pricing impacts including:
    1. repairs or maintenance costs, particularly while there are limited-service providers
    2. insurance costs, vehicle life and resale values
    3. vehicle range and recharging time impacts on operational costs
    4. uncertainty about future road-user charges for low emissions vehicles

### T.3.5 Workforce and skills shortages

The transport sector is currently facing significant labour supply challenges. Industry Skills Australia (2023) has identified shortages across the transport sector:

- Ground crew, pilots, and air traffic control staff in aviation
- Train drivers, controllers and signalling technicians, skill shortfalls
- Truck drivers across Australia, which can cause delays to infrastructure projects
- The maritime industry workforce

These shortages are felt more acutely in regional, rural and remote areas where attracting skilled workers is more difficult (Industry Skills Australia, 2023).

The uptake of new technologies can exacerbate or create new workforce shortages. For example, as the deployment of EVs increases, the demand for mechanics to service EVs will increase. The lack of automotive electricians has been linked with accelerated rates of avoidable write-offs of EVs with minor damage (Visontay, 2024). Local manufacturing of renewable fuels like hydrogen and SAF could also require a growing fuel production workforce (JSA, 2023).

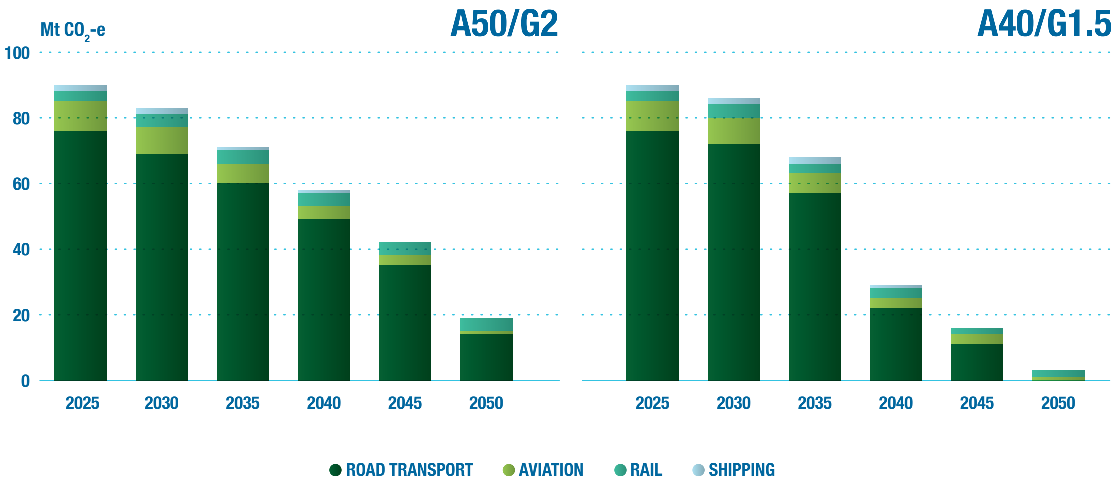
As non-ICE vehicles increase in market share the pipeline of technicians with relevant skills will need to be supported, particularly in regional areas that are more dependent on private road transport (AUSMASA, 2023; JSA, 2023; Leung et al., 2021). Enrolments in electric and hybrid vehicles VET modules are increasing rapidly – from 10 enrolments in 2018 to 597 in 2022 (NCVER, 2024).

The authority's consultation process for this report revealed support for specific training pathways to repair and maintain zero emissions vehicles that do not require workers to undertake traditional ICE mechanical training as well. There was concern about the potential for requiring a worker to be both a mechanic and electrician to work on EVs.

## T.4 Emissions pathways

CSIRO modelling commissioned by the authority shows steady decarbonisation of the transport sector in A50/G2 and steep drop in emissions in the A40/G1.5 scenario (Figure T.3).

Figure T.3 Transport sector emissions (AusTIMES), A50/G2 and A40/G1.5




*Source: CSIRO modelling in AusTIMES commissioned by the Climate Change Authority*

The authority also undertook ground-up analysis to estimate the abatement potential of technologies and compare to the modelling results.

The results of the modelling and ground-up analysis for road vehicles are broadly aligned (Table T.4).

Table T.4: Projected emissions reductions in the transport sector over the period to 2050

| | Estimate of abatement to 2050 (Mt $CO_2$-e)[a] | | |
|---|---|---|---|
| **Reference: emissions in 2022 were 90 Mt $CO_2$-e** | **AusTIMES modelling (A50/G2)** | **AusTIMES modelling (A40/G1.5)** | **Ground-up estimate** |
| Road vehicles | 62 | 76 | 59<br>(55 from light vehicles, 4 from heavy vehicles) |
| Domestic aviation | 8 | 9 | Not estimated |
| Domestic shipping | 2 | 2 | Not estimated |
| Rail | 0 | 2 | Not estimated |
| Transport total | 71 | 88 | 59 |

Note: Where ground-up analysis was not available, the results of the A40/G1.5 scenario were used for the purpose of estimating total sector abatement to 2050.

a Abatement was calculated as the difference between base year emissions and the projected 2050 emissions from each model. In AusTIMES the base year for the abatement calculation is 2025 and in bottom-up modelling the base year was 2022.

### T.4.1 Residual emissions

Total expected residual emissions in 2050 based on both the ground-up analysis and top-down modelling is expected to be between 3 and 23 Mt $CO_2$-e, comprising of:

- Approximately 0-18 Mt $CO_2$-e from heavy vehicles
- 1 Mt $CO_2$-e from domestic aviation
- 2-4 Mt $CO_2$-e from rail
- Less than 1 Mt $CO_2$-e from domestic shipping
- 0 Mt $CO_2$-e from light vehicles

The authority focused on the highest abating technologies for each transport subsector and the take-up of these technologies within the current asset replacement cycle. There is the potential for residual emissions to be addressed through the following additional emissions reduction activities:

- faster asset replacement cycles
- renewable diesel use in the remaining diesel heavy vehicle and rail fleet
- electric and hydrogen propulsion for planes and ships
- mode shifting freight from heavy vehicles to rail
- operational changes and fuel efficiency improvements in vehicles.

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