Australia's ENERGY FUTURE: 55 BY 35

Decarbonising Transport

AUSTRALIAN ENERGY COUNCIL

Executive Overview

The AEC has proposed an economy-wide interim emissions target of 55 per cent reduction on 2005 levels by 2035 as a milestone on the way to net zero. This paper is one in a series of papers exploring the implications of the 55 by 35 target. This paper looks at the opportunities for emissions reduction in transport.

As with many other emitting activities there are multiple ways to reduce emissions from transport. However, with the ultimate goal of net zero in mind, options that decarbonise the fuel source are preferable in the long-term over options that can only make marginal reductions. Greater efficiency of engines and transport mode switching are examples of the latter. These options should not be ignored but are not going to elicit major emissions reductions.

Light passenger vehicles, i.e., cars, SUVs are the largest source of transport emissions in Australia. It has become increasingly clear that the way to reduce emissions for this segment is through a switch to electric vehicles (EVs). Even at current grid emissions intensities, EVs are lower emissions, and this will only improve further as our electricity systems continue to decarbonise. Other options, such as ethanol, or fuel cells are expected to only play a niche role.

Australia is often portrayed as being behind our peers internationally on EV take-up. This reflects our relatively small domestic market and the fact that the leading countries use large subsidies of one form or another to drive the switch to EVs. Nonetheless Australian jurisdictions have a range of supportive policies for EVs and the need for subsidies will disappear over the next few years as the price premium for EVs erodes.

Non-price barriers to take-up appear to be based largely on out-dated misconceptions about EVs' range, charging, and cost. The report addresses these misconceptions.

Widespread take-up of EVs will have some impact on the grid. But the details are uncertain as it depends on when, where and how fast we charge our EVs. If autonomous vehicles take-off and start to affect car ownership, that could make a big difference to outcomes. In any case with sensible policies and forward planning, the impact should be manageable.

For larger vehicles the options are more complex. Electric drivetrains and batteries appear to have less of an advantage the larger a vehicle gets. So, biofuels or hydrogen are more likely to play a role for trucks, trains, ships and planes. In most cases there is still some prospective electrification option too.

Overall, decarbonisation of transport, and in particular electrification of passenger vehicles is one of the main opportunities for Australia to reach its interim targets and take strong steps towards net zero.

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Introduction

The Australian Energy Council (AEC) published its Net Zero by 2050 policy in June 2020. That policy has since been adopted by Australia, and focus has turned to interim targets to set the economy on a realistic pathway to this ambition. An interim target should be aspirational yet achievable, and consistent with the overall goal of net zero by 2050. An economy-wide target is more flexible and efficient than purely sectoral targets. With these factors in mind, the AEC has proposed an interim economy-wide target of 55% reduction from 2005 levels by 2035 ("55 by 35").

This paper is one in a series of papers exploring the implications of the 55 by 35 target. It focuses on the opportunities for emissions reduction arising from decarbonisation of transport. There are a range of options, varying by transport mode. For light vehicles, electrification is the most promising opportunity, while for larger road vehicles, hydrogen fuel cells may compete more effectively with electric drivetrains. Biofuels are an obvious option for aircraft, and hydrogen is being explored for shipping. In each case there are other potential routes to decarbonisation, and so for policymakers there is a line to be walked between supporting the most prospective options while not "picking winners".

Section I : Emissions Reduction Opportunities in the Transport Sector

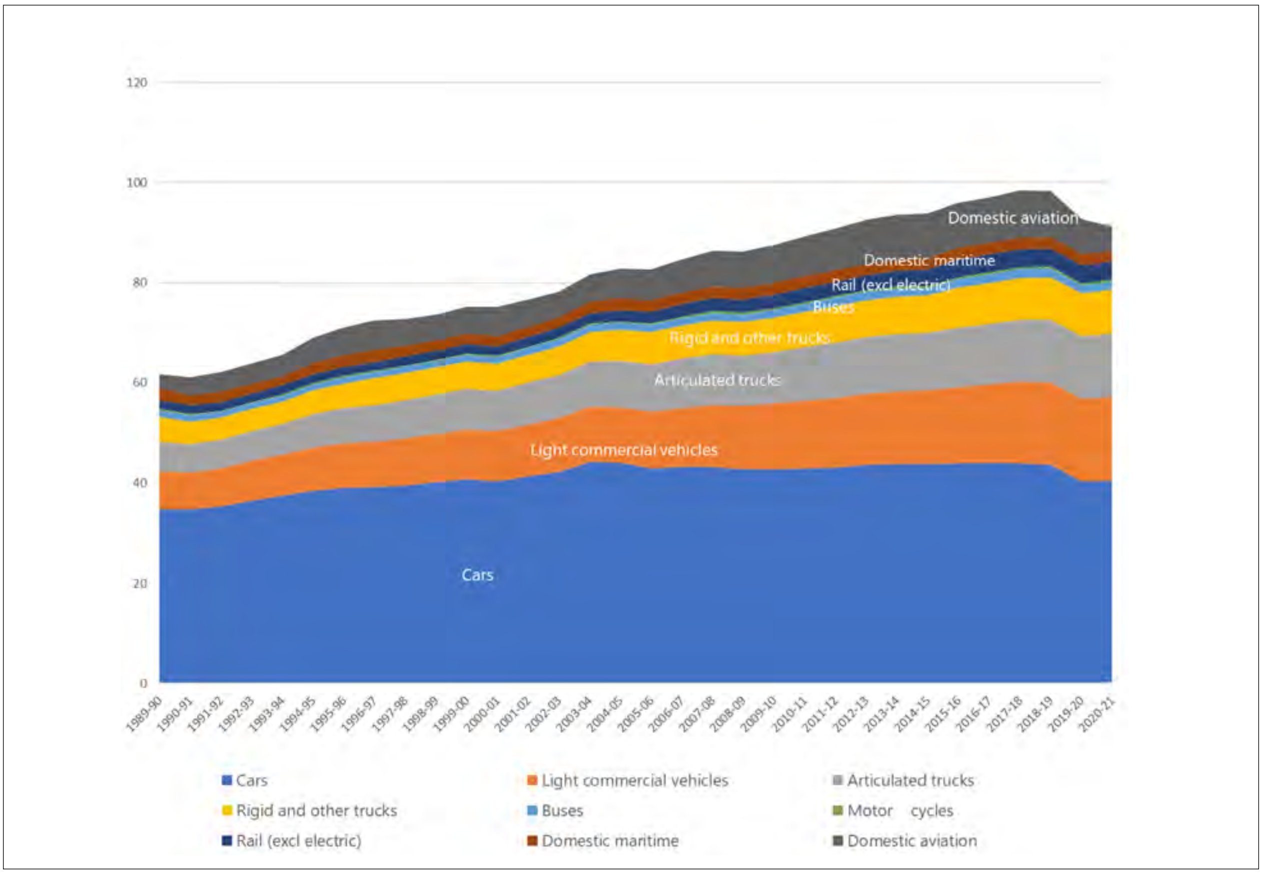
Transport modes and their relative emissions

Transport - of people and freight – is the lifeblood of any economy. Australia, with its low density cities and large distances between major population centres, depends on a range of transport modes to keep its economy going: cars, trucks, buses, bicycles, motorbikes, trains, trams, ships and planes. There are numerous metrics by which to compare these modes: passenger kilometres, freight tonnage, energy use, etc. but the one most relevant to this paper is emissions.

As Figure 1 below shows, emissions from cars are the biggest source of transport emissions, followed by light commercial trucks. Overall, road traffic emissions dominate, with rail, marine and aviation contributing only around 15 per cent.

Transport emissions have been on a steady upward trend for decades, with the downturn in the last two years due to COVID-related disruption rather than any significant underlying emissions reduction. So, the upward trend is likely to continue unless technological or behavioural changes can bend the curve. Such changes may happen as a result of underlying drivers, but supportive policies can play an important role too.

Figure 1 *Greenhouse emissions by mode, 1990-2020, Australia, kt CO2e pa*



Source: BITRE, Australian infrastructure and transport statistics yearbook 2021

Emissions reduction opportunities

IEA's Sustainable Development scenario projects that globally, the transport sector will reach net zero emissions by 2070. Small two/three wheel vehicles will be the first to reach zero emissions, followed by trains, and then light commercial vehicles. In 2070, aviation, shipping and heavy commercial vehicles will still be producing emissions, but these hard-to-abate emissions will be offset by negative emissions technologies.

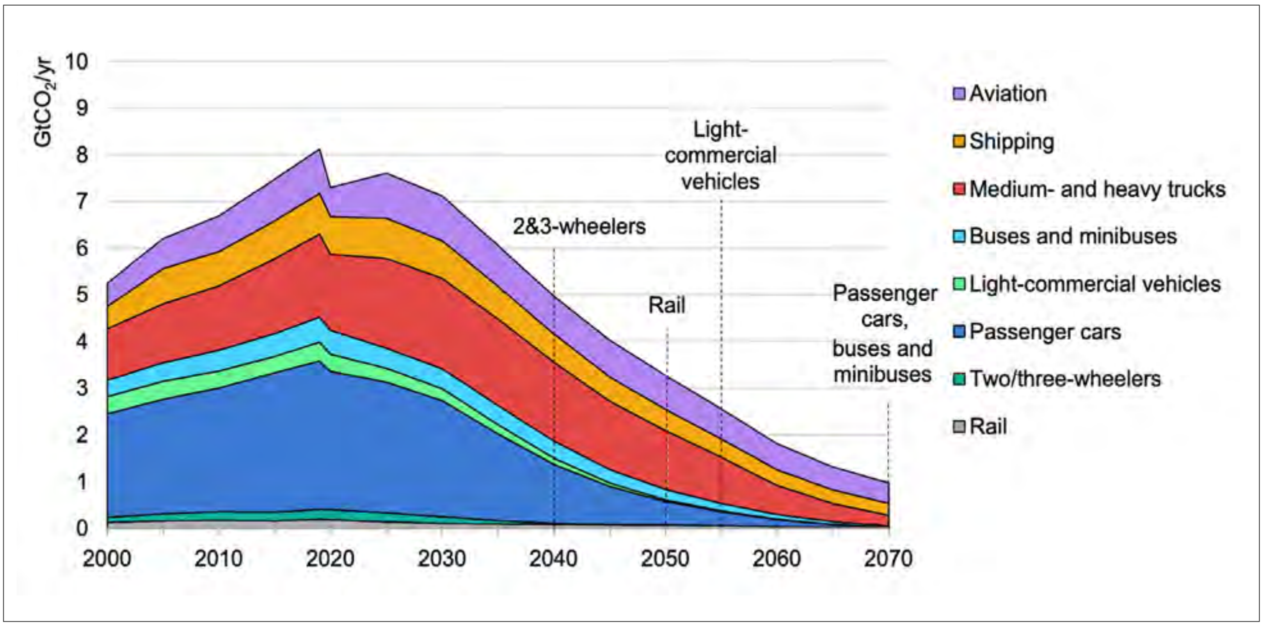
Like any projection, these figures are based on a range of assumptions, and this is only one of several scenarios the IEA has considered. Some emissions reduction options will turn out to be harder than expected or occur more slowly. Others will be easier and faster. These global projections also mask a difference in speed of change between different companies. Typically, emissions reduction is expected to occur earlier in developed countries such as Australia, whose economies are robust enough to begin the switch to new technologies that are - initially at least - more expensive than current transport technologies. Even so, it's notable that under this projection, global transport emissions may already have peaked.

As with other sectors of the economy, there are multiple ways that transport emissions can be reduced.

1. Energy efficiency – using the same type of transport, but using less fuel per distance travelled
2. Reducing usage and mode switching to lower emissions alternatives
3. Alternative lower/zero emissions fuels
4. Electrification

These opportunities are explored further in the sections below.

Figure 2 *Global transport emissions*



Source: IEA 2020.

Energy efficiency

Any way that emissions can be reduced is a positive step. During the 2010s, energy efficiency of all kinds was identified as a low cost – often a negative cost – way to reduce emissions. The Australian light vehicle fleet, for example is fairly low on energy efficiency. This is typically attributed to Australia adopting looser fuel efficiency standards than other developed countries.

The National Energy Productivity Plan, adopted by the Australian Government in 2015, sought to improve national energy productivity (energy use/$ GDP) by 40 per cent by 2030[1] . This was projected to also deliver emissions reductions. Transport emission reductions were forecast to contribute 16MtCO2e of emissions savings by 2030, or almost one third of the total. Light vehicles (i.e., cars) were expected to deliver a little over half of these savings.

Since then, there has been limited progress on the policy front, with no update to minimum fuel efficiency standards.

The shift to targeting net zero highlights the limitations of energy efficiency gains – they cannot get Australia to net zero. Accordingly, the focus of policymakers has switched to alternative energy sources, especially electric vehicles.

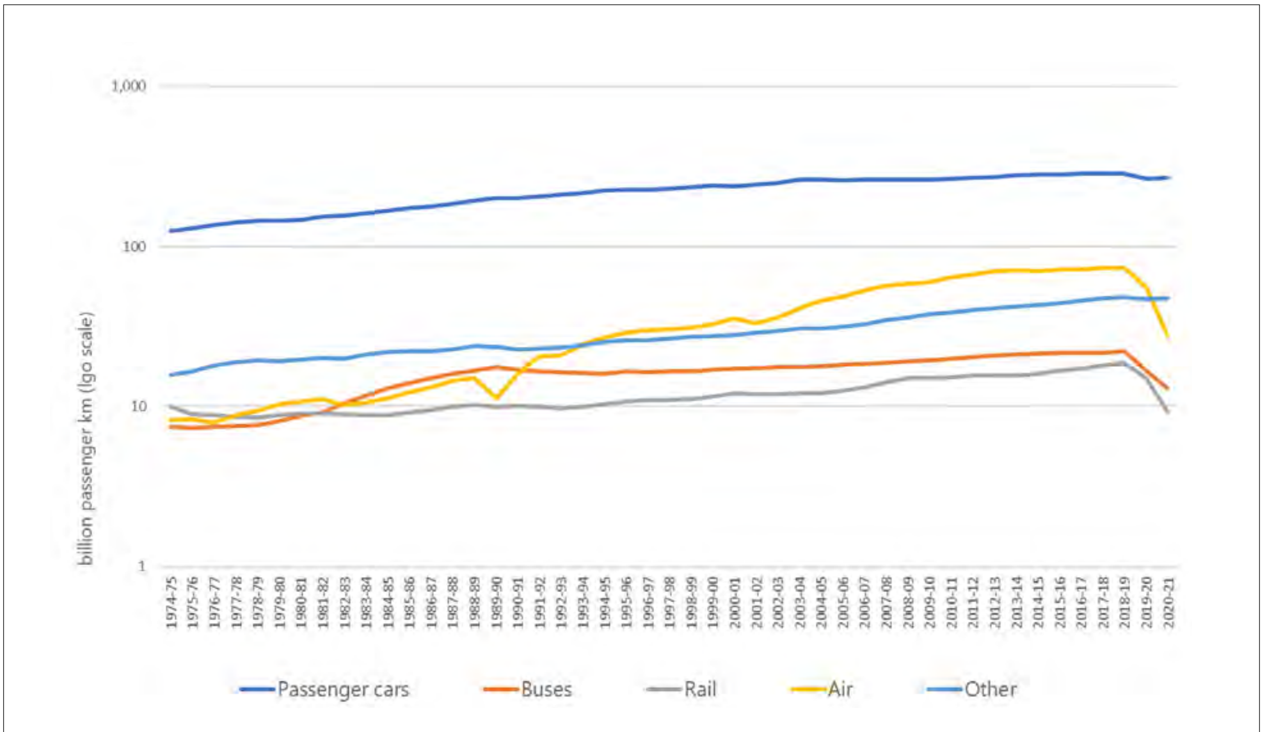
Even if the purchase of new vehicles has decisively switched to electric vehicles by 2035, many older cars will still be on the road. The average age of Australian cars is 10.6 years. Accordingly, if Australians begun buying more fuel-efficient cars, whether due to consumer choice or tighter legislated standards in the 2020s, this would contribute to lower emissions in 2035.

The National Energy Productivity Plan also set out scope for energy efficiency savings in the aviation and maritime sectors. These were largely predicated on existing national and international initiatives delivering progressive efficiency gains.

Reducing usage and mode switching

Australia's transport emissions declined for the first time in decades in 2020 and again in 2021. As discussed above this is due to lower transport usage resulting from COVID restrictions. This is illustrated in Figure 3 below.

Figure 3 *Passenger kilometres travelled annually*



Source: BITRE, Australian infrastructure and transport statistics yearbook 2021

1 National Energy Productivity Plan, Australian Government, 2015

It's clear that public transport modes – air, bus and rail, were especially affected. The likelihood is that use of these modes will return to trend in the next few years as COVID restrictions are lifted and Australians have the confidence to return to normal life. However, such significant events as a global pandemic can turn out to have lasting impacts. To the extent that urban travel makes a more permanent switch away from public transport, it's likely to put upward pressure on emissions. Conversely, if working from home remains more prevalent, and car commuting reduces this would put some downward pressure on emissions.

Aside from such dislocations, permanent reductions in transport usage are unlikely. Population growth is a key driver - kilometres travelled per capita for most modes peaked before 2019. Car passenger travel per capita peaked in 2004, and domestic air travel per capita peaked around 2014. Bus travel per capita peaked in 1990, the same year aviation was significantly disrupted by a pilot's strike[2] . In the case of freight, economic conditions are a key driver. Material changes in demand for Australia's export commodities could affect rail freight quantities (and in turn emissions). How much government policy can impact these trends either way is unclear, although there are some attempts to reorient major cities around a series of employment and leisure hubs to minimise commuting time and distances, such as Greater Melbourne's "20 minute neighbourhood" initiative. There are also perennial attempts to boost public transport use and to encourage walking or cycling instead of driving for short trips. Such initiatives may be laudable and have value in terms of reducing traffic congestion and improving public health but are not expected to deliver large emissions reductions.

Fundamentally, as with energy efficiency, mode switching or reduced usage can only reduce emissions at the margins, not eliminate them.

Alternative fuels

To fully decarbonise transport requires an alternative energy source to the oil-based fuels (petrol, diesel, bunker fuels) that currently power most vehicles. To do this while maintaining the internal combustion engine, requires zero carbon fuels. Biofuels are hydrocarbons that are carbon neutral because they are derived from plants that have absorbed carbon dioxide from the air. Partial use of biofuels is already common with small proportions of ethanol being blended with petrol and available at most service stations. Other potential biofuels include liquified or compressed biomethane (LRNG/CRNG).

It's unlikely that there will be a mass switch to fully ethanol powered vehicles, however. The biomass required would be very significant. This would require significant amounts of energy to power the ethanol conversion process and there would be community concerns about the displacement of agricultural production of food. Ethanol is costlier than the alternatives and is less energy dense than petrol or diesel. While E10 fuel currently sells at a discount this is because it benefits from lower fuel excise. This tax differential would not be sustainable if ethanol-based fuel became widespread. Engine modification is necessary to run on high proportions of ethanol. Some vehicle manufacturers already produce engines capable of running on up to 95 per cent ethanol, mostly for buses and trucks. So, a niche role for ethanol fuel is possible, for example for off-road uses where EV charging is not available, but widespread replacement of petrol/diesel is implausible.

Other forms of bioenergy may play a role. The Australian Government's Bioenergy Roadmap sets out a goal for 18 per cent of aviation fuel to come from bioenergy in the 2030s. A Qantas jet powered by biofuel flew LA-Melbourne in 2018 and the company recently signed a large scale biofuel supply deal to help fuel its flights out of London Heathrow. As always, the issue is in moving from trials and partial use of biofuels to a full-scale industry and reducing the cost premium to acceptable levels.

The alternative to carbon neutral hydrocarbons is hydrogen. The opportunities to develop green hydrogen for domestic use and export will be covered more fully in a separate paper. For transport, there are trials of hydrogen powered fuel cells for almost all modes of transport, including cars, buses, trucks, ships and even planes. A recent Goldman Sachs report suggests hydrogen could be cost-competitive with diesel for large trucks as early as 2027[3].

Broadly, the prospects for biofuels or hydrogen in transport are inversely correlated with the likelihood of electrification. Transport modes that are harder and costlier to convert to electrification are more likely to see biofuel/hydrogen penetration. This roughly correlates to the size/mass of the transport mode – the heavier the mode, the bigger a battery has to be to power it and so the less likely a commercially viable electric solution is. Length of journey and the feasibility of interim recharging are also a factor, but journey length is also loosely connected to size. The exception is rail transport, which utilise overhead or third rail sources of electricity and so are not dependent on battery. The fixed track nature of trains and trams is the characteristic that makes them suitable for powering this way.

2 https://chartingtransport.com/category/greenhouse-gas-emissions/
3 Goldman Sachs, Carbonomics: the clean hydrogen revolution, , February 2022

Electrification

The most promising technology for decarbonisation of light vehicles (and potentially some heavier vehicles) is in some ways the most radical as it entails a change in drivetrain away from the internal combustion engine (ICE). Battery-powered electric vehicles have far fewer moving parts, meaning they will have lower maintenance costs.

Hybrids represent an intermediate step between the two. Some hybrids are simply ICE with an auxiliary battery. These deliver fuel efficiency benefits but do not qualify as electric vehicles. Plug-in hybrids (PHEVs) have both types of drivetrains and the driver can switch modes as required. They typically have much lower battery range than pure battery EVs (BEVs), because they can switch to ICE mode as required. However, many commuter drives and other urban journeys could be carried out purely on the electric mode of a PHEV providing the battery was fully charged at the start of the journey. For the purposes of this report, references to EVs will cover PHEVs and BEVs.

Electrification does not deliver full decarbonisation immediately, as discussed below, EVs produce lower emissions per kilometre than equivalent ICE cars even at the current emissions intensity of both the NEM and the WEM. Progressive decarbonisation of these electricity systems mean that the emissions reductions will only grow as Australians switch to EVs. Section II below explores the implications of electrification of the light vehicle fleet in greater detail.

Section II : Electrification of Light Vehicles

As the IEA recently noted: *"in the world of clean energy, few areas are as dynamic as the electric car market. In the whole of 2012, about 130 000 electric cars were sold worldwide. Today [2021], that many are sold in the space of a single week."*[4] Currently the major markets are in China, Europe, and the US. Australia has lower take-up of electric vehicles than these other countries.

Supply of electric vehicles

Australia is a relatively small market, amongst the minority of countries with right-hand drive vehicles and has no domestic car manufacturers. Accordingly, we are dependent on international car firms for the mix of vehicles available to buy and prices. Australia is currently seen as a less attractive destination, and this is often attributed to lower incentives than some of the major markets. A fuller examination of existing policy support is carried out below, but it's important to note the high bar required to match the incentives available elsewhere. Norway has the highest take-up of EVs globally – at around 80 per cent of new cars. However, Norway has historically taxed car purchases heavily – the exact tax rate depends on the model, but it is typically in the thousands of dollars. Norway first exempted EVs from the car registration tax and then from sales tax (25 per cent). For a standard model such as a VW Golf, this could be worth around $20,000 and makes the electric version cheaper, even though its underlying price is around 50 per cent higher. Economically this is no different from a cash subsidy, but the optics of tax rebates are easier politically. Now that most car purchases avoid the taxes, the budget impact has become material and there are proposals to reintroduce taxation of EVs.

The EU has taken a different approach. By setting tough average emission targets for the major manufacturers, they leave it to the manufacturers to work out the cross-subsidy needed in order to meet the targets, so that they are not relying on government subsidies and tax breaks (although some EU countries have some of those to). This results in an estimated subsidy per vehicle equivalent to $26,000[5]. While EV sales are low, this translates to only $1,000 or so premium for ICE cars. But as sales of EVs grow, the incidence of the cross-subsidy will grow. The question is whether the underlying cost premium reduces quickly enough to mitigate this.

So, the reality is that if Australia wants to "compete" with other countries for the supply of EV, it will need to consider support mechanisms worth $20,000 or more. It's questionable how economically justifiable or politically palatable this is.

Fortunately, there is widespread agreement among forecasters that electric vehicles will fall in cost. Cost parity is expected between 2025 and 2030. A report focussed on European markets suggested sticker price parity around 2025-2027 (excluding subsidies). Australia may be a couple of years behind this timeframe, but the lower running costs of EVs mean lifecycle costs, even for low mileages will occur sooner.

In any case there are already at least 36 models available in Australia, including 2 PHEV SUVs. So, the limited supply and choice of models in Australia is a temporary phenomenon that will be resolved well before 2035.

Addressing misconceptions

"EVs aren't really better for the environment"

At present the default assumption for electric vehicle charging from the grid should be that it has the average emissions intensity of the grid. This has been declining steadily for over a decade as the energy mix shifts from

4 Electric cars fend off supply challenges to more than double global sales, IEA, January 2022
5 Australians want to buy electric cars, but car makers say government policy blocks supply, ABC, April 2021
6 NEM emissions intensity for 2021, calculated from AEMO data
7 https://www.reuters.com/business/autos-transportation/when-do-electric-vehicles-become-cleaner-than-gasoline-cars-2021-06-29/

fossil fuels to renewables. Even at the current level of 0.67 tCO_2e/MWh[6] , an EV generates fewer emissions per km than an equivalent ICE. The exact comparison depends on the specific models being compared, of course. But, in general, even an EV charging from a fully coal-fired electricity system would be less emissive than an equivalent ICE.[7] An Australian emissions/cost calculator can be found here. For example, a low mileage hatchback based in suburban Melbourne is estimated to have less than half the annual emissions of an equivalent ICE model, based on charging from the grid.

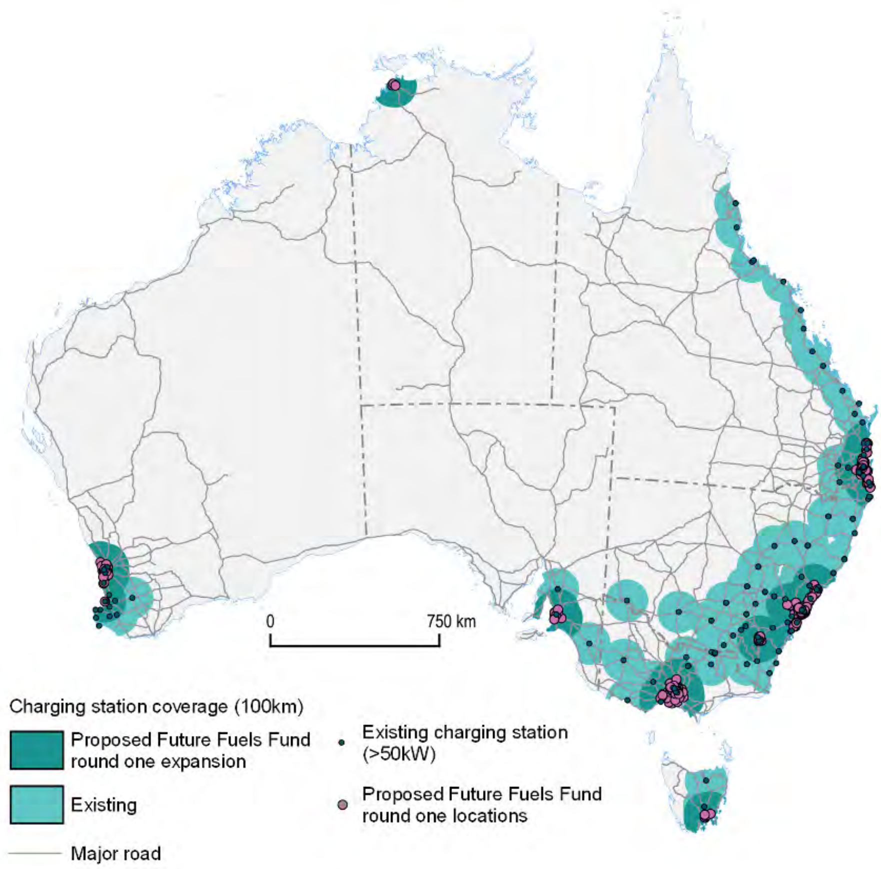
Emissions reductions may be greater if:

- EV drivers are motivated to offset the emissions from the electricity they charge their EVs with (e.g., by buying 100 per cent GreenPower), or;
- EV drivers are motivated to save money by charging their vehicles when wholesale prices are low, which typically correlates to high renewables penetration.

One objection to this analysis is that it doesn't account for higher lifecycle emissions. Estimates vary with assumptions about the battery (larger batteries are associated with higher embedded emissions), but a typical EV may have embedded emissions of around 3t CO_2e more than a similar ICE. This is consistent with the higher sticker price, which indicates EV manufacture currently consumers more resources. The embedded emissions of any type of car will fall as decarbonisation progresses, and the gap will close, but in any case, it does not take long for lifecycle emissions of an ICE to overtake an EV. If powered by zero emissions electricity, it would take less than a year, (under 10,000km of driving).

Similarly, there are broader environmental benefits to EVs. Noise pollution is lower and particulate emissions, too, even allowing for some fossil fuelled power in the charging mix.

Figure 4 *Existing and proposed electric vehicle charging station coverage in Australia*



Source: DISER

"EVs don't have adequate range"

EV range varies with model and battery options. Nevertheless, the trend is firmly upwards as battery technology improves. Current EVs have an average battery range of 480km. Given the wisdom of stopping every two hours on a long journey, it would be rare to exhaust the battery on a single non-stop trip. Recharging on longer journeys need not take significantly longer than fuelling up at the pump, as ultra-rapid chargers can add 300km of range in ten minutes. In any case, in practice, most Australian car journeys are a fraction of this distance.

Plug-in hybrids provide both range for longer distances and the opportunity to benefit from electric charging for short journeys.

"It is hard to find a charger"

EV owners will typically want to charge at home when they can. A relatively high proportion of Australians live in homes with off-street parking so home charger installation will be the norm. Overnight charging does not require expensive high wattage chargers. For apartment blocks, shared charge points will become an attractive selling point and may get added to planning requirements.

Public chargers are proliferating. As Appendix A shows, state and territory governments are making a significant public investment in charging facilities, as is the private sector. Shopping centres are adding chargers as a customer attraction – as these sites are large electricity users already, they can install fast chargers without straining the local network.

The federal government is supporting the rollout of chargers through its Future Fuels Strategy. In July last year ARENA announced the co-funding of 403 new fast charging stations, each capable of charging at least two vehicles concurrently at 50 kW or above.

Charging infrastructure has a chicken and egg relationship with EV sales. As more EVs take to the roads in Australia, the business case for new charging points improves. Whilst governments should monitor the ratio of cars: chargers to ensure charging availability grown in line with EV take-up, the private sector will likely respond to demand.

"EVs are too expensive"

The upfront cost of an EV is still significantly higher than ICE equivalents. While this could be mitigated by removal of luxury car taxes and duties that were predicated on supporting domestic car manufacturing, there remains an underlying cost premium, albeit one that will shrink over this decade. Conversely, EVs are significantly cheaper to run. Charging is cheaper than refuelling, by around two thirds at standard retail prices. Customers with their own solar power and the opportunity to charge during the daytime will pay even less – only the value forgone from solar feed-in tariffs, which are much lower than retail prices. Maintenance is much lower, potentially saving hundreds of dollars a year. When an EV buyer would "breakeven" on their investment will depend on the price premium, the value of government incentives (on registration fees, stamp duty etc) and their annual distance driven. But, for high annual distances at least, annualised costs for an EV already undercut ICE. This benefit is likely to be relevant initially to fleet users, who are more likely than private buyers to compare annualised costs of EVs v ICEs. But financing packages could help tip the balance for private buyers too, who may need assistance getting over the hurdle of higher up front cost.

The one downside on running costs is the potential to be charged road user fees. While these will not fully offset the lower fuel costs, they will affect the financial trade-off with ICEs. We should recognise that declining ICE sales will reduce fuel excise revenue, which is loosely hypothecated for road maintenance costs and that governments will need to replace that revenue source somehow. However, Victoria's early move to impose road user charges on EV drivers has been widely criticised for its disincentive effect. By contrast, the NSW approach of announcing a road use charge but deferring its introduction for several years allows the economics of EVs to improve to the point that the road user charge will be less of a barrier.

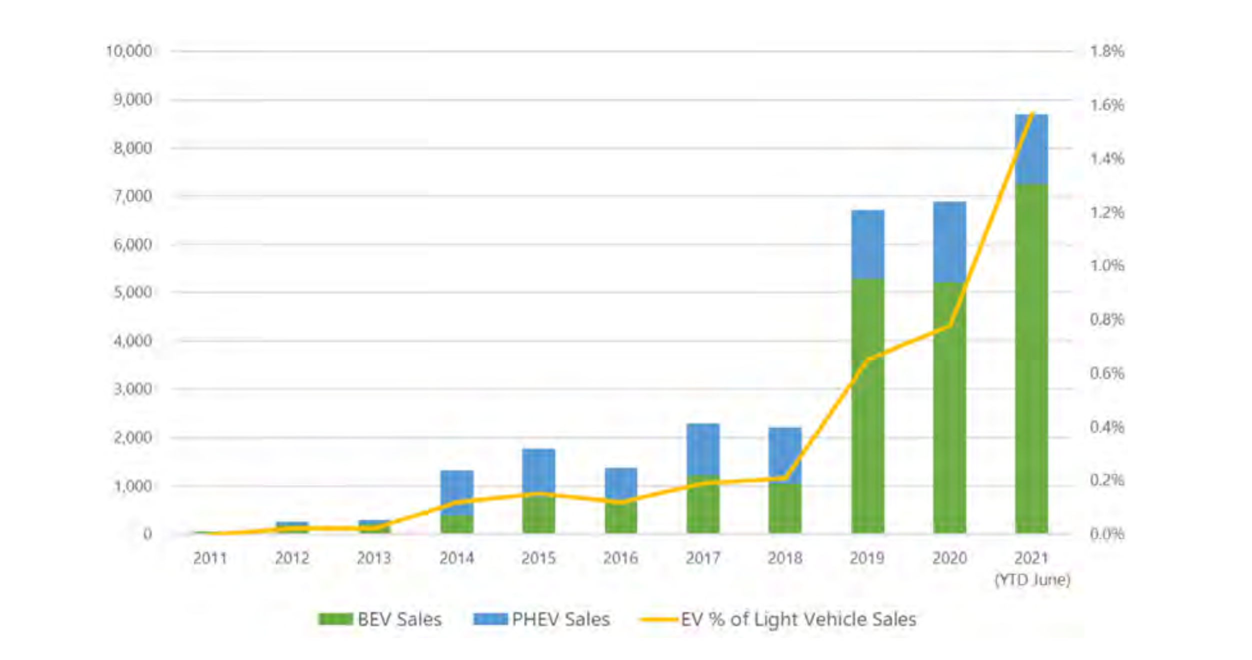
"EVs will break the grid"

There will undoubtedly be an impact on the grid from EV charging as EV take-up grows. However, it need not be a problem. The goal will be to encourage charging to take place at off peak times where possible. Given typical commuter patterns, there will be plenty of flexibility for EV users to top up at any time between, say, 6pm and 6am. Since residential peaks are typically in the early evening, the key is to encourage or incentivise households to defer charging for a few hours.

Fast chargers will draw a lot of power, and so in some locations this may require grid reinforcement. But these will largely be commercial chargers and will be located based on the economics of whether it's worth paying for grid improvements or finding a location that can already handle large power flows (e.g., at a shopping centre).

EVs may even be beneficial to the grid. If charging can mostly be directed to off peak times, then they will improve utilisation of existing networks, and this could bring down the cost per KWh for everyone. It's possible too that vehicle to grid (V2G) technology will allow car batteries to provide support back to the grid. However, given their primary purpose is to power a car, and owners will mostly want to reserve their capacity for that purpose, we shouldn't expect too much from V2G. Grid impacts are explored further below.

Figure 5 *EV sales and penetration rate, Australia (2021 to June only)*



Source: EV Council

Sales trends and forecasts

Forecasters have a patchy track record on predicting EV take-up, with several forecasts from the past decade predicting that EV penetration would be much higher by 2022 than is actually the case. Accordingly, specific predictions should be taken with a pinch of salt.

Nonetheless, sales are steadily increasing from a very small base. In 2021, between 1 and 2 per cent of all car sales were EVs (plug-in hybrids and battery EVs).

CSIRO have modelled the take-up of EVs under a range of scenarios as an input to AEMO's Integrated System Plan modelling. CSIRO note that car purchase is based on a range of "price and non-price" factors. This is an oblique way of admitting that households have a range of reasons for choosing a particular model, which can be difficult to capture in modelling exercises. The projections are shown in Figure 6 below.

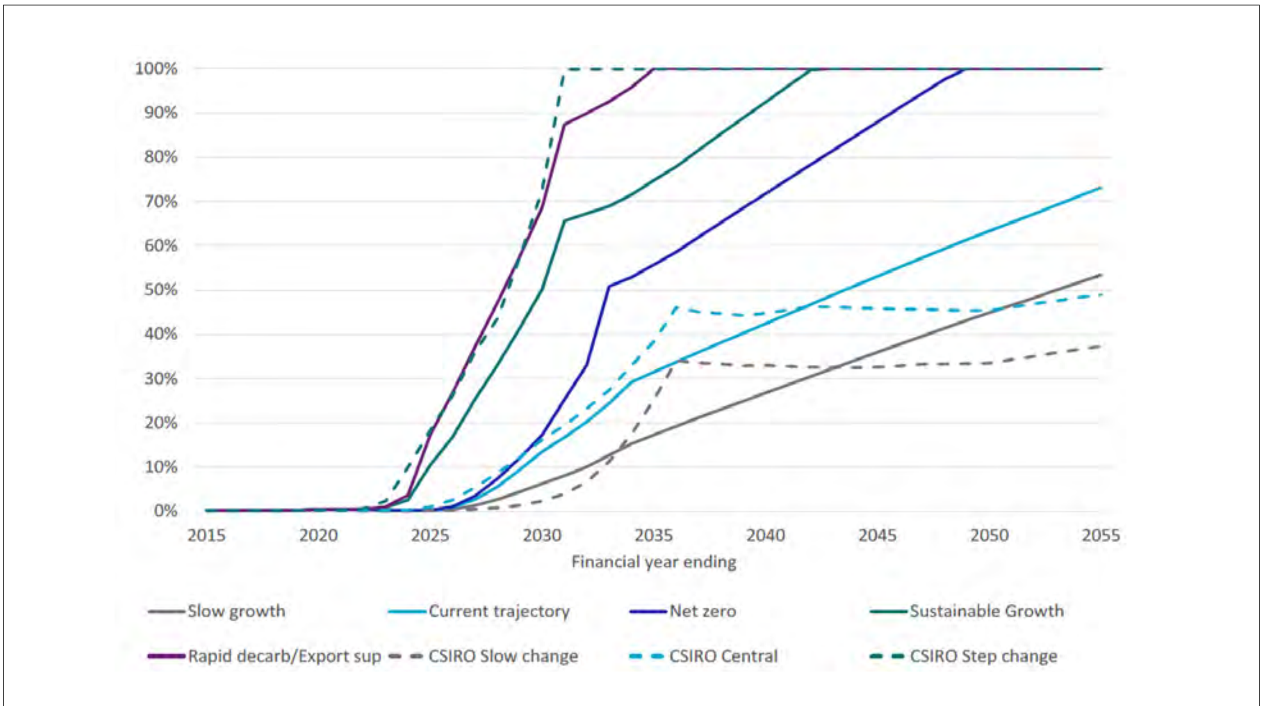
The projections vary widely. The "current trajectory" scenario, in which about 30 per cent of new car purchases in 2035 are electric may sound like it's the status quo projection. However, as part of its ISP work, AEMO received feedback that the energy transition is proceeding faster than previously expected and has adopted the "step change" scenario as its central projection. So implicitly, it is expecting penetration to be closer to 100 per cent. Noting that a number of major manufacturers have stated they intend to phase out ICE production around 2035-2040, there may be few non-EV models available by 2035.

Grid impact

As EV take-up increases, so will the demands on electricity grids. CSIRO's forecasts for 2050 are for between 7-24 million electric vehicles charging from the NEM and 1-3 million charging from the SWIS. The implications for additional energy demand in the NEM are shown in Figure 7 below.

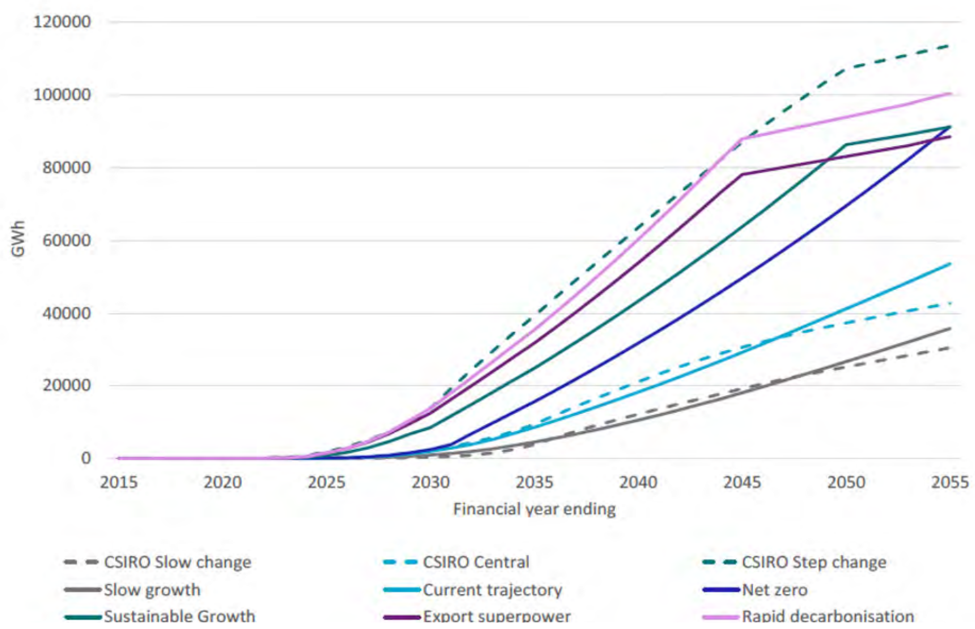
In 2035, assuming one of the higher take-up scenarios, EVs could add around 40,000GWh annually to NEM demand, or roughly 20 per cent of current total demand in the NEM.

Figure 6 *CSIRO projections of EV penetration (% of all car sales)*



Source: Electric vehicle projections 2021, CSIRO, May 2021

Figure 7 *Projected electricity consumption by EVs in the NEM*



Source: CSIRO

To put this into perspective, this is around a 1 per cent increase per year. This rate of demand increase should be manageable, noting that electrification of other energy processes, such as heat, may also be adding to demand. Given CSIRO's analysis is an input to the ISP, these changes are baked into the ISP output – they will not come as a surprise to system planners. Technological improvements are likely to increase efficiency and mitigate demand growth in any case.

The big unknown is where and when charging will take place. One of the reasons it is hard to predict this is that there are ways that we may be able to influence these decisions. EV drivers will charge based on convenience and cost. Cost can be strongly influenced by tariff design. Designing tariffs that consumers can and will respond to, and ensuring they are aware of their options is complex. It involves multiple parties, including networks, retailers, consumer representatives and market bodies. It's not necessary that end consumers themselves face particular tariffs, but someone along the supply chain has to be exposed to the costs in order to have the incentive to design services that will influence consumer charging patterns. A more rigid approach is to treat EV charging as a controlled load, but customers typically are (and should be) rewarded for accepting load control, so this is effectively an element of tariff design too. Figure 8 below shows a range of potential charging profiles with very different impacts on the grid.

The goal with tariff design is not necessarily to achieve a particular outcome, but to ensure that the right signals are sent about when it is cheap and when it is expensive to charge an EV. Networks will be concerned about the coincident peak whenever it occurs. In residential areas, this is normally in the evening (since rooftop PV depresses daytime demand), so network tariffs will encourage charging at other times. Wholesale markets appear to be heading for a daily price profile of very low prices in the daytime due to solar output, so this is likely to be the best time to charge from that perspective. It's possible that convenience will outweigh cost for some EV users, especially commercial vehicles where the business need will usually be paramount, but as long as tariffs are cost reflective, the incidence falls on the EV user and not on the rest of the consumer base. In this case, system planners will need to be able to respond to these signals so that system capacity (network and generation) can keep pace with growing peak demand. In practice, there are likely to be a variety of customer responses, and so peak demand growth should be manageable.

Autonomous driving

While the advent of electric vehicles presages a major shake-up in the energy source of vehicles, they aren't expected to have much direct impact on patterns of driving and ownership. But the change in fuel source

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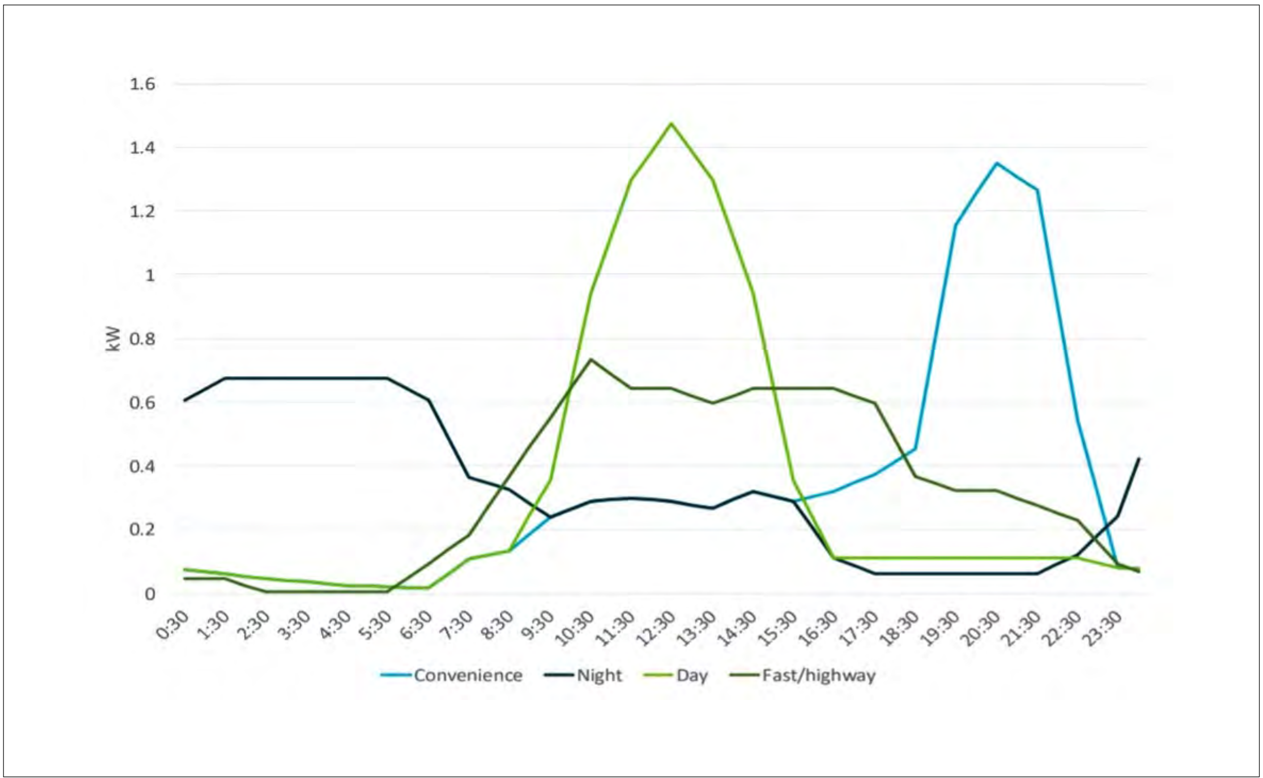
Figure 8 *Average passenger EV charging profiles*



Source: CSIRO, Electric vehicle projections 2021, May 2021

isn't the only evolution of the car. Companies such as Tesla, GM and Waymo have been developing autonomous driving capabilities for over a decade. Some elements of autonomous driving, such as self-parking and adaptive cruise control are diffusing into currently available models. Nonetheless these are currently only driver aids and represent levels 2/3 on the 5 -level scale developed by the Society of Automotive Engineers. Level 5 represents full autonomy, where no driver is required, and features such as steering wheels could become obsolete. Some driverless "robotaxis" have been trialled in pilot schemes in Singapore, San Francisco and elsewhere.

If driverless cars become prevalent, then this could truly revolutionise personal transport. Rideshare companies could become significantly more efficient and in cities, could become a credible and economic alternative to car ownership. If this was the case, then charging patterns could be very different. Rideshare fleets would have a strong economic incentive to optimise for efficiency, so overall consumption could be much less than expected. This may be partially mitigated by a higher number of kilometres driven, as fleet cars may drive around "looking" for customers, or cheap travel leads to more trips being taken. They would also be likely to charge at centralised depots, meaning that electricity consumption for EV charging would be concentrated at a smaller number of locations each with higher consumption. Low car ownership levels would have profound effects on the built environment, too, as homes have less need for garages and off-street parking while commercial districts need fewer carparks. Whether there is a significant impact on building energy consumption as a result remains to be seen.

These outcomes are by no means certain. Psychological barriers may inhibit the switch to full autonomy, while the convenience of car ownership may outweigh the costs. These are simply alternative scenarios of what could happen, and thus a reminder of the risks of locking in high levels of investment based on one set of forecasts about future charging requirements.

E-mobility

Electrification is not limited to cars and SUVs. Electric motorbikes, pushbikes and scooters are all growing in penetration, and have the potential to replace some short car journeys. In practice, however, given ICE motorbikes make a tiny contribution to transport emissions, this trend is unlikely to materially increase emissions reduction.

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Policy options for supporting EVs

There are numerous ways that governments can support EVs, though that does not mean that they are all necessary or even desirable. However, as with any new technology, especially one that requires changes in behaviour, and is a sizeable part of the household budget, some initial support may be very valuable in kickstarting take-up. The ICCT has identified 25 cities across the world that collectively account for 32 per cent of global EV sales and the policies they use to support them. Unsurprisingly, given the value of incentives in Norway and the EU highlighted above, European cities are prominent on these lists, along with several Chinese cities and a few from the US. Some of these cities have 16 or 17 separate policies supporting EVs. These include purchase discounts, sales targets, privileged access to low emission zones or extra lanes, subsidies for public and private charging facilities, building codes, government fleet targets, EV car-sharing schemes, toll road discounts, promotional activity and parking privileges. Not all of these are particularly costly, although in some cases this is because the incidence falls on other parties.

In Australia, states and territories are leading the way, with the Commonwealth determining that it does not see a case for purchase incentives. However, the Future Fuels Strategy has led to significant investment in charging facilities via ARENA and CEFC. Most of the jurisdictions have a mix of one of more of: purchase discounts (for a limited number of vehicles), stamp duty waivers and registration fee exemption. They are also investing in charging infrastructure and clear targets for EV take-up by government fleets this decade. While not as generous as the incentives in Europe and some US states, these policies are relatively sustainable and will help to bridge the initial cost gap. Victoria has undermined the value of its incentives with its road user charge, while SA and NSW have deferred theirs to allow time for the market to develop. A table of State and territory policies is set out in Appendix A.

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Section III : Other Transport Modes

As noted above, larger, heavier vehicles may be less suited to electrification than light vehicles. The mass of the fuel source that the vehicle must carry to power itself has to increase with the mass of the vehicle. This tends to favour the most energy-dense sources of power, and oil has been the dominant transport fuel for the last century because of its energy density. Current battery technologies are less energy-dense, i.e., heavier for the same amount of energy supplied. Nonetheless multiple alternative fuels are being explored for larger vehicles, including electrification, hydrogen fuel cells and biomass-based fuels.

Trucks

Alternative fuels for large trucks have had some false starts. Elon Musk predicted Tesla would have an electric semi on the road in 2019, but this has been delayed until later in 2022. Nikola launched itself onto the stock market in 2020 on the premise of delivering hydrogen fuel cell semis, but this has proved to be illusory to date. Nonetheless, progress has been made, with a local firm about to launch its first electric prime mover and plans to launch a network of battery swap stations for long-haul freight routes. The EV council estimates fuel savings of 65-90 per cent from switching to electric. Businesses looking at their own emissions reduction opportunities across the supply chain may put pressure on logistics firms to find ways to reduce their carbon footprint and may be prepared to pay a modest premium for low/zero emissions freight. Simultaneously, another local firm has contracted to deliver a fleet of hydrogen fuel cell tow trucks later this year. However, alternative fuelled trucks may be held back by Australian design rules around width limits and axle mass, so some modest regulatory reform may be needed to help the industry move to alternative fuels.

Trains

Trains have an advantage over other modes in that they run on fixed rails allowing scope to provide energy to them via an extra rail or overhead lines. This means they don't have to carry their fuel source. Passenger rail and light rail is largely already electrified for this reason.

Freight rail could be partially electrified. The main limitation is the cost of building electricity supply infrastructure along freight rail routes, which are often in remote areas such as the Pilbara. There is also the sunk cost of existing diesel rail engines which could be more cheaply converted to other low emission fuels.[8] These constraints mean that further electrification is expected to be low unless technology improves.

Shipping

Shipping fuel is low cost, making it hard for alternative fuels to compete. Electrification of small boat motors over time is likely but immaterial in terms of overall energy and emissions. There may be scope for electrification of ferry services. The world's largest electric ferry entered service in Norway last year and can carry 600 passengers, and electric ferry models are available in Australia. Fast charging will be essential for busy ferry services, so ferry operators will need to have robust electricity infrastructure – the Norwegian ferry draws up to 9MW when charging.

Planes

Electrification of air travel is subject to research and development at the present time, with a focus on smaller planes, especially with a view to the incipient aero-taxi model. Potential approaches include hybrids (single electric engine added to aircraft with other conventional propulsion), pure electric with modified air frame, vertical aero propeller / helicopter designs, hydrogen fuel aircraft designs and electric on-ground taxiing power.[9]

In the meantime, partial use of biofuel is reducing emissions on larger planes and longer flights. If this fuel source can scale up and 100 per cent biofuel shown to be feasible, then it's unlikely electrification will have much impact.

8 CSIRO, Electric vehicle projections 2021, May 2021
9 Op. cit.

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Appendix A : Jurisdictional Policies

STATE	EV REBATE/DISCOUNT	TAX BREAKS	REGISTRATION DISCOUNT	INFRASTRUCTURE INVESTMENT
NSW	$3000 for first 25,000 EVs <$68,750 from 1/9/21	Stamp duty waiver for EVs <$78,000 ; all others from 1/7/27 or when EVs >30% of new car sales	None	$171 million investment in state-wide charging network
VIC	$3000 rebate for 4,000 EVs < $68,740, future rebates for another 16,000.	Luxury low-emission vehicles (including EVs) avoid Victorian luxury duty; worth $1000 on a $100,000 car, more for dearer models (NB other states don't have a similar luxury car duty).	$100 annual discount	$19 million to accelerate rollout of EV charging infrastructure across regional Victoria
ACT	Interest free loans up to $15,000	Stamp duty waiver for all vehicles emitting under 130g CO2/km. Value from $400 on a $40,000 fuel efficient car up to $5100 on a $100,000 SUV.	Two years free registration for EVs purchased up to 30/6/24; 20% annual ongoing discount for EVs purchased before 1/5/21	Investing in 50 publicly accessible charging stations by mid-2022 and another 50 new public chargers after that.
QLD	None	EVs up to $100,000 pay 2% duty, while those over $100,000 pay 4% duty. ICE vehicles pay between 3% and 6%, depending on their engine and price.	None	Adding 18 new fast chargers to inland areas to complement the coastal-focused Queensland Electric Super Highway already up and running.
SA	$3000 for first 7000 EVs <$68,750 from 28/10/21	None	Three-year registration fee exemption for EVs first registered between 28/10/21 and 30/6/25	$2000 subsidy for installation of smart chargers for up to 7500 households. State-wide charging network planned by 2025
TAS	None	Stamp duty waiver on EVs until 1 July 2023. Tasmania charges a 4% duty on vehicles.	None for private buyers, two years free registration for rental cars	Up to $600K of grants available for charging installation as part of the ChargeSmart program.
WA	None	None	None	Plans for EV charging network from Kununurra to Perth and Esperance
NT	None	$1500 stamp duty discount on new and used EVs from July 2022 until July 2027	Free registration for EVs from July 2022 until July 2027	c. 400 EV chargers currently being installed at NT government buildings. Grants program planned from 2021 to 2026.

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STATE	EV SALES TARGET	GOVERNMENT FLEET EV USE	ROAD USER CHARGE	POLICY DOCUMENT
NSW	More than 50% of new cars sales by 2030	All government passenger cars EV by 2030 "where feasible"	2.5c/km charge for EVs and 2.0c/km for PHEVs from 1/7/27 or when EVs >30% of new car sales	NSW electric vehicle strategy
VIC	50% of new light vehicle sales (passenger cars, utes and SUVs) by 2030	Plans for 400 government cars to be EVs or FCEVs by 2023	2.5c/km for EVs and 2.0c/km for PHEVs from 1/721; rates to be indexed annually	Victoria's Zero Emissions Vehicle Roadmap
ACT	All new car sales to be zero-emissions by 2030	All new government passenger vehicles now EV or FCEV "where fit for purpose"	None	ACT's Transition to Zero Emissions Vehicles action plan
QLD	None	At least 288 EVs in the government fleet by 2022	None	Development of Queensland's Zero Emission Vehicle Strategy
SA	100 percent of passenger cars (ex utes and commercial vehicles) by 2035	Full electrification of government fleet by 2030, subject to certain exceptions	2.5c/km charge for EVs and 2.0c/km for PHEVs from 1/7/27 or when EVs >30% of new car sales	South Australian government EV Action Plan
TAS	None	Targeting a wholly EV fleet by 2030, which includes commercial vehicles and utes	None	Tasmania EV uptake fact sheet
WA	None	Targeting 25% of government fleet by 2026, ex large SUVs, utes and other commercial vehicles	None	Western Australia Electric Vehicle Strategy
NT	None	200 EVs by 2030	None	Northern Territory electric vehicle strategy

Sources: State and territory policy documents

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