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The Grattan car plan

Practical policies for cleaner transport and better cities

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This report was written by Marion Terrill, Ingrid Burfurd, and Lachlan Fox.

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Overview

The mobility that cars have brought us over the past hundred years has been a wonderful thing, but the carbon dioxide and pollution that come out of their back ends, not so much. Political parties are split between those wanting everyone in electric vehicles, preferably yesterday, and those worrying that pushing drivers into electric vehicles is a recipe for more expensive cars, charging anxiety, and – worst of all – tradies losing their utes.

It may sound too good to be true, but there's a proven way to reduce carbon emissions and unhealthy pollutants, without dictating to anybody what car they can drive. Australia should adopt an emissions standard, or ceiling, for new light vehicles, applied across the offering of each manufacturer, just like 80 per cent of the rest of the world does. The ceiling should be gradually lowered to zero emissions by 2035. We'd get a better range of low-emissions cars to choose from – even more so if we also insisted on cleaner petrol for cars with internal combustion engines. These policies wouldn't solve all the problems cars cause, but they'd certainly help.

Light vehicles cause 11 per cent of Australia's carbon emissions. This report shows that under a carefully designed emissions ceiling for new light vehicles, that figure could be dramatically reduced by 2035. An emissions ceiling could achieve at least 40 per cent of Australia's emissions reduction task between now and 2030.

As well as emitting less carbon dioxide, drivers would save money, and the cost to taxpayers would be negligible. Before 2035, manufacturers that wanted to sell high-emitting vehicles – such as large, petrol utes – could continue to do so, but would need to offset their above-the-ceiling emissions by selling enough low-emitting vehicles, such as electric vehicles or cleaner petrol or diesel vehicles.

At present electric vehicles cost more to buy than similar-sized petrol and diesel vehicles in Australia. But they cost less to run. Under an emissions ceiling, drivers who bought a zero- or low-emissions car would save at least $900 over the first five years of ownership, through reduced running costs.

Some people argue that fear of not being able to conveniently charge their vehicle, rather than cost price, is the real barrier to Australians switching to electric vehicles. Our analysis shows this fear is overblown. Nearly two-thirds of Australian households with a car also own a detached or semi-detached home, 95 per cent of which have off-street parking. These households will usually find it easy and inexpensive to install electric-vehicle chargers. Remaining households will be able to plug in to the publicly-accessible charging network, which is expanding rapidly.

Switching to cheap-to-run vehicles will be great in one way, but cheaper driving will also mean more driving, and more driving means more accidents, more congestion, and ever-increasing demands for roads and parking. Governments need to stifle this in advance. Australia's state governments should impose congestion charges in their capital cities, to reduce traffic congestion. Distance-based driving charges, COVID-safe public transport, and traffic-safe cycling would help ensure that we don't emerge from COVID more car-dependent than we went in.

Australians will continue to drive. What's important is that we have safe alternatives to driving, and that when we do drive, we use the best technology to do it with as little harm as possible. This report identifies the policies that make that possible.

Recommendations

Fewer tailpipe pollutants

The Federal Government should improve the quality of Australia's petrol, so that vehicles here can meet international pollutant standards by mid-2024.

The Government should tighten vehicle pollution standards so they are consistent with current international standards, immediately for diesel vehicles, and by mid-2024 at the latest for petrol vehicles.

Zero- and low-emissions vehicles

The Government should impose a single annual average emissions standard, or ceiling, covering all new light vehicle sales. The ceiling should come into force no later than 2024 and not exceed 143 grams of carbon per kilometre (g/km). It should not exceed 100g/km by 2027 and 25g/km by 2030. Carbon emissions from vehicles under the ceiling should fall to zero by 2035.

To ensure the emissions ceiling works:

- Australia should adopt the Worldwide Harmonised Light Vehicle Test Procedure, or WLTP, for vehicle emissions testing.
- All new vehicles sold in Australia should include on-board vehicle emissions monitors by 2024, with de-identified annual data released publicly.
- Technology multipliers should not be incorporated into the design of the ceiling.

Charging infrastructure for electric vehicles

Government funding should be limited to investments in publicly-accessible chargers that encourage substantial numbers of people to switch to electric vehicles, and which are not otherwise commercially viable. If governments invest in on-street chargers for local residents, governments should recover the costs from local drivers.

The state and territory governments should by 2022 require landlords and vendors to disclose at the point of lease or sale whether their property has charging infrastructure for electric vehicles.

The National Construction Code should be updated to require that new dwellings with off-street parking be ready for electric vehicles from 2022.

Support for buyers

The Federal Government should update the *Road Vehicle Standards Act* to permit the import of any new and second-hand vehicle that meets safety and environmental standards, including the annual average emissions ceiling.

Australia's fuel consumption labels should include an estimate of real-world emissions and indicative running costs of the vehicle.

More specific recommendations are detailed throughout this report.

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1 The switch is on

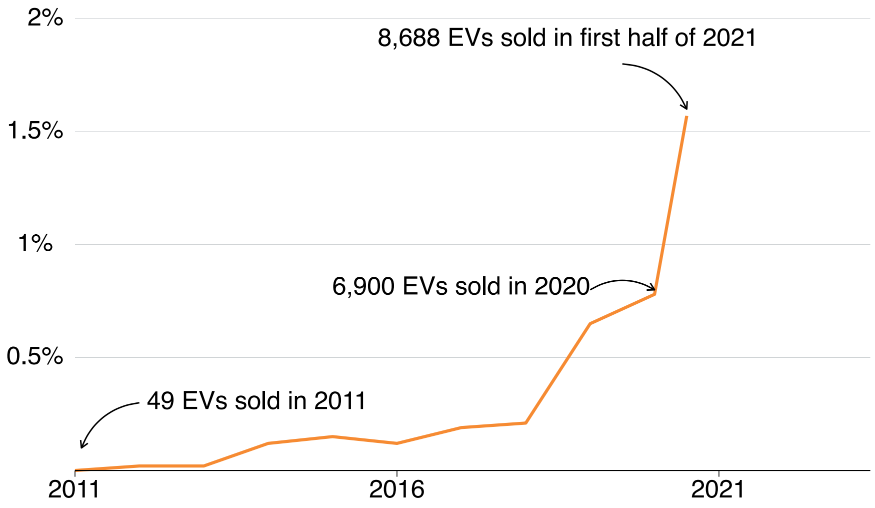
All of a sudden, it seems, electric vehicles have arrived in Australia. It's no longer such a rarity to spot one on city streets, or a charging point in a car park or on a roadside. The numbers are still very small, but they're picking up fast (Figure 1.1).

Electric vehicles create far fewer carbon emissions than petrol and diesel vehicles, and over time will contribute significantly to the emissions reduction task. But Australians are not about to stop buying petrol and diesel cars any time soon, and most of those cars will be on the road for at least 15 years.

The Federal Government therefore needs to reduce the harmful tailpipe pollutants from petrol and diesel cars, by improving fuel quality and vehicle standards (Chapter 2). It also needs to ensure that whatever cars Australians buy – petrol, diesel, or electric – these cars create fewer carbon emissions than the gas-guzzlers we tend to choose today. An average annual emissions standard, or ceiling, is how most of the world achieves this, and this report shows why Australia should follow suit (Chapter 3). Some inexpensive policy changes could make it easier to charge electric vehicles at home, at work, and on the road (Chapter Chapter 4).

At the moment it costs more to buy a lower-emitting vehicle – particularly an electric vehicle. But that is changing fast. And it costs less to run lower-emissions vehicles – substantially so for electric vehicles. Cheaper driving is great for drivers, but it's also likely to increase the amount of driving we do, and that brings downsides that affect other drivers and non-drivers alike. There are many strategies governments can and should adopt to manage urban congestion, reduce traffic accidents, and create public space for other road users (Chapter 5).

Figure 1.1: Electric vehicle sales in Australia are growing fast
Sales as a proportion of Australia's light vehicle sales



Source: Electric Vehicle Council 2021.

1.1 Electric vehicles sales are taking off

Although the number of electric vehicle sales in Australia is low, it is taking off fast. More electric vehicles were sold in the first half of 2021 than in the whole of 2020.[1]

Governments are fanning the spark of an electric vehicle surge. In the absence of an economy-wide carbon price, they are resorting to sector-specific carbon emissions reduction opportunities. In this environment, it's not surprising that governments are supporting electric vehicles, because the emissions from the light vehicle fleet are high, at 11 per cent of Australia's total emissions,[2] and also because the technology to reduce those emissions is well-established and proven elsewhere.

The NSW and Victorian governments are offering $3,000 subsidies for electric vehicles at the less expensive end of the spectrum, while federal Labor is offering, if elected, to exempt electric vehicles from import tariffs and fringe benefits tax.[3]

1.2 But what about the next 15 years?

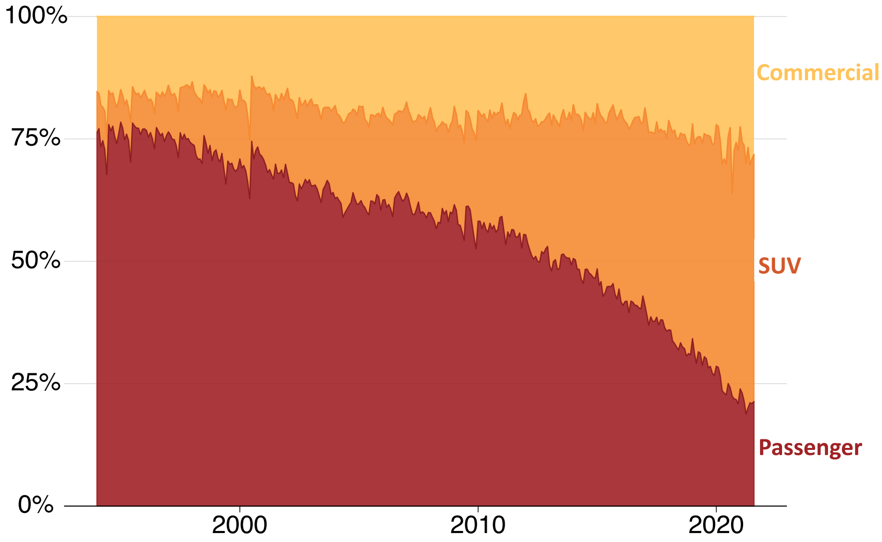
With all the attention devoted to electric vehicles, it would be easy to overlook the 99 per cent of new light vehicles sold in 2020 that weren't electric. Even if every new car bought from now on was electric, most of the cars bought yesterday will still be around in 15 years.

Petrol and diesel vehicles create tailpipe pollutants that harm health. While that's nothing new, the problem is liable to get worse before it gets better, unless governments act. Petrol and diesel vehicles also create carbon emissions. But there's no reason the light vehicle fleet

1. Electric Vehicle Council (2020); and Electric Vehicle Council (2021).
2. DISER (2020, pp. 13, 29).
3. NSW Department of Planning, Industry and Environment (2021); Victorian Department of Environment, Land, Water and Planning (2021); and Australian Labor Party (n.d.).

Figure 1.2: Australians are increasingly choosing SUVs over passenger cars

Vehicle type as a proportion of monthly vehicles sold



Notes: 'Passenger vehicles' includes hatches, sedans, wagons, people-movers, and sports cars – for example a Toyota Corolla, Hyundai I30, or Kia BD Cerato. 'SUVs' (Sports Utility Vehicles) are wagon-style vehicles with an elevated ride height, usually four-wheel drive or all-wheel drive – for example a Mazda CX-3 (a small SUV) or Toyota Prado (a large SUV). 'Commercial' includes heavy and light commercial vehicles. Heavy commercial vehicles include articulated and non-articulated trucks. Light commercial vehicles are predominantly utes, vans, and light buses – for example, the Holden Colorado, or Toyota Hiace. Heavy vehicles make up only a small proportion of the commercial category.

Sources: Data for 1994-2017 are from the ABS: ABS (2017). Data from 2018 onward are from MarkLines: MarkLines (2021).

needs to be as emissions-intensive as it actually is. Other countries are well ahead of Australia in curtailing the tailpipe pollutants and carbon emissions of petrol and diesel vehicles, as well as switching to electric.

1.3 Facilitate the switch to cleaner greener cars

Australians drive high-polluting, high-emitting cars.

That's partly because Australians increasingly choose bigger vehicles – SUVs (Sports Utility Vehicles) and utes – over passenger cars (Figure 1.2 on the previous page). Larger vehicles tend to consume more fuel and emit more carbon dioxide per kilometre travelled than smaller cars. About 40 per cent of vehicles sold globally are SUVs, but in Australia the figure is closer to 50 per cent.[4] Since 2016, the top-selling vehicle in Australia has been a ute, and preliminary data from 2021 indicates the top-three selling models are utes, for only the second year ever.[5]

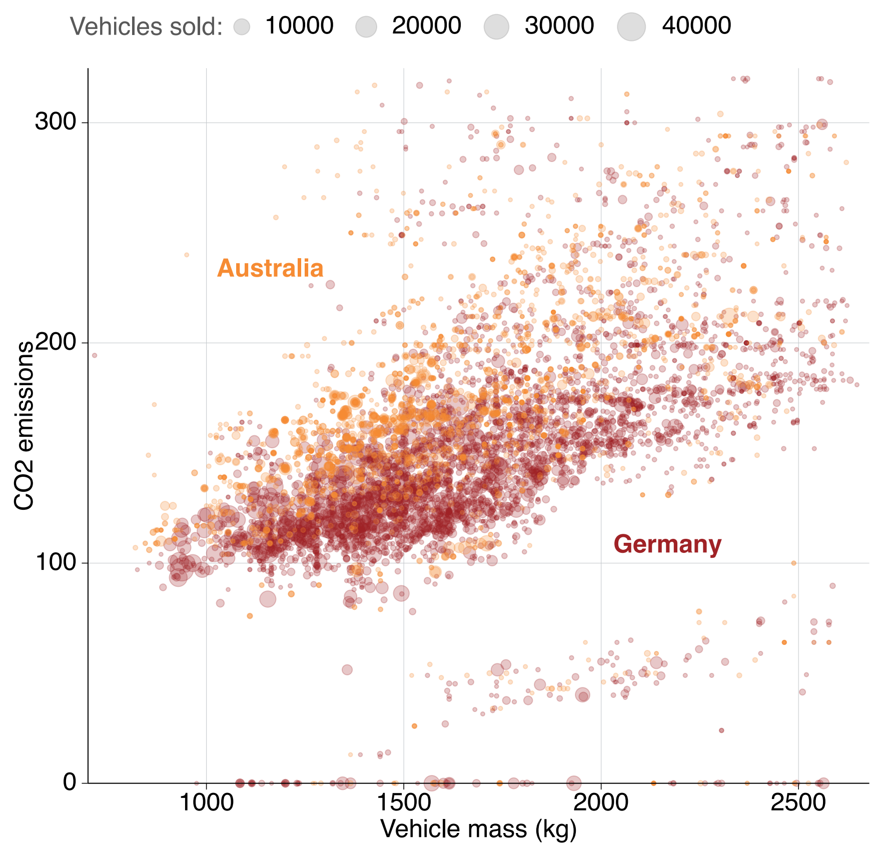
But size is only part of the story. Australia's passenger cars are large, but where they really stand out is in CO2 emissions. In 2019, the average passenger car in Europe emitted 123 grams of carbon dioxide per kilometre travelled. In Australia, the same figure was about 169gCO2/km – almost 40 per cent greater.[6]

Germany's fleet of passenger cars is similar to Australia's in weight. But the German fleet emits significantly less carbon dioxide per kilometre driven (Figure 1.3).

The average US passenger light vehicle (including utes and other light commercial vehicles) is more than 100kg heavier than the average Australian light vehicle, and has 180kW of power compared to less than

Figure 1.3: Germany's passenger car fleet is much cleaner than Australia's

Emissions (grams CO2/km) and mass (kg) of passenger car models sold in Australia (2020) and Germany (2019).



Note: Data obtained from FCAI and European Environment Agency (2021b).

4. Cozzi and Petropoulos (2019) and data supplied by FCAI.
5. Budget Direct (n.d.); and DRIVE (2021).
6. National Transport Commission (2020a); and European Environment Agency (2021a, p. 26).

150kW in Australia. Yet US vehicles emit 5g less carbon dioxide per kilometre travelled, on average.[7]

The lowest-emitting variants of top-selling car models available in Australia are more emissions-intensive than models available internationally. The best technology is simply not available to Australians.[8]

Strategies to facilitate the switch to cleaner greener cars are straightforward and proven elsewhere – and they're needed urgently in Australia.

1.4 Manage the downsides from more driving

Not only are Australia's cars getting bigger, they're also becoming more plentiful than ever.[9] And the preponderance of larger cars means they dominate public space more in Australia than elsewhere. Austroads' road design is based on a 'reference' car width of 1.9 metres – larger than in other countries, and corresponding to a large car such as a Holden Commodore, or a medium-sized SUV such as a Jeep Cherokee.[10] Parking spaces are big too; a standard Australian car parking space is 13-to-13.5 metres squared. In Hong Kong the standard is 12.5 metres squared, and in the UK and France it is 11.5 metres squared.[11]

And more cars means more driving. Immediately before COVID, the total kilometres travelled in cars and other light vehicles in Australia was higher than ever.[12]

Several forces are at work that are likely to increase rather than reduce driving.

One is COVID. Australian cities are very car-dependent. Before the pandemic, only about 14 per cent of workers commuted by public transport, and about 4-to-5 per cent walked or cycled.[13]

The pandemic has caused people to further turn away from public transport.[14] Even during periods when Sydney and Brisbane had no restrictions on travel, movement around public transport hubs was well below pre-pandemic levels (Figure 1.4 on the next page).

It is not yet clear what the long-term travel patterns may be, but there is now broad acceptance that we are 'living with COVID'; in other words, expecting periodic breakout infections, and facing ongoing precautions against contagion. In all likelihood, people will remain wary of public transport well into the future, or simply acquire new travel habits that stick even when the original reason for those changed habits has passed.

A second force is that lower-emitting vehicles, especially electric vehicles, are cheaper to run, and this is likely to lead to more driving.[15]

There are numerous studies of the relationship between price changes and how much people travel. In Australia, a 10 per cent reduction in the price of petrol can be expected to increase driving by about 1-to-1.4 per cent. The impact of cheaper running costs for electric vehicles is likely to be broadly similar. Over time, the increase in driving could be

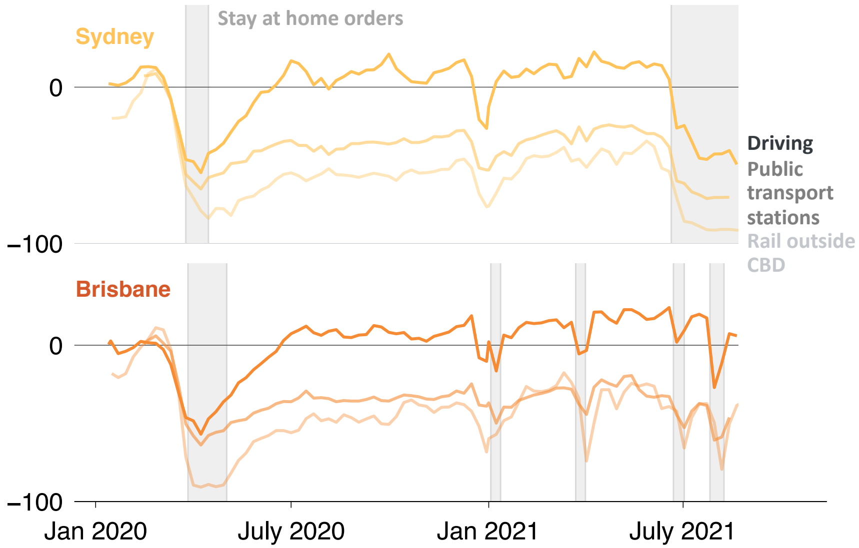
7. Grattan analysis of FCAI, and ICCT: International Council on Clean Transportation (2018a, p. 4). Power data obtained from United States Environmental Protection Agency (2021).
8. DIRD (2016a, p. 24).
9. BITRE (2020, p. 105).
10. Austroads is the collective of the Australian and New Zealand transport agencies, and represents all levels of government. Austroads (n.d.)
11. Terrill et al (2019a, pp. 22–23).
12. BITRE (2020, p. 100).
13. ABS (2016).
14. Infrastructure Victoria (2021a, pp. 14–16).
15. KPMG (2018, pp. 42–48).

expected to grow to about 2.5 per cent, as people adapt to the cheaper option.[16]

The amount of driving in Australia is likely to creep up over time. Governments should use a range of strategies to mitigate the impacts on congestion, accidents, and dominance of public space.

Figure 1.4: Even outside of lockdowns, travellers have been shunning public transport

Mobility, percentage change from baseline, weekly average



Notes: Public transport station data are collected statewide for the city indicated; all other data are for the city as specified. Shaded areas indicate periods of lockdown. A region is considered in lockdown if stay-at-home orders are in place either statewide or for the state capital for the whole or part of a given week.

Sources: The 'driving' category uses Apple mobility data: Apple (2021). The 'public transport stations' category includes bus stops and train stations, and uses Google mobility data: Google (2021). The 'rail outside CBD' category uses data supplied by Veitch Lister Consulting.

16. Breunig and Gisz (2008).

Box 1: Electric vehicles are green and getting greener

Electric vehicles are significantly greener than comparable vehicles with internal combustion engines, and are only going to become greener over time.[a]

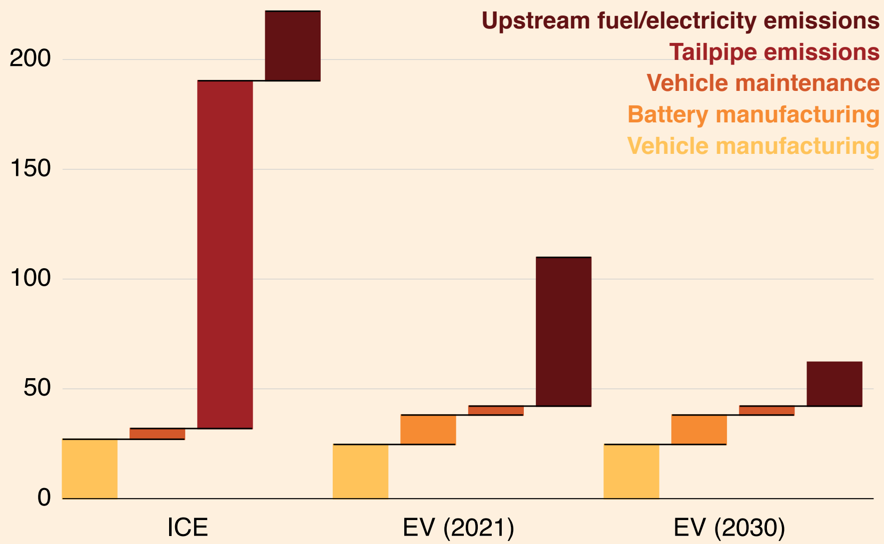
An electric vehicle purchased in 2021 is likely to produce only about half as many emissions, on average, as a comparable internal combustion vehicle per kilometre travelled, even after taking account of the higher emissions involved in manufacturing electric vehicles (Figure 1.5).

The greener the electricity source, the greater the benefits of an electric vehicle. Drivers in states with a high share of renewable energy, such as South Australia, create fewer emissions than those in states with lower shares, such as Victoria, but even in Victoria, emissions are still lower.[b] Over time, the increasing share of renewable sources of electricity across the country will reduce the emissions of driving an electric vehicle.

The International Council on Clean Transportation studied vehicle types across numerous counties and concluded: 'Only battery electric and hydrogen fuel cell electric vehicles have the potential to achieve the magnitude of life-cycle greenhouse gas emissions reductions needed to meet Paris Agreement goals.'[c]

Figure 1.5: The lifecycle carbon emissions of electric vehicles (EVs) are about half those of internal combustion engine (ICE) vehicles, and getting smaller

Life-cycle carbon emissions per km travelled (gCO2/km)



Notes: Manufacturing emissions data are from the International Council on Clean Transportation. Upstream fuel emissions include the emissions generated during electricity production, and upstream emissions associated with combustion engine fuel (such as transport of fuels to a petrol station). This analysis assumes relatively high electric vehicle electricity consumption of 0.183kWh/km in 2021 and 0.174kWh/km in 2030. It assumes manufacturing emissions for electric vehicles remain unchanged between 2021 and 2030, and that the grid decarbonises following the Australian Energy Market Operator (AEMO) 'step change' scenario: AEMO (2020). See Appendix A for further details.

a. International Council on Clean Transportation (2021).
b. Grattan analysis and Infrastructure Victoria (2021b, p. 7).
c. International Council on Clean Transportation (2021).

2 Cleaner petrol while we still need it

Sales of electric cars are rising in Australia, but less than 1 per cent of new cars sold here at present are electric. The reality is that petrol and diesel cars will continue to dominate our roads for at least the next decade.

Petrol and diesel cars emit damaging tailpipe pollutants, which kill hundreds of Australians each year (Section 2.1), and unfortunately these effects are likely to get worse before they get better (Section 2.2).

The Federal Government has plans to improve both fuel quality and vehicle standards – but slowly. In the meantime, other countries continue to forge ahead with standards that minimise damaging health effects, as well as improving fuel efficiency and vehicle performance. Australia should treat current plans to improve fuel quality and vehicle standards as a bare minimum, and accelerate future improvements (Section 2.3).

2.1 Petrol and diesel vehicles are bad for our health

Burning petrol and diesel in an internal combustion engine creates pollutants as a by-product.[17] These pollutants include particulate matter: notably PM10 and PM2.5,[18] nitrogen oxides (known as NOx), sulfur oxides (known as SOx), and various volatile organic compounds. Nitrogen oxides and volatile organic compounds also contribute to the formation of photochemical smog, including ozone.[19]

Pollutants from vehicle emissions kill about 280 Australians per year.[20] These pollutants increase the risk of cardiovascular illness, Ischamic heart disease, asthma, stroke, respiratory illnesses, lung cancer, bladder cancer, and breast cancer.[21] The International Council on Clean Transportation estimates transport-related air pollution carried an economic cost of about $10 billion in Australia in 2015.[22]

Diesel engines are a particular problem because they tend to emit significantly more pollutants than petrol vehicles per kilometre travelled, and are subject to less stringent pollution regulations in Australia than passenger vehicles. Diesel engines are also much more common in larger vehicles, such as light commercial vehicles, which tend to be driven further in a given year.[23]

2.2 The harm to Australians' health is likely to get worse before it gets better

About 99 per cent of the new light vehicles sold in Australia in 2020 had internal combustion engines (Figure 2.1 on the following page). Most of them will be burning petrol and diesel for the next 15 years or more.

17. This report uses the term 'pollutants' to refer to non-carbon dioxide compounds, such as nitrogen oxides, sulfur oxides, and volatile organic compounds. It uses the term 'emissions' to refer to carbon dioxide emissions.
18. PM10 refers to particulate matter with a diameter of less than 10um; PM2.5 refers to particulates with a diameter of less than 2.5um. Both of these types of particles are small enough to enter the lungs when inhaled.
19. Photochemical smog is the brown haze that can be seen over cities, particularly on sunny days.
20. In 2015, an estimated 620 deaths were attributable to transport-related air pollution in Australia. Of these, about 280 were attributed to pollution from on-road vehicles: International Council on Clean Transportation (2019a, p. 19).
21. Department of the Environment and Energy (2018, p. 9); Golder Associates (2013); International Council on Clean Transportation (2019a, p. 19); and Liu et al (2019).
22. Adjusted for inflation and converted from US dollars: International Council on Clean Transportation (2019a, p. 19).
23. ABS (2018).

Ultimately, having an electric fleet will resolve the problem of tailpipe pollutants. But that will take years.[24]

While tailpipe pollutants are a problem wherever people are subject to them, there is some evidence that Australians are particularly susceptible to the harmful health effects of heightened particulate concentrations. A study of 652 cities found that, on average, an increase of 10 micrograms per cubic metre in PM10 and PM2.5 concentration increased mortality by 0.44 per cent and 0.68 per cent respectively. But in Australian cities, an equivalent increase in PM10 and PM2.5 had more than double the effect on mortality, leading to an increase of 1.32 per cent and 1.42 per cent respectively.[25] This magnified effect in Australia was larger than in any other part of the world.[26]

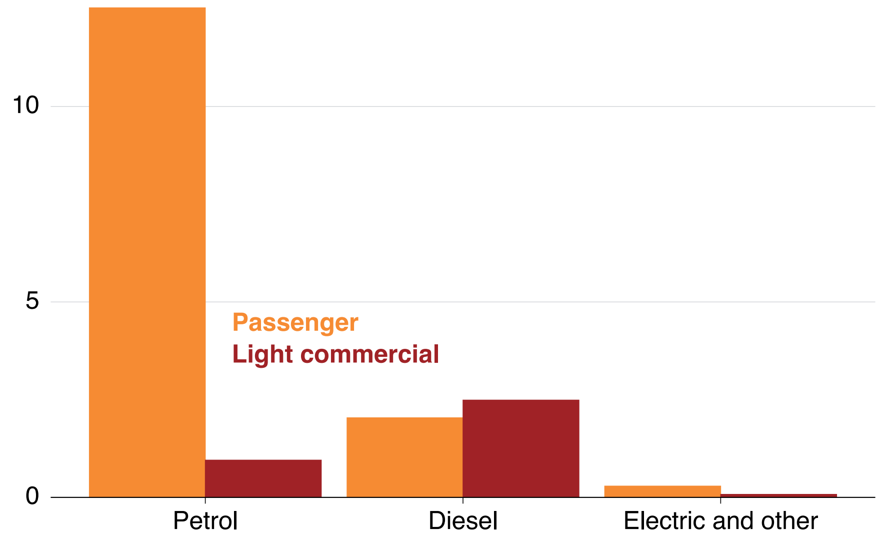
The health costs in Australia may grow as our population ages. In Japan, even as air quality improved between 1990 and 2017, mortality caused by airborne pollutants increased due to population ageing.[27]

2.3 A two-pronged approach to reducing harmful tailpipe pollutants in Australia

The production of harmful tailpipe pollutants in Australia comes about through the combination of the fuel and the type of technology in the vehicle.

Figure 2.1: The vast majority of the Australian fleet is fuelled by petrol or diesel

Number of vehicles (millions) by fuel type



Notes: 'Other' includes predominantly vehicles fueled by liquefied natural gas.

Source: ABS (2021).

24. Pollutants are produced when electricity is generated to power electric vehicles, but there will be fewer pollutants as the electricity grid decarbonises. Infrastructure Victoria estimates that in 2046, greater use of electric vehicles may provide an economic benefit of more than $700 million annually from avoided health costs in Victoria. Infrastructure Victoria (2018, p. 114).
25. The 95 per cent confidence interval ranges are 0.39 to 0.5, and 0.59 to 0.77 for all cities, and 0.22 to 2.44 and 0.12 to 2.99 for Australian cities.
26. Liu et al (2019, p. 710).
27. Health Effects Institute (2019, p. 13).

The low quality standard currently applied to petrol in Australia limits the pollution-reducing vehicle technology that can be used here. But regardless of the vehicle technology, a petrol vehicle produces more harmful pollutants when running on poorer-quality petrol.[28]

Improving the petrol quality would be helpful on its own, but much more so if done in concert with better vehicle technologies (Figure 2.2).

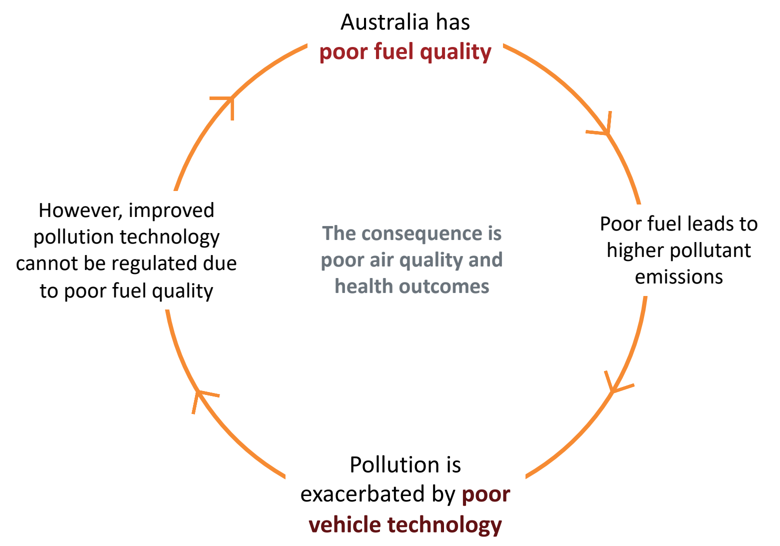
2.3.1 Improve the quality of our petrol

Australia sources more than 90 per cent of its automotive fuel from overseas; Singapore is the largest supplier. The remainder, sourced from the two remaining local refineries, in Brisbane and Geelong, is mostly refined from imported crude oil feedstock.

The petrol sold in Australia contains significantly more sulfur and aromatics than petrol sold in many other countries.[29] Sulfur and aromatics[30] are the main components of Australian petrol that, when burnt in an engine, give rise to a greater amount of particulate matter, SOx, and volatile organic compounds.

Based on sulfur content, Australia's petrol is ranked 73 of 100 countries, and 82 of 96 countries on aromatics (Figure 2.3 on the following page).[31]

Figure 2.2: Australia needs to improve both fuel quality and vehicle technology



28. For example, an increased aromatic fraction in fuel may lead to the formation of deposits in the combustion chamber, increasing the concentration of particulate and carcinogenic pollutants. DITRDC (2020, p. 9).
29. Australian regulations specify sulfur levels should not exceed 150ppm, whereas the limit is 10ppm in most comparable countries. Australian regulations permit aromatic content of 45 per cent, whereas the limit is 35 per cent or lower in most comparable countries.DITRDC (ibid, p. 8).
30. Aromatics are a class of compound, including benzene, toluene, and xylene, which are a component of fuel refined from crude oil, and can raise the octane number of fuel.
31. Department of the Environment and Energy (2018, p. 13).

If Australian standards remain unchanged, the amount of PM10 emissions from passenger vehicles here is forecast to rise in coming years.[32]

The Federal Government this year committed a subsidy of $300 million to Australia's remaining petrol refineries, 'to boost Australia's long-term fuel security'.[33] A condition of this funding is that fuel quality improvements, initially slated for 2027, are brought forward to mid-2024.

Whether imported or refined onshore, higher-quality petrol is necessary to reduce the pollutants emitted by Australian vehicles.

Recommendation 1

The Federal Government should ensure that petrol in Australia has no more than 10ppm of sulfur and 35 per cent aromatics by 2024, or is of sufficient quality for vehicles to comply with Euro 6d vehicle pollution standards.

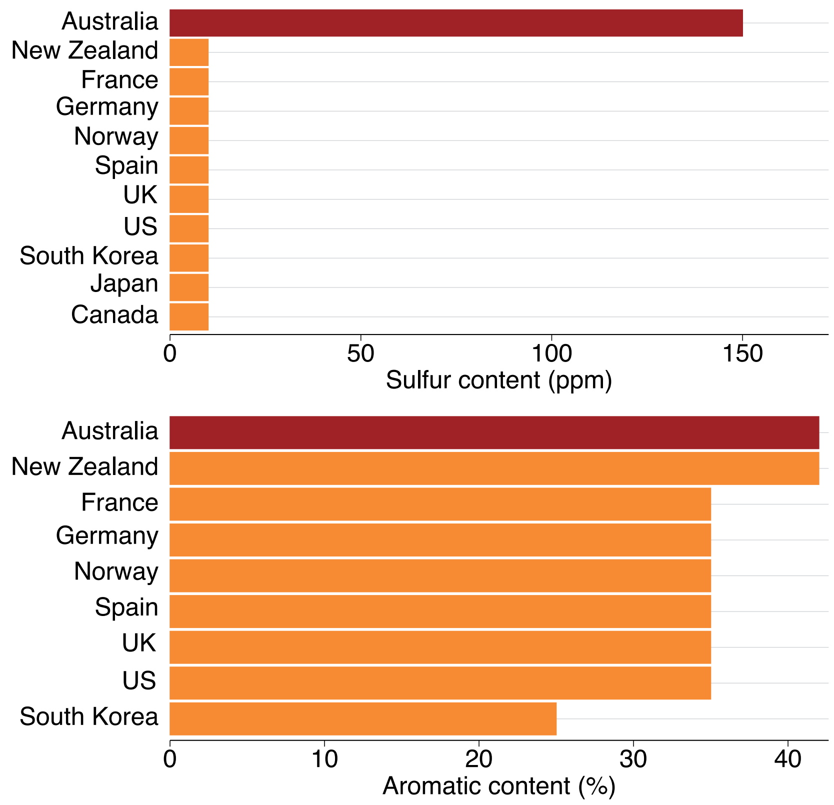
2.3.2 Quickly tighten pollution standards for our vehicles

International standards, known as the 'Euro' standards, impose limits on the quantity of harmful pollutants (such as NOx, SOx, and PM) that new petrol or diesel vehicles can emit.[34] Manufacturers respond to these regulations by upgrading pollutant-reducing technology – for example, advanced lean NOx traps and catalytic converters.

Australia's vehicle pollution standards lag well behind international best practice. Currently, Australian light vehicles are subject to Euro

32. Ibid (p. 9).
33. Morrison (2021).
34. Although the Euro standards are used in countries beyond Europe, some jurisdictions have also developed individual standards for testing vehicle pollutants.

Figure 2.3: Australia's petrol is poor by international standards
Regulated sulfur and aromatic content of petrol



Notes: Regulated limits are given as pooled limits where available, or maximum limits if no pooled limit applies. Japan and Canada do not prescribe an aromatic petrol content limit.

Sources: Department of the Environment and Energy (2018) and Grattan analysis.

5 regulation,[35] but the rest of the world has moved on. The EU adopted Euro 6d standards in 2014 and plans to move to Euro 7 by 2025.[36]

For petrol vehicles, Australia has limited scope to introduce the technologies that would enable Australia to meet Euro 6d. Poor-quality fuel can damage technology used to reduce vehicle pollution, and therefore manufacturers cannot make use of all the technologies that would otherwise be available to meet the vehicle pollution standards articulated in Euro 6d. For instance, pollutant-reduction technology performs poorly when sulfur content is greater than 30ppm.[37]

Tightening the regulations governing petrol vehicles in Australia should be possible by mid-2024 at the latest, provided petrol quality has improved by then, and sulfur levels are below 10ppm. At that point, the Federal Government should move to Euro 6d standards for petrol vehicles. There will be substantial benefits to doing so: in 2020, the net benefits were estimated to be substantial,[38] with a benefit-cost ratio of 5.8.[39]

Australia is moving in this direction: in October 2020 the Government published a draft regulation statement on pollution standards, and the department is now considering responding submissions.[40]

35. Commonwealth Government of Australia (2011).
36. DIRD (2016b); and Davis (2021).
37. European Automobile Manufacturers Association (2013).
38. Although tighter fuel quality regulations may lead to a slight increase in fuel prices for consumers, this is likely to be a very small effect, and the benefits have been estimated to considerably outweigh the costs. Department of the Environment and Energy (2018).
39. This cost-benefit analysis assumed Euro 6d will come into force in 2027: DITRDC (2020, p. 40). Previous work has indicated that the net benefit of introducing Euro 6d at an earlier date is likely to be even greater. DIRD (2016b).
40. The draft regulation statement has been published by Department of Infrastructure, Transport, Regional Development and Communications: DITRDC (2020).

For diesel vehicles, it is likely that better pollution-reducing technology could be regulated immediately. The quality of diesel in Australia is very similar to the quality of diesel overseas.[41]

Tightening regulation of diesel vehicle pollutants, by moving from Euro 5 to Euro 6d standards, would reduce NOx emissions from new diesel engine passenger and light vehicles by well over 50 per cent.[42]

The Federal Government should therefore remove any residual barriers and move immediately to tighten diesel vehicle pollution standards, conditional on ensuring that Australian diesel quality does not prevent vehicles from meeting tighter pollutant regulation.

Recommendation 2

The Federal Government should update the Australian Design Rules to require light vehicles to meet Euro 6d vehicle pollution standards. This should be done immediately for diesel vehicles, conditional on ensuring diesel quality is adequate, and as soon as fuel quality improvements are regulated for petrol vehicles.

Of course, by the time Australia adopts Euro 6d standards, other countries will be moving on, so the Federal Government should act to further narrow the gap between Australia and the rest of the developed world.

The adoption of Euro 6d standards, and Euro 7 standards when they are developed, will be smoother if the Federal Government also moves to reduce carbon emissions, as the next chapter explains.

41. The major differences between Australian and international quality diesel relates to the polycyclic aromatic hydrocarbon (PAH) content and cetane number. Department of the Environment and Energy (2018, p. 7).
42. From 180mg/kg to 80mg/kg for passenger vehicles, and from 280mg/kg to 125mg/kg for light commercial vehicles: DIRD (2016b, p. 13).

3 Accelerate the arrival of lower-emissions and zero-emissions vehicles

If Australia is to achieve net zero by 2050, new light vehicles sold after 2035 must be zero-emission. The best way to ensure that is to impose an annual average emissions ceiling,[43] which is gradually lowered to zero by 2035.

Carefully implemented, an annual average emissions ceiling could save drivers more than $900 within the first five years of purchasing a vehicle, through reduced running costs. Almost 500 million tonnes (Mt) of carbon abatement could be achieved by 2035, at negligible cost to taxpayers.

And there is no reason to fear such a policy would 'end the weekend': imposing an emissions ceiling would lead to Australia having a wider range of zero- and low-emissions vehicles, without prohibiting any particular type of vehicle.

3.1 Australia's high-emitting vehicle fleet undermines government efforts to get to net zero by 2050

Passenger cars and light commercial vehicles account for about 11 per cent of Australia's total greenhouse gas emissions. These emissions are projected to decline only marginally between now and 2030 under business as usual.[44]

If Australia is to achieve net zero by 2050, transport emissions must come down quickly. New light vehicles tend to last at least 15 years, so the emissions from petrol and diesel cars sold today are 'locked in' for that time.

43. Sometimes called a fleet-wide emissions standard, vehicle emissions standard, efficiency standard, or fuel economy standard.
44. DISER (2020, pp. 29–33).

If the Federal Government fails to take immediate action to reduce the emissions intensity of new vehicles sold in Australia, Australians are likely to continue buying and driving petrol and diesel vehicles, creating emissions until well beyond 2050.

3.1.1 Light vehicles are a safe bet for emissions reductions

As many analysts have argued for many years,[45] the best policy to achieve emissions reductions at least cost is an economy-wide carbon price. But unfortunately the political reality is that Australia will not have a carbon price any time soon, so its next best option is to pursue sector-by-sector policies. In this context, light vehicles are a safe bet for cost-effective emissions reductions, for two reasons.

Firstly, Grattan analysis shows that abatement achieved through an annual average emissions ceiling is likely to significantly reduce carbon emissions, and make a substantial contribution to Australia's emissions reduction task between now and 2030 (Box 2 on the next page). This is consistent with previous research, which has consistently demonstrated that emissions reduction in the light vehicle sector can be significant and achieved through regulation with negligible cost to taxpayers.[46]

Secondly, the light vehicle sector is well placed to achieve emissions reductions because the technology for decarbonisation already exists, and is cost efficient. Low- and zero-emissions vehicle technology has matured significantly over the past decade. Internationally, people are

45. For example, Wood et al (2021).
46. The Climate Change Authority and the Bureau of Infrastructure and Transport Research Economics (BITRE) have both previously estimated that regulating CO2 emissions from light vehicles could significantly reduce emissions and also create a net benefit to the community. See Australian Government Climate Change Authority (2014) and DIRD (2016a).

Box 2: We modelled an emissions ceiling under three different scenarios

An annual average emissions ceiling is a limit on the average emissions of new vehicles that manufacturers can sell in a given year.

We modelled the financial costs and savings for consumers of three different trajectories, by estimating the costs of technology required to meet each yearly target, the likely emissions that will be saved, and the decreased running costs for motorists.[a]

We assumed that manufacturers who overachieved their targets could trade credits with those who underachieved. We also assumed that the ceiling would be calibrated to reflect the mix of vehicle types that each manufacturer sold (which is known as an 'attribute-weighted' ceiling).

Each of the three trajectories achieves 0gCO2/km in 2035, but takes a different path. Although each trajectory reaches net zero from new vehicles, this is not a ban on combustion engine vehicles.

Up until 2035, manufacturers would be able to sell petrol and diesel vehicles, although in a decreasing share over time as the ceiling is lowered. From 2035, they could still do so, but would incur a financial penalty; only enthusiasts would be likely to be willing to cover the penalty by paying a higher purchase price.

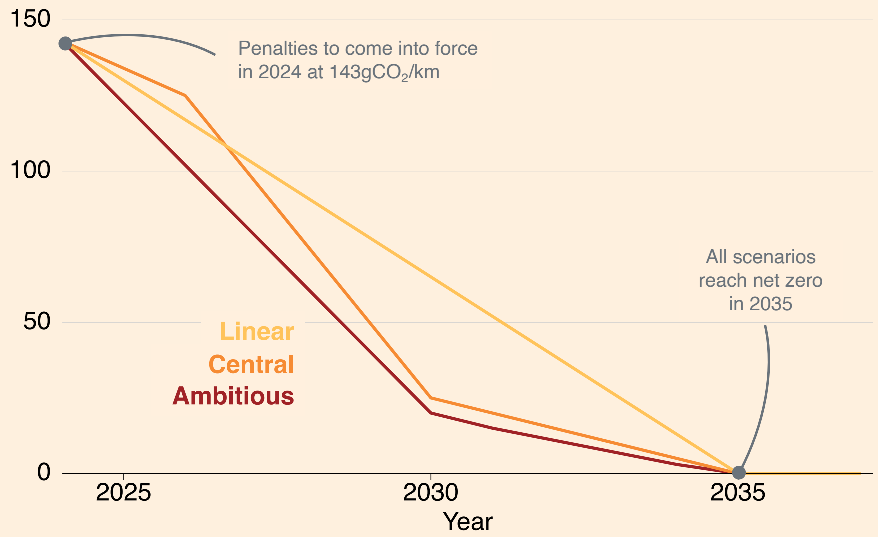
The 'linear' scenario takes the simplest path, decreasing consistently each year from now until 2035.

a. See Appendix A for further details on the modelling and on the assumptions we used.

The 'central' scenario assumes that manufacturers are given more lenient targets to begin with, before the targets quickly decline to reach 25g/CO2 in 2030 and net zero in 2035.

The 'ambitious' scenario has the steepest trajectory early, linearly declining to 20gCO2/km in 2030, and then to net zero in 2035.

Figure 3.1: The three scenarios we modelled
Average vehicle emissions targets under an emissions ceiling, gCO2/km



Note: See Appendix A for further details.

switching to electric vehicles: about 25 per cent of vehicles sold in the EU in August 2021 were zero-emissions vehicles.[47]

3.2 Under an emissions ceiling, vehicle running costs and emissions would fall, at negligible cost to the taxpayer

The remainder of this chapter explains the merits of an emissions ceiling, and how it would reduce vehicle emissions in Australia.

Our modelling indicates that an annual average emissions ceiling can save drivers money (Section 3.2.1), significantly reduce emissions at negligible cost to taxpayers (Section 3.2.2), and ensure Australians can continue to choose from a good range of vehicles (Section 3.2.3).

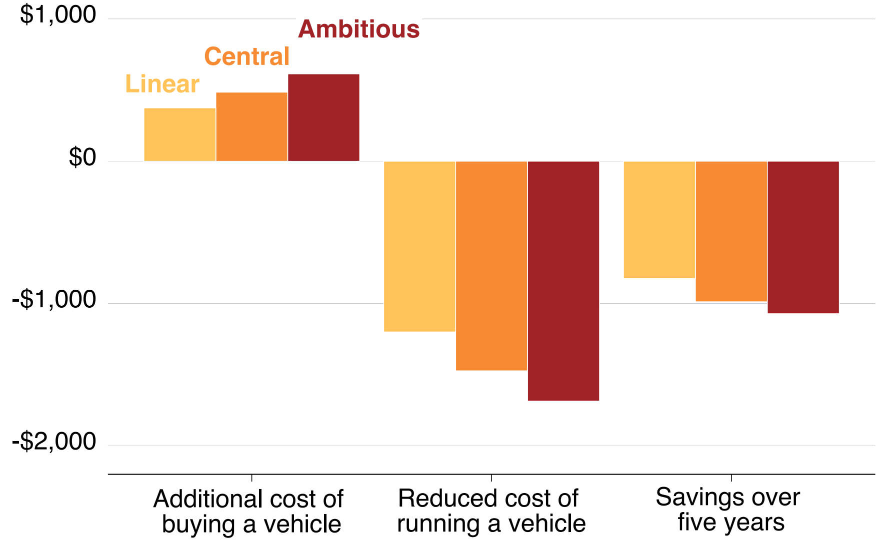
The final section of the chapter (Section 3.3) sets out how an emissions ceiling should be implemented to ensure it produces the emissions reductions and consumer savings it promises.

Recommendation 3

The Federal Government should implement an annual average emissions ceiling for new light vehicle sales. The ceiling should come into force in 2024. At that time it should not exceed 143g/km. By 2027 it should not exceed 100g/km. By 2030 it should not exceed 25g/km, and by 2035 it should reach zero.

Figure 3.2: Low-emissions and electric vehicles cost more to buy but less to run

Estimated change to consumer cost under a vehicle emissions ceiling



Notes: Average over 2024-2035, with a ceiling and 7 per cent discount rate applied. Average savings over five years shown; savings over the lifetime of a vehicle would be larger. This analysis does not account for the loss of tax revenue to government.

Source: Grattan analysis.

3.2.1 An emissions ceiling would save drivers money

Under an emissions ceiling, the mix of new cars for sale in Australia would include a larger share of electric vehicles and lower-emitting petrol and diesel vehicles than currently. These vehicles tend to be more expensive to buy, particularly electric vehicles. But they are

47. Vorrath (2021).

cheaper to run, particularly electric vehicles. Even petrol and diesel vehicles would be cheaper to run under an emissions ceiling, because they would, on average, use less fuel per kilometre travelled.

We calculate that a person who buys a new vehicle under an emissions ceiling would save on average more than $900 over the first five years (Figure 3.2 on the preceding page), and more than $2,000 over the life of the vehicle.[48]

Even if future petrol prices are lower than expected, or electricity prices are higher than expected, the driver savings from an emissions ceiling would still be likely to be considerable (Figure 3.4 on page 22).

3.2.2 An emissions ceiling would cut emissions at negligible cost to taxpayers

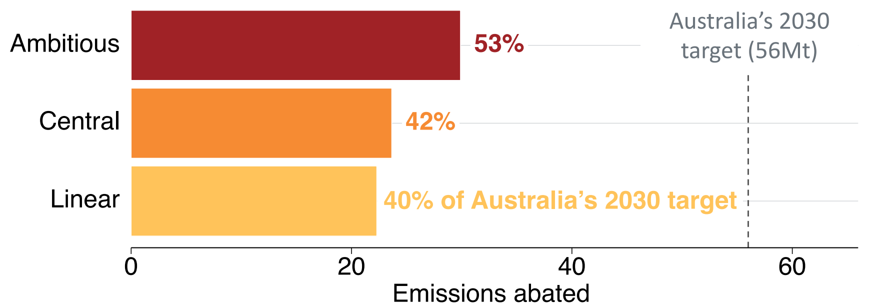
With no action, the lifetime emissions of vehicles sold in Australia between now and 2050 is expected to exceed 800Mt. Under our proposed vehicle emissions ceiling, this total could be more than halved.

The 'central' annual average emissions ceiling we modelled would reduce emissions by almost 500Mt.[49] And because these emissions savings would be achieved by regulation rather than direct funding, the only cost to the taxpayer would be the cost of administering the regulation.

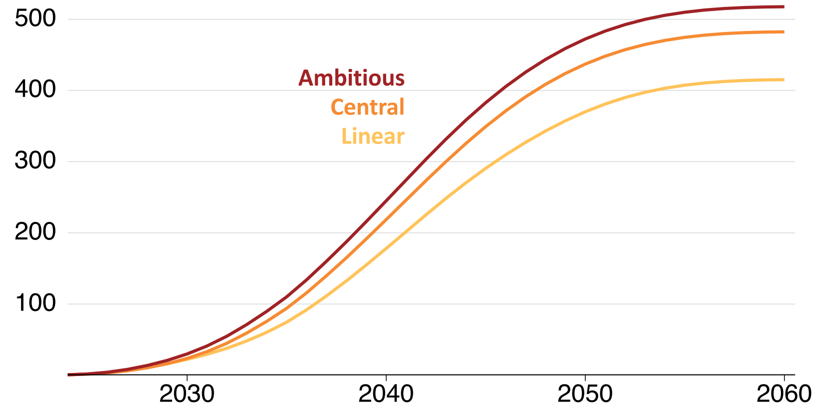
An emissions ceiling would also significantly help Australia to meet its emissions reduction commitments. Australia has committed to cutting emissions by 26-to-28 per cent from 2005 levels by 2030. To meet this

Figure 3.3: An emissions ceiling could achieve more than 40 per cent of the emissions reductions Australia needs to meet its 2030 target

Emissions saved (Mt) between 2021-2030 under an emissions ceiling



Cumulative emissions abated under an emissions ceiling (Mt)



Notes: What we call Australia's 2030 target refers to a 26 per cent reduction in emissions compared to 2005 levels, without the use of credits, and is calculated over the 2021-2030 period.

Sources: Grattan analysis and DISER (2020, p. 4).

48. Grattan analysis, calculated using a 7 per cent discount rate. With a 4 per cent discount rate, average net consumer savings would be about $3,500 over the lifetime of a vehicle.
49. The reduction between 2021 and 2060 would be 415Mt for the linear scenario, 482Mt for the central scenario, and 517Mt for the ambitious scenario.

target without using past over-achievement, a further 56-to-123Mt of economy-wide emissions cuts will be needed between now and 2030. As Figure 3.3 on the preceding page shows, a vehicle emissions ceiling could achieve more than 40 per cent of the cuts required.[50]

Achieving such cuts through the Federal Government's Emissions Reduction Fund (ERF) would probably cost more than $7.7 billion.[51]

3.2.3 An emissions ceiling would open up new options for Australian drivers

Cars are more than a means to get around. For many of us, they are part of our identity. Some of us like to do burnouts in hot rods. Some of us like to tow caravans and boats for holidays or weekends away. Others choose a car that will do as little damage to the environment as possible, even if it costs more to buy.

An emissions ceiling would change the balance of options available to Australian drivers. There would be a larger range of low-emissions and zero-emissions vehicles,[52] and a smaller offering of higher-emitting vehicles (Box 3).

But drivers who want or need specialist or niche vehicles wouldn't miss out: as more people switched over time to electric vehicles, there would be space under the emissions ceiling for manufacturers to sell higher-emitting vehicles to people who were willing to pay for them.

Meanwhile, drivers who care mostly about cost and general driving would end up better off.

50. Under the linear scenario, the quantity of emissions reduction would be 22Mt; under the central scenario, 24Mt; and under the ambitious scenario, 30Mt.
51. This figure is calculated using the April 2021 ERF auction rate of $16/tonne, and the emissions savings under a central scenario of 482Mt between 2024 and 2060: Australian Government Clean Energy Regulator (2021). Future auction prices are likely to be higher.
52. DIRD (2016a).

Box 3: The price of electric vehicles is dropping quickly

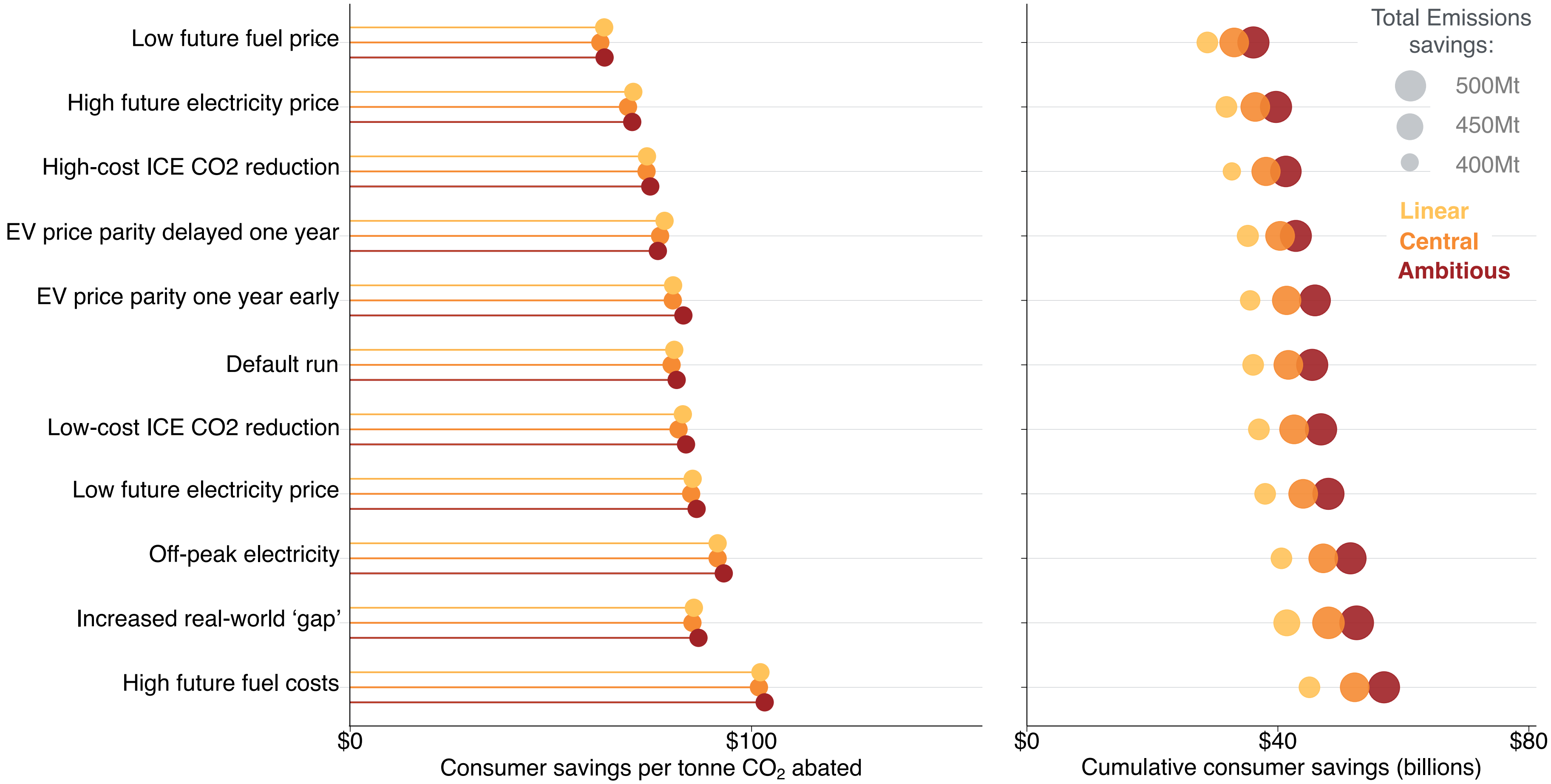
Various forecasts suggest electric vehicle prices in Australia will match the price of equivalent petrol and diesel vehicles before 2030 – not just for passenger vehicles, but also for mid-sized and larger SUVs.[a]

Many manufacturers are switching their fleets to electric, regardless of Australian policy. Jaguar Land Rover (by 2025), Volvo (2030), Mazda (2030), Nissan (early 2030s) and Honda (2040) have all committed to 100 per cent electric sales.[b] Other manufacturers, such as Toyota, have announced a range of electric vehicle models that will be available soon.[c]

If, in 2030, 10 per cent of light commercial vehicles sold in Australia were electric, 90 per cent of SUVs sold were electric, all passenger vehicle sold were electric, and the remaining sales were of hybrid vehicles, manufacturers would probably be able to come in under our proposed emissions ceiling.

a. International Council on Clean Transportation (2019b); and Transport and Environment (2021).
b. Electric Vehicle Council (2021).
c. Toyota Motor Corporation (2021).

Figure 3.4: Even if circumstances change, drivers are likely to save money under an emissions ceiling
Estimated consumer savings per tonne of CO2 abated, and total consumer savings



Notes: ICE = internal combustion engine. EV = electric vehicle. Calculated using a discount rate of 7 per cent. The 'increased real-world gap' scenario assumes a test-cycle to real-world emissions gap of 30 per cent. This is explained further in Box 4 on page 25. Costs and savings do not account for tax revenue lost to government. See Appendix A for further details.

Source: Grattan analysis.

Last year, there were 31 zero-emissions vehicle models available for purchase in Australia.[53] In the UK, which has an emissions ceiling, there are 130 zero-emission models available.[54]

Manufacturers have made clear that they could offer more models in Australia if policy settings were changed. According to Nissan Australia,[55]

> Clear and consistent direction from governments is a critical signal to car-makers to prioritise the importation of the latest low- and zero-emissions vehicles for Australian consumers.

And the technology for some of the more specialised functions is improving, particularly for larger vehicles and utes. In the US, there were more than 100,000 pre-orders in less than three weeks for the new Ford F150 Lightning, a large electric ute.[56]

Reports of the impending death of the ute and the great Australian weekend are exaggerated.

3.3 Emissions ceilings should be designed carefully

Vehicle emissions policies are common around the world. More than 80 per cent of the global light-vehicle fleet is subject to emissions ceilings, including in India, China, the US, the EU, Japan, and South Korea.[57]

This international evidence shows that vehicle emissions ceilings are very effective in reducing emissions.[58]

53. Electric Vehicle Council (2021, p. 4).
54. Ibid (p. 8).
55. Purtill (2021).
56. Ford Motor Company (2021) and Lawler (2021). When carrying about 450kg of load, it is expected to have a standard range of 370km, or 480km with an extender pack.
57. International Energy Agency (2019, p. 22).
58. Ibid (p. 7).

A form of emissions ceiling for light vehicles has been recommended by the International Energy Agency,[59] the Australian Climate Change Authority,[60] the International Council on Clean Transportation,[61] the Global Fuel Economy Initiative,[62] the Business Council of Australia,[63] Infrastructure Victoria,[64] ClimateWorks Australia,[65] and Grattan Institute.[66] The Bureau of Infrastructure and Transport Research Economics found that a vehicle emissions ceiling would produce significant benefits for Australia.[67]

Despite this, Australia has failed at numerous attempts to implement a form of a vehicle emissions ceiling. The result is higher emissions, and significantly higher vehicle running costs.[68]

Australian governments should learn from domestic and international experience as they design a vehicle emissions ceiling for Australia.

3.3.1 An emissions ceiling should be legislated and binding

Voluntary emissions targets are inevitably ineffective. The Federal Chamber of Automotive Industries (FCAI) has developed voluntary emissions policies on multiple occasions since the early 1980s. These targets have typically been lacking in ambition and have often not been met.[69]

59. Ibid.
60. Climate Change Authority (2014).
61. International Council on Clean Transportation (2017a).
62. GFEI (n.d.).
63. Business Council of Australia (2017).
64. Infrastructure Victoria (2021c).
65. ClimateWorks (2017).
66. Wood et al (2021).
67. DIRD (2016a).
68. Smit et al (2019).
69. Wood et al (2021).

Any emissions ceiling implemented in Australia should be legally binding, with sufficient penalties to motivate compliance.

3.3.2 A single target should be applied to all light vehicles

Many jurisdictions overseas have opted to apply two distinct emissions targets to new vehicle sales – one target for passenger vehicles, and a more lenient target for light commercial vehicles.[70] But the international experience demonstrates clear shortfalls in this approach.

In the US, for example, although targets within each segment have consistently been met, the effectiveness of the scheme has been undermined because people have continued to abandon passenger vehicles in favour of SUVs and light trucks.[71] Across its entire fleet, the US recorded an increase in average vehicle emissions from new car sales in 2019, compared to 2018 – despite most manufacturers meeting their targets.[72] There have been similar problems, although to a lesser extent, in many EU countries.[73]

A single target system also provides manufacturers with more flexibility in how they reach their targets. Australia should adopt a single target.

3.3.3 Emissions must be carefully monitored

International experience also underscores the need to carefully monitor emissions under any vehicle emissions ceiling.

Vehicle testing is conducted to monitor compliance with emissions policies. But there is a significant gap between test results and real-world emissions (Box 4 on the next page), because manufacturers 'game' the system by specifically designing vehicles for the tests.

70. Often including some SUVs.
71. Shepardson (2021).
72. Cozzi and Petropoulos (2019).
73. International Council on Clean Transportation (2018b).

In response to the growing gap between test results and real-world emissions, the EU now uses the Worldwide Harmonised Light Vehicle Test Procedure, or WLTP, instead of the New European Drive Cycle (NEDC). Australia should also adopt the WLTP, in line with our 'long-standing policy of harmonising Australian vehicle standards with international best practice'.[74]

Recommendation 4

Australia should adopt the Worldwide Harmonised Light Vehicle Test Procedure, or WLTP, for vehicle emissions testing.

Australia should require that all new vehicles be fitted with on-board vehicle emissions monitoring devices. These devices, used in the EU, collect data on energy efficiency and fuel consumption of vehicles under real-world conditions.[75] As in the EU, Australia should enforce strict privacy guidelines on the use of the data collected.

Annual data containing test and real-world results for all vehicle models sold should also be made public in Australia, as it is in the EU,[76] to enable scrutiny of test results, real world-emissions, and the gap between the two.

Recommendation 5

On-board vehicle emissions monitors should be required by 2024 for all new vehicles sold in Australia, with de-identified annual data released publicly.

74. Fletcher (2018, p. 8).
75. European Union (2021).
76. European Environment Agency (2021b).

Box 4: The gap between test results and real-world emissions

Vehicles sold in Australia are assessed for their fuel consumption and carbon emissions through procedures outlined in the Australian Design Rules. Vehicles are tested using the New European Drive Cycle (NEDC), which simulates a range of driving conditions.

But the NEDC is not perfect, and has become more imperfect over time. The gap between test results and real-world emissions has grown considerably, particularly in jurisdictions such as Europe that have an emissions ceiling.

In 2001, the gap between NEDC test results and real-world driving emissions in Europe was estimated at 10 per cent.[a] By 2017, that gap had grown to 39 per cent.[b] A similar picture has emerged in Australia, with best estimates indicating the gap grew from about 10 per cent in 2008 to more than 30 per cent between 2008 and 2017.[c]

Various jurisdictions have begun to use individual tests. This duplicates effort and has made international comparisons more difficult. To combat this, the United Nations Economic Commission for Europe developed and adopted the Worldwide Harmonised Light Vehicle Testing Procedure, or WLTP.

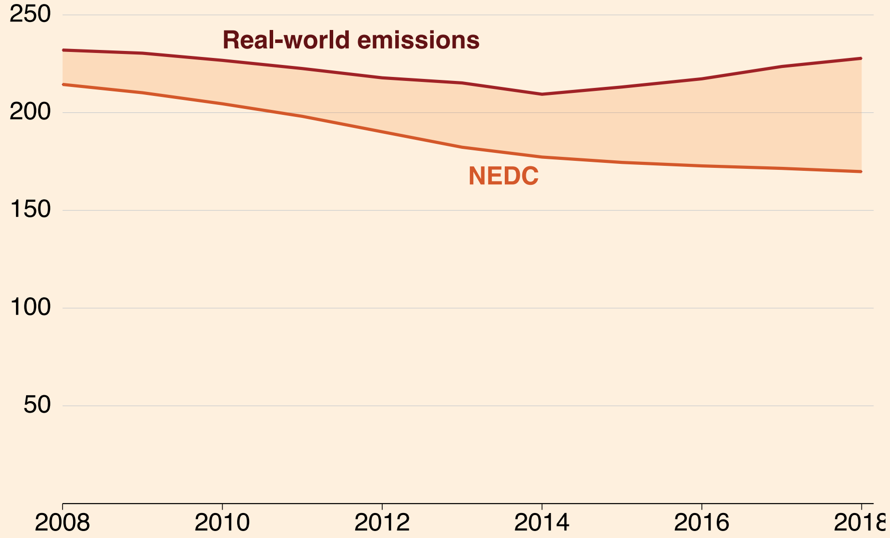
The WLTP test reflects real-world driving conditions more accurately than the NEDC, because it involves more aggressive driving at higher speeds and in more tightly controlled conditions.

a. International Council on Clean Transportation (2019c, p. 25).
b. Ibid (p. 25).
c. Smit (2019, p. 10).
d. International Council on Clean Transportation (2020, p. 21).

In 2018, the gap between WLTP and real-world emissions for European vehicles was estimated to be 14 per cent.[d]

Figure 3.5: The gap between test results and real-world emissions has grown

Average emissions intensity of new passenger vehicles (gCO2/km)



Note: NEDC = New European Drive Cycle.

Sources: Smit (2019) and National Transport Commission (2020a).

3.3.4 An emissions ceiling should allow some flexibility arrangements, but not technology multipliers

Flexibility arrangements

Australia's vehicle emissions ceiling should allow manufacturers some flexibility in how they meet their targets. This may be through allowing manufacturers who fail to meet their targets to purchase credits from manufacturers who overachieve, or through allowing overachieving manufacturers to accrue credits that they can use to hit targets in later years.

Most international schemes include some form of flexibility arrangements. If such arrangements are designed well, they can lower the compliance burden for manufacturers without undermining the policy.

Technology multipliers

In some jurisdictions, emissions ceilings include multipliers for certain vehicle technologies. These typically have been used for zero-emissions vehicles, with the rationale that these immature technologies require greater support.

Australia should not go down this path. These sorts of arrangements reduce the overall emissions reductions achieved through an emissions ceiling, and are inconsistent with a technology-neutral approach to reducing emissions in the transport sector.

By allowing zero-emissions vehicles to accrue a multiplier, technology credits allow a single vehicle to count as more than one vehicle. In some jurisdictions, zero-emissions vehicles have been given a weighting of 1.5 or 2 vehicles, despite the fact that the emissions reductions achieved through the specific technology are no greater than emissions reductions achieved in any other way.

This is typically justified on the grounds that it provides a boost to infant technologies, encouraging investment. However, globally, zero-emissions vehicles are no longer in their infancy. In the EU, for example, provisional sales data indicate that 15-to-20 per cent of all new vehicles sold in 2021 are battery electric.

Multipliers also enable manufacturers to emit more than the target specifies. For example, if zero-emissions vehicles accrue a 2x multiplier, a manufacturer that exclusively sells zero-emissions vehicles could 'meet' their target while achieving only half of the emissions reductions that would be required if no multiplier was in place.

Australia's policy should take a technology-neutral approach to reducing vehicle emissions.

Recommendation 6

Technology multipliers should not be incorporated into the design of an average annual emissions ceiling in Australia.

4 Australia is ready for the switch to electric vehicles

Australians have been slow to switch to electric vehicles (Section 4.1). Drivers are concerned about the price, worry that it will be inconvenient to charge an electric vehicle, and fear it won't be possible to make long trips in electric vehicles (Section 4.2).

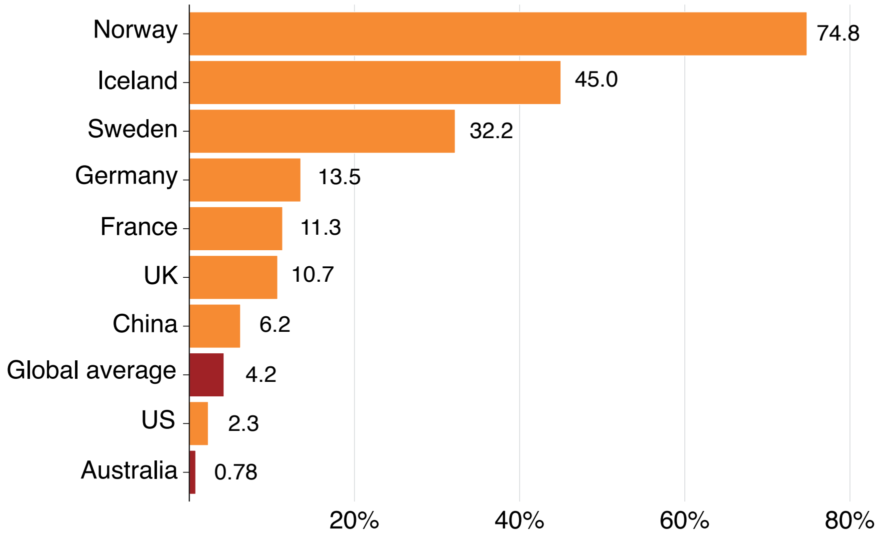
This chapter addresses each of these concerns, and shows that, despite drivers' concerns, Australia is ready for the switch to electric vehicles. Section 4.3 shows why most households will find daily and weekly charging straightforward. Section 4.4 details the developments in charging infrastructure for longer journeys. Section 4.5 proposes that restrictions on direct and second-hand vehicle imports be relaxed. Section 4.6 recommends government provide reliable and comparable consumer information on electric vehicles.

4.1 Australia is an electric-vehicle laggard

Australia lags well behind the rest of the world in the switch to electric vehicles. The National Transport Commission estimates that electric vehicles make up only 0.12 per cent of Australia's light vehicle fleet.[77]

The sales share of electric vehicles is much lower in Australia than in countries with comparable household disposable incomes. In 2020, 6,900 electric vehicles were sold in Australia – just 0.78 per cent of new vehicle sales. By comparison, electric vehicles were 10.7 per cent of new sales in the UK, 11.3 per cent in France, and 32.2 per cent in Sweden. The global average is 4.2 per cent (Figure 4.1).[78]

Figure 4.1: Australia is a global laggard on electric vehicles
Electric vehicle sales as a proportion of new vehicle sales, 2020



Source: Electric Vehicle Council (2021).

77. National Transport Commission (2021, p. 22).
78. Electric Vehicle Council (2020).

4.2 Australians are interested in electric vehicles, but worried about charging them

Although electric vehicle sales are low, they are increasing. Australians purchased 8,688 electric vehicles in the first six months of 2021, compared to 6,900 across the 12 months of 2020.

Australian drivers are increasingly interested in electric vehicles. A 2020 survey for the Electric Vehicle Council found 56 per cent of respondents would consider buying an electric car as their next vehicle,[79] up from 53 per cent in 2019 and 48 per cent in 2018.[80]

Drivers' most-cited concerns about switching to an electric vehicle were the availability of convenient charging, the battery and driving range, and the purchase price.[81] The following sections explain why these concerns are generally overstated.

4.3 Regular daily or weekly charging will be straightforward for most households

The electric vehicles sold in Australia have battery ranges that vary between 260km and 650km.[82] The average is about 400km. These batteries comfortably accommodate most Australians' driving needs on most days: on average, drivers travel less than 32km on workdays,[83] and 99 per cent of people who travel to work travel less than 100km.[84]

Households that can install dedicated at-home charging infrastructure are particularly well-positioned to switch to electric vehicles (Box 5). In

79. Ibid.
80. Electric Vehicle Council (2018); and Electric Vehicle Council (2019).
81. Electric Vehicle Council (2020, p. 17); and Infrastructure Victoria (2021b, p. 18).
82. Electric Vehicle Council (2020, p. 20).
83. Grattan analysis of ABS (2018).
84. ARENA (2018, p. 4), citing data from the Victorian Integrated Survey of Travel Activity (2013).

Box 5: A guide to charging infrastructure for electric vehicles

The time it takes to charge a battery depends on the battery capacity – how much there is to 'fill' – how much power the vehicle can draw from a charger, and the power made available by a charger.

Level 1	**Standard alternating-current (AC) power point: 10-15 Amp** 2kW of charging power with a 10 Amp socket 10-to-20km of range per hour of charge About 20 hours to fully charge a 40kW Nissan Leaf battery Typically used in homes Cord-style charger, usually provided with vehicle Ideal for 'top-up' charging and daily use
Level 2	**Dedicated AC charger: 32 Amp** 7.2kW of charging power Up to 40km of range per hour of charge About 6 hours to fully charge a 40kW Nissan Leaf battery Used in homes, apartments, and for on-street charging Provides a full recharge overnight
Level 3	**Dedicated direct-current (DC) charger:** **Often referred to as a 'fast' or 'ultrafast' charger** Requires three-phase power Fast chargers: 50-to-150kW of charging power Ultra-fast chargers: up to 350kW of charging power '400 Volt' electric vehicles cannot charge as fast as newer '800 Volt' electric vehicles 'Fast charging': charges from 10% to 80% in less than an hour A Nissan Leaf can fill to 80% in 40 minutes 'Ultra fast charging': charges from 10% to 80% in less than 20 minutes, adding charge for about 350-to-400km The ABB Terra 360: provides charge for about 100km in less than 3 minutes

Sources: Bonnici (2020), Gardner (2020), Electrive (2021) and The Economist (2021).

the US, households that have at-home charging infrastructure do more than 80 per cent of their charging at home.[85]

At-home charging can be used for everyday needs, and can be augmented with fast-chargers on long trips.

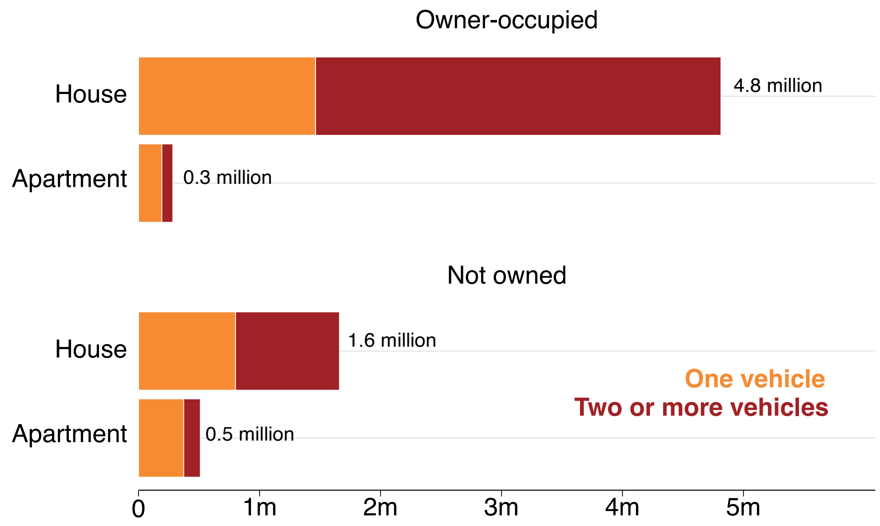
4.3.1 Nearly two-thirds of Australian households will find it easy to charge electric vehicles at home

Houses with off-street parking are ideal for charging electric vehicles. Of Australian households that own at least one vehicle, nearly two-thirds own a detached or semi-detached house. A further 23 per cent of households with vehicles rent a detached or semi-detached house, bringing the total to nearly 90 per cent (Figure 4.2).

About 95 per cent of detached and semi-detached houses in Melbourne have off-street parking.[86] Electric vehicle chargers can be installed in these houses quite easily and cheaply. In many cases, when there is an existing wall socket in a garage, an electrician will simply need to verify that the wiring can support a charger.[87] If garages don't have an existing socket, an electrician will need to install one for a Level-1 charger, or install a wall-mounted Level-2 charger. Some households will require an additional circuit to support a charger.[88] Installing a socket for a Level-1 charger can cost about $400, and installing a Level-2 charger about $2200.[89]

85. Grattan analysis of US Office of Energy Efficiency and Renewable Energy (2013). Modelling by KPMG predicts that in Melbourne, households with at-home chargers will do 90 per cent of their charging at home. See Infrastructure Victoria (2018, p. 119).
86. Grattan analysis of publicly available real-estate data, weighted by housing types, number of bedrooms, tenure, and location data from the 2016 Census. For details on methodology, see Appendix B.
87. Electric Cars Guide (2021).
88. Installation is regulated under the Australian/New Zealand Wiring Rules.
89. Based on Grattan analysis of publicly available estimates of installation costs, summarised in Appendix C.

Figure 4.2: Most households that own a vehicle own a detached or semi-detached home
Number of households



Source: ABS (2016).

Of Australian households that live in a house and own a vehicle, nearly two-thirds own more than one car.[90] These households are likely to lead the transition to electric vehicles. They could use a first electric vehicle for short-range driving and to familiarise themselves with the technology, while retaining a petrol or diesel vehicle for longer journeys. These households could switch to a second electric vehicle once they become more comfortable with the technology and as publicly-accessible chargers become more widely available.

More than half of Australian households that drive own two or more vehicles and live in a detached or semi-detached house with off-street parking. This suggests that most Australian households will find it straightforward to switch to electric vehicles.

4.3.2 Some households will rely on publicly-accessible charging infrastructure for their everyday charging needs

A large majority of Australian households can install at-home charging for electric vehicles. But a smaller number will find that it isn't possible, or isn't affordable, to charge their vehicle at home. This group will include some households that live in apartments, some renters, and households without off-street parking. These households will be more likely to rely on publicly-accessible chargers for electric vehicles.

In 2016 just under 30 per cent of households that owned a vehicle lived in homes that they didn't own, and just over 10 per cent of households lived in apartments. About a third of households that drive are in one or both of these groups (Figure 4.2).

In Melbourne, about 5 per cent of houses do not have off-street parking. Such houses are disproportionately located in inner suburbs, where public transport is generally good. Many people choose to live in these suburbs because of good public transport and options for walking or bike-riding, and with less need to own a car.

This suggests that, at most, only about a third of households will rely on publicly-available electric vehicle chargers for their everyday transport needs. In practice this group is likely to be much smaller, because many renters and households that live in apartments will be able to install chargers.

Some households in central and inner suburbs will find it harder to install at-home charging

Not all households in apartments will struggle to install chargers: one study of Sydney apartment blocks found that with good planning and coordinated investment, the cost can be comparable to installing a charger in a detached house.[91] But some drivers who live in apartments will find it difficult and costly to install at-home charging infrastructure, and will rely on publicly-accessible chargers if they drive an electric vehicle.

In Australia, people who live in apartments and own cars are concentrated in NSW (Figure 4.3 on the following page), and in NSW, they are concentrated in inner-city Sydney (Figure 4.4 on page 32).[92]

Real-estate data in Melbourne show that inner-city areas have far more houses without off-street parking. In most local government areas across Melbourne, more than 90 per cent of houses have

90. Grattan analysis of ABS (2016).

91. Appendix C provides further information on the costs of installing charging infrastructure in houses and apartments.

92. The share of households that own cars and live in apartments is highest in the Northern Territory and in NSW – about 17 percent of households that own a vehicle. In the ACT about 14 percent of households that drive cars live in apartments; in all other states less than 10 per cent of households who own a vehicle live in an apartment. ABS (2016).

off-street parking.[93] But more than 40 per cent of houses in the City of Melbourne do not have off-street parking, and more than 20 per cent of households in the inner-city areas of Port Phillip and Yarra also rely on on-street parking.

In central and inner-city areas, widespread adoption of electric vehicles will require local, publicly-accessible charging infrastructure

Having charging infrastructure close to home is a threshold issue for many households considering buying an electric vehicle. Many households without at-home charging will stay with petrol or diesel vehicles unless they can use local, publicly-available chargers for electric vehicles.

Local charging infrastructure includes on-street charging, and fast and ultra-fast chargers that fill a role similar to petrol stations.

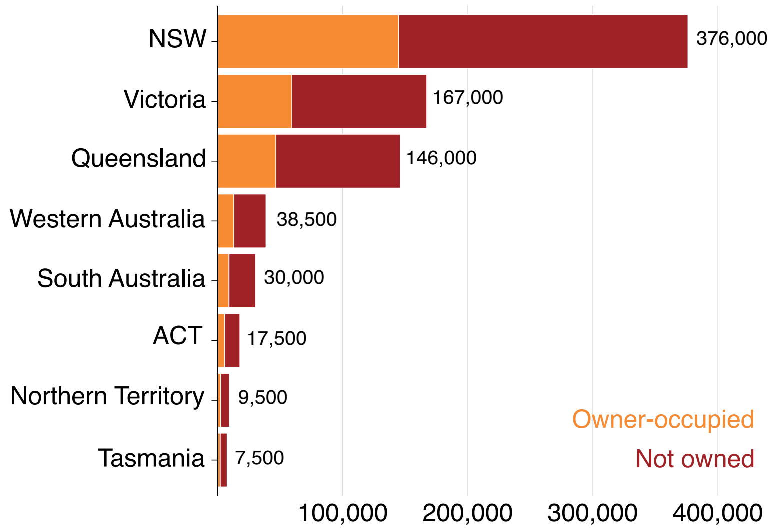
Commercial providers that install on-street charging infrastructure naturally aim to recover their costs over time. If councils or state governments invest in on-street charging infrastructure, a guiding principle should be that non-drivers are not expected to subsidise the facility. Instead, if councils install or subsidise charging infrastructure, they should recover capital costs, for example through fees for parking permits, and electricity costs via time-limited meters. And local councils should balance any support for local charging networks with support for residents who don't have cars. This could be done by investing in bike paths and pedestrian safety measures.

Imposing an annual average emissions ceiling, as we propose, will increase the number of electric vehicles sold in Australia each year. This will increase the pool of drivers who need publicly-accessible charging infrastructure, and should increase its commercial viability.

93. Real-estate data was analysed for 32 local government areas in the Melbourne region. In 27 local government areas, more than 90 per cent of households had off-street parking; many had nearly 100 per cent off-street parking.

Figure 4.3: Households that live in apartments and own cars are concentrated in NSW

Number of households



Source: ABS (2016).

Recommendation 7

If local councils invest in charging infrastructure, they should recover their costs from vehicle owners, not from residents who rely on public transport, walking and cycling.

4.3.3 Landlords and vendors should be required to disclose whether their property has charging infrastructure

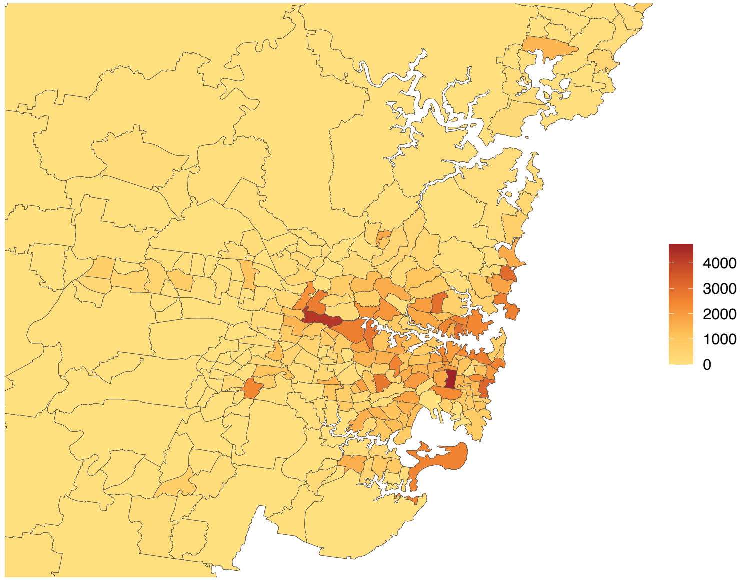
Government policies should encourage landlords and vendors to install electric vehicle charging infrastructure on their property, but should not make it mandatory. Installation costs can be high – potentially above $10,000 to upgrade a switchboard and rewire a older house.[94] In these cases, installing charging infrastructure would substantially push up rents, and may not be of any value to the tenant.

But when they are leasing or selling a property, landlords and vendors should be required to disclose to prospective renters or buyers whether the property has charging infrastructure. Mandatory disclosure would sharpen landlords' and vendors' incentives to make their properties ready for electric vehicles.

Recommendation 8

States and territories should introduce mandatory disclosure rules, requiring landlords and vendors to disclose at the point of lease or sale whether their property has charging infrastructure for electric vehicles. These rules should be introduced by 2022.

Figure 4.4: Households in NSW that live in apartments and own cars are concentrated in the inner suburbs of Sydney
Number of households



Notes: Household-level data has been used to identify households that own at least one vehicle, and live in an apartment. Results are reported for local government areas.

Source: ABS (2016).

94. See Appendix C for details on the cost of installing charging infrastructure.

4.3.4 New homes should be built to be ready for electric vehicles

Installing charging infrastructure during construction is often cheap and easy. For many houses, it will be as simple as ensuring that a separate circuit is available for a socket in a garage or driveway. It would be rare for the cost of installing charging infrastructure during construction to materially increase the price of a dwelling, or to cost more than retro-fitting.

The National Construction Code (NCC) should be updated in 2022 to provide an 'EV-ready' benchmark for new residential buildings. The Australian Building Codes Board is already considering these updates, which have stakeholder and public support.[95] There is no reason to delay or hold off on these changes to the Code.

In the absence of national codes, NSW and the ACT are independently introducing policies so that new residential buildings with off-street parking are ready for electric vehicles.[96] The Queensland Government wants 'EV ready' provisions included in the Code, but has foreshadowed that it may otherwise introduce requirements under the Sustainable Resilient Buildings program.[97] Provisions for 'EV-ready buildings' are also under consideration in Western Australia and Victoria.[98] An updated Code would set a benchmark and be relevant where states and territories hadn't already introduced their own policies.

95. Australian Building Code Board (2019, p. 19).
96. The NSW Government has committed to update regulations so new buildings are 'EV ready': NSW Department of Planning, Industry and Environment (2021). The ACT Government has committed to amending the Parking and Vehicle Access General Code to require that all new multi-unit and mixed-use developments are ready for electric vehicles: ACT Government (2018).
97. de Brenni (2021).
98. Department of Water and Environmental Regulation (2020); and Victorian Department of Environment, Land, Water and Planning (2021).

The Code should require new houses to include a dedicated circuit for a vehicle charger. It should require new apartment buildings to include a dedicated distribution board for charging equipment, a load management system, and a mechanism for cost allocation to residents for energy used when charging electric vehicles.

States and territories that do not already require new residences to be ready for electric vehicles should adopt the NCC updates by 2022.

Recommendation 9

The National Construction Code should be updated to require that new dwellings with off-street parking have wiring suitable for electric vehicles from 2022.

4.4 Many long journeys are now possible with Australia's network of publicly-accessible chargers

Australian drivers' concerns that that they may not be able to make longer-range journeys in electric vehicles are increasingly out-of-date. Drivers of electric vehicles used to have to rely on a sparse network of public chargers. But in recent years the network has been expanded rapidly, with commercial, state, and federal government investment.

Since 2018, more than 400 fast chargers and more than 1800 standard chargers have been added to the network. There are now more than 3000 publicly-accessible charging stations at more than 1,650 locations across Australia, including 470 fast and ultra-fast charging stations at more than 240 locations (Figure 4.5 on the following page).

When the number of electric vehicles is low, a sparse network of chargers can hold back uptake.[99] But countries with a greater

99. Infrastructure Victoria (2021b, p. 19).

share of electric vehicles in their fleet can support a lower density of publicly-accessible chargers to electric vehicles. Denmark and Norway are examples.[100]

In 2020, Australia's ratio of publicly-accessible chargers to electric vehicles was comparable to Belgium, the UK, and Germany (Figure 4.6 on the next page), and since then our publicly-accessible charging network has expanded further. Including 2021 sales of electric vehicles, Australia now has a ratio of almost 1 charger per 10 electric vehicles: more than 3,000 publicly-accessible chargers and nearly 32,000 electric vehicles.

Publicly-accessible chargers are now available in Australian cities, regional towns, and along highways. Electric vehicles can now travel, for example, from Port Douglas in far north Queensland, through Brisbane and Sydney, and on to Canberra or Melbourne. They can drive from Melbourne through to Adelaide. The West Australian Government recently committed to an extra 90 fast chargers stretching north from Perth to Kununurra, with chargers no more than 200km apart.[101]

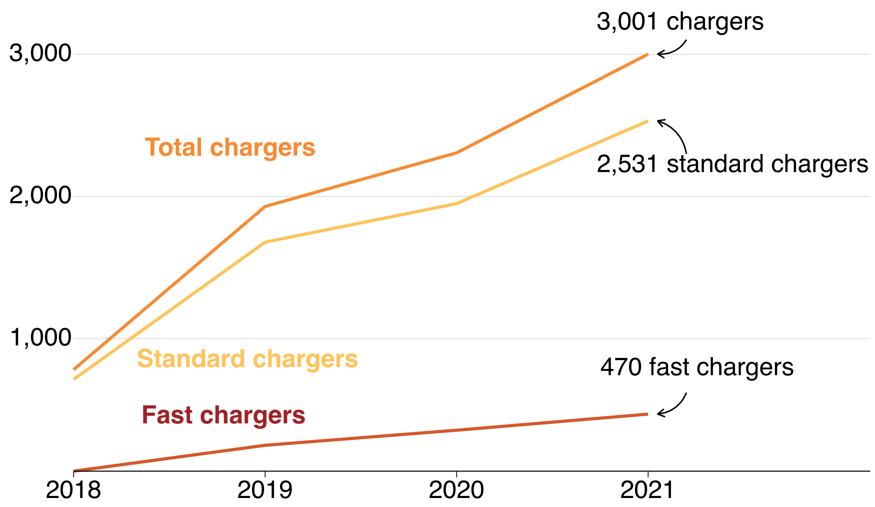
Not every journey in Australia is possible in an electric vehicle, but many are. The key components of a national network are already in place.

4.4.1 Charging technology continues to improve, and long journeys will get easier

Charging and battery technology are improving rapidly, and charging will get faster and easier as more Australians switch to electric vehicles.

Charging speeds depends on cars' batteries, which have built-in limits. Most electric vehicles operate at 400 volts, but recently Porsche,

Figure 4.5: The publicly-accessible charging network is expanding rapidly
Number of charging stations



Note: Publicly-available chargers include Tesla's network of chargers.

Source: Electric Vehicle Council (2018), Electric Vehicle Council (2019), Electric Vehicle Council (2020) and Electric Vehicle Council (2021).

100. International Energy Agency (2021a, p. 40).
101. Sanderson and Johnston (2021).

Hyundai, and Kia have all released 800-volt vehicles, which can charge about twice as quickly as 400-volt vehicles. An 800-volt vehicle can be charged from 10 per cent to 80 per cent in just 18 minutes on a 350-kilowatt ultra-fast charger,[102] with about 350km of range in the first 15 minutes.[103]

These ultra-fast chargers are already part of Australia's publicly-accessible charging network,[104] and ultra-fast charging 'stations' could soon resemble today's petrol stations. In January this year, Hyundai and SK Network opened an ultra-fast electric vehicle charging station in South Korea with 350kW chargers, and similar stations are being built around the world.[105]

Australia's network of publicly-accessible chargers is already well-developed, and it is growing. The next wave of ultra-fast charging will add flexibility and geographic range to our charging network.

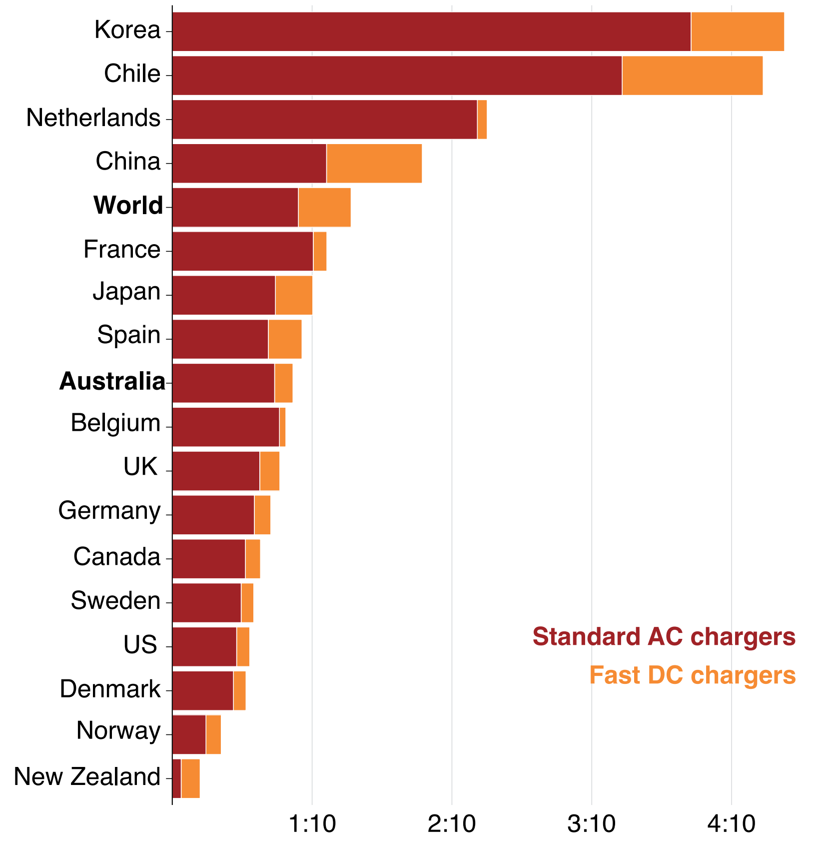
4.4.2 Government investments in chargers should not crowd out commercial investments

Australia's switch from petrol and diesel vehicles to zero-emissions vehicles will create public benefits relative to driving petrol or diesel vehicles, so there is an argument for government investment in the network of publicly-accessible chargers during the transition.

To the extent that they invest, governments should focus on chargers that fill gaps in the network that are not otherwise likely to be filled by commercial providers. These may be geographic gaps that are

102. The Economist (2021).
103. Electric batteries do not charge at a steady pace; the rate of charging slows as the battery fills.
104. See, for example, the Federal Government's Ultra Fast Highway project: ARENA (2019).
105. Hyundai Motor Company (2021).

Figure 4.6: Australia's chargers-to-electric-vehicles ratio compares well internationally
Ratio of publicly-accessible chargers to electric vehicles, 2020



Note: A ratio of 1:10 means that one publicly-available charger is available for every 10 electric vehicles in Australia.

Source: International Energy Agency (2021b).

important for long journeys, or gaps in access to everyday charging in local areas.

The challenge for governments will be to ensure that public investments continue to secure good value for money, and to avoid crowding out commercial investments or 'gold-plating' the network.

Governments should also ensure that public investments in charging infrastructure are 'technology neutral'. New zero-emission technologies, such as hydrogen fuel cell vehicles, are becoming available. The same principles for allocating funding should be applied to all charging infrastructure.

As electric vehicles become more popular, charging them will place more pressure on the electricity network. A crucial role for government will be managing the transition to electric vehicles while maintaining the security of Australia's electricity supply.[106]

Recommendation 10

Any government funding of charging infrastructure should be limited to investments that fill gaps in the network that are not otherwise likely to be filled by commercial providers.

4.5 Australians are paying more than they need to for electric vehicles

Electric cars at the moment cost more than petrol or diesel cars, but they are forecast to reach price parity in the mid to late 2020s.[107] Until then, the dealership price of electric vehicles will put them out of reach for many people. Government subsidies will help some people, but not everyone.[108]

Two policies would sustainably reduce the price of electric vehicles.

An emissions ceiling would provide policy certainty for manufacturers, and an incentive to import a broader range of low- and zero-emission vehicles at different price points (Section 3.2.3). And the Federal Government should change the law that prevents Australians importing any models and variations of vehicles that are sold, or have been sold, through manufacturers' distribution networks.[109]

This existing law substantially reduces price competition in the market for new low- and zero-emission vehicles, and stifles the second-hand market. And the problem will get worse: as manufacturers make available more models of low- and zero-emission vehicles, this will choke off Australians' access to these vehicles through direct-import channels.

A 2014 Productivity Commission inquiry into Australia's motor vehicle industry called for eased import restrictions from 2018, arguing that,

> ...the progressive relaxation of restrictions on the wide-scale importation of second-hand passenger and light commercial vehicles would have net benefits for the community as a whole ...through lower prices and/or improved product specification [that is, vehicle

106. See, for example, the discussion in Infrastructure Victoria (2018) about the relationship between different types of charging infrastructure and the electricity grid.
107. International Council on Clean Transportation (2019b); and Transport and Environment (2021).
108. For example, the Victorian Government is subsidising up to 20,000 zero-emission vehicles priced at up to $68,740, with the first 4,000 subsidies valued at $3,000: Victorian Department of Environment, Land, Water and Planning (2021). The NSW Government waives stamp duty and offers $3,000 subsidies for zero-emission vehicles priced up to $68,750: NSW Department of Planning, Industry and Environment (2021, p. 19) Federal Labor, if elected, will exempt electric vehicles that cost less than $77,565 from import tariffs and fringe benefits tax: Australian Labor Party (n.d.).
109. Vehicle imports are regulated under the *Road Vehicle Standards Act* (2018).

> features] as well as increased product choice and availability for vehicle buyers...[110]

The benefits of a thriving ‘parallel’ market for vehicles are evident in New Zealand, where there are no special provisions for manufacturers’ distributors. Parallel new and second-hand imports are so well-established in New Zealand that Nissan offers warranties on directly imported Nissan Leaf models.[111]

Australia’s current regulations protect manufacturers’ distributors at the expense of consumers. This protection should end.

> **Recommendation 11**
>
> The Federal Government should update the *Road Vehicle Standards Act* to permit the import of any new and second-hand vehicle that meets safety and environmental standards, including the annual average emission ceiling.

4.6 Government should provide information to encourage more Australians to make the switch to electric vehicles

When new technologies have public benefits, governments should take the lead on providing reliable information to the public.

Most Australian drivers have some knowledge about internal-combustion vehicles, but less about electric vehicles. Gathering information can be time-consuming and confusing.[112] The Federal Government should provide a single, accessible source of information on zero-emission vehicles, including information on charging infrastructure and installation.

In future, electric vehicles with vehicle-to-grid technology will be able store energy generated by a home’s solar panels. These vehicles will be able to supply the home with energy after the sun has gone down. Providing a trustworthy source of information on these technologies will accelerate Australia’s switch to a lower-emissions fleet.

4.6.1 Improving Australia’s vehicle labelling scheme would help consumers make informed decisions

Australians should be armed with good information when they buy vehicles. New light vehicles in Australia are required to have a fuel consumption label on their windscreen at the point of sale.[113]

Australia’s fuel consumption labels should be updated, so consumers can more accurately compare the carbon emissions from different vehicles. Carbon emissions should be estimated using the Worldwide Harmonised Light Vehicle Testing Procedure (WLTP), adjusted to reflect real-world emissions (Chapter 3). Labels should also provide indicative estimates of a vehicle’s running costs, so customers can weigh up the lifetime costs and the purchase price.

110. Productivity Commission (2014, p. 160).
111. EVENERGI (2020, p. 32).
112. Infrastructure Victoria reviewed online information about charging infrastructure and installation in Victoria, and found that most online information is provided by commercial interests. Infrastructure Victoria concluded that government information and guidance may be needed in this context. See Infrastructure Victoria (2018, p. 120).
113. Commonwealth Government of Australia (2008).

Recommendation 12

Australia's fuel consumption labels should estimate a vehicle's carbon emissions using the Worldwide Harmonised Light Vehicle Testing Procedure (WLTP), adjusted to reflect real-world emissions. Labels should provide indicative estimates of a vehicle's running costs, and labelling requirements should be extended to online as well as in-person sales.

5 Towards greener, safer, more-liveable cities

At the moment in Australia it costs more to buy an electric vehicle than a similar-sized petrol or diesel vehicle, but that is changing fast. And once it's bought, an electric vehicle costs much less to drive. To a lesser extent, this is also true of low-emissions petrol and diesel vehicles (Section 5.1).

Cheaper driving is great for drivers, but it's also likely to lead to an increase in the amount of driving people do, and that brings downsides that affect other drivers and non-drivers alike (Section 5.2).

There are many strategies governments can adopt to manage urban congestion, reduce traffic accidents, and create more public space for other road users (Section 5.3).

5.1 Electric cars are cheaper to run, and cheaper driving could lead to more driving

It's not surprising that less than 1 per cent of new cars sold in Australia in 2020 were fully electric,[114] since electric vehicles are substantially more expensive to buy than similar-sized petrol or diesel cars or plug-in hybrids. The price difference varies from about $10,00 for a hatchback and $20,000 for an SUV, to more than $100,00 for a big SUV with good towing capacity.[115]

But electric vehicles are much cheaper to run than petrol or diesel vehicles, because the electricity needed to power a kilometre of travel costs much less than the equivalent quantity of petrol or diesel (Figure 5.1 on the following page).

Maintenance costs are also lower for electric vehicles. Because an electric engine has only 20 moving parts compared to 2,000 in an internal combustion engine, there is less to break down and less to maintain.[116]

But cheaper running costs leads to more driving.[117] All sorts of small personal choices are likely to come down on the side of driving if it's cheaper – from choosing to drive rather than take public transport when rushing to work, or to take two trips for two errands rather than combining them, or to drive rather than walk if it looks like rain is coming. And all the more so in a world with COVID, where there's already a tendency to avoid public transport, as explained in Section 1.4.

5.2 There are social as well as private costs to driving

The cost of buying and running a car, whether petrol, diesel, or electric, is a private cost. People spend this money if they judge it worthwhile, according to where they need to go, what they need to do, and their own tastes and priorities.

114. Grattan analysis of Federal Chamber of Automotive Industries data and Electric Vehicle Council data.
115. For example, the Hyundai electric Ionique hatchback retails at $35,140, compared to the Hyundai i30 hatchback at $23,420; the MG ZS EV SUV retails at $40,990, compared to the petrol-powered ZS Essence at $26,490; and the Tesla X retails from $157,418, compared to the Hyundai Santa Fe, an internal-combustion SUV with comparable towing capacity, which retails at $43,990: Autotrader Media Solutions (n.d.).
116. Financial Times (2021).
117. Modelling by KPMG for Infrastructure Victoria estimated that the shift to electric vehicles would increase the total distance travelled by car by 1 per cent, while congestion would reduce speeds by 3 per cent in inner areas of Melbourne. See Infrastructure Victoria (2021b, p. 112).

Driving also affects the community as a whole. On the upside, it's good for people to be able to get about, and for workers to be able to conveniently get to a job that uses their skill and effort.

On the downside, driving petrol and diesel vehicles produces tailpipe pollutants (Chapter 2) and carbon emissions (Chapter 3). Driving any vehicle – petrol, diesel, hybrid, or electric – also creates three other substantial social costs: congestion, accidents, and dominance of public space (Table 5.1 on the next page).

The most obvious harmful effect of driving is congestion.[118] The 'avoidable cost' of congestion in Australia's eight capital cities has been estimated at $16.5 billion, including $6.1 billion in Sydney and $4.6 billion in Melbourne.[119] The total costs of congestion have been estimated at $8 billion in Sydney, the Hunter, and Illawarra, and $5.5 billion in Melbourne and Geelong.[120]

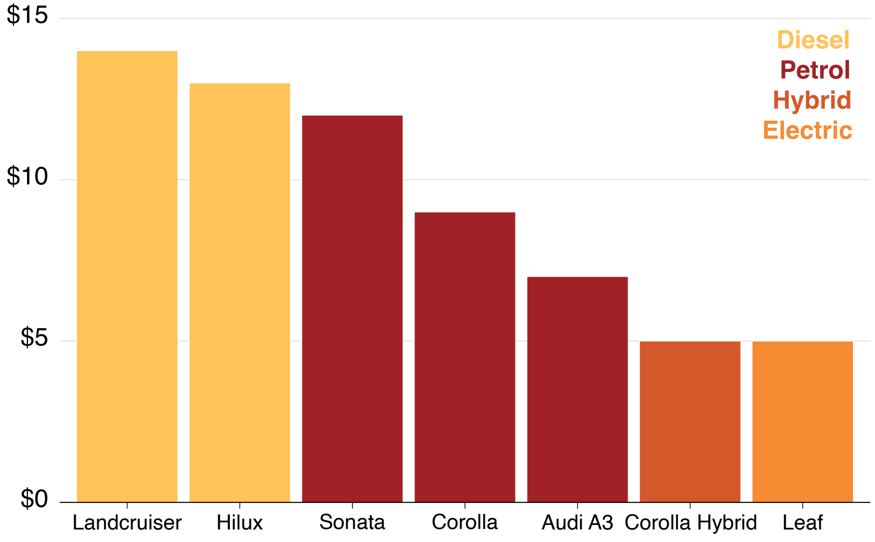
Accidents are another harmful effect of driving, regardless of how green the vehicles are.[121] The cost of road trauma to the Australian community was estimated at nearly $30 billion in 2015.[122] Drivers of SUVs and large utes are personally safer than drivers of small cars, but cause considerably more harm to others when they are involved in accidents.[123]

And cars take up a huge quantity of public space. Estimates from Melbourne suggest that half of shared street space is dedicated to roads and parking, which is consistent with estimates for many US cities.[124]

118. Parry et al (2006, p. 54).
119. BITRE (2015).
120. Infrastructure Australia (2019, p. 7).
121. Clarke and Prentice (2009, p. 52).
122. Potterton and Ockwell (2017, p. 9), using a methodology previously used by the Federal Government.
123. White (2004).
124. Eddie (2021); and Plumer (n.d.).

Figure 5.1: Zero-emissions and low-emissions vehicles are cheaper to run

Cost per 100km



Notes: The Toyota Corolla, Toyota Corolla Hybrid, Nissan Leaf, and the Audi A3 are all small passenger vehicles; the Hyundai Sonata is a medium-sized passenger vehicle. The Toyota Hilux is a light commercial vehicle, and the Toyota Landcruiser is a sports utility vehicle or SUV (FCAI classifications). Running cost estimates are based on the Green Vehicle Guide's 'combined' fuel consumption measures for each vehicle (L/100km): Green Vehicle Guide (n.d.). Petrol and diesel is assumed to cost $1.41, inclusive of GST and fuel excise. Electricity is assumed to cost $0.27 per kWh.

This privileged status is not matched by an equivalent allocation of public space for cyclists or pedestrians, or for non-transport public uses. Low-cost driving also encourages urban sprawl,[125] which in turn causes additional traffic congestion.

5.3 Planning today to reduce driving tomorrow

Now, more than ever, governments in Australia need to help reduce demand for driving. The objective should be to ensure that we don't come out of the pandemic more car-dependent than when we went in. The following sections identify policy options.

5.3.1 Introduce congestion charging

The most direct and effective way to manage demand for driving is to introduce congestion charging.

If or when state governments find that congestion at key times in key locations around capital cities is approaching pre-pandemic levels, they should introduce a cordon charging scheme. Previous Grattan Institute reports have shown that a cordon around the Sydney and Melbourne CBDs would provide clear net benefits to the community.[126]

Sydneysiders would benefit from at least 3,000 fewer cars on the road during the morning and afternoon peaks, with some people switching to public transport at those times. Fewer cars would mean better traffic flow. Across the Sydney metro area, speeds would increase by up to 1 per cent in the peaks. This is modest, but substantially greater than the speed improvements of 0.3 per cent across the day from the first stage of the F6 Extension, which will cost $2.6 billion.

125. See, for example, Brueckner (2000), Glaeser and Kahn (2003), Glaeser and Kohlhase (2003), and Infrastructure Victoria (2021d, pp. 221–232).
126. Terrill et al (2019a); and Terrill et al (2019b).

Table 5.1: Electric vehicles are preferable to petrol and diesel vehicles, but they're not perfect

Electric vehicles will lower these costs . . .	But not these . . .
Carbon emissions	The demand to build new roads or upgrade existing ones*
Particulate and pollutant emissions	Congestion
Noise pollution	Accidents
	Occupation of a large amount of public space

*Note: *Light vehicles make only a small contribution to wear and tear of sealed roads.*

In the Sydney CBD, traffic speeds would increase by an average of 11 per cent in the morning peak, which would benefit motorists and also tens of thousands of bus commuters, many of whom find getting through the CBD the most delayed and frustrating part of their commute.

Benefits would extend beyond the Sydney CBD too. The cordon would materially speed up a number of routes towards the city from the eastern suburbs, the airport, the inner west, and the north shore. And although the effects further out would be minor, a cordon could improve traffic flow as far from the CBD as Frenchs Forest in the north, Brighton-Le-Sands in the south, Burwood in the inner west, and Macquarie Park in the north west.[127]

A Melbourne cordon would be similarly effective. It would take about 5,000 cars off Melbourne's roads in the morning and afternoon peaks, increasing average speeds across the network by 1 per cent, and in the Hoddle Grid by 16 per cent. Major north-south tram corridors, such as Sydney Road and Brunswick Street, would become less congested,

127. Terrill et al (2019b, pp. 17–19).

and there would be small increases in speed on roads as far from the city as Niddrie in the north west, Mulgrave in the south east, Hampton in the south, and Altona North in the west.[128]

Cordon charges are powerful tools, proven to work in global cities from London to Stockholm to Milan, and being planned for New York, Vancouver, Beijing, Jakarta, and many more.[129] Australia's state governments should take advantage of these tools to manage excessive congestion in large cities.

5.3.2 Introduce distance-based driving charges

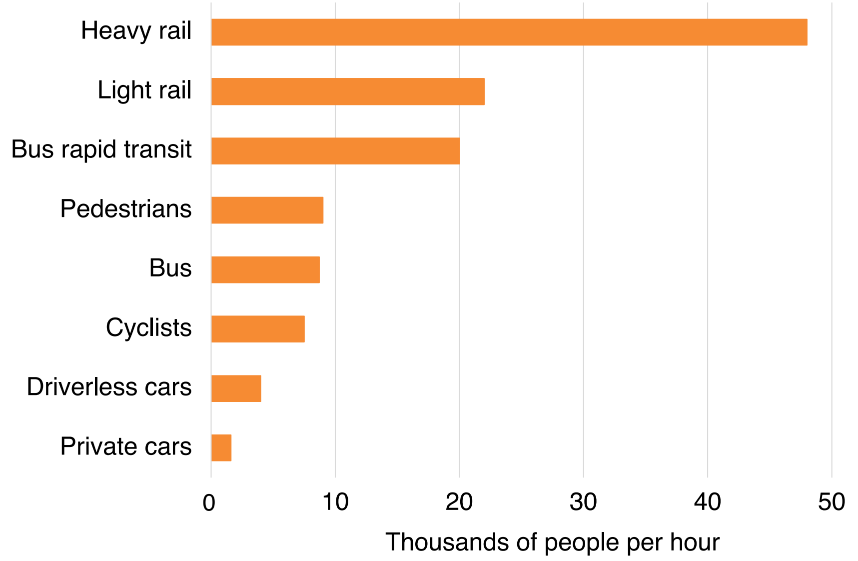
On 1 July 2021, the Victorian Government introduced distance-based electric vehicle charges. The NSW and South Australian Governments intend to do the same on 1 July 2027 or when electric vehicles make up 30 per cent of all new vehicle sales, whichever comes first.[130]

These charges are not a substitute for congestion charges; they apply equally in the middle of the night or on a wet Monday at 8.30am, on a quiet country road or in the CBD. What they provide is a gentle counterweight to the likely effects of cheap-to-run electric vehicles.

These charges should be introduced across Australia. They are a welcome – but very small – step towards making drivers of electric vehicles cover some of the costs they create by driving.[131]

128. Ibid (pp. 19–21).
129. Terrill et al (2019a, p. 13).
130. The charges are 2.5 cents per kilometre for electric vehicles and 2 cents per kilometre for plug-in hybrids. See VicRoads (n.d.[a]), NSW Government (n.d.) and Marshall (2021).
131. It is expected that typical drivers of electric vehicles will pay between $315 and $340 a year.

Figure 5.2: Cars are a very inefficient form of mass transport
Capacity of a protected 3.5 metre lane



Notes: 'Bus rapid transit' involves traffic signal priority, dedicated lanes, and upgraded boarding facilities: IV (2016, p. 126). 'Driverless cars' refers to connected and automated vehicles. Cars would be much more efficient if each vehicle were fully occupied, but this is rare – unlike on public transport.

5.3.3 Make alternatives to driving safer and more appealing

Whether they're powered by petrol, diesel, or electricity, cars take up a lot of space. Most of the time, they're parked, often on streets or in other public spaces. They're also space-hungry when they're being driven. The bigger the car, the worse these problems.

Public transport is a much more efficient way to use scarce space to move large numbers of people around (Figure 5.2).

The following sections highlight ways to increase the safety and attractiveness of public transport, and cycling and walking, often referred to as active transport.

5.3.4 Make public transport as COVID-safe as possible

If public transport is to regain public confidence once restrictions are eased and Australia begins to live with COVID, it will have to be made COVID-safe, or at least as safe as possible.[132]

Aerosol transmission is the main way people catch COVID-19.[133] Governments should ensure improved ventilation and air filtration on public transport. This may by a simple matter of requiring windows to be open whenever that does not compromise passenger safety or significantly reduce passenger comfort.[134] Or it may require upgrading from the MERV (minimum-efficiency reporting value) filters typically used on public transport to the HEPA (high-efficiency particulate air) filters that are used on aircraft.[135]

Governments should consider a variety of other strategies used in cities around the world to minimise the transmission of aerosol particles on public transport: enforcing mask-wearing, asking passengers to refrain from talking, and constraining occupancy levels, whether by using marshals at busy times in stations, by introducing a booking system for peak-period travel, or by offering substantially lower fares in off-peak periods.

Better information for prospective passengers is useful, such as the NSW app that enables people to check on crowding levels before they head to the bus stop or railway station.

132. Currie et al (2021).
133. CDC (2021a).
134. Public Transport Victoria recommends that people open windows.
135. Bushwick et al (2020).

Better still would be to reduce the number of infected people taking public transport in the first place. The simplest way to do this is with rapid antigen testing; if people could self-test every time before leaving home, they would have more information about their infection status. If they tested positive, they would know to avoid public transport and instead seek confirmation of their COVID status by getting a PCR test.[136] Governments should consider providing free rapid-antigen tests for public-transport users.

5.3.5 Make urban cycling safer and more appealing

Around the world, COVID-19 has sparked a cycling renaissance. People are taking to bicycles in droves, and they're also experimenting with electric bikes, electric scooters, electric skateboards, electric unicycles, and self-balancing electric roller-skates.

Governments are responding. New separated bike lanes have been built in Paris, London, Milan, New York, San Francisco, Toronto, Bogotá, Beijing, and many other places.[137] New walking spaces and car-free zones are being created as well. Sydney has introduced six new cycleways near the CBD, and Melbourne is adding 100km of pop-up cycling lanes.[138]

But many people are put off riding bikes and other small devices by the risk from cars. Riders feel safer when they have the protection of a physically separated bicycle lane.[139]

The risk to riders can be mitigated by reducing vehicle speeds on shared roads, and with physical infrastructure that lessens the likelihood of a cyclist being hit by a car.

136. For more detail on the use and usefulness in transport settings of rapid antigen tests, see: CDC (2021b).
137. Buehler and Pucher (2021, Table 1).
138. City of Sydney (n.d.); and VicRoads (n.d.[b]).
139. CDM and ASDF (2017, p. 4); and Infrastructure Victoria (2021a, p. 53).

Lower speed limits in shared environments

International evidence shows that a 1 per cent decrease in average vehicle speed results in about a 2 per cent decrease in the frequency of crashes that result in injuries, and a 4 per cent decrease in the frequency of fatal crashes.[140]

Australian evidence shows that reducing urban speeds by 5km/hr is likely to reduce the frequency of fatal crashes by about 26 per cent.[141]

When states changed default speed limits from 60km/hr to 50km/hr in built-up areas, there was a 41 per cent reduction in fatal and serious crashes involving pedestrians in Victoria, and a 51 per cent reduction in WA. Crashes causing serious injury fell by 3 per cent in Victoria, 4 per cent in WA, and 20 per cent in south-east Queensland and South Australia.[142] In 2018, a trial of 30km/hr speed limits in local streets in the City of Yarra in Melbourne was shown to reduce pedestrian injury risk by about 4 per cent.[143]

Around the world, city governments are setting speed limits in accordance with the World Health Organisation's 2020 Stockholm Declaration. These guidelines include establishing a 30km/hr limit where there is a mix of vulnerable road users and motor vehicle traffic, and otherwise limiting speeds on all urban roads to 50km/hr.[144]

The most recent city to adopt a 30km/hr limit is Paris, where it applies throughout the city except the Boulevard Périphérique and several other key routes. Mayor Anne Hidalgo says the measure is not anti-car, but a response to the fact that the overwhelming majority of serious or fatal accidents in Paris are caused by cars or heavy vehicles.[145]

The same arrangements apply in London, Lille, Berlin, Bordeaux, Strasbourg, Brussels, Amsterdam, Bilbao, Washington DC, New York, Philadelphia, Portland (Oregon), Minneapolis, and St Paul. They're also being implemented in sections of Bogotá (Columbia), Accra (Ghana) and Ho Chi Minh City.

Australian cities should consider taking a step in this direction, to make roads safer for cyclists, users of other small mobility devices, and pedestrians.

Physical separation of different road users

The bigger the speed differences between vehicles, the higher the crash rate.[146] This applies to cars driving at different speeds, to cars and bikes sharing the same road, and even to electric bikes sharing a path with pushbikes or skateboards.[147]

The key to safety is physically separating large and fast vehicles from small and slow vehicles. For instance, cyclists are safer – and feel more confident – when they can use a physically protected bicycle lane next to a road, rather than having to share the road with cars and trucks.[148]

Such measures can also improve traffic flow.[149]

140. International Transport Forum (2018).
141. Hall et al (2021, p. 2).
142. Ibid (p. 23).
143. Lawrence et al (2020).
144. World Health Organisation (2020, Resolution 11). The Stockholm Declaration also says reducing speed has a beneficial impact on air quality and climate change as well as reducing road traffic deaths and injuries.
145. Radio France International (2021).
146. International Transport Forum (2018, p. 24).
147. National Transport Commission (2020b).
148. CDM and ASDF (2017, p. 4).
149. Hall et al (2021, p. 2).

5.4 Cleaner transport and better cities

Our cars are extremely useful. They get us to work, shuttle friends and family to weekend activities, and take us on our occasional longer journeys. There are many private and public benefits to driving.

But Australians overwhelmingly drive high-polluting, high-emitting vehicles. This is bad for our collective health and our shared environment. In some areas, particularly our cities, vehicles also take up valuable public space and cause costly congestion. They cause accidents, and crowd out bicycles and other forms of light-weight transport.

This report has identified policies that can reduce the social and environmental costs of driving. With better petrol and diesel, we could drive cars that make use of modern pollution-reducing technology (Chapter 2). A carbon emissions ceiling would encourage the switch to lower-emission and zero-emission vehicles, and help Australia achieve net zero by 2050 (Chapter 3). Despite drivers' concerns, Australia is ready for the transition to electric vehicles (Chapter 4). Congestion charging and lower speed limits in city streets would improve traffic flow for drivers, and improve safety for people using bikes and scooters (Chapter 5).

These policies are widely used and successful overseas, yet many have been rejected by our governments, to the detriment of all Australians, whether they drive or not. The policies recommended in this report would ensure Australia embraces technology so that we can continue to enjoy the private and public benefits of driving, as well as enjoying cleaner transport and better cities.

Bibliography

ABS (2016). *Census of population and housing*. Australian Bureau of Statistics. https://www.abs.gov.au/statistics#census.

——— (2017). *Sales of New Motor Vehicles*. Australian Bureau of Statistics. https://www.abs.gov.au/statistics/industry/tourism-and-transport/sales-new-motor-vehicles/latest-release.

——— (2018). *Motor Vehicle Use Survey 2018*. Australian Bureau of Statistics. https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/12-months-ended-30-june-2018.

——— (2021). *Motor Vehicle Census, Australia*. Australian Bureau of Statistics. https://www.abs.gov.au/statistics/industry/tourism-and-transport/motor-vehicle-census-australia/latest-release.

ACCC (2020). *Report on the Australian petroleum market June quarter 2020*. https://www.accc.gov.au/system/files/20-27RPT_Petrol%5C%2520Quarterly%5C%2520Report%5C%2520-%5C%2520June%5C%25202020_FA.pdf.

ACT Government (2018). *The ACT's transition to electric cars: Action Plan 2018-2021*. https://www.environment.act.gov.au/__data/assets/pdf_file/0012/1188498/2018-21-ACTs-transition-to-zero-emissions-vehicles-Action-Plan-ACCESS.pdf.

AEMC (2020). *Residential electricity price trends: 2020*. https://www.aemc.gov.au/sites/default/files/2020-12/2020%5C%20Residential%5C%20Electricity%5C%20Price%5C%20Trends%5C%20report%5C%20-%5C%2015122020.pdf.

AEMO (2020). *2020 Integrated system plan*. Australian Energy Market Operator. https://www.aemo.com.au/-/media/files/major-publications/isp/2020/final-2020-integrated-system-plan.pdf.

Apple (2021). *Mobility Trends Report*. https://covid19.apple.com/mobility.

ARENA (2018). *Australian Electric Vehicle Market Study*. https://arena.gov.au/assets/2018/06/australian-ev-market-study-report.pdf.

——— (2019). *Ultra fast highway charging network for electric vehicles*. Australian Renewable Energy Agency. https://arena.gov.au/assets/2019/08/ARENA-Media-Release_Evie-ultra-fast-charging-network-260819.pdf.

Australian Building Code Board (2019). *Energy efficiency: NCC 2022 and beyond, outcomes report*. https://www.abcb.gov.au/sites/default/files/resources/2020//Outcomes_report_Energy_efficiency_NCC_2022_and_beyond.pdf.

Australian Government (2021). *Historical Excise Rates*. https://data.gov.au/data/dataset/excise-data/resource/b9227cdf-4c04-492d-bd84-65031adc408e.

Australian Government Clean Energy Regulator (2021). *Auction April 2021*. http://www.cleanenergyregulator.gov.au/ERF/auctions-results/april-2021.

Australian Government Climate Change Authority (2014). *Light Vehicle Emission Standards for Australia*. https://www.climatechangeauthority.gov.au/sites/default/files/2020-06/Light%20Vehicle%20Report/Lightvehiclesreport.pdf.

Australian Labor Party (n.d.). *Labor's electric car discount*. https://www.alp.org.au/policies/electric_car_discount.

Austroads (n.d.). *About Austroads*. Accessed on 19 October 2021. https://austroads.com.au/about-austroads.

Autotrader Media Solutions (n.d.). *2021 Carsguide: reviews, news and advice*. Accessed 13/10/21. https://www.carsguide.com.au.

BITRE (2015). *Traffic and congestion cost trends for Australian capital cities*. Bureau of Infrastructure, Transport and Regional Economics. https://www.bitre.gov.au/publications/2015/files/is_074.pdf.

——— (2019). *Electric Vehicle Uptake: Modelling a Global Phenomenon*. Bureau of Infrastructure, Transport and Regional Economics. https://www.bitre.gov.au/sites/default/files/bitre-report-151.pdf.

——— (2020). *Yearbook 2020:Australian Infrastructure Statistics*. Bureau of Infrastructure andTransport Research Economics. https://www.bitre.gov.au/sites/default/files/documents/bitre_aus_infrastructure_yearbook_2020.pdf.

Bonnici, D. (2020). *EV charging levels and plugs explained*. Accessed on 19 October 2021. https://www.whichcar.com.au/car-advice/ev-charging-levels.

Breunig, R. and Gisz, C. (2008). "An exploration of Australian petrol demand: unobservable habits, irreversibility and some updated estimates". Treasury Working Paper. https://treasury.gov.au/sites/default/files/2019-03/Australian_Petrol_Demand.pdf.

Brueckner, J. (2000). "Urban sprawl: diagnosis and remedies". *International Regional Science Review* 23, pp. 160–171.

Budget Direct (n.d.). *Most Popular Cars in Australia*. https://www.budgetdirect.com.au/car-insurance/guides/car-buying/best-cars/most-popular-cars-in-australia.html.

Buehler, R. and Pucher, J. (2021). "COVID-19 Impacts on Cycling, 2019–2020". *Transport Reviews* 41:4, pp. 393–400. https://www.tandfonline.com/doi/full/10.1080/01441647.2021.1914900?needAccess=true.

Bushwick et al (2020). Bushwick, S., Lewis, T. and Montañez, A. "Evaluating COVID Risk on Planes, Trains and Automobiles: stay safer on different forms of transportation". https://www.scientificamerican.com/article/evaluating-covid-risk-on-planes-trains-and-automobiles2/.

Business Council of Australia (2017). *Submission: Model Fuel Efficiency Stanard*. https://d3n8a8pro7vhmx.cloudfront.net/bca/pages/4196/attachments/original/1530766302/Model_Fuel_Efficiency_Standard_%28Business_Council_of_Australia_submission%29.pdf?1530766302.

CDC (2021a). *Scientific Brief: SARS-CoV-2 Transmission*. US Centres for Disease Control. https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/sars-cov-2-transmission.html?CDC_AA_refVal%20=https%5C%3A%5C%2F%5C%2Fwww.cdc.gov%5C%2Fcoronavirus%5C%2F2019-ncov%5C%2Fscience%5C%2Fscience-briefs%5C%2Fscientific-brief-sars-cov-2.html.

——— (2021b). *Overview of Testing for SARS-CoV-2*. US Centres for Disease Control. https://www.cdc.gov/coronavirus/2019-ncov/hcp/testing-overview.html.

CDM and ASDF (2017). *Cycling confidence study summary report*. Research conducted for the City of Melbourne. CDM Research and ASDF Research.

City of Sydney (n.d.). *Creating pop-up cycleways in Sydney*. Accessed on 19 October 2021. https://www.cityofsydney.nsw.gov.au/building-new-infrastructure/creating-pop-up-cycleways-in-sydney.

Clarke, H. and Prentice, D. (2009). "A conceptual framework for the reform of taxes related to roads and transport". https://cdn.governmentnews.com.au/wp-content/uploads/2009/08/31103731/Clarke_and_Prentice.pdf.

Climate Change Authority (2014). *Light vehicle emission standards for Australia*. https://www.climatechangeauthority.gov.au/sites/default/files/2020-06/Light%20Vehicle%20Report/Lightvehiclesreport.pdf.

ClimateWorks (2017). *Ministerial Forum on Vehicle Emissions: Fuel Efficiency Standard for Light Vehicles Proposed Model*. https://www.climateworksaustralia.org/wp-content/uploads/2017/08/ministerial_forum_on_vehicle_emissions_-_fuel_efficiency_standard_proposed_model_climateworks_australia_and_future_climate_australia.pdf.

Commonwealth Government of Australia (2008). *Vehicle Standard (Australian Design Rule 81/02 — Fuel Consumption Labelling for Light Vehicles) 2008*. https://www.legislation.gov.au/Details/F2011C00804.

——— (2011). *Vehicle Standard (Australian Design Rule 79/04 - Emission Control for Light Vehicles) 2011*. https://www.legislation.gov.au/Details/F2012C00284.

Cozzi, L. and Petropoulos, A. (2019). *Growing preference for SUVs challenges emissions reductions in passenger car market*. https://www.iea.org/commentaries/growing-preference-for-suvs-challenges-emissions-reductions-in-passenger-car-market.

Currie et al (2021). Currie, G., Jain, T. and Aston, L. "Evidence of a post-COVID change in travel behaviour – Self-reported expectations of commuting in Melbourne". *Transportation Research Part A* 153, pp. 218–234. https://reader.elsevier.com/reader/sd/pii/S0965856421002391?token=C44AF5DD2668F39B2D85140B102AFA06781D6597B27999D425838E6E5924F521D2FE0A1DA2F36AE41B5B7CB1096694DC&originRegion=us-east-1&originCreation=20211019065822.

Davis, W. (2021). "Euro 7 regulations will effectively "ban" internal combustion engines by 2030, industry lobby claims". *Drive*. https://www.drive.com.au/news/euro-7-regulations-will-effectively-ban-internal-combustion-engines-by-2030-industry-lobby-claims/.

de Brenni, M. (2021). *Speech, Carmaggedon, July 24*. https://mickdebrenni.com.au/news/news-from-mick/speech-carmageddon/.

Department of the Environment and Energy (2018). *Better Fuel for Cleaner Air – Draft Regulation Impact Statement*. Department of the Environment and Energy. https://www.industry.gov.au/sites/default/files/2020-07/better-fuel-cleaner-air-ris.pdf.

Department of Water and Environmental Regulation (2020). *State Electric Vehicle Strategy for Western Australia*. Department of Water and Environmental Regulation. https://www.wa.gov.au/sites/default/files/2020-11/State_Electric_Vehicle_Strategy_for_Western_Australia_0.pdf.

DIRD (2016a). *Improving the efficiency of light vehicles - Draft Regulation Impact Statement*. Department of Infrastructure and Regional Development. https://web.archive.org/web/20210218195831/https://www.infrastructure.gov.au/vehicles/environment/forum/files/Vehicle_Fuel_Efficiency_RIS.pdf.

——— (2016b). *Vehicle Emissions Standards for Cleaner Air – Draft Regulation Impact Statement*. Department of Infrastructure and Regional Development. https://web.archive.org/web/20200327082341/https://www.infrastructure.gov.au/vehicles/environment/forum/files/Vehicle_Noxious_Emissions_RIS.pdf.

DISER (2020). *Australia's emissions projections 2020*. Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/sites/default/files/2020-12/australias-emissions-projections-2020.pdf.

DITRDC (2020). *Light Vehicle Emission Standards for Cleaner Air – Draft Regulation Impact Statement*. Department of Infrastructure, Transport, Regional Development and Communications. https://www.infrastructure.gov.au/sites/default/files/migrated/vehicles/environment/forum/files/light-vehicle-emission-standards-for-cleaner-air.pdf.

DRIVE (2021). *VFACTS June 2021: New-car sales results show utes fill top three spots for second time in history*. https://www.drive.com.au/news/vfacts-june-2021-new-car-sales-results-show-utes-fill-top-three-spots-for-second-time-in-history/.

Eddie, R. (2021). "Car count supports drive for more wining and dining at the kerbside". *The Age*. https://www.theage.com.au/national/victoria/car-count-supports-drive-for-more-wining-and-dining-at-the-kerbside-20211015-p590c3.html.

Electric Cars Guide (2021). *Charging electric vehicles*. https://www.electriccarsguide.com.au/buyers-guide/charging-electric-vehicles/.

Electric Vehicle Council (2018). *State of Electric Vehicles 2018*. https://electricvehiclecouncil.com.au/wp-content/uploads/2018/11/The-state-of-electric-vehicles-in-Australia-2018_compressed.pdf.

——— (2019). *State of Electric Vehicles 2019*. https://electricvehiclecouncil.com.au/wp-content/uploads/2019/09/State-of-EVs-in-Australia-2019.pdf.

——— (2020). *State of Electric Vehicles 2020*. https://electricvehiclecouncil.com.au/wp-content/uploads/2020/08/EVC-State-of-EVs-2020-report.pdf.

——— (2021). *State of Electric Vehicles 2021*. https://electricvehiclecouncil.com.au/wp-content/uploads/2021/08/EVC-State-of-EVs-2021-3.pdf.

Electrive (2021). *ABB charging station has 360 kW for trucks cars*. Accessed on 19 October 2021. https://www.electrive.com/2021/09/30/abb-charging-station-has-360-kw-for-trucks-cars/.

European Automobile Manufacturers Association (2013). *Worldwide Fuel Charter, Fifth Edition*. https://www.acea.auto/uploads/publications/Worldwide_Fuel_Charter_5ed_2013.pdf.

European Environment Agency (2021a). *CO2 performance of new passenger cars in Europe*. https://www.eea.europa.eu/data-and-maps/indicators/average-co2-emissions-from-motor-vehicles-1/assessment.

——— (2021b). *Monitoring of CO2 emissions from passenger cars – Regulation (EU) 2019/631*. https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-20.

European Union (2021). *Collecting real-world data on the CO2 emissions and fuel consumption of new cars and vans*. https://ec.europa.eu/clima/news/collecting-real-world-data-co2-emissions-and-fuel-consumption-new-cars-and-vans_en.

EVENERGI (2020). *Grey Market Report*. https://arena.gov.au/assets/2020/06/evenergi-grey-market-report.pdf.

EVSE.com.au (2021a). *Ocular Home | Universal Charging Station*. https://evse.com.au/product/ocular-home-universal-charging-station/.

EVSE.com.au (2021b). *Residential EV Charger Installation | Single Phase*. https://evse.com.au/product/residential-ev-charger-installation/.

Financial Times (2021). “How green is your electric vehicle?” https://ig.ft.com/electric-car/.

Fleet Auto News (2018). *New car sales by fuel type – Fleet buyers*. https://fleetautonews.com.au/new-car-sales-by-fuel-type-fleet-buyers/.

Fletcher, P. (2018). *Road Vehicle Standards Bill 2018: Explanatory Memorandum*. https://parlinfo.aph.gov.au/parlInfo/download/legislation/ems/r6032_ems_5e5bdda4-3c40-4806-8ff9-0a94008a807b/upload_pdf/661946.pdf.

Ford Motor Company (2021). *2022 Ford F150-Lightning*. https://www.ford.com/trucks/f150/f150-lightning/2022/.

Gardner, D. (2020). *Here are the fastest-charging electric vehicles*. Accessed on 19 October 2021. https://www.whichcar.com.au/car-advice/fastest-charging-electric-vehicles.

Gaton, B. (2018). *The EVs are coming! But is your home EV-ready?* https://renew.org.au/renew-magazine/electric-vehicles/is-your-home-ev-ready/.

GFEI (n.d.). *The Global Fuel Economy Initiative: Cutting carbon emissions*. https://www.globalfueleconomy.org/media/790761/gfei-cutting-carbon-emissions.pdf.

Glaeser, E. and Kahn, M. (2003). “Sprawl and urban growth”. Discussion Paper 2004.

Glaeser, E. and Kohlhase, J. (2003). “Cities, regions, and the decline of transport costs”. Discussion Paper 2014.

Global Fuel Economy Initiative (2019). *Prospects for fuel efficiency, electrification, and fleet decarbonsiation*. https://www.globalfueleconomy.org/media/708302/gfei-working-paper-20.pdf.

Golder Associates (2013). *Exposure Assesment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PM10, O3, NO2, SO2*. http://www.environment.gov.au/system/files/pages/dfe7ed5d-1eaf-4ff2-bfe7-dbb7ebaf21a9/files/exposure-assessment-risk-characterisation.pdf.

Google (2021). *COVID-19 Community Mobility Reports*. https://www.google.com/covid19/mobility/.

Green Vehicle Guide (n.d.). *Vehicle Emissions*. Accessed on 19 October 2021. https://www.greenvehicleguide.gov.au/pages/Information/VehicleEmissions.

Hall et al (2021). Hall, C., Beer, K., Robertson, J., Nguyen, T., Zafar, F., Tan, T., Mani, A. and Beer, T. *Guide to Road Safety Part 3: Safe Speed*. https://austroads.com.au/publications/road-safety/agrs03/media/AGRS03-21_Guide_to_Road_Safety_Part_3_Safe_Speed.pdf.

Health Effects Institute (2019). *State of Global air 2019*. https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf.

Hewitt, S. (2019). “Premium petrol a waste of money, RACV research reveals”. https://www.racv.com.au/royalauto/transport/cars/premium-petrol-guzzling-cash.html.

Hyundai Motor Company (2021). *Charging into the Future: Inside Korea’s Fastest EV Charging Station*. https://www.hyundai.com/worldwide/en/brand/ev-charging-station-gangdong.

Infrastructure Australia (2019). *Urban transport crowding and congestion: The Australian Infrastructure Audit 2019 supplementary report*. https://www.infrastructureaustralia.gov.au/sites/default/files/2019-08/Urban%5C%20Transport%5C%20Crowding%5C%20and%5C%20Congestion.pdf.

Infrastructure Victoria (2018). *Advice on Automated and Zero-emissions vehicle infrastructure*. https://www.infrastructurevictoria.com.au/wp-content/uploads/2019/04/Advice-on-automated-and-zero-emissions-vehicles-October-2018.pdf.

——— (2021a). *Transporting Melbourne’s Recovery Immediate policy actions to get Melbourne moving*. https://www.infrastructurevictoria.com.au/wp-content/uploads/2021/01/Transporting-Melbournes-Recovery-January-2021-FINAL.pdf.

——— (2021b). *Driving down emissions: accelerating Victoria’s zero emission vehicle uptake*. https://www.infrastructurevictoria.com.au/wp-content/uploads/2021/08/Driving-Down-Emissions-Accelerating-Victorias-Zero-Emission-Vehicle-Uptake.pdf.

——— (2021c). *Victoria’s infrastructure strategy 2021-2051*. https://www.infrastructurevictoria.com.au/wp-content/uploads/2021/08/1.-Victorias-infrastructure-strategy-2021-2051-Vol-1.pdf.

Infrastructure Victoria (2021d). *Major transport program strategic assessment report*. https://www.infrastructurevictoria.com.au/wp-content/uploads/2021/08/Major-Transport-Program-Strategic-Assessment-Report.pdf.

International Council on Clean Transportation (2017a). *Impacts of World-Class Vehicle Efficiency and Emissions Regulations in Select G20 Countries*. https://theicct.org/sites/default/files/publications/ICCT_G20-briefing-paper_Jan2017_vF.pdf.

——— (2017b). *Efficiency technology and Cost assessment for U.S. 2025-2030 light-duty vehicles*. https://theicct.org/sites/default/files/publications/Camry_OMEGA_WorkingPaper_20180227.pdf.

——— (2018a). *Assessing Canada's 2025 passenger vehicle greenhouse gas standards: Characteristics of the Canadian fleet*. https://theicct.org/sites/default/files/publications/Canada_CAFE%201_Fleet_20180912.pdf.

——— (2018b). *The role of standards in reducing CO2 emissions of passenger cars in the EU*. https://theicct.org/sites/default/files/publications/Role_of_EU-CO2_Standard_20180212.pdf.

——— (2018c). *How things work: OMEGA modeling case study based on the 2018 Toyota Camry*. https://theicct.org/sites/default/files/publications/Camry_OMEGA_WorkingPaper_20180227.pdf.

——— (2019a). *A Global Snapshot of the Air Pollution-related Health Impacts of Transportation Sector Emissions in 2010 and 2015*. https://theicct.org/sites/default/files/publications/Global_health_impacts_transport_emissions_2010-2015_20190226.pdf.

——— (2019b). *Update on electric vehicle costs in the United States through 2030*. https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf.

——— (2019c). *From Laboratory to Road: A 2018 update of official and "real-world" fuel consumption and CO2 values for passenger cars in Europe*. https://theicct.org/sites/default/files/publications/Lab_to_Road_2018_corrected-jul2021.pdf.

——— (2020). *On the way to "real-world" CO2 values: The European passenger car market in its first year after introducing the WLTP*. https://theicct.org/sites/default/files/publications/On-the-way-to-real-world-WLTP_May2020.pdf.

——— (2021). *A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars*. https://theicct.org/sites/default/files/publications/Global-LCA-passenger-cars-jul2021_0.pdf.

International Energy Agency (2019). *Fuel Economy in Major Car Markets: Technology and Policy Drivers 2005-2017*. https://iea.blob.core.windows.net/assets/66965fb0-87c9-4bc7-990d-a509a1646956/Fuel_Economy_in_Major_Car_Markets.pdf.

——— (2021a). *Global EV Outlook 2021*. https://iea.blob.core.windows.net/assets/ed5f4484-f556-4110-8c5c-4ede8bcba637/GlobalEVOutlook2021.pdf.

——— (2021b). *Global EV data explorer*. https://www.iea.org/articles/global-ev-data-explorer.

International Transport Forum (2018). *Speed and crash risk*. https://www.itf-oecd.org/sites/default/files/docs/speed-crash-risk.pdf.

IV (2016). *Victoria's 30-year infrastructure strategy*. Infrastructure Victoria. http://www.infrastructurevictoria.com.au/30-year-strategy.

KPMG (2018). *Vehicles advice - Financial analysis*. https://www.infrastructurevictoria.com.au/wp-content/uploads/2019/04/Vehicles_Advice_-_Financial_Analysis.pdf.

Lawler, R. (2021). "Ford snags 100,000 F-150 Lightning pre-orders in three weeks". *Engadget*. https://www.engadget.com/f-150-lightning-sales-012134743.html.

Lawrence et al (2020). Lawrence, B., Fildes, B., Thompson, L., Cook, J. and Newstead, S. "Evaluation of the 30km/h speed limit trial in the City of Yarra, Melbourne, Australia". *Traffic Injury Prevention* 21.sup1, S96–S101. https://doi.org/10.1080/15389588.2021.1895990.

Liu et al (2019). Liu, C. et al. "Ambient Particulate Air Pollution and Daily Mortality in 652 Cities". *The New England Journal of Medicine*. https://www.nejm.org/doi/full/10.1056/nejmoa1817364.

MarkLines (2021). *Australia – Automotive Sales Volumes*. https://www.marklines.com/en/statistics/flash_sales/automotive-sales-in-australia-by-month.

Marshall, S. (2021). *$3,000 subsidies to drive electric vehicle take-up*. Media release. https://www.premier.sa.gov.au/news/media-releases/news/%5C$3,000-subsidies-to-drive-electric-vehicle-take-up.

Morrison, S. (2021). *Locking in Australia's Fuel Security*. https://www.pm.gov.au/media/locking-australias-fuel-security.

National Transport Commission (2020a). *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles 2019*. https://www.ntc.gov.au/sites/default/files/assets/files/Carbon-dioxide-emissions-intensity-for-new-Australian-light-vehicles-2019.pdf.

——— (2020b). *Barriers to the safe use of personal mobility devices*. Decision Regulation Impact Statement. https://www.ntc.gov.au/sites/default/files/assets/files/NTC-Decision-RIS-PMDs.pdf.

——— (2021). *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles 2020*. https://www.ntc.gov.au/sites/default/files/assets/files/Carbon%20dioxide%20emissions%20intensity%20for%20new%20Australian%20light%20vehicles%202020.pdf.

NSW Department of Planning, Industry and Environment (2021). *NSW Electric Vehicle Strategy*. https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/nsw-electric-vehicle-strategy-210225.pdf.

NSW Government (n.d.). *A fair and sustainable road user system*. Accessed 13/10/2021. https://www.nsw.gov.au/initiative/nsw-governments-electric-vehicle-strategy/road-user-charge.

Parry et al (2006). Parry, I. W. H., Walls, M. and Harrington, W. "Automobile externalities and policies". Discussion Papers 26. https://media.rff.org/archive/files/sharepoint/WorkImages/Download/RFF-DP-06-26.pdf.

Plumer, B. (n.d.). "Cars take up way too much space in cities. New technology could change that." *Vox* (). Accessed 13/10/2021. https://www.vox.com/a/new-economy-future/cars-cities-technologies.

Potterton, P. and Ockwell, A. (2017). *The cost of road trauma in Australia*. Economic Connections. https://www.aaa.asn.au/wp-content/uploads/2018/03/AAA-ECON_Cost-of-road-trauma-summary-report_Sep-2017.pdf.

Productivity Commission (2014). *Australia's Automotive Manufacturing Industry. Inquiry Report Number 70*. https://www.pc.gov.au/inquiries/completed/automotive/report/automotive.pdf.

Purtill, J. (2021). "Australians want to buy electric cars, but car makers say government policy blocks supply". https://www.abc.net.au/news/science/2021-04-20/australians-want-to-buy-electric-cars-what-is-stopping-us/100071550.

Radio France International (2021). "Paris caps speed limit to 30km/h in further boost to 'soft' transport". https://www.rfi.fr/en/france/20210830-paris-caps-speed-limit-to-30km-h-in-further-boost-to-soft-transport-road-safety-hidalgo.

Road Vehicle Standards Act (2018). https://www.legislation.gov.au/Details/F2021C00321.

Safoutin et al (2018). Safoutin, M., McDonald, J. and Ellies, B. "Predicting the Future Manufacturing Cost of Batteries for Plug-In Vehicles for the U.S. Environmental Protection Agency (EPA) 2017–2025 Light-Duty Greenhouse Gas Standards". *World Electr. Veh. J.* https://www.mdpi.com/2032-6653/9/3/42.

Sanderson, A.-J. and Johnston, B. (2021). *WA accelerates towards longest EV fast charging network*. https://www.mediastatements.wa.gov.au/Pages/McGowan/2021/08/WA-accelerates-towards-longest-EV-fast-charging-network.aspx.

Shepardson, D. (2021). "U.S. vehicle fleet fuel efficiency fell in 2019 to 24.9 mpg – EPA". https://www.reuters.com/article/us-usa-autos-emissions-idUSKBN29B1YQ.

Smit, R. (2019). *Real-World CO2 Emissions Performance of the Australian New Passenger Vehicle Fleet 2008-2018*. Transport Energy/Emissions Research. https://docs.wixstatic.com/ugd/d0bd25_e27faf5fcaaa4d8ba11c6aefc2d61774.pdf.

Smit et al (2019). Smit, R., Whitehead, J. and Surawski, N. "Australians could have saved over $1 billion in fuel if car emissions standards were introduced 3 years ago". https://theconversation.com/australians-could-have-saved-over-1-billion-in-fuel-if-car-emissions-standards-were-introduced-3-years-ago-117190.

Terrill et al (2019a). Terrill, M., Moran, G. and Ha, J. *Why it's time for congestion charging*. Grattan Institute. https://grattan.edu.au/report/why-its-time-for-congestion-charging.

Terrill et al (2019b). Terrill, M., Moran, G. and Ha, J. *Right time, right place, right price: a practical plan for congestion charging in Sydney and Melbourne*. Grattan Institute. https://grattan.edu.au/wp-content/uploads/2019/10/924-Right-time-right-place-right-price-low-res.pdf.

The Driven (2021). *How much will it cost to install an EV charger at home?* https://thedriven.io/2021/07/29/how-much-will-it-cost-to-install-an-ev-charger-at-home/.

The Economist (2021). *New, 800V, electric cars, will recharge in half the time*. https://www.economist.com/science-and-technology/new-800v-electric-cars-will-recharge-in-half-the-time/21803666.

Toyota Motor Corporation (2021). "Toyota announces its new BEV series, Toyota bZ, in establishment of a full line-up of electrified vehicles". https://global.toyota/en/newsroom/toyota/35083987.html.

Transport and Environment (2021). *EVs will be cheaper than petrol cars in all segments by 2027, BNEF analysis finds*. https://www.transportenvironment.org/discover/evs-will-be-cheaper-than-petrol-cars-in-all-segments-by-2027-bnef-analysis-finds/.

UBS (2017). *UBS Evidence Lab Electric Car Teardown — Disruption Ahead?* https://neo.ubs.com/shared/d1wkuDlEbYPjF/.

United States Environmental Protection Agency (2021). *The 2020 EPA Automotive Trends Report*. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010U68.pdf.

U.S. Environmental Protection Agency (n.d.). *Optimization Model for reducing Emissions of Greenhouse Gases from Automobiles (OMEGA)*. https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases.

——— (2016a). *Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation: Technical Support Document*. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3L4.pdf.

——— (2016b). *Draft Technical Assessment Report:Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025*. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100OYCH.PDF?Dockey=P100OYCH.PDF.

US Office of Energy Efficiency and Renewable Energy (2013). *The EV Project*. https://www.energy.gov/eere/vehicles/avta-ev-project.

VicRoads (n.d.[a]). *ZLEV Road User Charge*. Accessed 13/10/2021. https://www.vicroads.vic.gov.au/registration/registration-fees/zlev-road-user-charge.

——— (n.d.[b]). *Pop-up bike lanes*. Accessed on 19 October 2021. https://www.vicroads.vic.gov.au/traffic-and-road-use/cycling/pop-up-bike-lanes.

Victorian Department of Environment, Land, Water and Planning (2021). *Victoria's Zero Emissions Vehicle Roadmap*. https://www.energy.vic.gov.au/__data/assets/pdf_file/0014/521312/Zero-Emission-Vehicle-ZEV-Roadmap-FINAL.pdf.

Vorrath, S. (2021). "One-in-four new car sales in Europe are plug in electric vehicles". *The Driven*. https://thedriven.io/2021/09/24/one-in-four-new-car-sales-in-europe-are-plug-in-electric-vehicles/.

Wattblock (2018). *Electric Vehicle Recharging in Residential Strata Buildings*. Wattblock. https://www.wattblock.com/uploads/4/4/9/8/44984189/electric_vehicle_recharging_in_apartment_buildings_report_for_city_of_sydney_26-07-18_approved__by__ceo_wattblock_310718.pdf.

White, M. C. (2004). "The 'Arms Race' on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety". *Journal of Law and Economics* 47, pp. 333–355.

Wood et al (2021). Wood, T., Reeve, A. and Ha, J. *Towards net zero: Practical policies to reduce transport emissions*. https://grattan.edu.au/wp-content/uploads/2021/04/Towards-net-zero-Practical-policies-to-reduce-transport-emissions-Grattan-Report.pdf.

World Health Organisation (2020). *Third Global Ministerial Conference on Road Safety: Achieving Global Goals 2030 Stockholm*. https://www.roadsafetysweden.com/contentassets/b37f0951c837443eb9661668d5be439e/stockholm-declaration-english.pdf.

Appendix A: How we modelled an emissions ceiling

A.1 Purpose

This Appendix provides additional information to support statements made in Chapter 3 about the probable impacts of implementing an emissions ceiling, or standard, for light vehicles. It explains what we call the Grattan car model (an R package officially called *fleetEffSim*), which we developed to simulate the financial and carbon impacts of an annual average vehicle emissions ceiling in Australia.[150] These impacts are evaluated relative to a no-action, 'business as usual' scenario. The model can also be used to estimate specific social costs and benefits of an emissions ceiling.

What the model does

The Grattan car model estimates the financial impact of an annual average emissions ceiling. The model estimates:

- Increases to vehicle *production costs*: to produce vehicles that are less emissions intensive, manufacturers will add more expensive technology to vehicles.
- Reductions in vehicles' *running costs*: vehicles with improved fuel efficiency require less fuel. Electric vehicles are also cheaper to run than vehicles with internal-combustion engines, because electricity is cheaper than fuel.
  - The price of fuel includes three components: the commercial price, the Goods and Services Tax (GST), and fuel excise (tax) of 42.7 cents per litre.
  - The model can be used to estimate *consumer savings* based on the reduction in vehicle running costs – the money consumers save 'at the bowser', which includes the commercial price of petrol plus the cost of government taxes (GST and fuel excise).

The model also estimates reductions in carbon emissions as a result of the policy.

The model can be used to evaluate financial outcomes under a range of scenarios, by varying future fuel prices, electricity prices, vehicle sales trends, electric vehicle costs, and other features of the model.

The model supports sensitivity testing, which can include some dimensions of a social welfare analysis. Sensitivity testing is included in this Appendix to broaden the analysis beyond the financial and carbon impacts detailed in the body of this report. The sensitivity test places a social cost on carbon emissions, measured in dollars, and estimates the effects on consumers' utility by increasing the cost of technology upgrades (Appendix A.9 on page 70).

- In the sensitivity analysis the model estimates *net savings* from an emissions ceiling. This includes the financial impact of an emissions ceiling on both consumers and the government. Although increased fuel efficiency means that consumers spend less on GST and fuel excise, this represents an equal loss of revenue for the government. Net savings therefore 'factor out' the reductions in GST and fuel excise when estimating reductions in running costs.

150. Similar policies are also known as vehicle efficiency standards, fuel standards, emissions standards, or greenhouse gas standards.

Assumptions

- The Grattan car model assumes that manufacturers adopt the lowest-cost production path, using the lowest-cost technology to comply with an emissions ceiling. Due to manufacturer or consumer preferences for certain technologies, this is unlikely to be the production process and production-cost path that is followed in practice.
- The model assumes that these increases in production costs are passed onto consumers.
- The model assumes that credit trading is a feature of the vehicle emissions scheme, and does not estimate individual manufacturers' costs.

What the model does not do

- The Grattan car model does not comprehensively estimate the net welfare effects of an annual emissions ceiling. It does not estimate, by default:
  - Reductions in consumers' 'utility' – the personal loss to drivers if they are not able to purchase their preferred vehicle type or features due to the emissions ceiling, once purchase price and vehicle running costs are accounted for.
  - Social benefits from reduced carbon emissions.
  - The health benefits from reduced pollutants that are associated with technology adoption.
  - The health costs from any increases in pollutants at electricity sources (for example, increases in particulate emissions from coal-fired electricity generators). These arise because the switch to electric vehicles can increase demand for electricity.
- The Grattan car model does not incorporate changes to consumers' financial costs when servicing and maintaining their vehicle.
- It does not predict technology or electric vehicle uptake rates under an emissions ceiling, or predict how targets may be met among manufacturers.
- The model does not predict future driving patterns, or fuel or electricity costs. Instead, different scenarios can be tested to determine the possible costs and benefits of an emission ceiling under that specified scenario.

As noted, some dimensions of a social welfare analysis can be included as sensitivity tests, to complement financial impact estimates. Sensitivity testing can incorporate social costs of carbon emissions, the health costs of pollutants, and estimates of the effects on consumers' utility by increasing the cost of technology upgrades (Appendix A.9 on page 70). When considering the broader social effects of an emissions ceiling, we report the financial *net saving* to consumers and government.

A.1.1 Structure of the Grattan car model

The Grattan car model has two components. The vehicle *production model* generates estimates of the production costs of meeting an emissions ceiling. The vehicle *use model* generates estimated vehicle running costs and carbon reductions once a vehicle is 'on the road.'

The model is executed in a sequence that is analogous to real life.

1. *The vehicle production model*: A simulated fleet is generated, made up of simulated 'vehicles' – each with a vehicle type (sports utility vehicle/light commercial vehicle/passenger vehicle), base emissions level (gCO2/km), and other features. For default

model runs, the initial average emissions of the simulated fleet are representative of current Australian sales, at approximately 180gCO2/km.

- The production model assesses this simulated fleet and the technology that can be added to the vehicles. The production model iteratively upgrades vehicles with the lowest-cost emissions-reducing technology. This process is repeated until the average emissions of the simulated fleet complies with that year's emissions target.

2. *The vehicle use model*: The simulated fleet, now with improved technology, is passed to the vehicle use model. In essence, these vehicles have come out of the factory (the production model), and are driven on the road. The model then simulates the likely running costs and carbon emissions of each vehicle over its lifetime, based on assumed driving patterns.

The following two sections discuss the assumptions underpinning the vehicle production models and the vehicle use models in the Grattan car model.

A.2 The vehicle production model: estimating the running cost of complying with an emissions targets

Predicting how different vehicle technology options affect vehicle emissions is complex. In different scenarios the same technology is unlikely to have the same effect on emissions. For example, adding a specific technology may reduce the emissions of a certain type of vehicle by 5 per cent in one case, and 15 per cent in another vehicle type. Further, combining technologies is unlikely to linearly reduce emissions – two technology improvements that in isolation each reduce the emissions of a certain vehicle by 5 per cent may, when combined, only reduce emissions by 7 per cent. These interactions are complex to predict, and typically, sophisticated vehicle simulation models and physics simulators are required to produce accurate results.[151]

Establishing the most cost-effective series of technologies to comply with vehicle emissions targets requires the model to identify the most cost-effective option from an inordinate number of possible technology combinations. For example, if there are 50 possible technology options that could be added to a vehicle to reduce its emissions, and each upgrade interacts individually with each other upgrade,[152] the number of possible combinations is approximately 3e+64. Repeatedly choosing the most cost-effective upgrade to production ($ per CO2 reduced) from the available options would be far too complex for a simulation model to reasonably compute.

To avoid this issue, models such as the US EPA's OMEGA model and past modelling conducted by BITRE and the ICCT use 'technology cost curves' to estimate the production cost of reducing the emissions of a given vehicle by a certain amount. These production-cost curves are developed using physics and vehicle simulators to prepare 'packages' of technology that give cost-effective emissions reductions. Plotting these packages in order, from most cost effective to least cost effective, provides a curve that illustrates the likely production cost associated with a given reduction of emissions, and significantly reduces the number of calculations that must be computed.[153]

The Grattan car model uses production cost curves developed by the US EPA for the OMEGA model in order to estimate the production

151. International Council on Clean Transportation (2018c).
152. In reality, not all technology options are likely to be compatible with one another, decreasing the number of combinations, but increasing the complexity of modelling the effects.
153. For further detail of how the US EPA cost curves for the OMEGA model were calculated, see: U.S. Environmental Protection Agency (n.d.), the draft TAR documentation: U.S. Environmental Protection Agency (2016a), and appendix: U.S. Environmental Protection Agency (2016b).

costs of combustion engine vehicle technology required to meet emissions targets. These cost curves are adapted to represent the characteristics of the Australian fleet (Appendix A.2.1).

The Grattan car model also uses separate production cost curves to estimate the relative price of electric vehicles over time. These curves were developed specifically for The Grattan car model, based on battery cost research and data from vehicle tear-down studies (Appendix A.2.2 on the following page).

The following sections outline the inputs to the model.

A.2.1 Internal combustion engine cost curves

We adapted internal combustion engine (ICE) cost curves for an Australian setting from OMEGA model cost curves, and simplified them to represent three broad vehicle categories: light commercial vehicles (LCVs), sports utility vehicles (SUVs), and passenger vehicles. Production costs were estimated for all years over which the model runs.

OMEGA model data include cost curves for 19 different light vehicle classes, in two different years – 2021 and 2025. Each class is specified based on a specific engine characteristic and vehicle size among those available in the market, and is designed to ensure the performance of the 'upgraded' vehicle is at least as good as what is currently available.[154]

To simplify the 19 cost curves into three categories used for the Grattan car model, (LCVs, SUVs, and passenger vehicles) we used historical Australian vehicle sales data to estimate the proportion of vehicles sold in each of the 19 categories.[155] We then grouped the 19 categories provided by the OMEGA model based on their type (as LCV/SUV/passenger vehicles), and we calculated a sales-weighted average between the curves for each vehicle type. This produces simplified cost curves for the three vehicle types – passenger vehicles, LCVs and SUVs – while also ensuring that each category is representative of the vehicle mix of new Australian sales.

We converted the costs of the aggregated data to 2021 Australian dollars from 2015 US dollars, also adjusting for inflation. Figure A.1 on the next page demonstrates the final production cost curve for passenger vehicles in the model year 2021.

Over time, the production costs associated with specific vehicle technologies is likely to decrease as the technology matures. This is reflected in the costs curves for 2021 and 2025 model years as prepared for the OMEGA model.[156] To generate cost curves for all years required for the Grattan car model, we linearly interpolated data between 2021 and 2025. Learning curves are typically decaying exponential or similar type functions, so a linear interpolation is a conservative estimate; it probably underestimates price decreases in early years.

Given the high uncertainty beyond 2025, and the likelihood that many manufacturers may give priority to developing zero-emissions vehicle technology (such as battery electric vehicles) over combustion engine technology beyond this point, we assumed cost curves would 'freeze' at 2025 levels. This is a conservative estimate that is likely to overestimate the costs of improving vehicle efficiency.

154. The EPA class definitions are available in the appendix to the draft TAR: U.S. Environmental Protection Agency (2016b, pp. 94–95).

155. We obtained sales data from: ,National Transport Commission (2020a), and further details of vehicle characteristics such as engine configurations through vehicle manufacturer websites and vehicle spec sheets.

156. For information on the 'learning rates' used in the OMEGA modelling, see the US EPA documentation. U.S. Environmental Protection Agency (2016a).

It is also important to recognise that OMEGA model cost curves have historically proved to be conservative estimates, tending to underestimate the efficiency improvements that can be achieved for a given change in production cost. This is partly due to the fact that it cannot account for technology that manufacturers are yet to develop, but may prove very cost effective. This has been discussed in detail by the ICCT.[157]

A.2.2 Electric vehicle cost curves

We estimated electric vehicle (EV) costs in the Grattan car model by extrapolating data from vehicle tear-down studies and battery cost studies. The costs used by the Grattan car model are the ‘additional costs’ of an electric vehicle – that is, the difference between the cost of purchasing an EV compared to purchasing a comparable combustion engine vehicle. Bloomberg New Energy Finance and the ICCT both forecast price parity before 2030.[158]

Compared to industry estimates, the EV price parity forecasts developed for the Grattan car model are conservative, predicting EV price parity for passenger vehicles in 2027-2028 and for SUVs in about 2032.

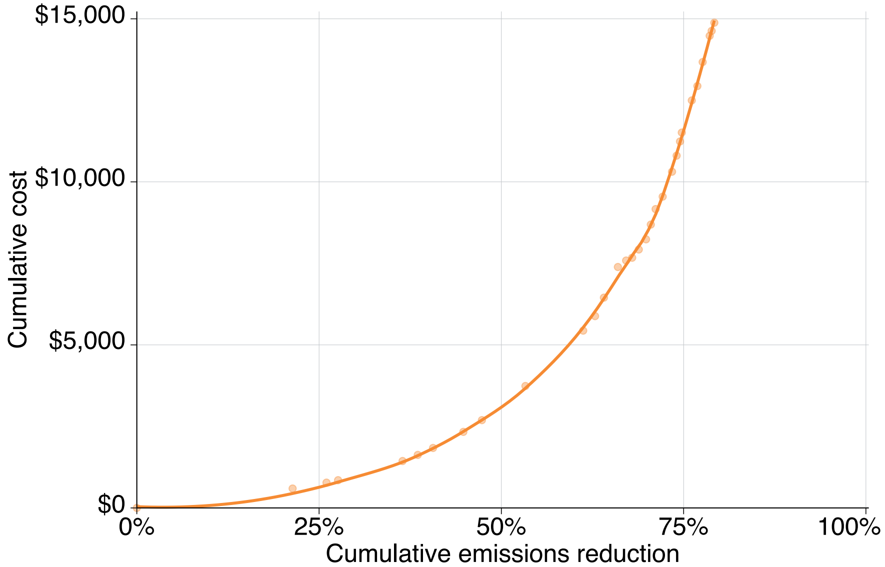
We developed EV cost curves in two main stages: by estimating the non-battery costs (direct and indirect) of comparable ICE and EV vehicles, and by estimating likely future battery costs for EVs.

The methodology we used draws heavily from electric vehicle price parity forecasts prepared by the ICCT,[159] and from data published in a vehicle tear-down study by UBS.[160]

157. International Council on Clean Transportation (2017b).
158. International Council on Clean Transportation (2019b); and Transport and Environment (2021).
159. International Council on Clean Transportation (2019b).
160. UBS (2017).

Figure A.1: Emissions cost curve for internal combustion engine passenger vehicles, 2021

Cumulative emissions reductions and cost



Notes: This is applicable for a ‘base model’ vehicle, and does not account for existing technology in the Australian fleet. Adapted from OMEGA model data: U.S. Environmental Protection Agency (n.d.).

Non-battery costs

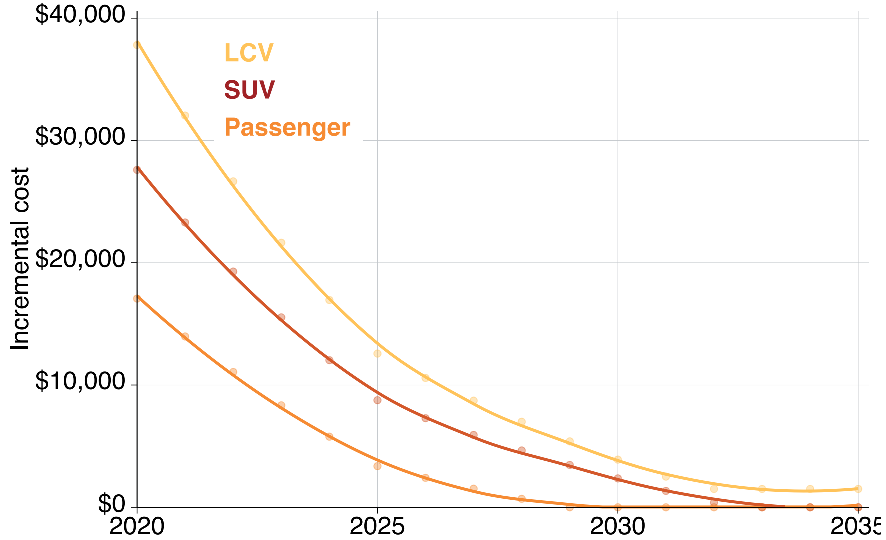
To estimate non-battery costs for both electric and ICE vehicles, we first used UBS data to estimate the production costs of a small passenger vehicle for 2017 and 2025 model years. This data is based on the tear-down studies of a Chevy Bolt and a VW Golf, and includes estimated direct and indirect costs of the vehicle components.[161] We adjusted these costs for inflation and converted them to Australian dollars (Table A.5 on page 66).

Given UBS provides costs for 2017 and 2025 model years only, we linearly interpolated power-train and other direct costs between the two model years. As discussed earlier, given that technology costs are often modelled following a decaying exponential learning rate, using a linear function produces a conservative estimate of the cost change over time.

Beyond 2025 model years, due to the significant uncertainty surrounding direct non-battery costs, we assumed power-train cost and other direct costs would freeze at 2025 model year levels. This assumption is conservative, given that improvements to costs beyond 2025 are likely to be faster for electric vehicles than for ICE vehicles, due to greater investment in development.

We treated indirect costs differently to direct production costs. For ICE vehicles, we assumed the indirect costs were held at a constant proportion, of 20.5 per cent of all other costs. For electric vehicles, we similarly assumed indirect costs as a proportion of total costs – however, we assumed this proportion would change over time as electric vehicle production increased. We assumed indirect costs would be 38 per cent of total costs (including battery costs) in 2017, linearly

Figure A.2: EV price parity forecasts used in the *fleetEffSim* model
Incremental cost of purchasing an electric vehicle, by vehicle type



Notes: LCV = light commercial vehicle. SUV = sports utility vehicle.

161. Ibid (pp. 26, 43).

falling to 14 per cent of total costs by 2025 and remaining at that level beyond 2025.[162]

The UBS vehicle component cost estimates are some of the most comprehensive available and have been widely used. But they apply only to a small passenger vehicle. Therefore, to estimate costs for the three vehicle categories (SUV/LCV/passenger) required for the Grattan car model, we scaled these costs based on ICCT methodology. We made adjustment to account for the difference in vehicle classes used in the ICCT methodology and those used in our model.[163]

The factors we used to scale costs between vehicle types are based on the US vehicle fleet – with power-train costs scaled by the ratio of the base vehicles power to the average power of each vehicle type, and direct assembly costs scaled by the ratio of the base vehicle footprint to the average vehicle footprint of the required vehicle type. For example, if the base vehicle has a power of 100kW, and an SUV had an average power of 150kW, we would have scaled the power-train costs by a factor of 1.5.[164]

Given that vehicles in the US tend to be on average larger and more powerful than vehicles in Australia, these scaling factors are likely to be conservative – overestimating the costs of electric vehicles in an Australian context. The exact figures we used differ slightly from the figures used by the ICCT, because the ICCT modelled passenger, crossover, and SUV categories, whereas we compared passenger, SUV, and LCV categories. We calculated weighted averages using past sales data to convert between the categories used.

162. These assumptions follow those used by the ICCT to model price parity of electric vehicles in the US: International Council on Clean Transportation (2019b).
163. Ibid.
164. Values are for indicative purposes only.

Table A.1: Estimated non-battery passenger vehicle direct costs for base vehicles

Vehicle type	Cost type	2017 cost
ICE	Power-train costs	$9,834
ICE	Other direct costs	$17,244
ICE	Indirect costs	$2,016
EV	Power-train costs	$5,496
EV	Other direct costs	$18,181
EV	Indirect costs	$15,272

Notes: Battery costs are excluded from this table, because they are treated separately in the data. Data is summarised into power-train, direct, and indirect costs from UBS tear-down studies. These are not the final costs used in the Grattan car model, but initial costs used to produce estimates.

Source: UBS (2017).

LCV costs were assumed to be 20 per cent greater than SUV costs. The resulting costs for the 2021 model year are included in Table A.3 on page 61.

Battery costs

The process we used to estimate battery costs follows a similar methodology to the other vehicle production costs detailed above. First, we established costs for each vehicle type, based on OMEGA data. Then, we extrapolated these costs to provide estimates of future battery costs.

OMEGA model data provide estimates of battery pack costs for five of the six vehicle classes used by the US EPA:[165]

1. small car

165. Safoutin et al (2018, p. 8).

2. standard car
3. large car
4. small MPV (multi-purpose vehicle)
5. large MPV
6. truck (no battery costs are provided)

For our model, we simplified battery costs for these categories into passenger/SUV categories, calculated as a sales-weighted average of the relevant vehicle classes.[166] We used only costs provided for 200 mile (about 320km) range battery electric vehicles, and we adjusted all costs for inflation and converted them to Australian dollars.

Once sales-weighted averages were taken, the EPA data indicates that the BEV-200 cost estimates correspond approximately to vehicles with a 45kW/h battery capacity (passenger vehicle) and 60kW/h battery capacity (SUV).[167]

However, in practice, electric vehicles, particularly SUVs, are consistently sold with battery capacities well above these figures.[168] Currently available small SUVs have battery capacities that are routinely above the estimated 60kWh. For example, the small SUV Hyundai Kona has a capacity of 64 kWh, and larger, more expensive SUVs such as the Tesla model X, Jaguar I-PACE, and Mercedes EQC have batteries in the 80-to-100kWh range.

166. We did not calculate LCV data in this step, because no class 6 data is provided for BEV-200 battery costs in the OMEGA model data. We used NTC 2019 data to calculate the proportion of vehicles in each of the 6 categories, and thus the weights.
167. UBS (2017, p. 8).
168. A long range is also likely to be particularly important in the SUV and LCV vehicle markets, because some drivers are anxious about the range of those vehicles.

We scaled EPA battery costs upwards, to account for the likely longer range and larger battery capacities of available vehicles. The approximate final battery capacity is detailed in the table below.

Table A.2: Battery scaling factors, capacities, and costs

Vehicle type	Scaling factor	Final battery capacity	Final battery cost (2021)
passenger	No scaling	45kWh	$15,991
SUV	1.37	85kWh	$24,634
LCV	1.86	110kWh	$33,419

We determined the cost of the assumed LCV battery capacity by scaling the SUV battery cost figure to a size of approximately 110kWh. This very large battery size is intended to take account of consumer preferences in the vehicle sector, such as short-range towing.

Once we established base year battery costs for all vehicle categories, we forecast that battery costs would decline at a rate of 7 per cent per year. We based this estimate on an ICCT review of industry announcements and academic papers on future battery costs.[169]

We then integrated battery costs with the non-battery costs (Appendix A.2.2), to provide total production cost estimates for ICE vehicles and EVs. We calculated the difference between these production costs (the additional cost of an EV). This is the data used in the Grattan car model (as depicted in Figure A.2 on page 58).

We built into the model a final assumption, so that the incremental production cost does not fall below $1,500 for the LCV category of EVs. We made this adjustment to account for hard-to-reach sectors. It is likely that within the LCV category, some consumers may not be

169. International Council on Clean Transportation (2019b).

able to purchase an equivalent electric or zero-emissions vehicle with necessary features or specifications, such as extended-range towing.

A.2.3 Estimating current levels of technology in the Australian fleet

The cost curves discussed in Appendix A.2 provide an estimate of the technology costs required to reduce the emissions intensity of vehicles, by segment. However, it is important to note that these production costs apply to a base-level vehicle – that is, a vehicle that is assumed to have only limited technology to reduce emissions. This is approximately equivalent in spec to a base 2008 model, petrol engine vehicle with an inline 4-cylinder engine.[170] However, vehicles have developed considerably since 2008, and most current vehicles available on the Australian market already have some level of technology.

Determining this level of existing technology is important when specifying which parts of a cost curve are 'available' for a given vehicle. If it was assumed that the entire curve was available, double counting of some technology already incorporated into the vehicle would underestimate the costs of reducing CO2 emissions.

The Grattan car model treats existing technology as the position a vehicle starts at on the cost curve. This specifies which parts of the curve are available to further reduce emissions. It also implicitly assumes that the existing technology corresponds to the lowest-cost upgrades available on the technology cost curve.

This assumption will not necessarily hold true. While some existing technology in vehicles may be at the cheaper end of the cost curve, other technologies which, for example, reflect consumer preferences for specific engine or transmission technology, or fuel type and drive trains, may be relatively expensive 'upgrades' for the emissions they reduce.

170. International Council on Clean Transportation (2017b, pp. 4–6).

Table A.3: Final components costs for electric vehicles and internal combustion engine vehicles (2021 cost)

Vehicle type	Cost type	Cost type	2021 cost
EV	passenger	Power-train	$4,933
EV	SUV	Power-train	$5,871
EV	LCV	Power-train	$7,632
EV	passenger	Battery cost	$15,995
EV	SUV	Battery cost	$24,634
EV	LCV	Battery cost	$33,419
EV	passenger	Other direct costs	$18,737
EV	SUV	Other direct costs	$19,886
EV	LCV	Other direct costs	$25,852
EV	passenger	Indirect costs	$10,313
EV	SUV	Indirect costs	$13,102
EV	LCV	Indirect costs	$17,395
ICE	passenger	Power-train	$11,604
ICE	SUV	Power-train	$13,965
ICE	LCV	Power-train	$18,154
ICE	passenger	Indirect costs	$6,126
ICE	SUV	Indirect costs	$6,839
ICE	LCV	Indirect costs	$8,891
ICE	passenger	Other direct costs	$18,278
ICE	SUV	Other direct costs	$19,399
ICE	LCV	Other direct costs	$25,219

Notes: Initial (non-scaled) power-train and direct costs are adapted from UBS data. Initial (non-scaled) battery costs are adapted from EPA OMEGA model costs: U.S. Environmental Protection Agency (n.d.). Indirect costs are estimated using ICCT methodology, as a proportion of total vehicle costs.

Assuming all existing technology is taken from the lowest points of the cost curves is a very conservative assumption that is likely to lead to an overestimation of the costs of technology remaining and available to be applied to vehicles to reduce emissions.

We first estimated the level of existing technology for petrol vehicles, by tracking the changes in emissions of vehicles sold between 2008 and 2021. Given that the base model vehicle assumed in the technology cost curves is approximately equivalent to a vehicle of these specifications, tracking the changes in emissions from 2008 onward in each vehicle category provides an estimate of the percentage CO2 reduction already achieved by adding new technologies to the base engine. Thus, this provides the starting point on the cost curve for that vehicle.

Given that the base engine is assumed to be a petrol engine, an adjustment must then made for the proportion of diesel vehicles in 2008, by vehicle type. A base diesel engine is more efficient than a base petrol engine, and thus reflects an upgrade, or step on the cost curve. We assumed that the upgrade from a base petrol to base diesel engine is equivalent to a 16 per cent reduction in emissions, based on ABMARC (2016) data.[171]

We determined the total adjusted figure as:

$$\text{Existing technology (\%)} = \text{Proportion diesel} \times \frac{16}{100} + \text{\% change since 2008}$$

171. DIRD (2016a, p. 22). The proportion of diesel sales was calculated from: Fleet Auto News (2018), and the improvements since 2008 obtained from data provided by the National Transport Commission.

Table A.4: Existing technology estimates

Vehicle type	Change since 2008	Proportion diesel	Final existing technology estimate
Passenger	21%	6%	22%
SUV	21%	30.4%	26%
LCV	13%	60%	18%

Notes: Data on passenger and SUV vehicle efficiency improvement from 2008 are available only as an aggregated category. We have assumed that this improvement is equal between categories.

However, due to the uncertainty in these variables, these values are set as a default that can be modified by the user, and were extensively sensitivity tested.

A.3 The vehicle use model: estimating vehicle running costs and carbon emissions

The previous section outlined the main assumptions embedded in the vehicle production-cost component of the Grattan car model. The following section details the main assumptions embedded in the vehicle-use model, and the process we used to estimate running costs and carbon emissions. The primary assumptions include:

1. Vehicle age and distance travelled per year
2. Future fuel prices and vehicle fuel consumption
3. The proportions of vehicles that run on different fuels, including diesel and premium fuels
4. Future electricity prices
5. Future electric vehicle energy consumption rates

6. The future energy intensity of the electricity grid, and upstream emissions
7. The real-world and test-cycle emissions 'gap'

A.3.1 Distance travelled and vehicle life

We model vehicle age as a static parameter, and we assume a vehicle was on the road for 17 years. This is simpler than some other approaches using survival curves or vehicle attrition rates, and is used partly because it is simple and partly because of the uncertainty surrounding the attrition rates and lifetime of electric vehicles.

We used ABS Motor Vehicle Use survey data to estimate the distance travelled by each vehicle in a given year, depending on the vehicle's age and type.

The Motor Vehicle Use survey suggests that older vehicles tend to be driven a far shorter distance than newer vehicles, and that light commercial vehicles tend to be driven further than passenger vehicles in a given year.

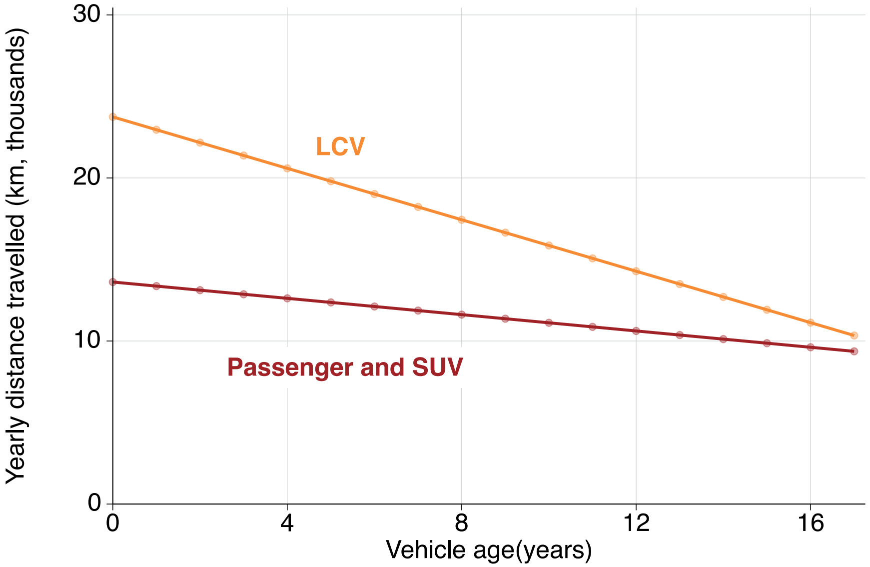
To account for these factors in the model, we used the ABS data to plot a linear relationship between distance travelled and vehicle age for the two specified vehicle types (passenger vehicles and light commercial vehicles). We assume the vehicle reaches the end of its life after 17 years.

Given that the data is not dis-aggregated between passenger and SUV vehicle types, we assume the 'passenger' curve applies to both types of vehicles.

Rebound effects

A rebound effect occurs when reduced running costs lead to longer trips, because driving becomes a cheaper and more attractive option.

Figure A.3: We assume vehicles travel less as they get older
Distance travelled by vehicle type and age



Source: ABS (2018).

The Grattan car model uses an elasticity of 0.1 to model the rebound effect introduced by cheaper driving. This means that for every 10 per cent reduction in running cost, the vehicle is assumed to travel 1 per cent further in a given year. This is consistent with the approach used by the EPA in the OMEGA model.[172]

A.3.2 Future fuel prices

The Grattan car model assumes (under the 'central' estimate scenario) that fuel prices remain constant. This is in line with long-term historical real fuel costs, which fluctuate around a relatively steady price, as outlined by the ACCC.[173]

The Grattan car model can be run two ways:

- To estimate the private financial impact of an emissions ceiling on consumers. This includes taxes that are applied to fuel (GST and fuel excise).[174] These are the financial impacts reported in Chapter 3 as the cost to consumers of an emissions ceiling.
- To estimate the private and public financial impact of an emissions ceiling, as part of a broader social welfare analysis. This use of the model considers financial impacts on consumers and on the government, so fuel taxes are 'netted out'. This is because the GST and fuel excise are a transfer of money: when consumers buy less fuel, and pay less tax, this is a private saving – but it also results in a reduction in public revenue. The transfer creates an equal saving and loss. These are the financial impacts reported in Table A.8 as part of a sensitivity test that explores the broader social costs and benefits of an emissions ceiling.

172. Global Fuel Economy Initiative (2019, p. 18).
173. ACCC (2020).
174. Australian Government (2021).

We assume the price for octane-91 fuel under the central scenario remains steady at $1.48/L. We estimated the price difference between octane-91, octane-95, and octane-98 from RACV data.[175] Under the central scenario, we assumed the price of diesel is remain steady at $1.54/L, octane-95 at $1.57/L, and octane-98 at $1.62L.

We deal with the significant uncertainty about future fuel prices through sensitivity testing, under a 'low-price' and 'high-price' fuel price estimate. The low price estimate assumes the same initial 2021 costs as the central estimate, however prices fall by 1 per cent per year between 2021 and 2050. For octane-91, this results in a 2050 price of $1.21/L. The high-price estimate assumes fuel prices rise by 1 per cent per year. For octane-91, this results in a 2050 price of $1.85/L.

Vehicle fuel consumption and upstream emissions

We determined vehicle fuel consumption (L/100km) based on the relationship between vehicle emissions and fuel consumption. We assumed a linear relationship for petrol and diesel vehicles, based on NTC data provided by the National Transport Commission:[176]

We used this data to convert between assumed vehicle emissions and fuel consumption.

Upstream fuel emissions (scope 2 emissions) are also included in the Grattan car model, to ensure consistency and a fair comparison between emissions produced by ICE vehicles and through electricity generation for EV vehicles. These 'upstream' emissions generally refer to emissions created through, for example, the transport of petrol from a refinery to a petrol station, and are significant. The Grattan car model assumes an upstream emissions factor of 1.2 for all petrol and diesel fuels.[177]

175. Hewitt (2019).
176. National Transport Commission (2020a).
177. Global Fuel Economy Initiative (2019, p. 18).

A.3.3 Vehicle fuel types

A proportion of new vehicles sold each year in Australia are designed to run on fuels other than octane-91 petrol. These alternative fuels, such as diesel or premium blends, have different costs and may translate to different performance.

The RACV estimates that about 20 per cent of new vehicles sold run on premium fuel.[178] The Grattan car model assumes that 15 per cent of non-electric vehicles run on octane-95 fuel, and 5 per cent run on octane-98 or other premium blend fuel. We hold these proportions constant across business-as-usual (BAU) and target trajectories in all years, because there is high uncertainty surrounding how emissions standards may effect these figures.

A.3.4 Future electricity prices

Similarly to fuel price forecasts, there is significant uncertainty in future electricity prices.

To account for this, our central scenario assumes a conservative future electricity price of $0.25kW to remain steady over the 2021-2050 period. Although this forecast is in line with current average electricity prices,[179] it is likely to exceed actual prices used for vehicle charging. This is because it is likely that vehicle charging will predominantly occur at off-peak times, such as overnight, where prices tend to be lower. A conservative estimate of future electricity prices underestimates the benefits of an emissions standard policy.

The Grattan car model includes options for sensitivity testing. Alternative scenarios included are a high-price scenario, where electricity prices are assumed to increase by 2 per cent per year to 2031 before remaining steady; a low-price scenario, where prices are assumed to drop by 1 per cent per year to 2030 before remaining steady; and an off-peak charging scenario, where prices are assumed to remain steady at $0.20kW over the entire forecast period (to estimate the effects of a larger proportion of vehicles being charged at off-peak times).

178. Hewitt (2019) (as of 2019).
179. AEMC (2020).

A.3.5 Electric vehicles' future electricity consumption

To determine how much electricity is used by an electric vehicle, and thus the running costs for that vehicle, our model includes an estimate of EV energy consumption. This is assumed to vary by vehicle type, over time, with the rates of change assumed to broadly follow ICCT estimates.[180]

The ICCT provides estimates of electric vehicle energy consumption in the years 2018 and 2030. The ICCT data do not perfectly fit into the categories used by the Grattan car model. So, we use a sales-weighted average of the ICCT categories corresponding to crossover and SUV vehicles, to determine the energy consumption for SUV vehicles in our model. The weights used are 20 for crossover vehicles and 15 for SUVs.

The ICCT data assumed a decrease in energy consumption for electric vehicles of 0.0013kWh/year and 0.0017kWh/year for passenger and SUV vehicles respectively. The Grattan car model uses slightly more conservative data – we assume that energy consumption will decline at a rate of 0.001kWh/year and 0.0015kWh/year for passenger vehicles and SUVs respectively.

The final values for some years are included in the table below. We use a linear relationship to plot between each of the intervals. When compared to the energy consumption of currently available

180. International Council on Clean Transportation (2019b).

electric vehicles, these assumptions are likely to be conservative, overestimating energy consumption (and thus costs and emissions).

Table A.5: Estimates of electric vehicle energy consumption

Vehicle type	kW/km (2021)	kW/km (2030)
Passenger	0.183	0.174
SUV	0.255	0.242
LCV	0.255	0.242

Note: The ICCT does not provide energy consumption data for LCV vehicles, so we assume that these are the same as for SUV vehicles.

A.3.6 Future emissions intensity of the electricity grid

Although the bulk of emissions from vehicles are likely to come from ICE vehicles, it is important to factor into the model the emissions created through electricity generation to power EV vehicles. To do this, we use the Australian Energy Market Operator (AEMO) 'step change' scenario to estimate the emissions intensity of the electricity grid between 2021 and 2040. This scenario applies only to the National Electricity Market (NEM). But given that the NEM covers the vast majority of vehicle users, we use this scenario to estimate the trajectory for all Australians.

The AEMO figures include projections to 2040. Beyond this point, we assume that the electricity continues to decarbonise on a linear trajectory, from the emissions intensity level in the final year of AEMO data, to 0gCO2/kWh in 2050.

A.3.7 The real-world and test-cycle emissions 'gap'

Internationally, emissions test cycles have routinely been used to enforce vehicle emissions standards, or ceilings. However, as manufacturers have aimed to meet their targets, they have tended to optimise their vehicle performance for the test cycle. The result is that a 'gap' has emerged between test-cycle CO2 figures and real-world driving conditions.

The Grattan car model assumes a 20 per cent gap for ICE vehicles in all years. Given the significant uncertainty that exists, this is used for sensitivity testing.

A.4 Model runs

Section A.1 outlined the key assumptions incorporated into the Grattan car model. This section presents the results of model runs we conducted, as well as detailing forecast vehicle sales used in model runs, and the 'no action' emissions trajectory scenario that serves as the baseline comparison for results under an emissions ceiling.

A.5 Assumed vehicle sales

Over time, annual vehicle sales have increased in Australia, and the type of cars that Australians drive has changed. A far larger proportion of SUVs are sold today than in 2010 – and far fewer passenger vehicles are sold.

The simulated fleet used in all our model runs assumes that to an extent, these trends continue.

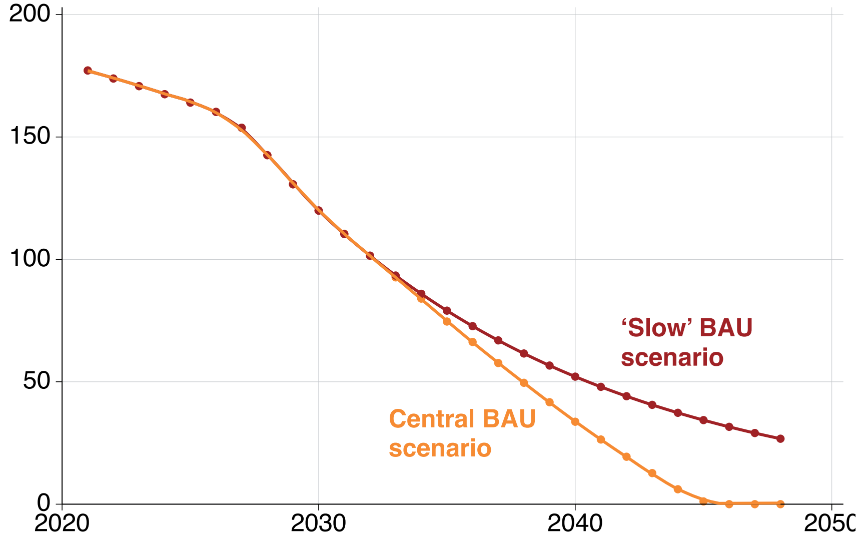
In 2021, the assumed vehicle proportions are: 33 per cent passenger vehicles, 47 per cent SUVs, and 20 per cent LCVs. Passenger vehicle sales are assumed to remain constant, SUV sales are assumed to grow by 2 per cent per year, and LCV sales are assumed to grow by 1.5 per cent per year. This scenario results in an assumed 19 per cent increase in total sales between 2021 and 2035, with the final sales proportions in 2035 being approximately 27 per cent, 52 per cent, and 28 per cent for passenger, SUV, and LCV vehicles respectively.

A.6 Business-as-usual emissions trajectory

To estimate the effect on carbon emissions of a fleet-wide emissions ceiling, it is important to produce a comparative estimate of the expected emissions trajectory under business as usual (BAU).

Figure A.4: The business-as-usual (BAU) scenarios assumed in the Grattan car model

Average vehicle emissions (gCO2/km) of new vehicle sales



The BAU case is estimated as an emissions trajectory, based on forecast ICE emissions improvements and EV uptake rates. We then use this emissions trajectory as if it were a 'target' to be applied to the fleet. Doing so means that the pathway used to meet the BAU emissions trajectory estimated by the model does *not* correspond to a prediction of the EV or technology uptake likely to occur. Instead, the model produces the lowest production-cost pathway to meeting a likely BAU emissions trajectory. It is important that this path is, like the target scenario, a lowest production-cost path and not 'most likely' or 'expected' path. This ensures a fair comparison with the lowest production-cost path outputs determined by the Grattan car model under an emissions target.

The BAU scenario for model runs used in the the report is referred to as the 'central BAU scenario', and was determined by combining a forecast of EV take-up with a forecast of future ICE emissions across new vehicle sales. We combined the emissions to provide an emissions 'trajectory' under a no-ceiling scenario.

The EV uptake forecasts we use are those proposed by the Australian Renewable Energy Agency (ARENA), under its 2018 'no intervention' scenario.[181]

We assume the emissions intensity of the ICE component of the fleet will decline by 1.5 per cent per year. This is in line with longer-term historical declines, and represent a faster improvement than has been achieved in the past five years. When combined, this produces the trajectory shown in Figure A.4.

The 'slow BAU scenario', used for sensitivity testing, assumes that EV uptake is slower than forecast in the central BAU scenario. To produce this estimate, we assume the slow scenario follows the central scenario until 2030, and that between 2030 and 2050, the slow scenario assumes a constant rate of improvement across the entire fleet, of 8 per cent per year.

A.7 Alternative BAU scenario

Under our assumed slow BAU scenario, the emissions abated under proposed emissions standards or ceilings are significantly greater than under the central scenario (Table A.6 on the following page).

181. ARENA (2018).

Table A.6: Estimates of costs and benefits under a business-as-usual scenario with reduced EV uptake

Target	Total CO2 emissions abated (Mt)	Total consumer savings (billions)
Central	675	$46
Linear	608	$41
Ambitious	711	$50

Note: We calculated all values using a 7 per cent discount rate, and we estimated all values over the 2024-2060 period.

A.8 Results included in this report

To account for the inherent uncertainty in estimating the future costs and benefits of an emissions policy for light vehicles, we sensitivity test our modelling extensively. Table A.7 on the next page details the results of sensitivity testing for the central target scenario, under 4 per cent and 7 per cent discount rates.

Table A.7: Detailed results included in this report

Sensitivity test scenario	Consumer cost per tonne CO2 abated (7% discount)	Consumer cost per tonne CO2 abated (4% discount)	Total consumer savings (7% discount, billions)	Total consumer savings (4% discount, billions)	Ratio of consumer savings to costs (7% discount)	Ratio of consumer savings to costs (4% discount)
Low future fuel price	-$62	-$16	$30	$8	5.2	1.9
High future electricity price	-$69	-$104	$34	$51	5.7	6.5
High ICE costs	-$74	-$35	$35	$17	5.6	2.7
Late EV price parity	-$77	-$132	$38	$64	5.1	6.4
Central run	-$80	-$135	$39	$66	6.4	8.1
Early EV price parity	-$80	-$135	$39	$65	8.2	10.4
Low ICE costs	-$82	-$137	$40	$67	6.8	8.6
Low future electricity prices	-$85	-$143	$41	$70	6.7	8.6
Increased real-world emissions gap	-$85	-$143	$45	$76	7.3	9.2
Off-peak EV charging costs	-$85	-$154	$45	$75	7.3	9.2
High future fuel costs	-$92	-$173	$45	$84	7.2	10.2

Notes: All costs and savings assessed are financial costs and savings to consumers. Potential changes to maintenance costs are not included in this analysis. All results relate to the central Grattan target trajectory, and assume there is credit trading between manufacturers. The ‘Late EV price parity’ and ‘Early EV price parity’ scenarios assume that the EV cost curves are shifted one year backwards and forwards respectively. The ‘Increased real-world emissions gap’ scenario assumes a constant real-world emissions gap of 30 per cent for ICE vehicles.

A.9 Economic considerations

The economic costs and benefits of an emissions ceiling are broader than the financial costs and savings.[182] Economic considerations include the social cost of carbon emissions, the health costs of vehicle pollutants, and potential losses of consumer utility under an emissions standard.

These wider economic considerations are not assessed under the default execution of the Grattan car model. However, these factors are important and can be included in sensitivity tests. Table A.8 includes estimates of the net present value and benefit-cost ratio of proposed targets when the loss of tax revenue to government, social cost of carbon, and potential losses of consumer utility are considered. These results are intended as sensitivity tests on the financial impacts reported in Chapter 3.

To evaluate potential utility costs, under a 'moderate utility cost scenario', we assume that the additional cost incurred by emissions reduction technology is 15 per cent greater than otherwise expected – either due to a loss of consumer utility, or as consumers must pay more to receive features they otherwise would have bought without an emissions ceiling. Under a 'high utility cost scenario', we assume that the additional cost incurred by emissions reduction technology is 50 per cent greater than otherwise expected.

Some consumers may incur a loss of utility under an emissions ceiling. However, the magnitude of potential losses in consumer utility are difficult to estimate, and in an economy-wide analysis must be weighed alongside other economic considerations such as the social benefits of reduced carbon emissions, and the health benefits of an emissions ceiling.

182. Financial costs and savings include, for example, the increased purchase price of vehicles, reduced fuel/running costs, and, although not considered in this report, changes in maintenance costs.

Table A.8: Estimates of select economic costs and benefits

Emissions target	Social cost and benefit, select scenario	Net social value (billions)	Social benefit-cost ratio
Central	Social cost of CO2 at $20/tonne	$15	3.0
Central	Social cost of CO2 at $35/tonne	$17	3.3
Central	Moderate utility cost	$11	2.3
Central	High utility cost	$8	1.8
Linear	Social cost of CO2 at $20/tonne	$13	3.3
Linear	Social cost of CO2 at $35/tonne	$15	3.6
Linear	Moderate utility cost	$10	2.6
Linear	High utility cost	$8	2.0
Ambitious	Social cost of CO2 at $20/tonne	$16	2.4
Ambitious	Social cost of CO2 at $35/tonne	$17	3.0
Ambitious	Moderate utility cost	$11	2.1
Ambitious	High utility cost	$8	1.6

Notes: All included values are calculated using a 7 per cent discount rate. All scenarios account for the tax losses to governments. The moderate utility cost scenario assumes that the additional cost incurred by emissions reduction technology is 15 per cent greater than otherwise expected. The high utility cost scenario assumes that the additional cost incurred by emissions reduction technology is 50 per cent greater than otherwise expected. Two other major benefits – reduced maintenance costs and avoided health costs from reduced pollutant emissions – are not considered in this analysis.

Appendix B: How we estimated the number of dwellings without off-street parking

B.1 Purpose

This Appendix describes the method we used to estimate the number of dwellings with off-street parking, based on commercially-available real estate data. This process is the basis for the estimates we provided in Chapter 4.

Our analysis is based on real estate data for Melbourne. Sydney is Australia's most populous city, but the balance of houses compared to apartments is unusual there (Figure 4.3). Melbourne is Australia's second-most populous city, with nearly as many residents as Sydney, and its dwellings are more representative of the balance in other cities.

B.2 Methodology

Real estate data include information on the number of car spaces at each dwelling, which makes it possible to estimate the share of dwellings without off-street parking. But real estate data are not a representative sample of the housing stock.

To estimate the number of households without off-street parking in Melbourne, we weighted real estate data on dwellings and car spaces according to 2016 ABS data on the number of each type of dwelling. We looked at:

- Postcode and local government area;
- The number of bedrooms in a dwelling;
- Classification as a house or apartment;
- Ownership (tenure) status.

B.3 Data

B.3.1 Data set 1: Real estate data

We gathered data on households from a commercial real estate website in August 2021. Each dwelling was described according to:

- Postcode, number of bedrooms, number of car spaces, type of dwelling, and whether the dwelling was for sale or lease.

We determined postcodes based on a 'Melbourne region' search. There were 44,788 observations in the initial data set, and 44,349 when data were restricted to dwellings with five or fewer cars paces and seven or fewer bedrooms.

We sorted dwellings were sorted into 'Houses' and 'Apartments':

- Dwellings that were identified as 'Apartment / Unit / Flat', 'Penthouse', 'Studio', 'or Villa', were classified as 'Apartments'.
- Dwellings that were identified as 'House', 'Townhouse', 'Terrace', 'Duplex', or 'Semi-Detached' were classified as detached or semi-detached houses.
- Dwellings yet to be built, retirement living, blocks of units, new home designs, and house and land packages were dropped from the sample.

Our final sample size was 41,207 observations.

The average share of dwellings with no car space on-title, separated according to dwelling characteristics, is summarised in Table **??**.

In our data set, 29.4 per cent of apartments have no off-street car space, and 6.23 per cent of houses have no off-street car space.

B.3.2 Data set 2: 2016 ABS Census data on dwellings

We extracted data on households from the 2016 Census. Tenure is limited to owned, mortgaged, and rented houses. This excludes, for example, dwellings occupied under life-tenure schemes and shared-equity schemes. We limited the data to dwellings that are unambiguously houses or apartments. This excludes, for example, caravans, and households without permanent dwellings.

We described each dwelling was described according to its postcode, number of bedrooms, type of dwelling, and whether it was occupied by an owner or somebody who did not own the dwelling.

We sorted dwellings were sorted into 'Houses' and 'Apartments':

- Dwellings that were identified as 'Apartment one or two levels', 'Apartment three levels', 'Apartment four-plus levels', 'Apartment attached to a house', or 'Apartment attached to a shop' were classified as 'Apartments'.
- Dwellings that were identified as 'Detached', 'Semi-detached, single storey', or 'Semi-detached, double storey' were classified as detached or semi-detached houses.

There are 224,684 apartments in the ABS data set, and 1,238,840 houses, for a total of 1,463,524 dwellings. The number of dwellings in the real estate data set is 2.82 per cent of the number of dwellings in the ABS data set.

B.4 Assumptions

The real estate data set distinguishes between dwellings for sale and dwellings for lease. The ABS data set distinguishes between dwellings that are owned and not owned by the occupants. To merge these two data sets, we assumed that:

Table B.1: Share of dwellings without off-street parking

Tenure	Type	Bedrooms	Share with no off-street car space
Lease	Apartment	0	0.82
Lease	Apartment	1	0.55
Lease	Apartment	2	0.21
Lease	Apartment	3	0.12
Lease	House	0	0
Lease	House	1	0.46
Lease	House	2	0.16
Lease	House	3	0.07
Sale	Apartment	0	0.74
Sale	Apartment	1	0.38
Sale	Apartment	2	0.12
Sale	Apartment	3	0.02
Sale	House	0	0.5
Sale	House	1	0.52
Sale	House	2	0.07
Sale	House	3	0.03

Note: Publicly-available real estate data, gathered in August 2021.

- Houses for lease are representative of houses that were not occupied by owners during the 2016 Census.
- Houses for sale are representative of houses that were occupied by owner-occupiers during the 2016 Census.

Based on this assumption, we matched dwellings that were 'not owned' in the Census with dwellings for lease, and we matched dwellings that were owned in the Census with dwellings for sale.

B.5 Data analysis

B.5.1 Merging data

We merged data sets based on: postcode, bedrooms, type (house/apartment), and tenure (owned/not owned).

B.5.2 Data aggregation

The real estate data set is restricted to dwellings with seven or fewer bedrooms. Figure B.1 depicts the share of dwellings without an off-street car space according to the type of dwelling and the number of bedrooms.

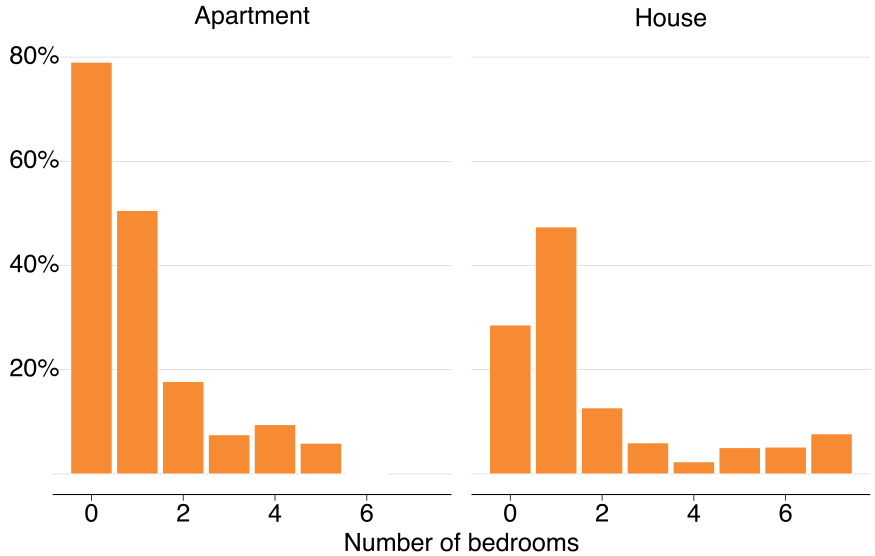
We aggregated dwellings with more than three bedrooms into a '3 or more' category to thicken the data set.

B.5.3 Sample size

Real estate data are not available for every combination of {postcode, bedroom, type, tenure} in the ABS data set. In other instances the number of real estate observations is very small as a percentage of the number of dwellings observed in the Census.

We measured sample size as the number of real estate observations (the sample) as a fraction of ABS observations (the population). We set the sample-size threshold at 0.075.

Figure B.1: Relationship between bedrooms and off-street car spaces
Share of dwellings without an off-street car space



Source: Publicly-available real estate data, Melbourne region.

For example, if the ABS recorded 1000 dwellings described as {postcode 3999, 3 beds, house, owned} and real estate data are available on only 74 households that are {3999, 3 beds, house, owned}, we treat this as a small-sample observation. We replaced small-sample observations with observations drawing on larger pools of real estate data, as detailed below.

B.5.4 Replacing small samples

Step 1: Estimates based on {postcode, beds, tenure, type} data

If the sample size met or exceeded our sample-size threshold, we used real estate data to estimate the share of dwellings without off-street parking for dwellings with a particular combination of {postcode, beds, tenure, type}.

If the sample size did not meet the threshold, we used a hierarchy of steps to generate estimates of the share of dwellings without off-street parking. Each step aggregates real estate data at a higher level, to increase the size of the sample.

Step 2: Estimates based on {LGA, beds, tenure, type} data

When real estate data were not available for a dwelling with a particular combination of {postcode, beds, tenure, type}, or if the sample of data was small, estimates of the share of dwellings without off-street parking were generated based on local government area (LGA) data. Planning processes usually occur at the LGA level, and dwellings within an LGA will share characteristics.

To generate LGA data, we summed the number of dwellings in the real estate data set were across an LGA's postcodes. We also summed the number of dwellings without off-street parking. This created an estimate of the share of dwellings without off-street parking in each LGA. This process was performed for each type of dwelling, creating estimates of the share of dwellings without off-street parking at the {LGA, beds, type, tenure} level.

This new sample of data was then used to evaluate sample size. If the number of real estate observations at the {LGA, beds, type, tenure} exceeded the sample-size threshold based on ABS {postcode, beds, type, tenure}, we used real estate data to estimate the fraction of dwellings in a postcode without off-street parking.

Step 2b: Postcodes that occupy multiple LGAs

Some postcodes occupy more than one LGA. If more than 5 per cent of a postcode area was within an LGA, we treated the postcode as having membership in that LGA.

Data are organised at the postcode level, so it is not possible to identify which LGA is associated with each dwelling. So for postcodes with more than one LGA, we divided dwellings and dwellings-without-car-spaces equally between LGAs. This process smooths differences between LGAs that have shared-membership postcodes; it under-estimates dwellings without car spaces in some LGAs, and over-estimates in others.

Step 3: Estimates based on {postcode, beds, type} data

If neither the postcode-based nor the LGA-based sample sizes meet our threshold sample size, we aggregated postcode-level data across dwellings occupied by owners and dwellings that are not owner-occupied. We used this process to generate a new estimate of the share of dwellings without off-street parking.

Step 4: Estimates of dwellings with car spaces are based on {beds, tenure, type} data

For each ABS {postcode, beds, tenure, type} dwelling that still did not have an estimate of the share of dwellings without off-street parking, or which had an estimate based on a small sample, we based our estimates on a weighted average of the share of dwellings without off-street parking, matched according to {beds, tenure, type} across the full sample of real estate data.

B.6 Results

We've used real estate data to estimate the share of dwellings without off-street parking. We've used 2016 Census data on the frequency of each {postcode, beds, type, tenure} dwelling to weight observations from the real estate data set, to generate high-level estimates of the number of households without off-street parking in the Melbourne region.

Based on this analysis, we estimate that 23.8 per cent of apartments and 5 per cent of houses have no off-street car space.

B.7 Summary

The initial real-estate dataset included 29.4 per cent of apartments with no car space, and 6.23 per cent of houses with no car space. When weighted according to ABS data on dwelling characteristics, 23.8 per cent of apartments have no car space, and 5 per cent of houses have no car space.

The initial real estate data set 'over-samples' properties without off-street parking. Weighting with ABS data has corrected for this sampling bias.

Our estimate is based on a sample of data, and therefore should be treated with the usual caution. Data were weighted according to the 2016 ABS Census, and the housing stock has changed since 2016. Nonetheless, we believe these results are a useful guide for policy makers.

Table B.2: Estimated share of dwellings without off-street parking

Tenure	Type	Bedrooms	Share with no car space
Lease	Apartment	0	0.86
Lease	Apartment	1	0.44
Lease	Apartment	2	0.18
Lease	Apartment	3	0.12
Lease	House	0	0
Lease	House	1	0.38
Lease	House	2	0.14
Lease	House	3	0.06
Sale	Apartment	0	0.78
Sale	Apartment	1	0.33
Sale	Apartment	2	0.11
Sale	Apartment	3	0.03
Sale	House	0	0.23
Sale	House	1	0.47
Sale	House	2	0.08
Sale	House	3	0.03

Note: Real estate data weighted by ABS (2016) frequency.

Appendix C: Estimating the costs of installing charging infrastructure

C.1 Purpose

This Appendix provides additional information to support assertions made in Chapter 4 about the probable cost of installing electric vehicle charging infrastructure in houses and apartments.

C.2 The cost of charging equipment

Electric vehicles typically come with a Level 1 charger. Spare chargers can be purchased for about $300.

Level 2 (wall-mounted) chargers are available for less than $1,000.[183] Chargers that monitor the power generated by home solar panels, and use this power to charge an EV, start at about $1,350. The most advanced chargers, which include Bluetooth, can cost $3000.[184]

C.3 Installing charging infrastructure in detached and semi-detached houses

Home charging is possible with a 10-Amp (240 volt) standard socket outlet. The cost of having an electrician install a socket can be $400.[185] Some companies that supply residential charging equipment offer fixed-price installation packages for $895.[186]

The not-for-profit organisation Renew estimates that buying and installing a Level 2 charger in a detached or semi-detached house costs about $2,000.[187] The Bureau of Infrastructure and Transport Research Economics (BITRE) estimates the cost at $2,200.[188]

If a detached or semi-detached dwelling does not have a spare circuit, a new switchboard will increase installation costs by between $1,000 and $2,500, including inspection fees. Dwellings that do not have enough power for their new charger will need a power supply upgrade their power supply, usually adding another $1,500-to-$2,000.[189]

Dwellings older than 20 years may need to be re-wired to safely install home charging infrastructure, with costs starting at about $6,000. A complete switchboard and supply upgrade together with full home rewiring may cost more than $10,000.[190]

C.4 Installing charging infrastructure in apartments

The cost of installing residential charging in apartment blocks depends on the existing electric infrastructure in the building, including the supply of electricity, and:

- The size of the apartment block and its existing electrical infrastructure.
- The type of charging arrangement (whether chargers are connected to the common meter board, or to apartment meters).
- Whether the investment in charging infrastructure is coordinated across all apartments, or arranged in an ad-hoc fashion when individual owners install chargers.

183. For example, EVSE.com.au (2021a).
184. The Driven (2021).
185. Gaton (2018).
186. EVSE.com.au (2021b).
187. Renew.
188. BITRE (2019, p. 32).
189. Gaton (2018).
190. Ibid.

- Whether the building has infrastructure that manages electricity demand from chargers.
- Whether the building has infrastructure that links its chargers to solar panels.

These variables make it difficult to estimate installation costs. To provide an indication of scenarios and prices, this Appendix includes information drawn from a comprehensive assessment of 20 different apartment blocks in Sydney, ranging from blocks with 48 apartments across four levels, to blocks with 646 apartments across 31 levels. This assessment was done by Wattblock and funded by a City of Sydney Environmental Innovation Grant.[191] The following sections draw from that assessment.

C.4.1 Summary of arrangements and costs

Level 1 charging, with individual installation and connected to an apartment electricity board:

- Suitable for small apartment blocks, but difficult to manage in large blocks.
- Estimated to cost the individual up to $1000.

Level 1 charging, with individual installation and connected to a common electricity board:

- Requires a new electricity sub-meter behind the socket for billing.
- Suitable for small apartment blocks, but difficult to manage in large blocks.
- Estimated to cost the individual up to $1000.
- Will mean administrative costs for the owners' corporation in organising billing adjustments based on individual meters.

Level 2 charging, with individual installation and connected to an apartment electricity board:

- Suitable for small apartments and as an interim solution in larger buildings.
- Existing electricity boards will be able to support only a limited number of chargers.
- Estimated cost to the individual: $1,500-to-$8,000.

Level 2 charging, with individual installation and connected to a common electricity board:

- Requires a new electricity sub-meter behind the socket for billing.
- Existing electricity boards will be able to support only a limited number of chargers.
- Estimated cost to the individual: $1,500-to-$8,000.
- Will mean administrative costs for the owners' corporation in organising billing adjustments based on individual meters.

Level 2 charging, with coordinated installation of electrical infrastructure:

- Owners' corporation organises 'EV ready' electrical infrastructure; residents incur the cost of 'last mile' installation (installing a socket or charger and connecting it to the electrical infrastructure).
- Smart chargers installed to manage electricity demand and to automate billing.
- Long-term solution for larger apartment blocks.

191. Wattblock (2018).

- Estimated cost to the individual: $500-to-$800, plus a typical billing fee of $30 a month.
- The cost to the owners' corporations varies substantially.

C.4.2 Costs of installing 'EV ready' electrical infrastructure, borne by owners' corporations

If an owners' corporation invests in shared electrical infrastructure to support charging, individuals bear the cost of 'last mile' installation. Shared costs vary substantially with each building.

Across the participating strata schemes, Wattblock estimates that a basic infrastructure upgrade, with installation of distribution boards in different car park levels, costs about $600 per apartment. The cost of upgrading a main switchboard and increasing electricity supply to the building is put at$5,000-to-$15,000, based on a project in Queensland.

The cost of installing charging infrastructure varies with the number of energy-efficiency measures and demand-management measures that are bundled with the installation. Owners' corporation rules, such as restrictions on the chargers that can be installed, can be used to increase the scope for collective charging.

More expensive up-front investments allow a larger number of electric vehicles to be charged and typically have shorter pay-back periods. For selected Sydney apartments in the study, investment cost ranges were:

- Redfern apartment block: 112 apartments
  - $17,026 to support six electric vehicles
  - $162,760 to support 135 electric vehicles.
- Haymarket apartment block: 646 apartments
  - $115,982 to support 74 electric vehicles
  - $663,080 to support 779 electric vehicles.

C.5 Notes

The costs outlined in this Appendix are not intended to serve as a guide for any individual house or apartment. They are indicative costs based on publicly-available data.