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The Grattan truck plan

Practical policies for cleaner freight

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Overview

Truckies may be enjoying a newfound status as essential workers since COVID lockdowns – but that appreciation vanishes the minute a dirty big diesel truck thunders past on an urban road. People want the truck task to be done, but dislike the side-effects of pollution, noise, and carbon emissions. While those side-effects can't be eliminated, they can be reduced.

People may wonder why more freight can't go by rail – after all, governments have been spending a fortune on freight rail infrastructure. But road and rail mostly do different jobs. Rail mainly carries bulk consignments of commodities such as coal, iron ore, and grain, heading to ports on fixed schedules. Road freight, on the other hand, encompasses all sorts of goods travelling from many origins to many destinations. Road and rail rarely compete for freight.

The typical Australian truck is older than its overseas counterpart, and that means it's more polluting. Fourteen per cent of the Australian fleet is pre-1996, and these trucks emit 60 times the particulate matter of a new truck, and eight times the poisonous nitrogen oxides. Exhaust-pipe pollutants from trucks kill more than 400 Australians every year. Even when they're not killing people, they're causing respiratory illnesses and cancer, and impairing decision-making and cognitive functioning.

Hundreds of cities around the world handle this problem with low-emission zones. State governments should introduce low-emission zones in Sydney and Melbourne, prohibiting highly-polluting vehicles from densely-populated areas. The oldest trucks that are most harmful to health would still be allowed to operate outside the city bounds, but businesses operating in the city would need to upgrade to cleaner trucks, and could be offered government assistance to do so.

Even the new trucks coming into Australia aren't as clean as they should be. Our pollution standard for trucks is a decade behind those of the US and Europe. And the range of less-polluting trucks available in Australia is limited by pointless regulations demanding that trucks be 2 per cent narrower than the global standard. Australia should catch up to the international pollution standard from 2024, and update other regulations that needlessly limit the options available to Australian truck operators.

Trucks contribute 4 per cent of Australia's carbon emissions. It's unlikely that the sector will reach zero carbon emissions by 2050, but governments should minimise the cost of offsets to future consumers, shareholders, and taxpayers. This means lowering barriers to the uptake of electric and hydrogen trucks. These trucks still cost more over their life than diesel trucks, and operators will need to figure out how to adapt their scheduling, garaging, and fuelling arrangements as technologies develop. The federal government should introduce binding sales targets for zero-emissions trucks, starting at 2 per cent in 2024 and gradually increasing to cover most new sales by 2040.

In the meantime, we need to ensure new diesel trucks emit less carbon, by imposing standards on engines and tyres, and ratcheting up those standards each year.

This report shows how Australia can substantially reduce the harm caused by noxious exhaust-pipe pollutants from trucks, lower their carbon emissions, and bring more trucks into the fleet that are quieter and safer. A happier co-existence with trucks is well within reach.

Recommendations

Keep the most-polluting trucks away from people

State governments should establish low-emission zones in Sydney and Melbourne, prohibiting highly-polluting pre-2003 diesel trucks from the capital city areas from 2025.

Catch up to global pollution standards for trucks

The federal government should impose Euro-VI Stage-C pollution standards from 2024 for new models, and from 2025 for all models of new heavy vehicles.

Reduce the carbon emissions from trucks

To accelerate the switch to zero-emissions trucks, the federal government should set binding zero-emissions sales targets for sellers of new trucks. Targets for rigid trucks should reach 100 per cent, and for articulated trucks 70 per cent, by 2040.

While diesel trucks remain widespread, the federal government should apply progressively tighter carbon-emission requirements on the engines and tyres of new diesel trucks.

Reduce regulatory barriers to better trucks

To make it easier and more viable for owners to choose a cleaner truck, the federal government should scrap regulations requiring Australian trucks to be 2 per cent narrower than the global norm, and update regulations that limit allowable loads based on tyre configurations and tyre widths.

More specific recommendations are detailed throughout this report.

Table of contents

1 Trucks . . . just keep on trucking

Much as we may love parcels turning up on the doorstep, or appreciate the convenience of popping out to the shops for something to eat, the trucks that make this possible are hard to love.

In fact, plenty of people hate trucks. The headlines show just how much people hate them:

> Parents concerned pollution from proposed WestConnex exhaust stack near school will harm children.[1]
>
> Yarraville trucks linked to high asthma rate.[2]
>
> Melbourne residents brace for more congestion and pollution, as truck numbers rise.[3]

People may not love trucks, but Australians' reliance on trucks keeps on growing. That's unlikely to change much any time soon, and it's not as if rail can really compete.

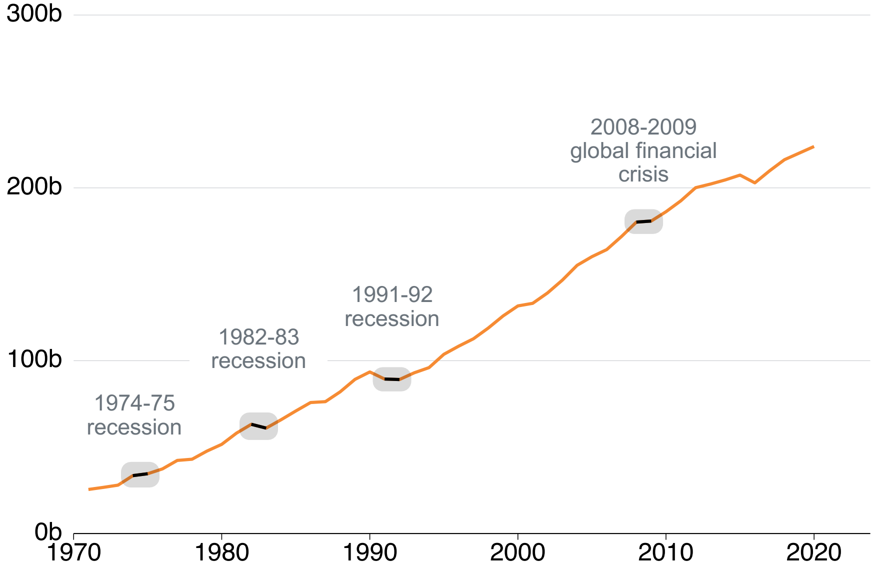
Since trucks are likely to be with us for the long haul, this report investigates how to reduce the harm they cause.

1.1 Australians' reliance on trucks keeps on growing

For most people, the most visible aspect of trucks' work is carrying goods to homes and businesses. But food, drink, and manufactured goods constitute a smaller share of the truck task than construction materials, fuels, and tools of trade.[4]

1. 9News (2017).
2. Dow (2015).
3. Razak (2018).
4. BITRE (2019, p. 7).

Figure 1.1: Road freight has proven resilient to economic disruptions
Total yearly road freight (tonne-kilometres)



Note: The black lines show the recessions of the 1970s, 1980s, and 1990s, and the global financial crisis of 2008-09.

Source: BITRE (2021).

The road freight industry touches all sectors of the economy. It's therefore unsurprising that truck freight has barely been affected by economic shocks. It recovered quickly from small dips associated with the recessions of the 1970s, 1980s, and 1990s, and the global financial crisis of 2008-09 (Figure 1.1). And by the end of 2021, the congestion associated with freight vehicles had already returned to 2019 (pre-COVID) levels in the five mainland capital cities.[5]

5. BITRE (2022, p. 2).

The amount of truck freight is forecast to continue to grow by about 2 per cent per year.[6] Fuel prices have been on the rise since December 2021, and oil has cost more than US$100 per barrel for much of the period since March 2022, but these prices are unlikely to make much of a dent on the amount of road freight, for two reasons.[7]

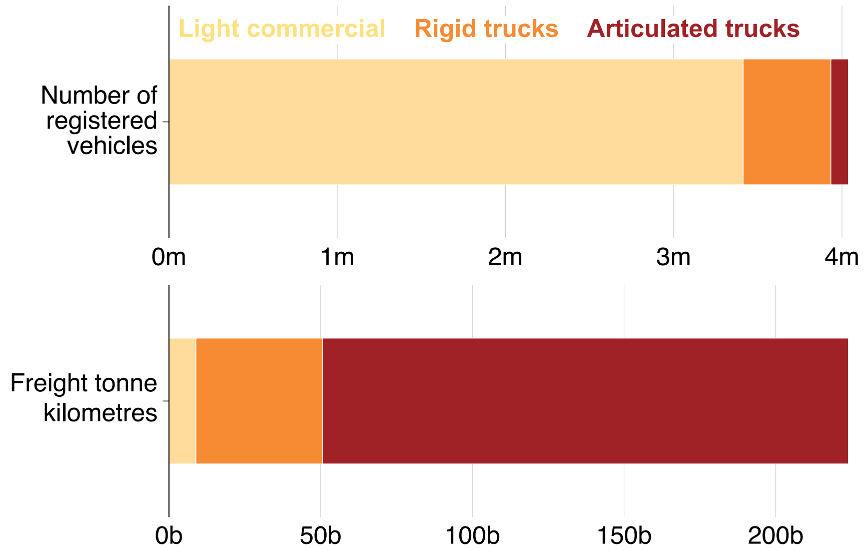
First, there has been a counterbalancing improvement in the productivity of road freight vehicles, going back as far as the 1980s.[8] About 80 per cent of road freight is now moved by articulated trucks (Figure 1.2), which have lower operating and maintenance costs than moving the same freight on smaller trucks.[9] Better truck technology has also been matched by a generation's worth of road improvements,[10] enabling greater use of bigger and higher-mass trucks.

Second, even when transport costs rise, they are generally only a small share of the total price of the good paid by consumers.[11]

The amount of road freight generally depends on the amount of consumption,[12] and consumption is forecast to grow by 4.5 per cent in 2021-22 and 5 per cent in 2022-23.[13]

Figure 1.2: High-productivity trucks do the lion's share of the work

Number of registered vehicles, and freight activity, by vehicle type



Note: Not all light commercial vehicles carry freight, therefore these results will understate the productivity of the share of light commercial vehicles that do carry freight.

Source: ABS (2020).

6. BITRE (2019, p. 13). Forecasts run to 2040.
7. Oil prices are high but by no means unprecedented. The price of Brent crude exceeded US$100 per barrel between March 2011 and August 2014, and for six months in the middle of 2008. Diesel prices have long tended to be volatile.
8. Between 1971 and 2016 the productivity growth of heavy vehicles increased almost six-fold, with more than 90 per cent of the gains attributed to articulated trucks: NTC (2016a, p. 3).
9. Productivity Commission (2007, F6).
10. DIRC (2018a, p. 16).
11. Transport costs can vary between as low as 1 per cent to more than 10 per cent of all intermediate inputs costs for different types of goods: Productivity Commission (2007, F1-2).
12. Specifically, of gross national expenditure, or GDP less net exports: BITRE (2019, p. xiv).
13. Australian Government (2022a, p. 37).

So there's little reason to expect any appreciable slowing in Australians' reliance on trucked goods.

1.2 Why rail can't really compete

Even accepting that the size of the domestic freight task is unlikely to shrink, does so much of it have to travel by road?

It used to be the case that a larger share of domestic freight travelled by rail and sea. In 1970, about 40 per cent of domestic freight between Sydney and Melbourne travelled by rail, but that is now down to just 1 per cent.[14] Rail's share of the total non-bulk freight task has fallen from 25 per cent in the mid-1970s to 18 per cent today.[15] Coastal shipping's share has shrunk from 13 per cent to 5 per cent over the same period.

The following sections explain why there is little scope to make a wholesale shift from road to rail.

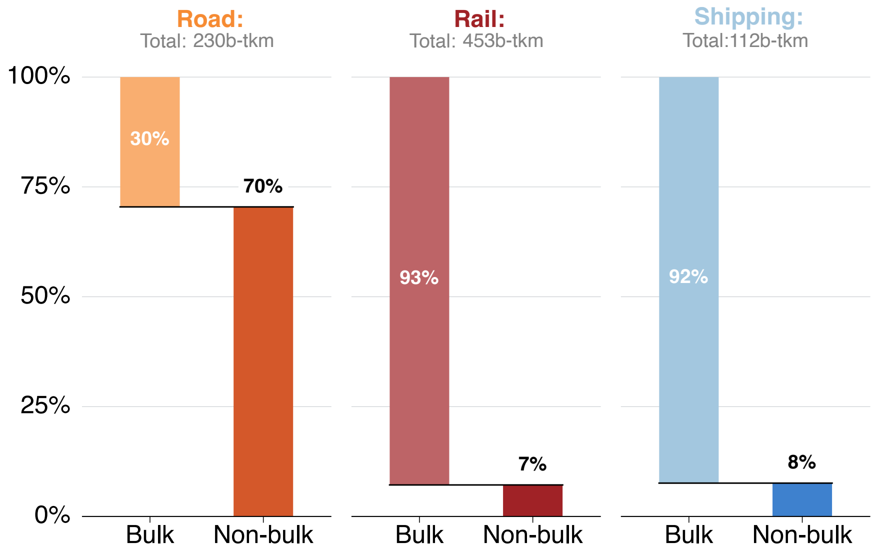
1.2.1 For the most part, road and rail do different jobs

Rail is best suited to bulk consignments between few locations on a predictable schedule. For this reason, it mostly carries bulk goods: coal, iron ore, grains, fertiliser, and other goods that can usually be poured or dropped without damage.

Rail carries a small share of non-bulk freight as well: disparate packaged and containerised goods such as construction materials, consumer goods, groceries, and live animals. But non-bulk freight mostly travels by road (Figure 1.3). That's because road freight is ideal for delivering many types of goods from a wide range of pick-up points to a wide range of destinations. It's a faster and much more flexible form of transport.

14. Laird (2021).
15. BITRE (2021, p. 81).

Figure 1.3: Road dominates the transport of non-bulk freight



Note: Domestic freight task only.

Source: BITRE (2021, pp. 80–81).

The main segment where there is any real competition between road and rail is non-bulk freight travelling between capital cities: it's generally only when distances exceed about 1,500km that rail becomes price-competitive with road.[16] There is most likely to be competition where:

- the task is not highly time-critical, and
- the distance is sufficient that cheaper per-kilometre charges of rail outweigh the extra expense of getting the goods from the origin to the rail terminal, and from the rail terminal to the final destination.

This contested component has been estimated to be about 18 per cent of the task currently done by trucks,[17] or 10 per cent of the total freight task.[18]

Because rail tends to be more expensive over shorter distances, most of the non-bulk inter-capital freight carried by rail occurs between the eastern states and Perth, and between Melbourne and Brisbane. For other trips between capital cities, rail does less than 20 per cent of the job, and less than 10 per cent between Sydney and either Brisbane or Melbourne.[19]

Businesses are more likely to respond to road freight price increases by changing their intensity of heavy vehicle use, for example by changes to scheduling or loading, than by switching to rail.[20]

16. See, for example, BITRE (2009, p. 7) and BITRE (2006, p. 78). Exceptions include port-related trips, particularly where road costs are high and the local community active: BITRE (2016).
17. NTC (2016b, p. 76); and BITRE (2009, p. 6).
18. Productivity Commission (2007, p. 13).
19. BITRE (2009, pp. 6–8).
20. In more technical terms, mode share elasticities tend to be smaller than tonne or tonne kilometre elasticities: BTE (1995, p. 34).

1.2.2 Governments are trying to increase rail's share of the task

Governments have been explicitly seeking to increase rail's share of the freight task.

In NSW, the Freight and Ports Plan for 2018 to 2023 laid out a plan to increase the use of rail at Port Botany, from 17.5 per cent in 2016 to 28 per cent by 2021.[21] The Victorian Freight Plan also says it is a government priority to make better use of rail freight assets, including by supporting port rail freight shuttles and increasing axle loads on regional rail.[22] Former Deputy Prime Minister John Anderson is heading a review, funded by the federal government and industry, of freight rail. The review aims to find ways to bring more freight onto rail. It is due to report later this year.[23]

Governments have been backing up their intentions to increase the rail share of freight with a major step-up in rail investment. In 2001, Australian governments invested $0.5 billion in rail; 10 years later, that had increased eight-fold to $4.1 billion; by 2021, it had more than doubled again, to more than $10 billion.[24]

Much of the investment has been specifically for freight rail. The biggest investment to date has been $15.4 billion allocated so far by the federal government to Inland Rail. On top of that investment have been further investments designed to get the most out of Inland Rail; for example, the March 2022 federal Budget included a $3.1 billion commitment to the Melbourne Intermodal Terminal Package, including investments in both the Beveridge and Western sites and related infrastructure.[25]

21. Audit Office of NSW (2021, p. 14).
22. Transport for Victoria (2018, p. 28).
23. Chan (2022).
24. ABS (2022).
25. Australian Government (2022b, p. 142).

There have also been major federal and state government investments in Sydney's Moorebank Intermodal Terminal, which is located in the suburb of Moorebank and connected to Port Botany with a dedicated freight rail line.

Regional freight rail has also been expanded. In the past decade, NSW has upgraded the Sydney-to-Newcastle freight rail connection, while Victoria is upgrading freight rail in the north-east of the state through the Murray Basin Rail Project.

Complementary actions agreed by federal and state governments and key members of the rail industry include finding ways to meet the rail sector's skills and labour needs, and to align standards for rolling stock and components, and operating rules for rail infrastructure and for communications and control systems.[26]

For those segments of the market where rail competes with road, rail struggles to commercially justify investment in productivity and capacity enhancements, and is often reliant on government grant funding for such projects.[27] Major freight rail investments could potentially bring advantages, in the form of lower transport costs, fewer accidents, lower air and noise pollution, and fewer greenhouse gas emissions. But there's no compelling reason to think that such investments will deliver as promised. While the business case for Inland Rail claims that it will give rise to a substantial shift from road to rail for inter-capital freight,[28] questions remain over the rail sector's competitiveness in the face of changing technology.

26. NTC (2019).
27. See, for example, Terrill and D. Wood (2018) and IPART (2012, pp. 5–7).
28. The central assumption for the price elasticity of demand is 2 per cent, and is based on stated-preference surveys in 2008-09 with up to 40 companies. The business case also applied an elasticity developed for a long distance corridor (Melbourne to Brisbane) to intermediate-distance corridors: Australian Rail Track Corporation (2015, p. 120).

1.2.3 . . . but most non-bulk freight will continue to travel by road

Even with the substantial increase in government spending on rail, the scope for rail to increase its share of the contested part of the freight task is limited.

Non-bulk rail freight between capital cities is most feasible for rail between far-flung capital cities, because the fuel costs for rail are lower per tonne kilometre than they are for road – and for long-distance trips, a greater portion of the trip is by rail. But it's still usual for goods to travel by truck to the terminal at the beginning of the journey, and from the terminal at the end of the journey. This is the main reason that bulk freight accounts for 30 per cent of the road freight task, as shown in Figure 1.3 on page 8.

The additional handling costs of moving from truck to train, and train back to truck, are an important component of the door-to-door transport costs for rail freight. As well as adding cost, this additional handling adds time to the trip. In all, rail freight generally takes longer than road on most of the main corridors.[29]

Some of the other barriers to the use of rail may be easier to lower or remove. Different gauges, different standards for rolling stock and infrastructure, and different operating rules, communications and control systems all act as barriers to businesses that might otherwise choose freight rail.[30] These shortcomings are the subject of a national rail plan.

Addressing these shortcomings may arrest the long-term drift from rail to road freight, but the fundamental reasons for the drift are unlikely to change to any great degree, if at all.

29. Ibid (p. 134).
30. NTC (2019).

1.3 The structure of this report

Even though trucks are hard to love, there is unlikely to be much change in either the demand for non-bulk freight, or the tendency to choose trucks for the task. Governments should therefore focus on reducing the negative impacts of trucks. This report focuses on that challenge.

Chapter 2 details the exhaust-pipe pollutants from trucks, which are harmful to health even at low concentrations, and which therefore should be minimised in densely-populated areas.

Chapter 3 shows how new trucks coming onto the roads can be less-polluting.

Chapter 4 focuses on the carbon emissions of trucks, which constitute 4 per cent of Australia's total emissions, and which could be reduced with some modest government actions.

As well as exhaust-pipe pollution and carbon emissions, trucks cause noise pollution and can cause accidents. While these two negative impacts are not the focus of this report, both would be ameliorated by some of the actions we recommend. Trucks also contribute to congestion, which will be the subject of a future Grattan Institute report.

2 How to reduce the damage inflicted by trucks already on the road

It's not surprising that trucks create air pollution. What *is* surprising is just how bad this pollution is for people's health. Exhaust-pipe pollution from trucks kills hundreds of Australians each year.

One way to reduce the damage inflicted by trucks is to focus on the worst trucks in the fleet – and the worst trucks are old trucks. A truck sold before 1996 emits about 60 times more particulate matter – a dangerous component of pollution – than a truck sold after 2011.

Since old trucks are so harmful, the largest capital cities should introduce low-emission zones to keep the most-polluting ones away from people.

2.1 Trucks are a major source of harmful air pollution

Although trucks are only 3 per cent of Australia's road vehicles, they create about a quarter of transport-related air pollution.[31]

The air pollution pumped out of trucks' exhaust pipes contains a cocktail of dangerous gases, solids, and liquids (Box 1 on the following page).

Trucks emit more than 20 per cent of the urban nitrogen oxide (NO_x) load,[32] and trucks are responsible for about 15 per cent of fine particulate matter ($PM_{2.5}$) emissions in urban areas.[33]

There are two reasons trucks create so much air pollution. First, almost all trucks burn diesel.[34] Diesel does not burn as cleanly as petrol, and diesel engines typically emit more pollutants per kilometre than petrol engines.[35]

Second, trucks are hard-working: on average they cover longer distances than other vehicles. Trucks are responsible for more than 7 per cent of kilometres travelled: on average rigid trucks drive more than 20,000km each year, and articulated trucks nearly 80,000km.[36] Trucks therefore burn through a lot of fuel – 22 per cent of all the diesel and petrol consumed in 2018 – and in the process they produce a lot of air pollution.[37]

Trucks create exhaust-pipe and non-exhaust air pollution. Non-exhaust pollution is mainly caused by friction between brakes and tyres, and between tyres and the road. When tiny pieces of material are chafed into the air, the smallest particles remain suspended while heavier particulates settle on the ground. As a vehicle's speed increases, tyres heat up and release particulate matter.

31. DIRD (2016a, p. 11).
32. On-road vehicles are responsible for more than 55 per cent of NO_x emissions in the Sydney region, and diesel trucks are responsible for about 40 per cent of on-road NO_x emissions: DITRDC (2020, p. 12). Nearly 97 per cent of trucks use diesel; including emissions from non-diesel trucks would increase the share of pollutants attributed to trucks.
33. There are many sources of fine particulate matter, including dust, pollen, and sea salt. Vehicles and wood heaters are the main human-made sources in urban areas: Chang et al (2019, p. 2). Exhaust emissions, including from off-road vehicles, can be responsible for up to 30 per cent of urban $PM_{2.5}$; research in NSW found that diesel trucks are responsible for more than 55 per cent of $PM_{2.5}$ exhaust emissions in the Sydney region: DITRDC (2020, pp. 13–14).
34. Nearly 97 per cent of trucks use diesel: ABS (2020). We use the term 'diesel trucks' to refer to all trucks.
35. DIRD (2016a, p. 11) and Alexander and Schwandt (2022, p. 4).
36. Passenger cars typically travel about 12,000km and utility vehicles about 16,500km: ABS (2018). We used data from 2018 rather than 2020 to avoid potential distortions caused by the COVID pandemic.
37. Ibid.

This report focuses on trucks' exhaust-pipe pollutants, because they are a lot more dangerous than non-exhaust pollution.[38] And we focus on fine particulate matter ($PM_{2.5}$) and nitrogen oxides (NO_x), because these two components of exhaust-pipe air pollution have the most damaging effects on people's health.[39]

2.1.1 Air pollution causes fatal diseases

Because Australia's skies usually look pretty clear, it's tempting to think that air pollution is not a problem.

But that's wrong. Air pollution from trucks is estimated to be responsible for at least 400 deaths in Australia each year.[40]

Because air pollution is inhaled, it isn't surprising that it damages people's lungs. Nitrogen dioxide (NO_2) is one of the nitrogen oxides (NO_x) produced by diesel engines, and research shows that it is the component of air pollution that is most responsible for respiratory

38. In Australia a significant share of PM_{10} generated by trucks is non-exhaust, but the vast majority of $PM_{2.5}$ is from trucks' exhaust-pipes: Grattan analysis. See Appendix Appendix A for more information. Non-exhaust particles are usually larger than exhaust-pipe particles and therefore less likely to be absorbed by the body. Only 0.1-to-10 per cent of tyre wear particles are airborne, and recent reviews suggest the risk to human health is low: see Baensch-Baltruschat et al (2020, p. 5).
39. Particulate matter and ozone are the most damaging air pollutants: DITRDC (2020, p. 10). As ozone is a by-product of NO_x, we therefore focus on $PM_{2.5}$ and NO_x emissions. Emission standards for trucks are expressed in terms of PM_{10}, of which $PM_{2.5}$ are the most damaging component. Our modelling also includes coarse particulate matter and sulfur dioxide. Further detail on our modelling is in Appendix A.
40. Recent estimates suggest that air pollution from Australian vehicles causes more than 1,700 deaths each year: Schofield et al (2017, Overview); EVC and Asthma Australia (2019, p. 2). Older estimates attribute between 900 and 2000 deaths to pollution from vehicles: BTRE (2005, p. ix). Trucks are responsible for about a quarter of this air pollution (DIRD (2016a, p. 11)) and trucks are more likely than other vehicles to burn diesel, which is particularly dangerous.

Box 1: What comes out of trucks' exhaust pipes?

The World Health Organisation has identified four key pollutants that are harmful to people's health.[a] All four are produced by trucks, or are a by-product of exhaust-pipe pollutants.

1. Particulate matter (PM) is a mix of tiny solids and droplets. Black carbon, or 'soot', is a major component of exhaust-pipe particulate matter. Particulate matter is measured in thousandths of a millimetre, called 'microns'. PM gets more dangerous as it gets smaller, because it can more easily penetrate lung tissue to move through people's bloodstreams and into other organs.[b] 'Coarse' PM_{10} particulates are up to 10 microns, 'fine' $PM_{2.5}$ are smaller than 2.5 microns, and 'ultra-fine' $PM_{0.1}$ are smaller than 0.1 microns.

2. Nitrogen dioxide (NO_2) is a brownish gas. Along with nitrogen monoxide (NO), NO_2 is referred to as a nitrogen oxide (NO_x). NO_x contributes to $PM_{2.5}$, and in sunny weather it mixes with oxygen to create ozone.

3. Ozone (O_3) is a colourless gas that is not produced directly by trucks, but in sunny weather it is a by-product of exhaust-pipe NO_x. Ozone is also an important component of smog.

4. Sulphur dioxide (SO_x) is a colourless gas that causes inflammation to people's lungs and eyes.

In addition to these four pollutants, exhaust-pipe air pollution contains a mix of volatile organic chemicals, or VOCs, including carcinogens such as benzene. VOCs combined with ozone create smog.

a. WHO (2021).
b. See, for example, Schraufnagel (2020, p. 313).

problems.[41] A study of 12 Australian cities found that even a small increase in annual nitrogen dioxide levels is associated with a 54 per cent increase in asthma.[42]

Long-term exposure to $PM_{2.5}$ also causes lung diseases.[43] Diseases caused by NO_x and particulate matter include emphysema, chronic bronchitis, chronic asthma, pneumonia, and lung cancer.[44] Ozone, created by NO_x in sunny weather, also triggers lung inflammation.

The City of Maribyrnong in Melbourne's west includes many major truck routes, and it has an adolescent asthma rate 50 per cent higher than the state average.[45] Maribyrnong's hospital admission rate is estimated to be more than 70 per cent higher than the Australian average for people aged 3 to 19,[46] and the inner west has a higher incidence of lung cancer than the general Australian population.[47]

But air pollution doesn't just damage lungs. Because it penetrates lung tissue, fine particulate matter is also responsible for diseases all through people's bodies. Long-term exposure to $PM_{2.5}$ is linked to coronary heart disease, strokes, bladder cancer, and type-2 diabetes.[48]

In Australia, $PM_{2.5}$ is estimated to be responsible for more than 8 per cent of the coronary heart disease burden, nearly 7 per cent of the type-2 diabetes burden, more than 5 per cent of the burden of lower respiratory infections, and more than 3 per cent of the lung cancer burden.[49]

Children are particularly vulnerable to air pollution – including in the womb. Air pollution increases the risk of low birth weight,[50] long-term damage to lung function,[51] childhood leukaemia,[52] and other cancers.[53]

Older people, and people with existing respiratory conditions such as asthma and allergies, are also more sensitive to air pollution.[54]

2.1.2 Cognitive functions are affected by air pollution

Even if people are spared disease, that doesn't mean that air pollution isn't damaging their health. There is growing evidence to show that high daily levels of particulate matter have subtle but damaging effects on people's bodies, including their cognitive function.[55]

For example, chess players and baseball umpires make more mistakes on days with higher levels of particulate matter.[56] And children who are exposed to a greater number of high-$PM_{2.5}$ days achieve lower average results in maths and English tests.[57]

These might seem like minor problems, but they hint at the harm that air pollution inflicts on people's cognitive processes and productivity. The bigger picture is evident in European research showing that a 10

41. Walter et al (2021, p. 9).
42. Ibid (p. 9).
43. DITRDC (2020, p. 10).
44. Regarding diseases caused by NO_x, see Huangfu and Atkinson (2020, p. 23). Regarding NO_x and lung cancer, see Hamra et al (2015, p. 1107). Regarding diseases caused by $PM_{2.5}$, see DITRDC (2020, p. 10). See Chapter 2 of Parliament of Victoria (2021) for a recent overview of the health effects of air pollution.
45. DEECD (2010, p. 9).
46. Grattan analysis of ACSQH (2015).
47. Inner West Air Quality Community Reference Group (2020, p. xii).
48. DITRDC (2020, p. 10).
49. AIHW (2018). Disease burden is a measure of the years of healthy life lost because of death and illness.
50. Currie and Walker (2011, p. 67) and Currie et al (2011, p. 2394).
51. Gehring et al (2013) and CARB (n.d.)
52. Childhood leukaemia is associated with benzene, a carcinogen contained in exhaust-pipe air pollution: Filippini et al (2019, p. 13).
53. Hvidtfeldt et al (2020).
54. DITRDC (2020, p. 10).
55. See, for example, La Nauze and Severnini (2021).
56. See Künnt et al (2019) regarding chess players, and Archsmith et al (2018) regarding baseball umpires.
57. Mullen et al (2020, pp. 10–11).

per cent increase in $PM_{2.5}$ levels causes an 0.8 per cent reduction in annual GDP. Nearly all of this effect is attributed to reduced workplace attendance or reduced worker productivity.[58]

Being exposed to higher average levels of particulate matter also has a cumulative effect. Long-term exposure is associated with an increased risk of Alzheimer's disease and dementia,[59] and reduced cognitive abilities among the elderly.[60]

2.1.3 There is no safe level of air pollution

Particulate pollution does damage even at very low concentrations, including levels that meet Australian air-quality standards.[61] There is no 'safe' level of exposure to $PM_{2.5}$.[62]

Evidence from the US shows that pollution from a single dirty vehicle is enough to affect local air quality and health, even in areas with clean air. A recent study estimates that a single highly-polluting diesel car can increase local infant mortality rates, and severe asthma attacks in children under 4.[63]

In high-income cities that have relatively clean air, living close to a major road or highway is risky: evidence from Vancouver shows that people who live within 150 metres of a freeway or within 50 metres of a major road are nearly 70 per cent more likely to die of coronary heart disease.[64]

These findings are even more concerning for people on lower incomes. The most disadvantaged 20 per cent of Australians suffer more than twice the disease burden from air pollution as the most advantaged 20 per cent.[65]

2.1.4 The more we learn about air pollution, the worse it gets

The more we learn about the damage done by air pollution, the worse the story gets.[66]

In 2012 the World Health Organisation (WHO) reclassified diesel exhaust and particulate matter as known carcinogens, rather than probable carcinogens.[67] And last year, the WHO halved its recommended maximum allowable levels of $PM_{2.5}$, and sharply reduced the recommended maximum allowable levels of nitrogen dioxide.[68]

As researchers use better technology to study smaller and more dangerous particles, new evidence is also emerging on the dangers of ultra-fine particles.[69] These are the particles that are most able to penetrate lung tissue. Because they have a relatively large surface area compared to their size, they can also transport surprisingly large quantities of toxic pollutants through people's bodies,[70] creating 'systemic' damage.[71]

58. Dechezleprêtre et al (2019).
59. Fu et al (2019, p. 1242).
60. Weuve et al (2012).
61. Schofield et al (2017); EPA Victoria (2018, p. 41); Zosky et al (2021) and Barnett (2014).
62. WHO (2021).
63. This finding is based on analysis of the 'dieselgate' scandal, when diesel cars were revealed to emit 40 times as much NO_x as advertised. The estimated effect of an extra dieselgate car per 1,000 cars is to increase infant mortality by 1.7 per cent, and severe asthma attacks by 7 per cent: Alexander and Schwandt (2022, pp. 2, 25).
64. Gan et al (2010, p. 644).
65. AIHW (2018, p. 123).
66. WHO (2013).
67. WHO (2012).
68. IQ Air (2022).
69. Schraufnagel (2020).
70. Diaz et al (2019, p. 3).
71. Schraufnagel et al (2018, p. 411).

The good news is that reducing air pollution leads to rapid improvements in people's health.[72] Switching to electric trucks will dramatically reduce exhaust-pipe air pollution, and as a consequence people's health will improve.[73] But in the meantime people's health is being damaged, and Australia's governments should take practical steps to reduce air pollution from the existing fleet of diesel trucks (Section 2.2), and from new trucks (Chapter 3).

2.2 Old trucks are much more polluting than new trucks

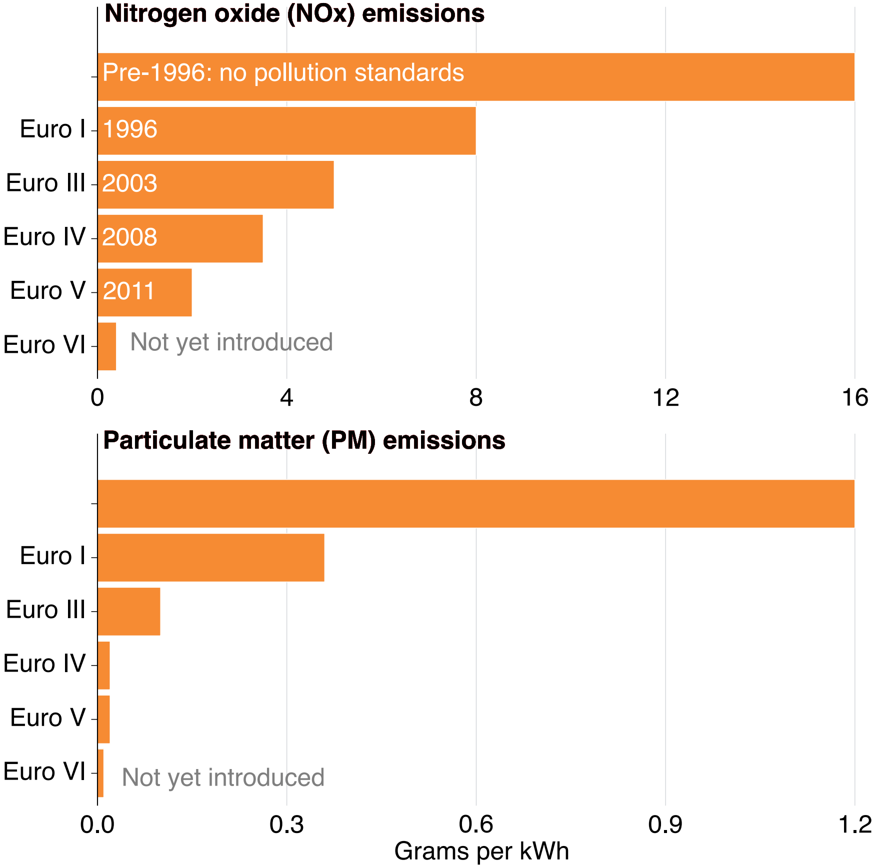
There are more than 550,000 rigid trucks on Australian roads, and nearly 110,000 articulated trucks.[74] As shown in Section 2.1, these trucks collectively produce a lot of air pollution. But some trucks are dirtier than others.

Each old truck emits a lot more pollution than a comparable newer model – and there are plenty of old trucks on Australian roads. When they drive through densely-populated areas, millions of people breathe in their pollution.

2.2.1 Much of the fleet predates pollution standards

Until 1996, trucks sold in Australia did not need to meet any pollution standards. These old trucks emit at least 60 times more particulate matter than trucks that meet current pollution standards, and about eight times the NO_x (Figure 2.1).[75]

Figure 2.1: Old trucks are particularly dirty
Pollution limits under Euro standards, and year of introduction



Notes: Pollutants from trucks are measured in 'grams per kilowatt hour' (g/kWh). 'Kilowatt hours' are a measure of the power produced by a truck. Pollutant limits are for diesel heavy vehicles. Australia did not introduce Euro-II standards.
Source: DITRDC (n.d.) and Sustainable Transport (n.d.).

72. WHO (2013, p. 7).
73. Electric and hydrogen fuel-cell vehicles create no exhaust-pipe airborne pollutants, but dangerous pollutants are often generated through the electricity production process – for example, at coal mines. These pollutants create health problems at the source, rather than at the exhaust pipe. Research for Infrastructure Victoria finds that urban areas will derive the greatest health benefits from the transition to a zero-emissions fleet of cars and trucks: Aurecon (2018, p. 17).
74. ABS (2021a).
75. Sustainable Transport (n.d.); McMullan (2019, p. 20).

In 1996 Australia introduced pollution standards based on the international 'Euro' framework. The Euro-I standard was introduced, which reflected the pollution-reducing technology that was available at that time. Trucks sold between 1996 and 2002 emit about 20 times the particulate matter and nearly four times the NO_x of a truck that meets current pollution standards.

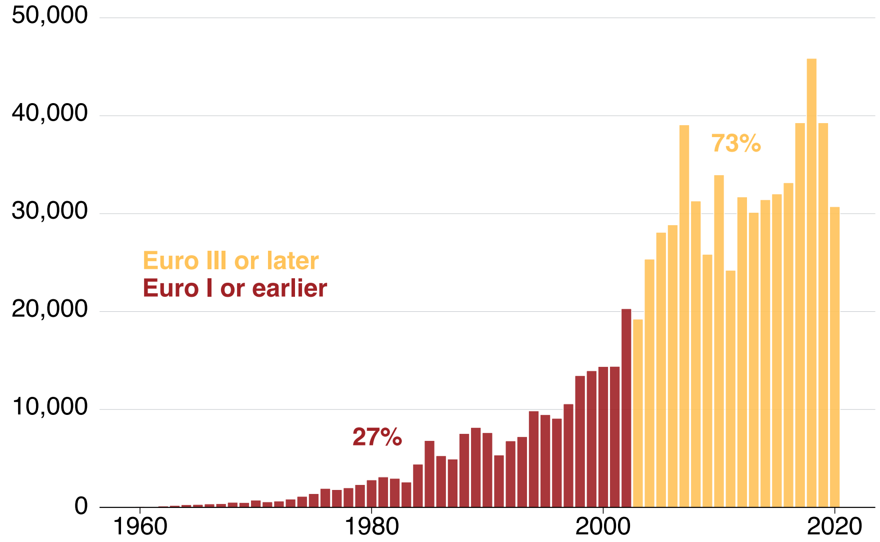
In 2002, standards were tightened to Euro-III for new models, and for existing models in 2003. Australia has progressively adopted higher Euro standards, although it is yet to adopt the most stringent Euro-VI standard.

Old, very dirty trucks make up a large share of the fleet, because Australians hold onto trucks for a lot longer than owners in other countries. The average age of an Australian truck is 15 years,[76] compared to 6 years in Austria, and 9 years in France, Germany, and the Netherlands.[77]

There are trucks on the road that are more than 40 years old, and more than 14 per cent of Australian trucks were manufactured before 1996. Another 12 per cent were manufactured between 1996 and 2002. This means that more than a quarter of the Australian fleet has not been required to satisfy any more than the most minimal pollution standards, or none at all (Figure 2.2).

Figure 2.2: More than a quarter of trucks on the road today were bought when there were minimal or no pollution standards

Number of heavy vehicles registered in 2021, by year of manufacture



Source: ABS (2021a).

76. Austroads (2021, p. 9).
77. EVC & ATA (2021, p. 3).

2.2.2 Old trucks inflict a large 'health cost'

Trucks sold before 2003 drive only about 8 per cent of the kilometres covered by trucks, but because their technology is so out-of-date they generate about 32 per cent of dangerous $PM_{2.5}$ emissions (Figure 2.3).

Old, dirty trucks aren't just driving around paddocks: each year they drive more than a billion kilometres through capital cities, and another 800 million kilometres in urban areas.[78] And more that 17 million Australians live in the capital cities, where they will breathe in pollution from dirty, old trucks.[79]

Between now and retirement, each truck will inflict a 'health cost' on Australians.

'Health costs' measure the effects of pollution in dollars, including the effects of reduced quality and length of life. Health costs don't include treatment costs – for example, the cost of treating heart disease, or childhood asthma.

The total health cost inflicted by each truck will depend on the type of truck, its standard of pollution-reducing technology, and the number of kilometres it will be driven before it is retired. It also depends on the location of the truck and its driving patterns: whether it will be driven in densely or sparsely-populated areas, and whether the health of people in these areas is more or less vulnerable to air pollution.

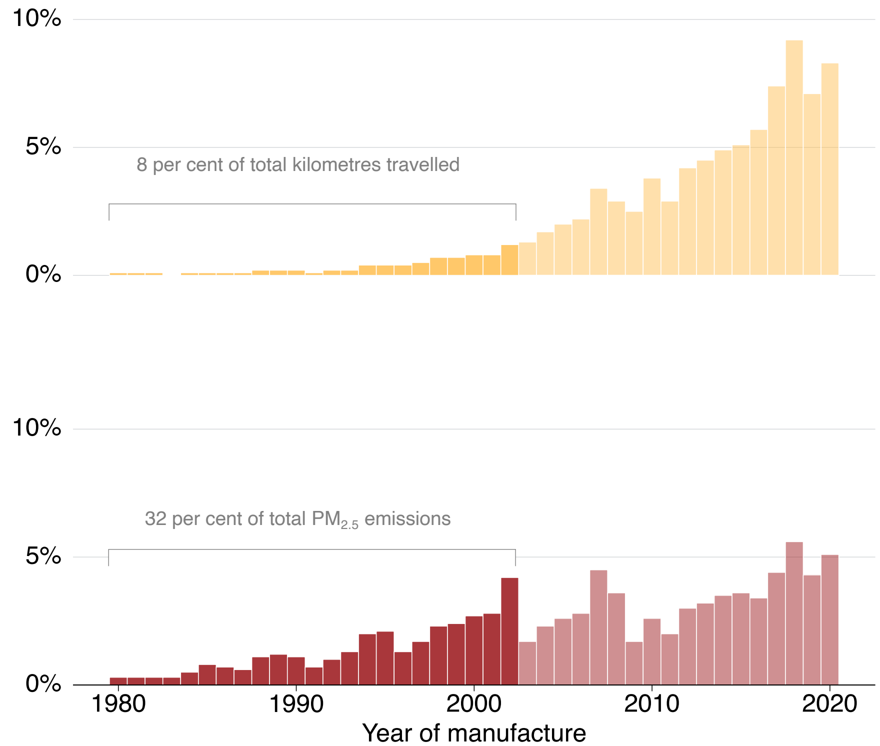
Within each generation of a Euro standard, the number of kilometres driven – and therefore health costs – decline with a truck's age. Newer trucks meet higher Euro standards and are fitted with better

78. ABS (2018). The Motor Vehicle Use Survey classifies vehicles by year of manufacture: older than 15 years; five to 15; and less than five years. In 2018 this was equivalent to manufacture in: 2002 or earlier; 2003 to 2012; and 2013 and later. This roughly accords with vehicles that are, respectively: pre-Euro and Euro-I; Euro-III and Euro-IV; and Euro V.

79. ABS (2021b).

Figure 2.3: Although they don't drive far, trucks manufactured before 2003 are big polluters

Proportion of kilometres travelled and $PM_{2.5}$ emissions, by year of vehicle manufacture



Notes: Estimates are for the 2022 fleet year. $PM_{2.5}$ emissions include exhaust emissions, brake and tyre wear, and secondary pollution. Road dust and road wear are not included in these estimates.

Source: The Grattan truck model (see Appendix A).

pollution-reducing technology, but drive more kilometres. This creates a distinctive 'saw-tooth' relationship between the age of trucks and the health costs they inflict (see Figure 2.4).

The average articulated truck purchased in 1995 will inflict about $75,000 worth of health damage between now and when it is retired.[80] By comparison, the average articulated truck purchased in 2020 will carry more goods, cover far more kilometres, and will be on the road for more years into the future – but it will inflict less health damage between now and its retirement.

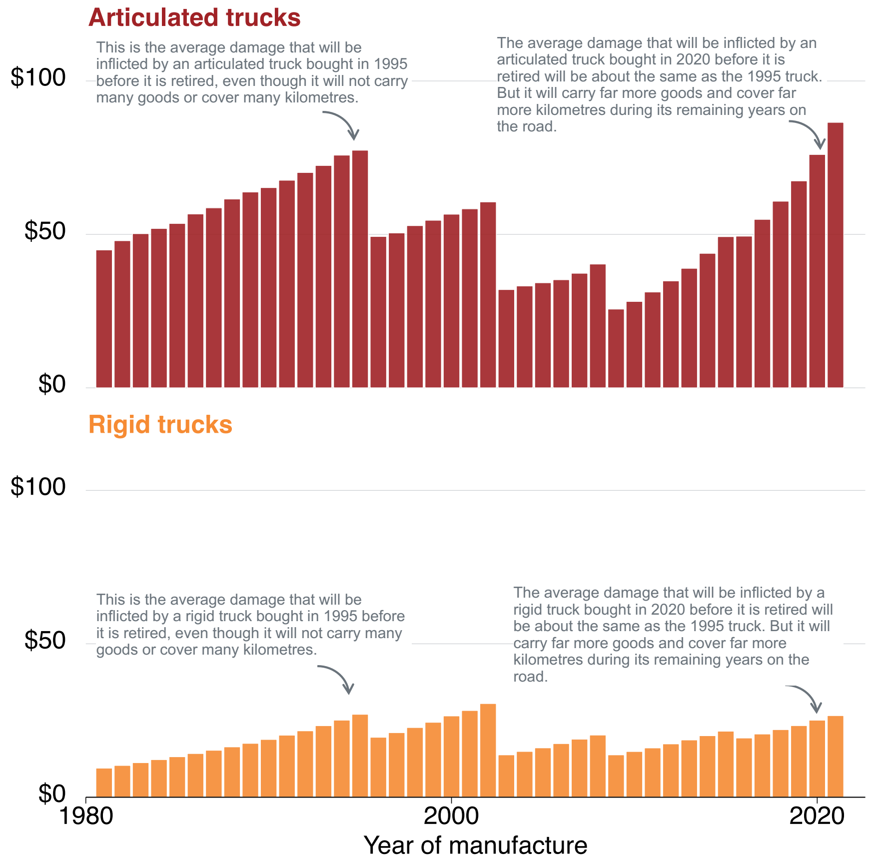
Similarly, the average rigid truck purchased in 1995 will cover fewer kilometres and be retired well before a truck sold in 2020. But it will inflict about the same amount of health damage in its remaining years as an average rigid truck purchased in 2020 – even though the newer truck will be far more productive.

The more kilometres a truck covers in a densely-populated area, the more harm it inflicts. For example, the average articulated truck sold in 1995 drives just over 25,000km each year. If it drives these kilometres exclusively in urban areas, it will inflict more than $120,000 worth of damage to people's health. If it drives these kilometres in sparsely-populated rural areas, the cost of the damage falls below $25,000. And if it drives the average mix of urban and rural kilometres, it inflicts just over $60,000 of health costs on the community (Figure 2.5 on the next page).

80. Articulated trucks include a powered unit, which contains the engine, which is attached to a trailer or trailers. Only the powered unit is responsible for air pollution. We use the term 'articulated truck' to refer to the powered unit.

Figure 2.4: There are big benefits in getting old, dirty trucks off the road as soon as possible

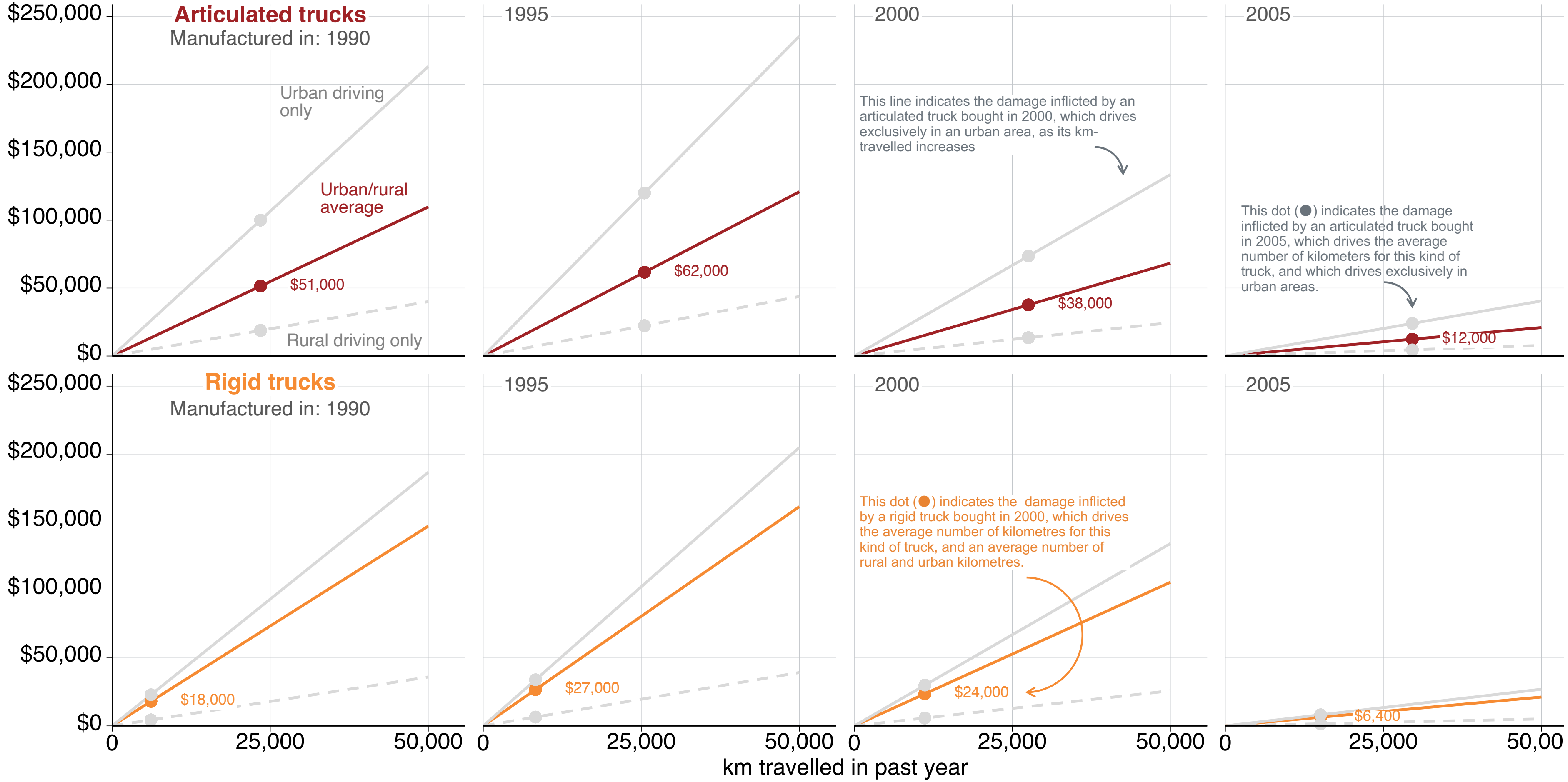
Estimated average health cost over the remaining lifetime of a truck (000s), by year of manufacture



Notes: Costs are discounted at 7 per cent, and averaged across urban and rural vehicle use. Only costs from air pollution are included; if carbon emissions, vehicle safety, or noise were included, estimated costs would be larger, particularly for older vehicles. Estimates do not account for deterioration of or tampering with pollution-control technology; as a result, actual costs may be higher, particularly for older vehicles.
Source: The Grattan truck model (see Appendix A).

Figure 2.5: The health cost inflicted by a truck depends on the type of truck, its age, the kilometres it travels, and where it travels

Estimated public health cost of trucks. Dots represent the estimated average km travelled in 2022, by a vehicle of the relevant type and year of manufacture



Notes: Costs are discounted at 7 per cent, and we assume vehicles are replaced with a Euro IV equivalent vehicle. Values have been rounded to the nearest thousand. Only costs from air pollution are included; if carbon emissions, vehicle safety, or noise were included, the estimated costs would be larger, particularly for older vehicles. Estimates do not account for deterioration of or tampering with pollution-control technology; as a result, actual costs may be higher, particularly for older vehicles.

Source: The Grattan truck model (see Appendix A).

2.3 Keep the most-polluting trucks away from people

Cities overseas have introduced low-emission zones to reduce the damage inflicted by the dirtiest trucks, and to encourage truck owners to upgrade. Australian cities should do this too, with financial support to help the owners of old trucks switch to cleaner trucks.[81]

2.3.1 Introduce low-emission zones to reduce air pollution in major cities

Low-emission zones ban highly-polluting vehicles from particular areas. They are well-established as an effective, practical way to reduce the damage done by trucks.

Some governments have introduced low-emission zones around shipping ports, because deliveries to and from ports attract large volumes of trucks. Governments in Long Beach and Santa Monica in California,[82] and in Vancouver,[83] have taken this approach.

Other governments have introduced low-emission zones in urban areas. In Europe there are more than 250 low-emission zones that cover trucks, including more than 50 in Germany. Urban low-emission zones for trucks also have been introduced in London,[84] Tokyo,[85] and Beijing.[86] Many cities are already planning a graduation from low-emission zones to zero-emission zones for trucks.[87]

Enforcement can be relatively simple. Germany, Spain, Austria, and France use stickers to signal the pollution emitted by each truck[88] – for example, based on Euro levels. The stickers must be displayed on each truck's windscreen or numberplate, and trucks with particular stickers are prohibited from low-emission zones. Trucks that do not display a sticker, or violate low-emission zone rules, receive a fine. Police and parking inspectors help enforce the rules.

Low-emission zones can also be enforced with cameras and number-plate recognition technology, drawing on databases that include information on vehicles' Euro standard. Denmark, Brussels, Antwerp, Ghent, Barcelona, and London use cameras to monitor their low-emission zones.[89]

Madrid's low-emission zone has resulted in an estimated 30 per cent reduction of nitrogen dioxide (NO_2).[90] On average, low-emission zones in Germany have secured 10 per cent reductions in PM_{10}.[91] And London's low-emission zone has led to an average reduction in NO_2 of about 20 per cent.[92]

Air pollution is distressing to people whether they live in a densely or sparsely populated place. But the damage is greatest in densely populated places, because they have more people and truck traffic.

The boundaries of low-emission zones need to be set to balance the goals of minimising harm to health while keeping the wheels of the economy and society turning.

81. Infrastructure Victoria has recommended a related approach, of reviewing restrictions on zero-emissions vehicles on freight routes:Infrastructure Victoria (2021a, p. 43).
82. EPA (2021, pp. 12–13).
83. Port of Vancouver (n.d.).
84. Transport for London (n.d.).
85. Tokyo Bureau of Environment (2018).
86. WRI (n.d.).
87. London and Rotterdam have schemes in place, and Shenzhen is running a pilot. The Dutch government has announced plans to implement zero-emission zones for trucks in 30-to-40 of the country's largest cities by 2025: ICCT (2021a). And California's Los Angeles Port is rolling out zero-emission technology in its low-emission zone: The Port of Los Angeles (n.d.).
88. Green Zones Europe (2022).
89. London's low-emission zone uses the same camera network that supports its congestion charging: Lemage (2019).
90. Transport & Environment (2019, p. 1).
91. Wolff (2014, F482).
92. GLA (2020, pp. 32, 43).

Although Australia's cities are sprawled, Sydney and Melbourne are home to large numbers of people living in densely-populated areas. In Sydney more than 3.5 million people live in suburbs with densities exceeding 2,000 people per square kilometre; in Melbourne, there are more than 2.75 million people living at these densities, which are comparable to cities like Hamburg, Cologne, and Edinburgh, which already have urban low-emission zones.

Sydney and Melbourne are also home to Australia's two busiest container ports,[93] which rely heavily on trucks.[94]

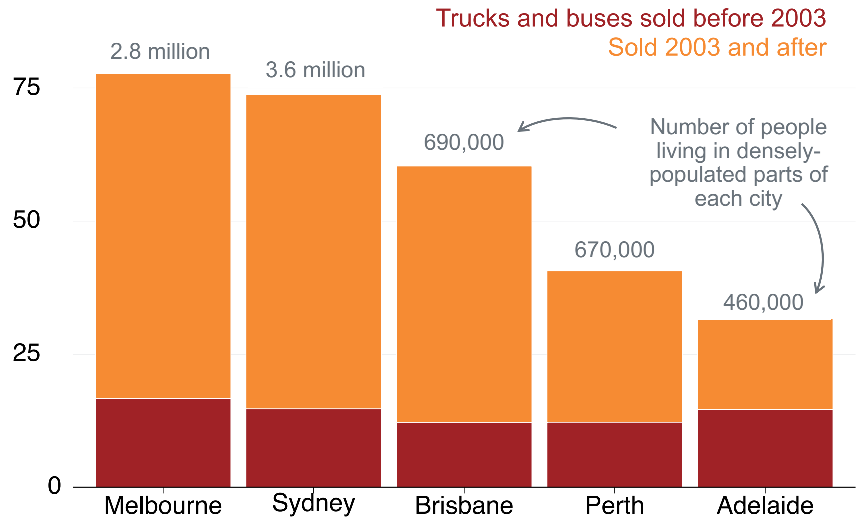
In the Sydney area there are nearly 15,000 highly-polluting trucks and buses manufactured before 2003, including about 1,500 old buses. There are nearly 17,000 highly-polluting heavy vehicles in Melbourne, including about 700 buses. This is equivalent to about 20 per cent of the heavy vehicle fleet in these cities (Figure 2.6).[95]

Sydney and Melbourne could remove large numbers of old trucks and buses, while experiencing only modest disruption to freight and other transport activity.

Brisbane and Perth have about 700,000 people living in densely-populated areas; in Adelaide the number is over 450,000 people. These three cities are also home to plenty of old trucks. The Queensland, West Australian and South Australian governments should review the case for low-emission zones in light of their capital cities' growing populations.[96]

Figure 2.6: All cities have plenty of old trucks, but they harm more people in bigger cities

Number of trucks and buses ('000s)



Notes: 'Densely-populated' is defined as a density of 2,000 people or more, per square kilometre, in 2016. The location of trucks and buses is based on the postcode where each vehicle is registered. Capital city definitions are based on the ABS greater capital city areas.
Sources: ARTSA-i (2022) and ABS (2016).

93. Port Technology (2022).
94. Laird (2021).
95. Registration data is at the postcode level: ARTSA-i (2022). Capital city statistics are based on ABS greater capital city areas: ABS (2016).
96. Grattan Institute is preparing more detailed work on the design of low-emission zones in urban and port areas.

Recommendation 1

State governments should introduce low-emission zones in Sydney and Melbourne in 2025. Trucks and buses sold before 2003 should be banned from the zones. Low-emission zones should be implemented with a low-cost sticker scheme, with police and parking inspectors authorised to monitor compliance. Fines should be high enough to deter banned trucks and buses from entering the zones.

After the zones have operated for five years, state governments should consider imposing tighter restrictions.

2.3.2 Give financial support to businesses to help them adjust to low-emission zones

Low-emission zones erode the value of old trucks, because they limit the places where the trucks can be used to generate income. Governments should provide financial support to truck owners affected by the introduction of a low-emission zone, because while the public benefits from the zone, owners bear the costs.

A truck-replacement support fund is a practical form of assistance. Truck owners should receive a voucher to help cover the purchase of a less-polluting truck, in exchange for proof that their higher-polluting truck has been scrapped. The value of the voucher should not cost taxpayers more than the health costs that are saved when a truck is scrapped.

To secure value for taxpayers, funds should be awarded competitively through a tender program (see Box 2). Owners whose bids are unsuccessful would be allowed keep their old truck, but not drive it in the low-emission zone without risking a penalty.

Box 2: How tender-based truck replacement funds work

Tender-based truck replacement funds invite the owners of old trucks to place a binding bid for how much money they would be prepared to accept in return for scrapping their truck. Participation is voluntary.

Bids include information about the truck's age and how far it drives in a year, so the government can estimate the quantity of air pollution created by the truck, and therefore the public health benefits of scrapping the truck.

The goal is for the government to spend the minimum necessary for each tonne of pollution prevented. A tender-based fund can achieve this by identifying the truck owners who are most willing to scrap their highly-polluting truck. All the bids can be compared, enabling the government to prioritise trucks for the replacement fund program.[a]

Similar schemes have been introduced in parallel with many low-emission zones, including in California's ports, across the US, and in Germany, Tokyo, and Beijing.[b]

a. For a review of best-practice truck upgrade programs, see Posada et al (2015, p. 10).
b. Ibid.

The loss of older trucks would reduce the number of trucks in use, but should not be particularly disruptive. Trucks manufactured before 1996 are responsible for only 3 per cent of tonne-kilometres covered by the fleet, while trucks manufactured between 1996 and 2003 are responsible for only 5 per cent of tonne-kilometres.

Recommendation 2

A truck-replacement support fund should be introduced from 2023, to help operators prepare for low-emission zones. Vouchers should be allocated by tender, with preference given to those truck owners for whom truck-scrapping would be least costly.

Some governments allow truck owners to retrofit pollution-reducing technology. Retrofit technologies can reduce particulate matter by more than 90 per cent, and NO_x by more than 60 per cent.[97] But not all trucks are candidates for retrofit technology.[98] Heavy-vehicle retrofit programs have typically been successful when they target similar heavy vehicles in a coordinated program, such as bus fleets and large fleets of trucks.[99]

Recommendation 3

State governments should evaluate the benefits and costs of retrofit programs for buses and trucks.

97. Kubsh (2017, p. 11).
98. Trucks need to be well maintained and to pass a vehicle inspection test. See, for example: MECA (n.d.).
99. Kubsh (2017).

3 How to reduce pollution from new trucks

Every year about 40,000 new trucks are sold in Australia,[100] and many of them are more polluting than necessary.

Pollution-reducing technology costs money, and businesses don't have much incentive to spend that money unless government regulations require it. And Australia's pollution standards for heavy vehicles are weak and out-of-date compared to the rest of the world's, even though pollution-reducing technology is readily available and the benefits of tighter pollution standards clearly exceed the costs.

New trucks could be less polluting, if the federal government found a way to balance the community benefits of reduced pollution with the additional costs to operators that this would entail. This could be done by adopting the most rigorous international standard, Euro-VI, and subsequent standards as they are set. To mitigate the costs to operators of tighter standards, the government should get rid of pointless truck regulations that make it more expensive than necessary to buy and operate a cleaner truck.

3.1 Australia's pollution standards for new trucks are weak

The technology to reduce pollution to Euro-VI standards is widely available. It is operational in about 80 per cent of the world's new trucks, because these trucks are sold in countries that require new trucks to comply with the latest international standards.[101]

International standards, known as the 'Euro' standards, impose limits on the quantity of harmful pollutants, such as nitrogen oxides and particulate matter, that new trucks can emit.[102] Manufacturers respond to these regulations by upgrading pollutant-reducing technology.

Australia introduced the Euro-V standard for trucks in 2011. More than 10 years later, the standard hasn't been updated. Moving from Euro-V to Euro-VI standards requires trucks to reduce nitrogen oxide emissions by 80 per cent, and to halve particulate matter.

Other countries moved on long ago. Canada and the US tightened their pollution standards to Euro-VI in 2010, Japan in 2011, and the UK and Europe in 2014.[103]

In fact, the vast majority of international truck sales meet the more stringent Euro-VI requirements. Australia is one of only six G-20 countries that have not adopted, or committed to, Euro-VI pollution standards. This puts us in the company of Saudi Arabia, Argentina, Russia, Indonesia, and South Africa. In the meantime, more ambitious countries are expected to announce even more stringent, Euro-VII, standards in 2022.[104]

3.2 Australia's truck operators currently have little incentive to opt for cleaner trucks

There are clear health benefits to the community to implementing Euro-VI pollution standards. But while the benefits would be felt broadly across the community, the cost of buying pollution-reducing technologies would initially fall on truck operators. Unless their

100. DITRDC (2020, p. 9).
101. BIC (2021, p. 4).
102. Emission standards for trucks are expressed in terms of PM_{10}, of which $PM_{2.5}$ are the most damaging component.
103. US EPA-2010 standards are equivalent to Euro-VI, while Japan's 'Post New Long-Term Emissions Standards' (pPNLT standards) are equivalent: TransportPolicy.net (n.d.[a]) and TransportPolicy.net (n.d.[b]).
104. Jin et al (2021, p. 2).

customers are prepared to pay for less-polluting transport services, truck operators that choose to invest in pollution-reducing technologies are at a potential cost disadvantage relative to their competitors. But if all companies were required to adopt these technologies, companies would be in a better position to pass on these costs to consumers.[105]

The public would benefit from tighter pollution standards

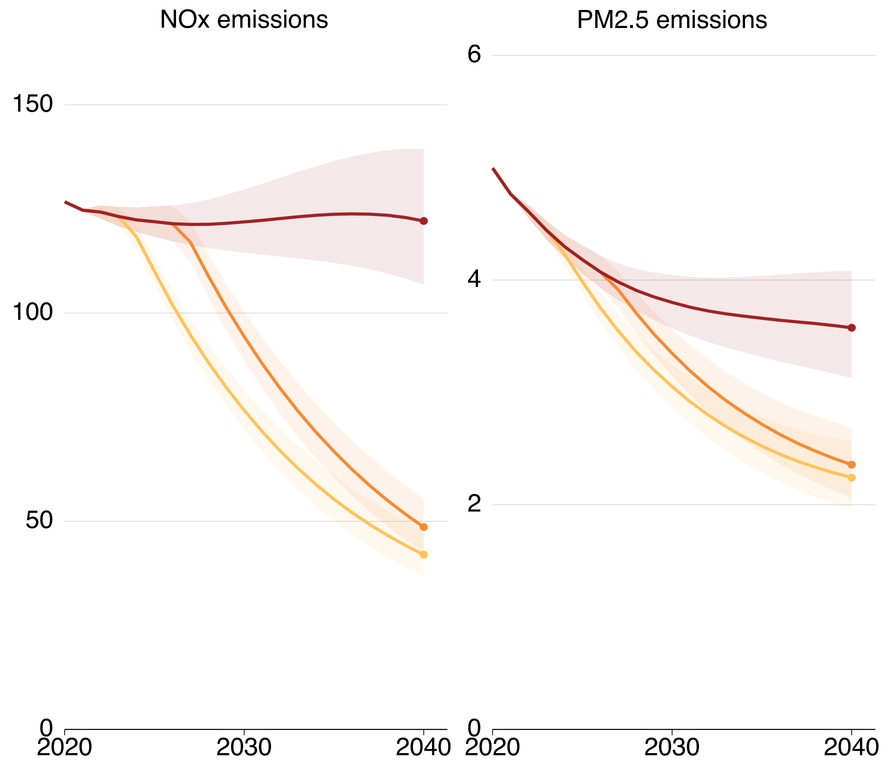
The federal government has been considering whether to introduce Euro-VI standards in 2027.[106] But these standards should be introduced from 2024.[107] The sooner Euro-VI standards are introduced, the sooner Australians can breathe cleaner air (Figure 3.1).

If Euro-VI standards for trucks were introduced in 2024, this would reduce nitrogen oxide emissions by more than 89,000 tonnes a year by 2040, or more than 65 per cent. The volume of $PM_{2.5}$ would be reduced by more than 1,000 tonnes each year by 2040, or about 35 per cent.

The resulting reduction in early death and disease can be quantified in dollars. Our analysis indicates that the cost of disease and death from air pollution would be reduced by about $1.7 billion a year by 2040 (Figure 3.2 on the following page). The total reduction in health costs between 2024 and 2040 would be about $6.5 billion.[108]

Figure 3.1: The sooner Euro-VI standards are introduced, the sooner dangerous exhaust-pipe pollutants will be reduced

Annual pollution from heavy vehicles ('000 tonnes) if Euro-VI standards are: not introduced, introduced in 2027, introduced in 2024



Notes: Confidence intervals represent upper and lower bound estimates of future freight activity only, and do not include uncertainties in pollution estimates. Pollution estimates include exhaust emissions, tyre wear, and brake wear. $PM_{2.5}$ estimates include secondary particulates formed from NO_x and SO_x emissions. Pollution from road dust and road wear is not included. For further detail, see the Appendix.
Source: The Grattan truck model (see Appendix A).

105. Some truck operators voluntarily adopt Euro-VI technologies when customers are prepared to pay for more socially and environmentally-friendly transport services. For example, Woolworths' truck operator has committed to a Euro-VI fleet: Prime Mover Magazine (2019).
106. DITRDC (2020).
107. Euro-VI could be introduced for petrol trucks from 2024, when Australia's refineries will produce petrol compatible with Euro-VI technology.
108. These savings in health costs have been calculated using a 7 per cent discount rate. See the Appendix for information on how we modelled the health costs.

Introducing Euro-VI standards would also have benefits beyond reduced air pollution, because Euro-VI trucks typically include other advanced safety and fuel-saving technologies.[109]

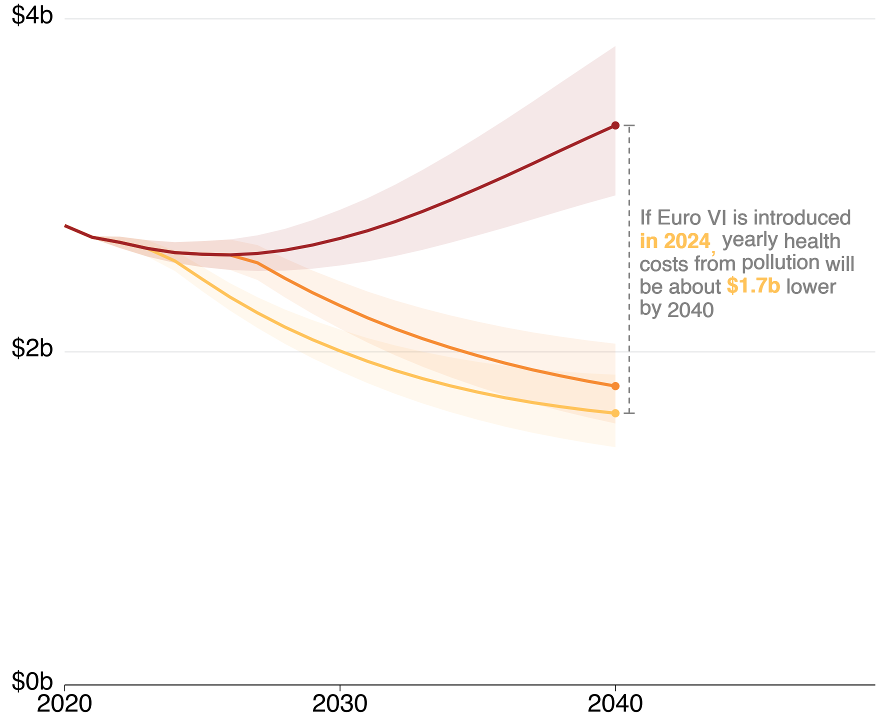
. . . but there would be costs

The biggest single cost of introducing Euro-VI standards would be installing pollution-reducing technologies, such as selective catalytic reduction technology to reduce exhaust-pipe nitrogen oxides, and diesel particulate filters to reduce exhaust-pipe particulate matter.[110] Euro-VI technologies are estimated to cost about 3-to-5 per cent more to produce than older technologies,[111] and the federal government has estimated that the increase in capital costs would amount to about $925 million over the period to 2040.[112]

Because Euro-VI trucks are about 100-to-150kg heavier than equivalent Euro-V models,[113] and because trucks must comply with mass limits, Euro-VI trucks have a lower maximum payload than their Euro-V equivalents. Government estimates put the cost to industry of reduced loads at about $230 million between 2027 and 2040.[114]

Figure 3.2: Euro-VI standards for heavy vehicles would reduce health costs by about $1.7 billion a year by 2040

Yearly health costs from pollution if Euro-VI standards are:
not introduced, introduced in 2027, introduced in 2024



Notes: Costs are not discounted. Confidence intervals represent upper and lower bound estimates of future freight activity, and do not include uncertainties in pollution estimates. Health costs are derived from estimates of NO_x, SO_x, $PM_{2.5}$, PM_{10}, and VOC emissions, and calculated using damage costs. Pollution estimates include exhaust emissions, tyre wear, and brake wear. $PM_{2.5}$ estimates include secondary particulates formed from NO_x and SO_x emissions. Pollution from road dust and road wear is not included, and is not reflected in health costs. For further detail, see the Appendix.

Source: The Grattan truck model (see Appendix A).

109. DITRDC (2020, p. 10).
110. ICCT (2016a, p. 8).
111. DITRDC (2020, p. 9).
112. Government estimates assume that Euro-VI would be introduced in 2027 rather than 2024. The estimate of $925 million brings forward government estimates by three years. Estimated costs are discounted at a rate of 7 per cent. See DITRDC (ibid, pp. 35–36) for a breakdown of estimated annual costs.
113. DITRDC (ibid, p. 10). This is likely to be a lower-bound estimate.
114. Government estimates of productivity costs assume that Euro-VI would be introduced in 2027 rather than 2024. If costs were unchanged, and brought forward by three years, the total estimated cost would be just under $230 million between 2024 and 2040. Estimated costs are discounted at a rate of 7 per cent, and also account for expected changes to road wear. See DITRDC (ibid, pp. 35–36) for a breakdown of estimated annual costs.

As well as the costs of the technology and the reduction in payload, the federal government has estimated that businesses would face a regulatory burden cost of about $275 million each year.[115]

The costs of introducing Euro-VI standards would initially be paid by businesses – manufacturers and operators. As far as possible, businesses would pass these costs on to their customers.[116] Lower running costs could also mitigate some of these costs, because Euro-VI models are 5-to-10 per cent more fuel efficient than Euro-V models.[117]

3.3 Ensure new trucks are less polluting

The challenge for the federal government is to achieve community gains from tighter pollution standards, while minimising the impact on truck operators and consumers. The following subsections propose a path.

3.3.1 Introduce Euro-VI standards for new trucks

In all, the federal government has estimated that the benefits of introducing Euro-VI would far outweigh the costs.[118] If Euro-VI standards were introduced in 2024, the benefits to the community would be more than double the costs in the period to 2040.[119]

We recommend Euro-VI standards be introduced at what is called Stage C. Later stages exist – Stage D and Stage E – but these would require additional on-road testing of different truck configurations.[120] Such testing is less important than it used to be, because the gap between laboratory and on-road tests has narrowed in recent years.[121]

The mechanism to implement the Euro-VI Stage C standard is an update to the Australian Design Rules (ADRs).[122]

Recommendation 4

The federal government should update the Australian Design Rules to require compliance with Euro-VI Stage C standards from 2024 for newly-approved models of heavy vehicles, and from 2025 for all new heavy diesel vehicles.

Recommendation 5

When Euro-VII pollution standards for heavy vehicles are announced, the federal government should assess the costs and benefits of adopting them.

115. The regulatory impact statement does not explain the components of the additional cost of complying with Euro-VI compared to Euro-V.
116. Whether costs are passed on by manufacturers to freight customers, such as retailers and building companies, would depend on those customers' price sensitivity and availability of other options. Where possible, those customers would further pass on costs to final consumers. We expect that the costs of Euro-VI standards would be primarily borne by final consumers.
117. Euro-VI trucks are more fuel-efficient, but also incur higher fuel additive (AdBlue) costs, than Euro-V trucks. The net effects of changes to these two running costs are contested: NatRoad (2021, p. 6).
118. The federal government has twice evaluated the merits of introducing Euro-VI in 2027. Both times it has concluded that the public health benefits substantially outweigh the costs to manufacturers and industry, delivering 'significant benefits'. It estimates a direct health and well-being benefit of $6.67 billion by 2050: DITRDC (2020, p. 27).
119. Based on government estimates of annual costs and benefits, updated to bring forward implementation from 2027 to 2024, and discounted from 2022. The benefits would be close to $13 billion over the period between 2024 and 2040.
120. DITRDC (2020, p. 29).
121. ICCT (2016a, p. 12).
122. ADRs are regulated through the *Road Vehicle Standards Act 2018a* (RVSA); see DITRDC (2020, p. 8).

3.3.2 Update regulations that make it hard to adopt best-practice pollution standards

Some regulations in Australia are costly and out-of-date. Truck operators and consumers would benefit if these regulations were updated to reflect modern technology and global norms, as the following subsections explain.

There is no need for Australian trucks to be 2 per cent narrower than the global norm

Australian trucks are limited to a maximum width of 2.5 metres.[123]

But the vast majority of internationally-manufactured trucks are slightly wider than 2.5 metres: trucks in the UK, Europe, and New Zealand are allowed to be 2.55 metres for most and 2.6 metres for refrigerated vehicles; in the US, widths of 2.6 metres are allowed.[124]

Australia's width rule is costly. While there can be exemptions to the width rule, truck operators must apply for this exemption through the Performance Based Standards scheme and satisfy additional safety requirements. This makes it unnecessarily difficult to import the full international range of trucks with modern pollution-reducing technology.

Australia is only about 1 per cent of the global market for trucks,[125] so some Australian firms specialise in providing trucks to meet the local width requirement. But modern safety and fuel-saving technologies are developed for 2.55m and 2.6m trucks sold in the international market.

Local firms will find it increasingly difficult to include these technologies in a narrower truck – for example, to improve drivers' field of vision, truck cabs may need to be redesigned to benefit from technology providing indirect vision.[126] And non-compulsory, modern safety technologies are often removed from imported trucks to comply with Australia's width limits. Width limits can also prevent Australian operators from purchasing optional safety technologies that are used overseas.[127] An additional benefit of wider trucks is that they are more stable, reducing the risk of rollovers.[128]

There is no reason Australian trucks should be narrower than trucks overseas.[129] Although critics point out that Sydney's Parramatta Road has lanes as narrow as 2.7 metres wide at one point, it makes little sense for a handful of idiosyncratically narrow roads, important as they may be, to stymie access to better trucks for all operators.

In general, Australian traffic lanes are comparable to or wider than lanes in the US, the UK, and Europe. A standard traffic lane in Australia is 3.5 metres wide, narrowing to 3 metres for low-speed roads with low truck volumes.[130] This is comparable to traffic lanes in Europe, the UK, and the US.[131]

Indeed, the recommended width of traffic lanes has crept up over time; the 2009 official guidance recommended general traffic lanes be 3.3-to-3.5 metres wide, and low-speed roads with few trucks be 3.0-to-3.3 metres wide.[132] The recommended widening of traffic lanes has occurred at the same time as improvements in safety technologies, including lane departure warning systems and cameras, which help

123. The ADRs are given effect through the Heavy Vehicle (Mass, Dimension, and Loading) National Regulation 2013, which is a state- and territory-based law that sits under the *Heavy Vehicle National Law Act 2012*: NTC (2022a).
124. NVHR (2020, p. 23).
125. DITRDC (2020, p. 9).
126. DITRDC (2021, p. 10).
127. NVHR (2020, p. 23).
128. NHVR and NTC (2020, p. 53).
129. Grattan Institute has previously recommended that the heavy vehicle width be increased to 2.6 metres: T. Wood et al (2021a, p. 30).
130. NVHR (2020, p. 23).
131. DITRDC (2021, p. 6).
132. Austroads (2009, pp. 44–46).

wider trucks remain safely in their lane.[133] And the trucks in Australia that are 2.55 metres wide are no more likely to be involved in crashes than 2.5 metre-wide trucks.[134]

Recommendation 6

The Australian Design Rules should be updated to allow truck widths up to 2.6 metres from 2023, provided trucks satisfy safety requirements consistent with the Performance Based Standards.

The federal government should increase mass limits so cleaner trucks aren't penalised

To limit the damage that trucks inflict on road surfaces, governments impose limits on the mass trucks can carry. For trucks with a single steer-axle, which is the axle at the front, the limit is 6.5 tonnes for a truck that complies with Euro-IV standards, which were introduced in 2008. Older trucks have a mass limit of 6 tonnes.[135]

Dealing with the damage to road surfaces is mainly the responsibility of state and local government road managers. Although heavy vehicles incur a road-user charge designed to cover maintenance as well as new road spending, road managers may prefer prevention to remediation, for two reasons. One is that heavy vehicle charges have been essentially static since 2014, even though the cost of pavement improvements, road rehabilitation, and the like, have increased significantly over recent years.[136] The second is that, even if the revenue was keeping up with costs, there is no specific mechanism by which the revenue from the road-user charge necessarily flows through to maintenance budgets.[137]

Current mass limits make it more expensive to meet Euro-VI standards because, under Euro-VI standards, operators must adhere to lower payloads to compensate for the additional weight of heavier vehicles.[138]

There are opportunities to increase trucks' payload without increasing the burden on taxpayers, because wider tyres can be used to minimise damage to roads by distributing mass across more of the road.

Most trucks use 295mm tyres on their steer axle. But a 7-tonne load on a single steer-axle with tyres at least 375mm wide causes less road damage than a 6.5-tonne load on 295mm tyres.[139]

When it is possible to carry heavier loads without doing more damage to roads, national regulations should be updated to improve productivity.

133. NVHR (2020, p. 23).
134. DITRDC (2021, p. 5). The same is true in New Zealand: Austroads (2019).
135. These rules apply in all states and territories except Western Australia and the Northern Territory. A Northern Territory permit process also allows additional increments of 100 kg, up to 7 tonnes. Road trains are allowed to carry up to 6.7 tonnes on their steer axle if their tyres are wider than 375mm. Austroads (2016).
136. NTC (2022b, pp. 7, 13–15).
137. The disconnect between road infrastructure charges, and road quality, investment and maintenance, has been identified as a barrier to freight productivity. Road pricing has been identified as a priority reform for improving productivity: DIRC (2018b, pp. 10, 31).
138. NVHR (2020, p. 23).
139. Austroads analysis based on sealed unbound granular road surfaces, which are the surfaces on most sealed roads in Australia: Austroads (2016).

Recommendation 7

The *Heavy Vehicle National Law Act 2012* should be updated to allow trucks to carry up to 7 tonnes on their steer axle from 2023, as long as the truck is fitted with tyres that are at least 375mm wide. All signatory states and territories should adopt these changes. The Western Australian Government should implement these recommendations through the *Road Traffic (Vehicles) Act 2012*, and the Northern Territory Government through the Motor Vehicle (Standards) Regulations 2003.

The federal government should conduct further research on whether wider tyres successfully mitigate additional road damage for twin-steer axle trucks, and non-steer axle trucks, with a view to increasing load limits.

4 How to reduce carbon emissions from trucks

Trucks and buses generate a significant and growing share of Australia's carbon emissions.

Although the federal government has committed to achieving net-zero emissions by 2050, the heavy vehicle sector is unlikely to reduce its emissions to zero by 2050. There is scope, however, to make good progress towards that goal, with actions that would be less costly than the expected cost of carbon offsets.

In the period before widespread uptake of zero-emissions vehicles, engine- and tyre-specific standards would reduce emissions from diesel trucks. In the longer-term, the focus should be on accelerating the uptake of zero-emissions heavy vehicles.

4.1 Carbon emissions from trucks are increasing

Heavy vehicles account for 4 per cent of Australia's carbon emissions. That was nearly 22 million tonnes (Mt) of carbon dioxide in 2020,[140] and it is forecast to grow to about 26Mt by 2030 (Figure 4.1).[141]

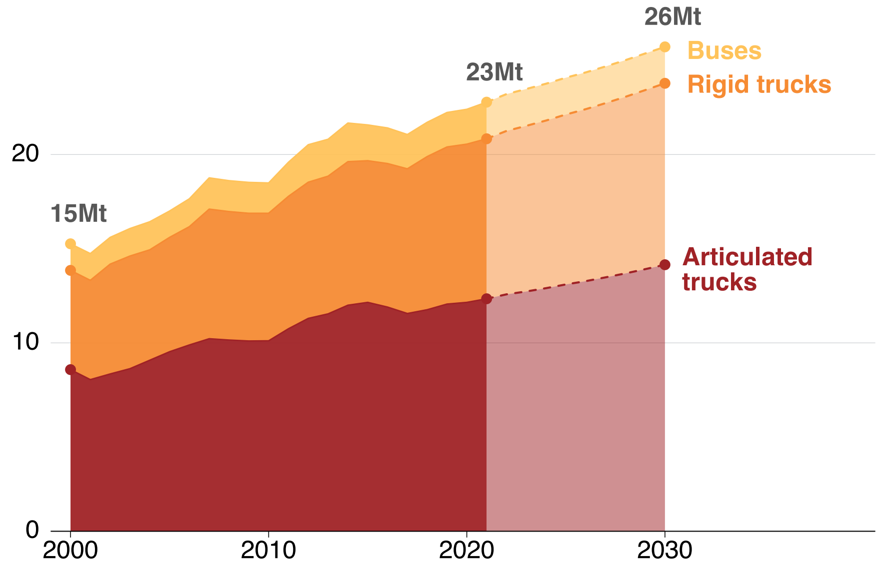
The federal government has committed to reducing carbon emissions by 43 per cent by 2030, relative to 2005 emissions, and to achieving net-zero emissions by 2050. It plans to achieve these targets using sector-specific policies. But because the heavy vehicle sector is unlikely to achieve zero carbon emissions, any emissions from the sector will need to be offset.

This could be extremely costly. If heavy vehicle emissions keep rising on their current path, and assuming today's offset price of \$35 a tonne,[142] the cost of offsetting emissions from trucks could

140. DCCEEW (2021).
141. Grattan analysis.
142. Jarden Australia (2022).

Figure 4.1: Emissions from heavy vehicles are forecast to rise between now and 2030

Annual greenhouse gas emissions (Mt, CO_2-e) from heavy vehicles



Notes: CO_2-e is the volume of carbon emissions with equivalent global-warming potential to the volume of greenhouse gases emitted by heavy vehicles. Historical data is from DISER (2021a). Forecasts are based on Grattan Institute analysis.
Sources: DISER (ibid) and the Grattan truck model (see Appendix A).

exceed $980 million in 2050. But $35 a tonne is probably a very low assumption, since Australia does not yet have binding annual targets to achieve net zero by 2050, and the integrity of the Australian carbon credit system has been subject to scathing criticism.[143] In the European market, the most established in the world, prices have climbed as high as $140 a tonne in 2022.[144] At $140 a tonne, the cost of offsetting emissions from trucks in Australia would be $3.9 billion. And the cost could end up much higher; by 2050, according to CSIRO forecasts of different policy scenarios, offsets could cost as much as $1,000 a tonne.[145]

But there is scope to minimise the future offset bill by abating some of those emissions at relatively low cost.[146]

4.2 There are barriers to buying and using zero-emissions trucks

There are very few zero-emissions trucks in Australia, and sales are only marginally higher internationally – just over 2 per cent of heavy vehicle sales in Europe during 2020.[147]

These vehicles, powered by electric batteries or hydrogen fuel-cells, produce no carbon emissions or pollutants at the exhaust pipe, and they are quieter than diesel trucks.

143. Greber (2022). See T. Wood et al (2021b) for a detailed discussion of the Australian carbon offset market.
144. Chestney (2022) and Trading Economics (2022).
145. Whitten et al (2022).
146. If truck operators have a legal obligation to offset emissions, they will pass these costs on to end-consumers as much as market circumstances allow. We expect truck operators' offset costs to be borne primarily by final consumers.
147. ICCT (2021b, p. 2).

Battery electric or hydrogen trucks are carbon-neutral only if they are powered by renewable electricity or green hydrogen.[148] But even today, based on the average emissions intensity of the main Australian energy grid, an electric truck has a substantially smaller carbon footprint than a comparable diesel truck (Figure 4.2 on the next page). As Australia's energy mix shifts to renewables, the environmental and health benefits of zero-emissions trucks will increase.

Over its lifetime, an electric articulated truck would emit about half the carbon dioxide of its diesel alternative. And by 2030, lower-emissions electricity sources will mean that an electric truck will emit only a fraction as much carbon dioxide as a diesel truck.

But in the short term there are barriers to buying and using zero-emissions trucks. The key barriers are cost, functionality, and the uncertainty for operators in switching to a different technology. The following subsections explain these barriers and their impacts.

4.2.1 The cost barrier is falling

It is far more expensive to buy a zero-emissions truck than it is to buy an equivalent diesel truck. For an articulated truck, the difference in upfront cost can be as much as $200,000.[149]

But zero-emissions vehicles are cheap to run.[150] Per kilometre, the cost of electricity is far less than the cost of diesel. Because zero-emissions vehicles have fewer moving parts, they are also significantly cheaper to maintain than diesel vehicles.[151]

148. Green hydrogen is hydrogen generated solely through renewable energy sources. This is distinct from blue or grey hydrogen, which is produced using fossil fuels such as natural gas: Purtill (2021).
149. EVC & ATA (2021).
150. The analysis in this chapter is based on battery-electric trucks.
151. ICCT (2021c, p. 14).

The purchase price of a battery electric truck is expected to fall about 26 per cent on 2020 prices by 2025, and 50 per cent by 2030.[152] As the purchase price of zero-emissions trucks falls, there will be a point when the total cost of owning and operating a zero-emissions truck becomes lower than that of a comparable diesel truck. This point, known as total-cost-of-ownership parity, is not far away. Overseas estimates suggest that in many countries, articulated trucks could reach total-cost-of-ownership parity by about 2030, and rigid trucks in 2027 or earlier.[153]

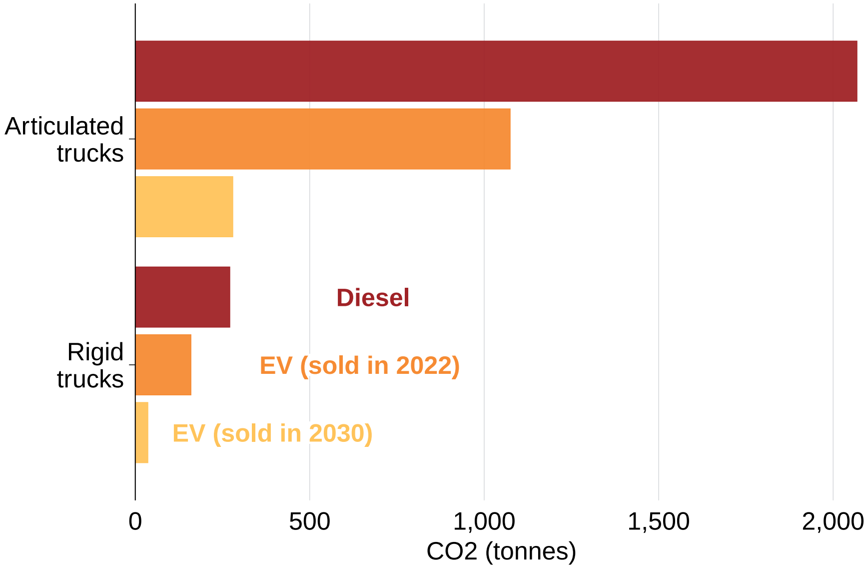
It's likely to be similar in Australia for most classes of truck. We estimate that the average articulated truck will reach total-cost-of-ownership parity between 2025 and 2029, and rigid trucks between 2024 and 2029.[154] Our estimates are consistent with other Australian studies – for example, a study in Queensland reported that for specific operations, such as regional and urban hauls, battery electric trucks could achieve total-cost-of-ownership parity by 2025.[155]

4.2.2 Practical barriers are also starting to come down

The key practical barrier to switching to zero-emissions vehicles is refuelling. Diesel trucks can refuel quickly at petrol stations, but publicly-accessible hydrogen refuelling stations and charging stations are few and far between.[156] Battery-electric trucks can also be slow to recharge, eating into the time a truck can spend on the road and therefore making scheduling and rostering harder.

Figure 4.2: Electric trucks produce significantly lower carbon emissions than diesel trucks

Estimated lifetime carbon emissions from a heavy vehicle



Notes: EV = electric vehicles. Grattan analysis, based on average vehicle use and estimated fuel and electricity consumption. Emissions from electric vehicles are calculated using the Australian Energy Market Operator (AEMO) 'step change' scenario for emissions intensity of the electricity grid.
Source: The Grattan truck model (see Appendix A).

152. ICCT (2021d, p. 13).
153. ICCT (2021e).
154. Timelines for trucks that are not widely used overseas, such as B-triples, are more uncertain.
155. QTLC (2022).
156. Dowling (2021).

This practical barrier is starting to fall.[157] Battery technology is improving rapidly. Solid-state batteries and lithium-sulfur batteries are much more energy-dense than conventional batteries, and will allow zero-emissions trucks to travel further per charge, without sacrificing payload.[158] Tesla battery pack supplier Panasonic is aiming to improve battery density by 20 per cent in the next five years.[159]

Better charging options are also emerging. Ultra-fast chargers, including 500kW and megawatt chargers, are coming online. A truck with a 600kWh battery pack could be fully re-charged in just over an hour with a 500kW charger, and slightly over half an hour with a megawatt charger. And Australian company Janus is building a battery-swap route along the eastern seaboard for its electric trucks.[160] Battery swaps would eliminate the effects of charging time on operators.

In light of these advances, truck manufacturers are preparing for increased demand for zero-emissions trucks. Scania and Renault have both announced a target of 10 per cent of zero-emissions truck sales by 2025. Daimler, MAN, Scania, Volvo, and Renault have all announced zero-emissions truck sales targets between 35-and-60 per cent by 2030.[161] And the Australian Trucking Association, representing Australian truck operators, advocates ambitious government targets of 30 per cent of new truck sales to be zero-emissions by 2030, and 100 per cent by 2040.[162]

As noted in Section 3.3.2, updating the Australian Design Rules to allow truck widths up to 2.6 meters would give Australian truck operators more access to the best, and cheapest, technologies from overseas – including zero-emissions technologies.[163]

4.2.3 Switching costs are a potential stumbling block

Another barrier operators face is a more subtle one: the costs of switching to zero-emissions trucks. Switching costs include costs such as researching new technology, developing consensus across a business, and dealing with unknown risks.

Each low- and zero-emissions technology has its own operational trade-off between weight, range, refuelling and recharging flexibility, and refuelling and recharging time. Operators will need to weigh up operational priorities, figure out when and where their electric trucks might charge, and whether to rely on publicly-accessible infrastructure or invest in private infrastructure. These hassles, costs, and uncertainties can be avoided by sticking with diesel trucks.

By 2030, many types of zero-emissions trucks will have a lower total-cost-of-ownership than diesel trucks. Once price parity has been reached, and if zero-emissions trucks meet operators' functional needs, operators would financially benefit from buying zero-emissions instead of diesel trucks. And every purchase of a zero-emissions truck that displaces a diesel truck means fewer carbon emissions.

157. Infrastructure Victoria (2018).
158. See Transport & Environment (2022, p. 5) regarding solid-state batteries, and McAlpine (2022) regarding lithium-sulfur batteries. Electric vehicles typically use lithium-ion batteries.
159. Road & Track (2021).
160. Janus Electric (2021).
161. ICCT (2021b, p. 17).
162. EVC & ATA (2021). The ATA has called for Australian governments to become signatories of a Netherlands-led global memorandum of understanding on zero-emissions trucks. The memorandum calls for zero-emissions truck sales targets of 30 per cent by at least 2035, and 100 per cent by 2040 to 2050: TDA (2021).
163. DITRDC (2021, p. 7).

But before operators take the plunge and buy their first zero-emissions truck, they will want to know that it's going to be worthwhile. The easiest way to do this is to wait for another operator to move first. This makes sense for each operator, but collectively holds back the transition.

Some truck operators are dipping their toe in the water. Victoria Bitter and Linfox are making deliveries with zero-emissions Volvo trucks,[164] and Australia Post has 20 Fuso eCanters on the road.[165] Rio Tinto, BHP, and Fortescue have established partnerships with zero-emissions truck manufacturers.[166]

But for many businesses, switching will take time. And an apparent lack of demand dampens manufacturers' willingness to make zero-emissions trucks available, limiting Australian buyers' access to the international range of zero-emissions trucks. There are currently 58 models of zero-emissions trucks available across the US, Europe, and China, but only 9 models available in Australia.[167]

There are actions governments can take to accelerate the transition to zero-emission trucks, and to curtail emissions from diesel trucks in the meantime.

The rest of this chapter focuses on low-cost, practical policies to reduce carbon emissions from trucks: engine- and tyre-specific technology standards for new diesel trucks, and sales targets for zero-emissions trucks. These policies are expected to be cheaper than offsetting the equivalent volume of emissions in future, and would reduce annual emissions by about 2.5 million tonnes by 2030. By 2040, annual emissions from trucks would be almost half the emissions under a business-as-usual scenario (Figure 4.3 on the following page).

By reducing the scale of the future offset challenge, these policies also reduce environmental and economic risks. Carbon offset policies in 2050 cannot be guaranteed, and there is considerable uncertainty about the future costs, permanence, and measurement of many offsetting activities.[168]

4.3 Near-term actions to reduce carbon emissions from trucks

The most common type of scheme to reduce truck emissions around the world is an emissions ceiling, or standard. Section 4.3.1 explains how these schemes work. But they take 7-to-9 years to set up, as Section 4.3.2 explains, which effectively means Australia has missed the boat on this approach.

However, much of the gain available from an emissions ceiling is available by implementing specific technology standards. Section 4.3.3 on page 38 explains how engine-specific and tyre-specific standards could work.

4.3.1 Many countries impose truck emissions ceilings

Around the world, the most common type of scheme to reduce emissions from new trucks is an emissions ceiling.[169] Sometimes called an emissions standard, an emissions ceiling sets a limit on the average carbon intensity of new trucks.[170] Each year manufacturers must not exceed the limit, based on the average emissions intensity of all their

164. Volvo (2021).
165. Hill (2021).
166. Rio Tinto (2021); Australian Mining (2021); FMG Fortescue (2022).
167. EVC & ATA (2021, p. 18) and EVC (2022, p. 4). The lack of available models is a major barrier to buying zero-emissions trucks: QTLC (2022) and EVC & ATA (2021).
168. T. Wood et al (2021b).
169. Emissions ceilings for trucks have been introduced in the EU, the US, Canada, China, India, and Japan: Kodjak et al (2015).
170. The carbon intensity of a truck is measured in grams of carbon per kilowatt hour, with kilowatt hours being the measure of a truck's power.

truck sales. Over time the emissions ceiling is lowered, so that new trucks become progressively less emissions-intensive, on average.

To reduce the carbon intensity of a truck, manufacturers use design features and technologies that make it easier for trucks to gather and maintain momentum. They may reduce the weight of a truck, make it more aerodynamic, fit low-rolling-resistance tyres,[171] or upgrade the transmission to conserve fuel by improving the way the truck moves through its gears.[172]

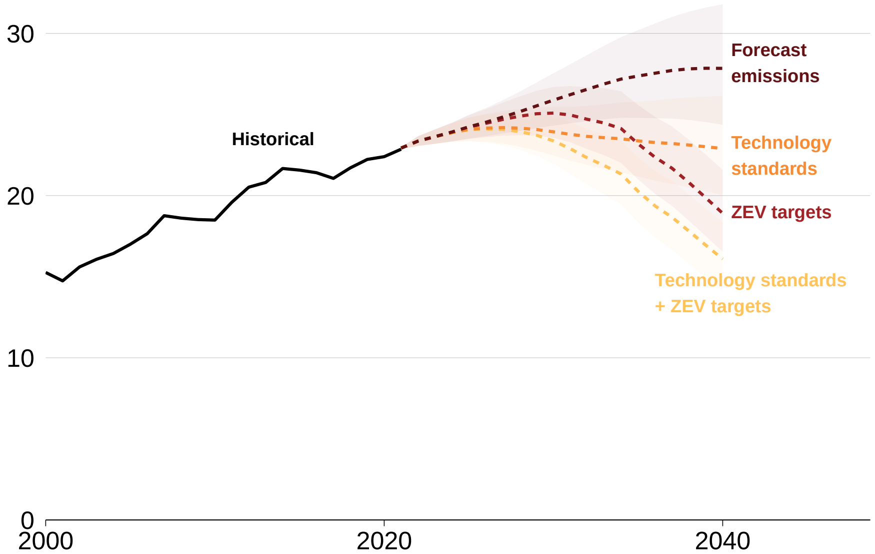
4.3.2 . . . but Australia has missed the boat on an emissions ceiling

An emissions ceiling offers manufacturers flexibility, but creates a measurement challenge: regulators need to measure the carbon intensity of a truck either by simulation modelling or vehicle testing. Neither of these tools can be developed and implemented quickly.[173] The wide variety of truck configurations means that emissions ceilings are harder to implement for trucks than for cars.

Other countries have typically needed 7-to-9 years to develop an emissions ceiling scheme for heavy vehicles.[174] It's therefore unlikely that a carbon emissions ceiling for heavy vehicles could be implemented in Australia before about 2029.

Figure 4.3: Carbon emissions from trucks could be reduced with tyre- and engine-specific standards in the near-term, and longer-term zero-emissions sales targets

Forecast carbon emissions from heavy vehicles under different policy scenarios (Mt)



Notes: ZEV = zero-emissions vehicle. Historical emissions are from DISER (2021a). Confidence intervals represent upper- and lower-bound estimates of future freight activity only, and do not include uncertainties in pollution estimates. Emissions from electricity generation to power zero-emissions vehicles are included in totals. For diesel vehicles, upstream emissions (scope 2) are not explicitly included in estimates.
Sources: DISER (ibid) and the Grattan truck model (see Appendix A).

171. About one-third of the energy produced by the engine of a truck is used to overcome rolling resistance, so tyres with a high rolling resistance slow a truck down, and require more energy – in the form of fuel – to travel the same distance (Popov et al (2003, p. 1071) and NACFE (2020)).
172. ICCT (2015a, p. 4).
173. If Australia regulated emissions by adapting an existing international simulation tool, such as the EU's Vehicle Energy Consumption Tool, lead times might be shorter: ICCT (2019a). But it is not certain that international models could be easily adapted for Australia.
174. ICCT (2015b, p. 6).

And even if the federal government were to develop an emissions standard, by the time it was ready an emission standard would be less useful than simpler near-term actions to reduce carbon emissions.

4.3.3 The low-hanging fruit is technology standards for engines and tyres

Australia lags many countries in not having an emissions ceiling for trucks. But Australia does have the opportunity to bypass that stage and introduce other policies to cut emissions.

Two types of technology have been shown to deliver particularly low-cost emissions reductions: more fuel-efficient engines, and tyres with less rolling-resistance (Figure 4.4).

In fact, manufacturers often choose to meet emission ceilings requirements overseas by focusing on improvements to engines and tyres.[175]

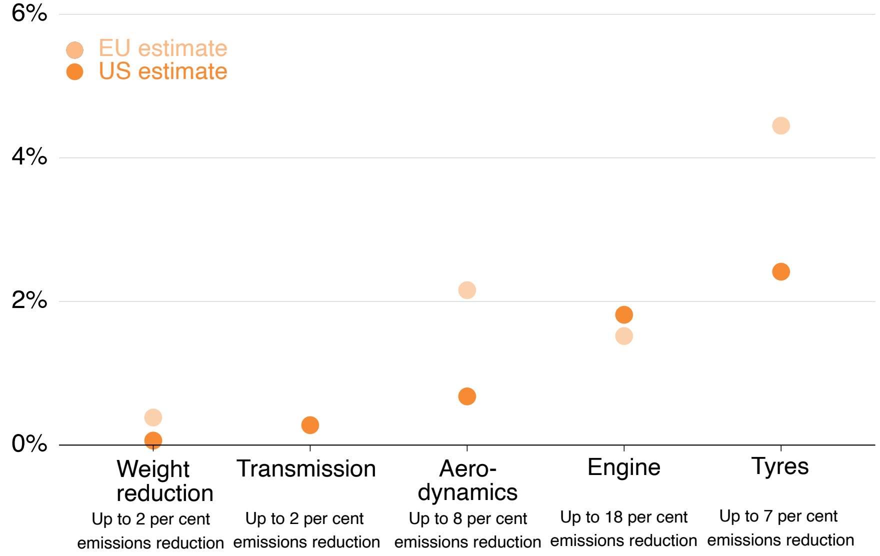
Engine-specific standards and tyre-specific standards are regulations that require truck manufacturers to reduce the carbon emissions associated with the engines and tyres that they sell with new trucks (Figure 4.5 on the next page).

For example, $1,000 spent on a more fuel-efficient engine will reduce emissions by almost 2 per cent per kilometre, and carbon reductions of about 18 per cent can be achieved compared to current engines.[176] And $1,000 spent on less rolling-resistant tyres can deliver emissions reductions of between 2.5 per cent and 4.5 per cent per

175. Manges (2021).
176. ICCT (2015a), ICCT (2017, p. 38), ICCT (2019b) and ICCT (2015c). The reported emissions reductions are based on estimates of fuel efficiency improvements that are achievable by 2030, based on estimates of the baseline fuel efficiency of a 2022-era Euro V Australian trucks. Additional reductions beyond 18 per cent may be more expensive or not possible.

Figure 4.4: Engine- and tyre-specific standards achieve more reductions in carbon emissions per dollar than other technologies

Estimated vehicle fuel-efficiency improvements available for a cost of $1,000 (per cent carbon dioxide reduction per kilometre)



Notes: Values are EU and US estimated emissions reductions, achievable by 2030, calculated for long-haul trailer trucks from ICCT data. No EU estimates are available for transmission data. Costs are based on carbon reductions achieved with investments of $1,000, and these costs are valid up to the total percentage gains possible for each technology. For example, $1,000 spent on improved engine efficiency yields an average reduction in emissions of just under 2 per cent, and spending $9,000 on improved engine efficiency will on average reduce carbon emissions by just under 18 per cent. Additional reductions beyond 18 per cent may be more expensive or not possible.
Source: The Grattan truck model (see Appendix A).

kilometre. Further expenditure on tyre technology can deliver emissions reductions up to about 7 per cent, compared to the average current tyre. Improved aerodynamics might also deliver substantial reductions in carbon emissions per dollar, but the evidence is more mixed.

By 2030, tyre and engine standards could reduce the emissions from an average new truck by nearly 25 per cent and deliver significant fleet-wide emissions reductions.[177]

There are no regulatory barriers to engine-specific standards

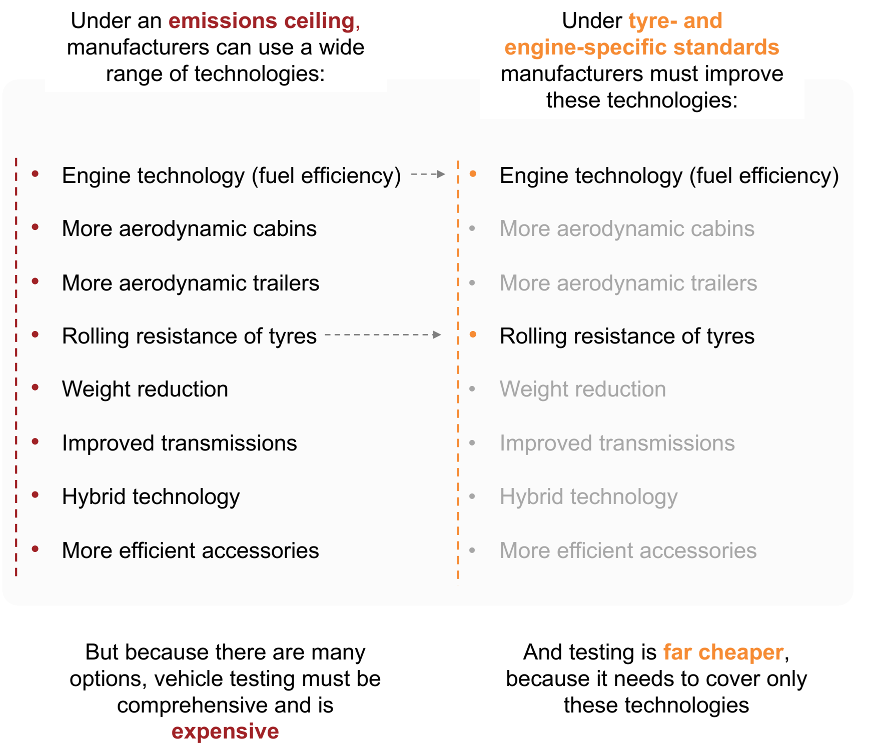
Engine standards are based on fuel efficiency. Regulation of engine standards is well-established overseas, and often used in tandem with emissions ceilings.

The first carbon emissions regulations for heavy vehicles were introduced in Japan in 2005, and exclusively regulated engine efficiency.[178] Engine standards came into force in the US in 2011,[179] and an engine standard has been proposed for India as a first step to broader heavy vehicle emissions policies.[180]

Engine-specific standards would be cost-effective for truck operators in Australia. More efficient engines increase the upfront cost of a heavy vehicle, but we estimate that reduced fuel use would provide operators with net savings within 6-to-12 months for an average articulated truck.[181]

177. Emission reductions are relative to a 2022-era Euro V vehicle. In the US, between 2010 to 2020, regulations for heavy vehicles mandated emission reductions of about 20-to-40 per cent for common heavy vehicle categories. By 2027, the total mandated emission reductions will exceed 35 per cent compared to 2010 levels for most common heavy vehicle categories: NACFE (2020, p. 31).
178. TransportPolicy.net (2019).
179. EPA (n.d.).
180. ICCT (2015d).
181. Grattan Institute analysis, calculated using a 7 per cent discount rate. We assume a diesel cost of $1.59/L. This price includes a base diesel price of $1.33/L, and

Figure 4.5: Technology standards are simpler to implement than an emissions ceiling



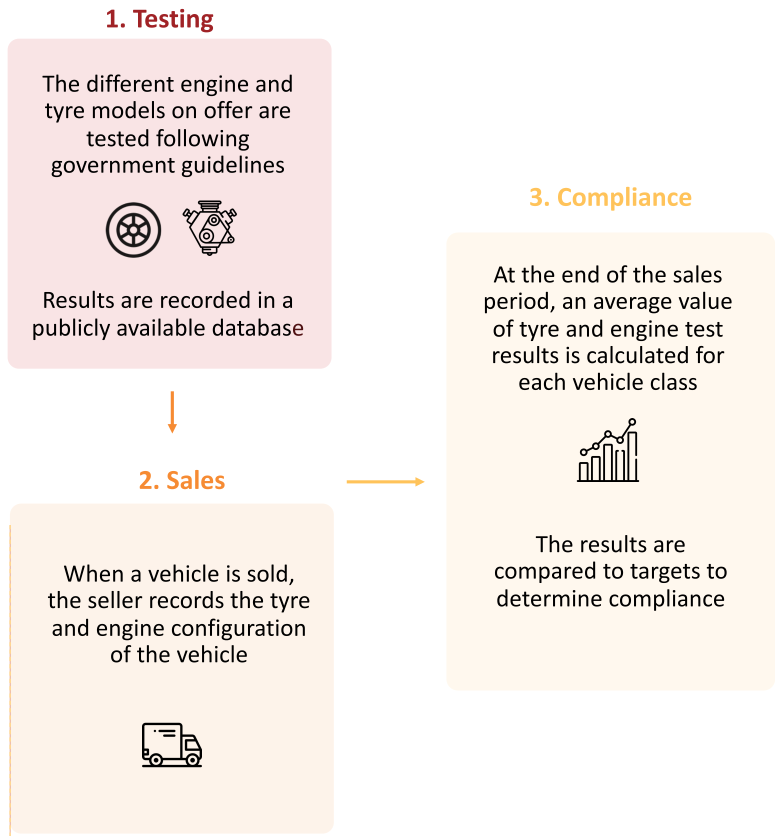
Source: Grattan analysis.

Engine-specific standards would be relatively straightforward for the government to administer in Australia. Each engine model would be tested to determine its fuel efficiency; since engine tests are already used in Australia to measure exhaust-pipe pollutants, testing could be expanded to evaluate fuel efficiency without adding significant costs.[182] Over the course of a year, manufacturers would record details of the engines they sell. At the end of the year, sales records would determine the average fuel efficiency across the engines sold by each manufacturer. Average engine fuel-efficiency would then be assessed against a manufacturer's targets (Figure 4.6).

Based on improvements in fuel-efficiency that have already been achieved in the US and Europe, and based on US and European targets, we estimate that average engine fuel-efficiency improvements of 3 per cent per year are possible in Australia, compared to a baseline of a 2022 Euro-V engine. Between 2024 and 2030, engine standards could achieve an 18 per cent improvement in fuel efficiency and carbon emissions from trucks.

These fuel-efficiency targets could be refined if, as a first step, Australian authorities collected data on current average fuel efficiency across the heavy vehicle fleet. The government could then establish ambitious annual targets for the years between 2024 and 2030, and beyond.

Figure 4.6: Implementing technology standards



Note: Icons from https://www.flaticon.com/
Source: Grattan analysis.

the current heavy vehicle user charge of 26.4c/L. The price does not include the fuel excise, because this is rebated to most truck operators.

182. ICCT (2016b, pp. 2–4).

Recommendation 8

In 2024 the federal government should introduce an engine-specific standard for new heavy vehicle sales. The standard should initially require average fuel-efficiency improvements of 3 per cent per year compared to a baseline 2022 Euro-V engine, subject to an assessment of the current average fuel efficiency of heavy vehicles in Australia.

The barriers to tyre-specific standards are not high

Tyre-specific standards are based on the rolling-resistance of a tyre. The higher the rolling resistance, the more energy it takes to propel the vehicle, and the higher the carbon emissions. The relevant measure is known as the coefficient of rolling resistance. A 3 per cent improvement in the coefficient of rolling resistance of a truck's tyres is estimated to deliver about a 1 per cent reduction in the truck's carbon emissions.[183]

The coefficient of rolling resistance is relatively simple and cheap to measure, and international testing and labelling schemes already exist – for example, in the EU and US.[184]

Tyre-specific standards could be cost-effective for truck operators in Australia. Upfront costs would generally be paid back in less than six months for an articulated truck, because tyres with less rolling-resistance deliver fuel savings.[185]

183. ICCT (2017, pp. 44–45).
184. In the EU, tyres are required to be labelled according to their rolling resistance: European Commissions (2009). In the US, the EPA uses tyre rolling-resistance test data to produce a list of verified 'low rolling-resistance' tyres, known as the SmartWay list: EPA (2022).
185. ICCT (2021f, p. 21).

Tyre-specific standards would be relatively straightforward for the government to administer in Australia. Each year, the average coefficient of rolling resistance would be calculated, based on the rolling resistance of all tyres fixed to new trucks. Over the course of a year, manufacturers would record details of the tyres fixed to each new truck. At the end of the year, sales records would determine the average coefficient of rolling resistance, and that average would be assessed against a manufacturer's targets (Figure 4.6). Annual improvements in average rolling resistance of about 2-to-4 per cent are feasible, corresponding to a carbon-emissions reduction of about 4-to-8 per cent by 2030.[186]

Recommendation 9

In 2024 the federal government should implement tyre standards for new trucks. Targets should be expressed as per cent annual improvements in the average rolling resistance of tyres, and secure average carbon reductions of about 1 per cent per year.

The main impediment to a tyre-specific standard is out-of-date regulations governing the width of tyres, as the following subsection explains.

Overcoming regulatory barriers to tyre-specific standards

Current regulations discourage the use of low rolling-resistance tyres known as wide singles. Wide single tyres are designed to replace dual

186. Based on evidence from the EU and analysis of a 2020-to-2030 timeframe: ICCT (2017, pp. 44–45). Studies from the US estimate similar improvements are possible: ICCT (2021f). Based on the characteristics of Australia's truck fleet and existing tyres, we expect potential annual improvements in the coefficient of rolling resistance to be at the upper limit, or even greater, than these estimates.

tyre configurations, in which two narrow tyres are placed close together at each end of an axle. Dual tyre configurations are extremely common.

Current mass limits are based on the number of tyres fitted to axles, regardless of the width of those tyres. The mass limit for a non-steer axle is 8.5-to-11 tonnes for a dual-tyre configuration, depending on the type of truck; the mass limit for non-steer axles with single tyres is between 6 and 7 tonnes.[187] Replacing two tyres with a wide single tyre penalises truck operators by limiting their allowable mass.

Wide single tyres reduce the risk of rollovers by more than 15 per cent,[188] so current mass limits are also a potential barrier to truck safety improvements.

Previous research has shown that wider tyres on steer axles cause less damage to the road surface than narrower tyres, even when bearing additional weight.[189] And current research is assessing whether wide single tyres on non-steer axles cause more road damage than dual tyre configurations with conventional tyres.[190] Further research is needed to assess road damage under the full range of modern tyre technologies, tyre pressures, and tyre configurations – for example, twin-steer axles – so that mass limits and tyre-pressure limits can be updated to balance the goals of reducing carbon emissions and minimising road damage.[191]

187. NHVR (2016, p. 5).
188. Based on evidence from New Zealand; see Big Rigs Tech Talk (2021).
189. Austroads (2016).
190. trucksales.com (2021).
191. The maximum allowable tyre pressure in Australia is 825 kPa (120 psi), but some modern tyres have recommended inflation pressures that exceed this limit: TERNZ Transport Research (2019, p. 8)

Recommendation 10

The federal government should work with state and territory governments to update the National Heavy Vehicle Law to reflect current research, so that mass limits do not penalise wide single tyres with low rolling-resistance. All signatory states and territories should adopt these changes. The Western Australian Government should implement these changes through the Road Traffic (Vehicles) Act 2012, and the Northern Territory Government through its Motor Vehicle (Standards) Regulations.

The federal government should research road damage under the full range of modern tyre technologies, tyre pressures, and tyre configurations and update mass limits.

The database of tyre rolling-resistance values should be made publicly available.

4.3.4 What about biodiesel and renewable diesel?

Biodiesel and renewable diesel have a potential role as part of the low-carbon technology mix, particularly if future governments limit carbon emission from trucks already on the road.

Biodiesel and renewable diesel are lower-carbon alternatives to conventional diesel (Box 3 on the next page). But these options are not widely used.

Biodiesel and renewable diesel are more expensive than conventional diesel.[192] And while some businesses are voluntarily reducing emissions from trucks, most businesses' operational decisions are based on cost. Without an economy-wide price on carbon, there is no

192. Pedrick and McGurty (2022).

regulatory incentive for most operators to reduce emissions from their trucks.[193]

Current fuel quality standards also limit the share of biodiesel that can be blended into conventional diesel,[194] so businesses that want to use higher blends of biodiesel face administrative hurdles.

The government could facilitate the use of biodiesel by lowering administrative barriers to businesses using biodiesel blends above 5 per cent. The government should also consider introducing a renewable fuel standard requiring retailers and wholesalers to blend renewable diesel with conventional diesel,[195] which would help reduce carbon emissions from the existing fleet of diesel trucks.

4.4 Longer-term actions to reduce truck emissions

The barriers to zero-emissions trucks may be falling, but more slowly than many might wish.

A common approach used overseas to accelerate the transition is to set binding targets for zero-emissions truck sales and phase-out dates for combustion engines.

For instance, the UK plans to end the sale of combustion-engine heavy vehicles weighing less than 26 tonnes by 2035, and by 2040 for vehicles weighing more than 26 tonnes.[196] Fifteen countries signed the COP26 pledge to aim for 100 per cent zero-emissions truck and bus

193. The exception is companies that emit more than 100,000 tonnes of greenhouse gases each year. Such companies are covered by the government's Safeguard Mechanism: CER (2022) These businesses, including the transport companies Toll and Centurion, are required to satisfy carbon emission limits that will decline to net-zero by 2050.
194. Kinrade et al (2015, p. 32).
195. See T. Wood et al (2021a, p. 32) for more detail on this policy.
196. UK Department for Transport (2021).

Box 3: What is low-carbon diesel?

Conventional diesel is a carbon-dense fossil fuel. But there are two types of diesel that are less carbon-intensive.

Biodiesel is similar to conventional diesel, but creates fewer carbon emissions when it is burned.[a] It is produced from vegetable oils and waste fats using a process known as 'transesterification'. Since 2009, regulations have allowed blends of up to 5 per cent biodiesel to be sold without additional labelling. Blends up to 20 per cent are permitted subject to an approvals process. A 20 per cent blend of biodiesel lowers carbon emissions by up to 15 per cent per litre.[b]

Renewable diesel is processed the same way as conventional diesel, and it is chemically identical. It is sometimes referred to as a 'synthetic diesel'. Like biodiesel, it can be made from vegetable oils and waste fats. It can also be made from agricultural waste and other feedstocks. It is often called a 'drop-in' fuel because it can replace conventional diesel without major changes to diesel engines or fuel distribution networks. Carbon emissions from renewable diesel are typically about 75-to-80 per cent lower than emissions from conventional diesel.[c]

a. Alternative Fuels Data Centre (n.d.).
b. EPA (n.d.).
c. Mu et al (2022).

sales by 2040,[197] and Norway has set a 50 per cent zero-emissions sales target for new heavy vehicles by 2030.[198] In the US, 15 states have signed a memorandum of understanding that heavy vehicle sales should be 100 per cent zero-emissions vehicles by 2050, phased in from 30 per cent no later than 2030. California is aiming for 75 per cent of rigid truck sales and 40 per cent of articulated truck sales to be zero-emissions vehicles by 2035.[199]

A similar approach would be effective in Australia, particularly if combined with targeted assistance to help truck operators to adapt. The following subsections explain.

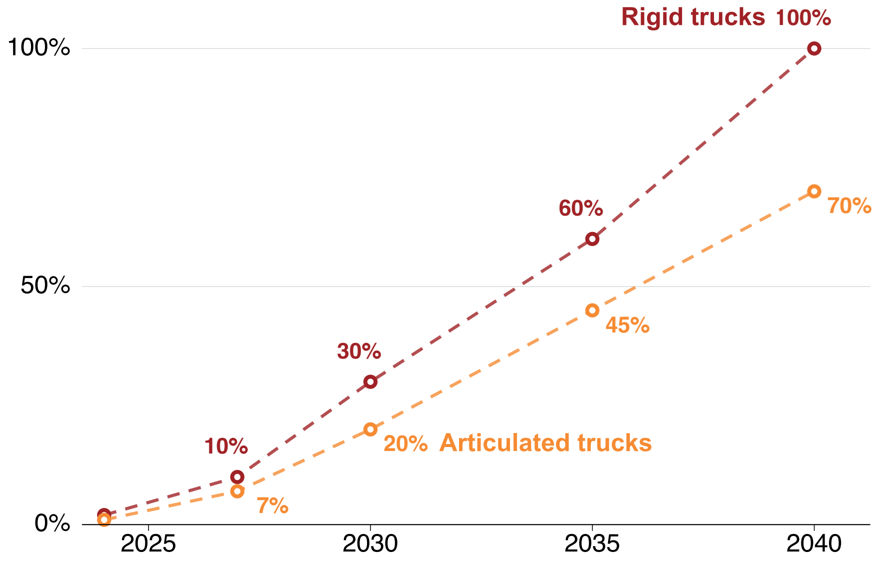
4.4.1 Introduce binding sales targets for zero-emissions trucks

Binding sales targets for zero-emissions heavy vehicles would bring forward some purchases of battery-electric and hydrogen fuel-cell trucks, hastening the switch to a zero-emissions fleet.

We propose sales targets for zero-emissions rigid and articulated trucks, expressed as a share of new truck sales, be introduced from 2024.[200] This is an ambitious start date, but valuable as a signal of policy direction. From 2027 sales targets should be enforced with financial penalties that are big enough to achieve compliance. In the first year of the scheme, manufacturers would be required to make sure that 2 per cent of their sales of rigid trucks were zero-emissions, and 1 per cent of their sales of articulated trucks. These sales targets would then increase over time, reaching 100 per cent of new rigid trucks and 70 per cent of new articulated trucks in 2040 (Figure 4.7).

Figure 4.7: Grattan Institute's proposed sales targets for zero-emissions trucks

Sales targets for zero-emissions rigid and articulated trucks as a share of new sales



Source: Grattan analysis.

197. Global Drive to Zero (2021).
198. ICCT (2021g).
199. Ibid.
200. Zero-emission sales targets would increase demands on the energy grid. Cost-reflective electricity tariffs and network pricing would help smooth the transition: T. Wood et al (2021a, pp. 22, 34).

Our modelling indicates there would be net benefits to such a policy.

The benefits to the community would be worth $10.3 billion between now and 2040. These benefits would be shared by businesses and the public, with the larger share going to businesses.

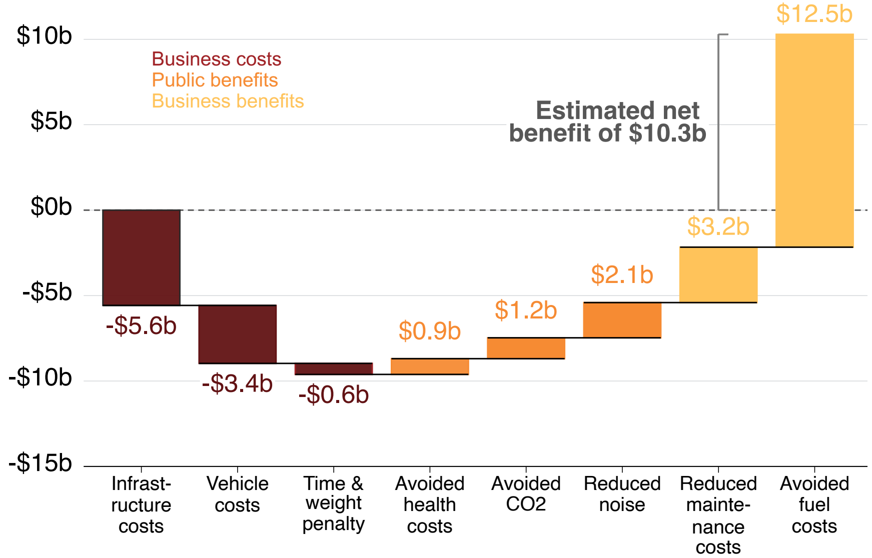
The costs of introducing binding sales targets would initially fall on businesses, and total about $5.6 billion between 2024 and 2040. The largest component would be vehicle-charging infrastructure, at $5.6 billion. Businesses would also bear about $4 billion of vehicle costs, and $0.6 billion of time and weight penalty costs.

But businesses would secure in total $15.7 billion of benefits. By far the largest component of these benefits would be reduced fuel costs, at $12.5 billion. Reduced maintenance costs would also be substantial, at $3.2 billion. Taken together, sales targets for zero-emissions vehicles would generate more than $6 billion in benefits for businesses.

The community as a whole would also benefit from an accelerated switch to zero-emissions trucks. A monetary value of more than $4 billion can be placed on these benefits, with the largest component coming in the form of reduced noise pollution. Reduced carbon emissions can be valued at $1.2 billion over the period. Health benefits from lower levels of air pollution are additional to the health benefits associated with adopting Euro VI standards discussed in Chapter 3, and can be valued at close to $1 billion (Figure 4.8).

Figure 4.8: Businesses and the public would benefit from our proposed sales targets for zero-emissions trucks

Estimated costs and benefits between 2024 and 2040 of zero-emissions targets for heavy vehicles



Notes: Calculated using a 7 per cent discount rate, over the period 2024 to 2040 (with residual values included). Assumes a diesel price of $1.33/L, electricity price of $0.15/kW, and a social cost of carbon of $35/tonne, consistent with DIRD (2016a, p. 58) and current offset prices (Greber (2022)). This diesel price does not include the fuel excise tax or the heavy vehicle road-user charge, because both are payments made to governments, and therefore do not have a total net cost. Maintenance costs includes AdBlue costs, lubricants, and oils. Infrastructure costs relate to vehicle-charging infrastructure only. The time and weight penalty category assumes: 1.5 per cent more zero-emissions trucks are required than diesel trucks, to account for payload loss from weight; and 3 per cent more zero-emission trucks are required to account for time loss from vehicle-charging requirements: ICCT (2019c). The avoided health cost category includes estimates of health costs associated with large-scale power generation. We assume that Euro VI regulations become mandatory in 2024. If Euro VI does not become mandatory until 2027, the avoided health costs will be significantly larger than estimated here.

Source: The Grattan truck model (see Appendix A).

Recommendation 11

The federal government should set binding zero-emissions sales targets, applied to the sellers of new heavy vehicles. Initial targets for rigid trucks should come into force at 2 per cent in 2024, rising to 30 per cent by 2030, and 100 per cent by 2040. Initial targets for articulated trucks should come into force at 1 per cent in 2024, rising to 20 per cent by 2030, and 70 per cent by 2040.

These sales targets should be enforced with financial penalties from 2027.

4.4.2 Provide targeted assistance to help truck operators to adapt

Truck operators would benefit over the long term if binding zero-emissions sales targets were introduced. But in the short term, before total-cost-of-ownership parity with diesel trucks, operators do not have an incentive to switch to a zero-emissions truck.

More operators would switch sooner if the total-cost-of-ownership gap was reduced. Because the public would benefit from sales targets – through reduced carbon emissions, noise pollution, and exhaust-pipe pollutants – the federal government should, for a limited time, offer support to businesses that buy zero-emissions trucks.

The government and the business should share 50:50 the cost gap between buying a zero-emissions truck or a diesel truck. As happens overseas, the government should offer vouchers to businesses at the point of purchase.[201]

201. California, for example, has a voucher program for zero-emissions trucks which complements mandated sales targets for manufacturers: California HVIP (2021).

For example, if the total-cost-of-ownership gap between a diesel and zero-emissions truck is $50,000, the government would provide a voucher of $25,000 – as long as the public benefits over the vehicle's life exceeded this value. The vouchers should not cover more than half the cost gap, because businesses, as well as the public, would ultimately benefit from an accelerated, taxpayer-supported transition to zero-emissions trucks.

As the total-cost-of-ownership gap closes, the value of vouchers would shrink. When zero-emissions trucks reach total-cost-of-ownership parity with diesel trucks, the voucher scheme would end, because there would be no justification for taxpayer support.

Recommendation 12

While zero-emissions trucks have a higher total-cost-of-ownership than diesel trucks, binding sales targets should be accompanied by a government voucher program to subsidise the cost of new zero-emissions trucks. The vouchers should not exceed the value of public benefits associated with each sale, and should not exceed half of the total-cost-of-ownership gap.

4.4.3 Provide non-financial incentives for zero-emission trucks

State and local government rules prevent trucks' access to some roads, or limit access to fixed hours. These policies are sometimes motivated by concerns about congestion in peak hours, but also by concerns about air pollution and disruptive levels of noise in residential areas.

State and local governments should ease noise-based curfew and access restrictions for zero-emissions trucks, because they are far less polluting and disruptive.[202]

This would support faster uptake of zero-emission trucks,[203] and benefit both truck operators and residents. The benefits would be particularly pronounced in areas with high-traffic freight routes servicing ports, and in densely-populated residential areas where delivery and service trucks can be very disruptive.

202. For example, the Electric Vehicle Council and the Australian Trucking Association (see EVC & ATA (2021, p. 5)) and Infrastructure Victoria (see Infrastructure Victoria (2021b, p. 39)).
203. Infrastructure Victoria (2021a, p. 43).

Appendix A: The Grattan truck model

Much of the analysis in this report is based on the 'Grattan truck model'. We developed the model using the programming language *R*. Our truck model is publicly available on the Grattan Institute GitHub: https://github.com/grattan/grattan-truck-model.

The Grattan truck model covers the years 2022 to 2040. We designed it to estimate:

- a 'simulated fleet', which estimates the mix of heavy vehicles in the fleet, and the activity of the fleet under different policy scenarios;
- carbon emissions, air pollution, and the health costs of pollution from the simulated fleet under different policy scenarios; and
- the costs and benefits of zero-emissions sales targets.

The mix of heavy vehicles in the fleet, distance travelled, and location of travel

Our 'simulated fleet' is a model of the whole fleet of heavy vehicles. We estimated the mix of different types of heavy vehicles, in the past and in the future, and the number of kilometres they have travelled in the past and will travel in the future.

The model includes vehicles weighing more than 3.5 tonnes, which we classified by:

- type of vehicle: articulated truck, rigid truck, bus, or non-freight-carrying truck;
- year of manufacture; and
- type of engine (diesel or zero-emissions).

We used data from the ABS Survey of Motor Vehicle Use (SMVU) to estimate vehicle scrappage rates and vehicle sales.[204] We estimated the historical mix of vehicles, and historical kilometres travelled, because SMVU data provide information on only a small sample of vehicles and we needed to generalise it to the whole fleet.

We assumed future vehicle sales will grow in line with population forecasts. We assumed all internal combustion engines were diesel engines. We assumed that the proportion of zero-emissions vehicle sales over time will follow projections from McKinsey, with a five-year lag behind European estimates.[205] And we assumed that all zero-emissions trucks will be battery-electric.

To estimate how the activity of the Australian heavy vehicle fleet will change over time, we needed to estimate how 'vehicle kilometres travelled' has changed, and will change, as a vehicle gets older. This depends on the year that a vehicle was, or will be, manufactured.

Because the SMVU provides data on only a small sample of vehicles, and because we needed to estimate the general decline in kilometres travelled as vehicles age, we augmented SMVU data with the US EPA Motor Vehicle Emissions Simulator (MOVES) model, which we adjusted to reflect Australian conditions.[206] We based the mix of urban and rural kilometres travelled on data from the SMVU. We assumed that future vehicle activity will reflect future economic growth, based on GDP forecasts.

204. ABS (2020).
205. McKinsey & Company (2017).
206. EPA (2009).

Carbon emissions, pollutants, and health costs from Australian heavy vehicles

The volume of carbon emissions from diesel trucks depends on diesel consumption.

We used data on fuel use, drawn from the SMVU, to estimate the diesel consumption of heavy vehicles that were sold before 2021. For diesel vehicles sold in or after 2021, we assumed that fuel efficiency will improve at a rate of 0.5% per year. We calculated greenhouse gas emissions by converting diesel consumption into carbon dioxide emissions.[207]

To estimate future carbon emissions from vehicles with zero exhaust-pipe emissions, we used energy consumption and energy efficiency values proposed by the International Council on Clean Transportation.[208] We used forecasts of the carbon intensity of the National Electricity Market (NEM) under the Australian Energy Market Operator's 'step change' scenario.[209]

We estimated exhaust, non-exhaust, and secondary pollutant emissions from heavy vehicles for each vehicle in the simulated fleet. The Bureau of Infrastructure and Transport Research Economics (BITRE) provided us with exhaust pollutant 'emission factors' for different vehicle ages, types, and classes.[210] We used 'non-exhaust emission values' for brake and tyre wear from the US EPA MOVES model.[211] We did not include estimates of pollution from road wear. We estimated secondary pollutant emissions (PM2.5) using methods proposed by the National Association of Clean Air Agencies (NACAA).[212]

We modelled the costs of air pollution from trucks using a 'damage cost' approach. BITRE provided us with damage cost values for each pollutant category in the model, based on modelling conducted as part of the 2016 fuel quality standards review by Marsden Jacobs & Associates.[213]

The costs and benefits of zero-emissions heavy vehicle targets

We modelled key costs and benefits of binding zero-emissions targets.

We modelled costs to businesses, including:

- business investments in charging and refueling infrastructure;
- the purchase cost of zero-emissions vehicles compared to diesel vehicles;
- the time that will be spent charging zero-emissions vehicles;[214] and
- weight penalties: these penalties capture the reduction in the allowable load of each truck, resulting in a truck fleet 3 per cent larger than it would be if diesel trucks were doing the equivalent task.

We modelled the benefits of zero-emissions trucks for businesses, including:

- reduced maintenance costs; and
- reduced fuel costs.

207. DISER (2021b).
208. ICCT (2020); and ICCT (2021c).
209. AEMO (2021).
210. Personal communication.
211. EPA (2014).
212. NACAA (2011).
213. Personal communication.
214. ICCT (2019c).

We also modelled the benefits of zero-emissions vehicles for the public, including:

- reduced health costs, which are additional to the benefits of introducing Euro-VI standards in 2024;
- reduced carbon emissions; and
- reduced noise pollution.

We assumed that electricity and diesel prices were, and will be, consistent with the assumptions made by the Australian Trucking Association (ATA) and Electric Vehicle Council (EVC): $0.15kWh for electricity and $1.33/L for diesel. We assumed that all diesel operators have received the fuel tax credit in the past, and will continue to receive it in the future.

We assumed that the difference in upfront costs of electric and diesel vehicles will be consistent with values proposed by the CSIRO.[215] We used charging infrastructure costs proposed by the ICCT, using low volume costs until 2030, medium volume costs between 2030 and 2035, and high volume costs after 2035. To account for the increased weight of zero-emissions vehicles, we assumed that 3 per cent more zero-emissions trucks than diesel trucks will be required to complete the same task.[216] To account for the time that zero-emissions vehicles will be charging, we assumed a further 1.5 per cent additional zero-emissions trucks will be required to complete the same task.[217]

We used truck maintenance and AdBlue costs proposed by Australian Transport Assessment and Planning (ATAP), and oil and lubricant costs proposed by the ICCT.[218] To estimate the costs of noise pollution, we used values estimated by Austroads, and we assumed that noise costs are 90 per cent lower for a zero-emissions vehicle than a diesel vehicle. We estimated the cost of carbon at $35/tonne, based on past assumptions by the Department of Infrastructure and Regional Development.[219]

We assumed that under sales targets for zero-emissions vehicles, manufacturers could aggregate their sales for compliance purposes, and that penalties would be sufficient to ensure that manufacturers achieved sales targets.

We sensitivity-tested costs and benefits for a range of scenarios, using 7 per cent and 4 per cent discount rates.

215. Graham and Havas (2021).
216. ICCT (2019c).
217. Ibid.
218. ATAP (2013); and ICCT (2019c).
219. DIRD (2016b, pp. 73–74).

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