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Towards net zero

A practical plan for Australia's governments

Tony Wood, Alison Reeve, and James Ha

October 2021

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Grattan Institute Report No. 2021-15, October 2021

This report was written by Tony Wood, Alison Reeve, and James Ha.

Susan McKinnon Foundation

We would like to thank the Susan McKinnon Foundation for its generous and timely support of this project.

We would also like to thank the members of Grattan Institute's Energy and Climate Change Program Reference Group for their helpful comments, as well as numerous government and industry participants and officials for their input. In addition, Holly-Rose Browne provided research assistance.

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This report may be cited as: Wood, T., Reeve, A., and Ha, J. (2021). *Towards net zero: A practical plan for Australia's governments*. Grattan Institute.

ISBN: 978-0-6452739-3-9

Overview

Australia's climate change commitment is net-zero emissions by 2050. The latest projections indicate the target of 26-to-28 per cent below 2005 levels by 2030 will be bettered. However, continuing at that rate of reduction will leave a very big offsetting challenge in 2050. Practical actions taken by governments now can close the gap.

Australia's governments can and should act now to create momentum towards the net-zero goal. This report, the fifth in a series on net zero, recommends policies for all the key sectors that contribute to Australia's greenhouse gas emissions. These recommendations accept today's political constraints and build on existing policies and priorities with low impact on industries or consumers.

Addressing climate change brings costs and benefits, challenges and opportunities. Across the sectors, there will be areas where the benefits of lower-emissions technologies will outweigh any costs of the transition. And there will be other areas where real financial costs will remain even after our best cost-reduction efforts.

Exports will be resilient (iron ore and other minerals) or they will be replaced (coal and LNG). Now is the time to plan for the replacement. Australia has a transformational opportunity, because of its vast renewable energy and mineral resources, to more than replace the export revenues and jobs currently accruing from fossil fuels.

Adopting the policy suite recommended in our reports will connect short-term actions and proven technologies – to bend the curve now – with technology development and deployment to sustain the momentum and get to net zero. Technology must be complemented by policies and markets.

Sector-specific policies include vehicle emissions ceiling; bigger roles for the Emissions Reduction Fund, the Safeguard Mechanism, and energy efficiency obligations; enhanced electricity grid investment; and better integration of state renewable electricity schemes. Setting clear rules on the use of domestic and international offsetting credits will protect the integrity of policy and help build the market.

In the short term, government funding for immediate, low-cost actions and to support R&D will be required. In the medium to longer term, such funding from governments will be unsustainable and regulation should have a limited but valuable role. More ambitious emissions reductions targets are likely to be required. Market-based policies will mobilise finance and deliver outcomes at lowest cost. Governments will need to decide how and when to turn to such policies.

This suite of policies can deliver steadily reducing emissions across the economy well into the 2030s, and real momentum towards net zero by 2050. To give this framework substance, the Federal Government should commission the Climate Change Authority to monitor and report progress, including with recommendations as required.

All governments need to plan more directly for the physical and economic consequences of a changing climate, and to integrate climate change issues into all decisions on infrastructure planning, land use, and resource extraction. This policy challenge requires greater policy coordination across jurisdictions.

The scale and structure of the policies implemented today will determine the cost. Capitalising on Australia's advantages will deliver the opportunities.

Action today is crucial to create momentum and to avoid locking in emissions for decades to come. Governments have set the objective; this report identifies the practical, no-regrets policies that can head Australia in the right direction.

Recommendations

Recommendation 1: Start with sector-based policies today

Implement sector-based policies to reduce emissions now, where the technologies and actions are clear, and the costs are modest or negative and justified by the benefits.

Adopt market-based policies for efficient and effective sharing, within and between sectors, of the effort required to reach net zero.

Ensure that such policies can be scaled up as circumstances change.

Recommendation 2: Expand R&D funding

Expand focused funding support for research and development to drive down costs of existing but non-commercial zero-emission technologies, and to develop and demonstrate technologies for sectors where there are currently few zero-emissions options.

Take a supply chain approach to setting goals for priority technologies.

Recommendation 3: Integrate technology support with market-based policy

Build on the Technology Investment Roadmap to bring low-emissions technologies to pre-commercial and commercial deployment more quickly.

Recommendation 4: Work with industry to realise new opportunities

Work with industry to mobilise transformative technologies at scale where Australia has an advantage.

Recommendation 5: Re-launch and empower the Climate Change Authority

Relaunch the Climate Change Authority with a formal remit to advise on emissions budgets, track Australia's progress towards net zero, and advise governments on new policies or adjustments to existing policies to build momentum over the coming decades.

Recommendation 6: Push on with near-term reforms and plan for the future of the electricity system

Implement the recommendations of the Energy Security Board to keep the National Electricity Market operating securely and reliably as coal-fired power stations close and new renewable supply enters.

Ensure that planning and regulatory processes are aligned to deliver the major investments in the transmission grid required to support high levels of decarbonisation of the electricity sector in the 2030s or early-2040s.

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1 A net-zero world is coming and Australia must prepare for it now

After more than a decade of policy uncertainty on climate change, Australian governments and industry are committed to net-zero carbon emissions by 2050. The scale and pace of change inherent in a net-zero target are daunting, but they are outweighed by the consequences of the alternative. Factors outside Australia's control will shape the flow of capital and the demand for our exports, while climate change itself will increasingly threaten Australians' lives and livelihoods.

What Australia can control is how to respond, and its best option is to act now to adapt to the net-zero world that is approaching. Governments can – and must – change underlying settings so that inevitable economic change is as smooth as possible and the benefits and costs are born fairly. This will take more than technology. It needs policies and markets.

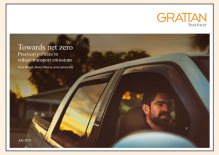
Australia has no economy-wide policy framework to achieve net zero (such as a carbon price), and little political appetite to develop one currently. In that context, Grattan Institute has taken a pragmatic approach to identify a combination of sector-based, technology-driven policies that will create momentum towards the long-term target. Over the past five months, we have published individual reports on the transport, industrial, and agriculture sectors, and a report on the vexed question of how to offset emissions.

This fifth and final report in the series combines these sector-based reports with two earlier Grattan reports on Australia's electricity and gas sectors (Box 1). It summarises actions that can be taken now to deliver cost-effective emissions reductions, drive down the cost of low- and zero-emissions technologies, and support the case for greenhouse gas removals. This report lays out a policy framework for moving towards net zero, which can be scaled up to achieve more ambitious targets.

Box 1: This report brings together six previous Grattan publications

Reports in the *Towards net zero* series

Towards net zero: Practical policies to reduce transport emissions (July 2021)



Towards net zero: Practical policies to reduce industrial emissions (August 2021)

Towards net zero: Practical policies to reduce agricultural emissions (September 2021)

Towards net zero: Practical policies to offset carbon emissions (October 2021)

Previous Grattan reports

Flame out: The future of natural gas (November 2020)

Go for net zero: A practical plan for reliable, affordable, low-emissions electricity (April 2021)

1.1 The numbers that matter

Australia is committed to helping limit global warming to well below 2℃, and ideally to below 1.5℃.[1]

Achieving global net-zero emissions by about 2050 is the bare minimum to have a decent chance of limiting global warming to 1.5℃.[2]

1. UNFCCC (2015).
2. Without achieving net zero, global average temperatures will continue to rise: IPCC (2021, p. 36).

But it matters how the world – and Australia – gets there.[3] As they are emitted, greenhouse gases accumulate in the atmosphere. That means the key factor to mitigate climate change is the cumulative emissions over time.[4] These cumulative emissions are in effect a 'carbon budget' – a limit that emissions must stay within. To have a two-thirds chance of keeping warming at 1.5°C, the world has a carbon budget of about 400 billion tonnes of CO_2 emissions from 2020.[5].

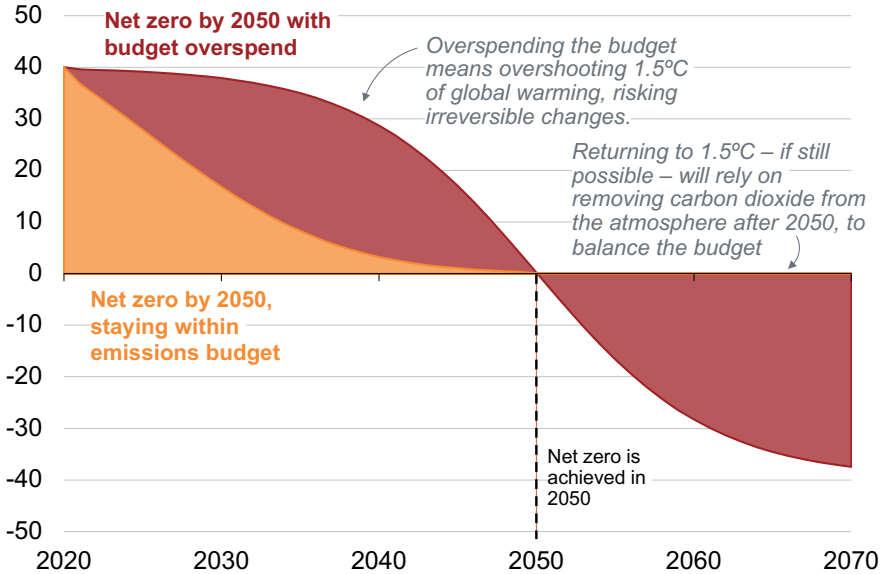
Staying within that budget is the real objective. Annual global CO_2 emissions averaged about 40 billion tonnes over the past decade. At current emissions rates, the carbon budget will be exhausted in 10 years, implying 1.5°C could well be breached.[6]

Inherent in the concept of net-zero emissions is a strategic balance – more aggressive reductions sooner mean lower absolute emissions; more conservative reductions mean higher absolute emissions and a greater risk of triggering irreversible climate change. Once the emissions budget is gone, our only option for returning the global climate back below 1.5°C is to deliberately remove more carbon dioxide from the atmosphere than is emitted each year, as illustrated in Figure 1.1.[7]

Although it is common to refer to an emissions target at a point in time (e.g. 2030 or 2050), the real target for a country, or indeed the world, is limiting cumulative emissions over a period of time. For example,

Figure 1.1: The world has an emissions budget it must stay within to meet the 1.5°C goal of the Paris Agreement

Global net CO_2 emissions (billions of tonnes)



Notes: Both pathways start at 40 billion tonnes in 2020. The total emissions for each pathway (the area under each curve) between 2020 and 2070 is the same – 400 billion tonnes, consistent with keeping warming below 1.5°C: IPCC (2021).

Source: Grattan analysis.

3. Hoegh-Guldberg et al (2018).
4. This is particularly the case for long-lived greenhouse gases such as carbon dioxide and nitrous oxide. Methane is a potent greenhouse gas but it lasts only about a decade in the atmosphere – its impact on warming is largely determined by the rate at which humans are causing methane to be emitted compared to the rate at which existing atmospheric methane breaks down.
5. IPCC (2021, p. 38).
6. Ibid (p. 6).
7. Achieving net zero will require policies that encourage deep cuts to emissions, and considerable effort to deploy carbon dioxide-removal projects for any residual emissions.

Australia's 2030 target is referred to as 26-to-28 per cent below 2005 levels, which means limiting cumulative emissions between 2021 and 2030 to between 4.8 billion tonnes and 4.9 billion tonnes.[8]

1.1.1 Australia's contribution to the global task

At the Paris COP21 in 2015, the Australian Government committed to its current Intended Nationally Determined Contribution (INDC) of reducing emissions by 26-to-28 per cent against 2005 levels.

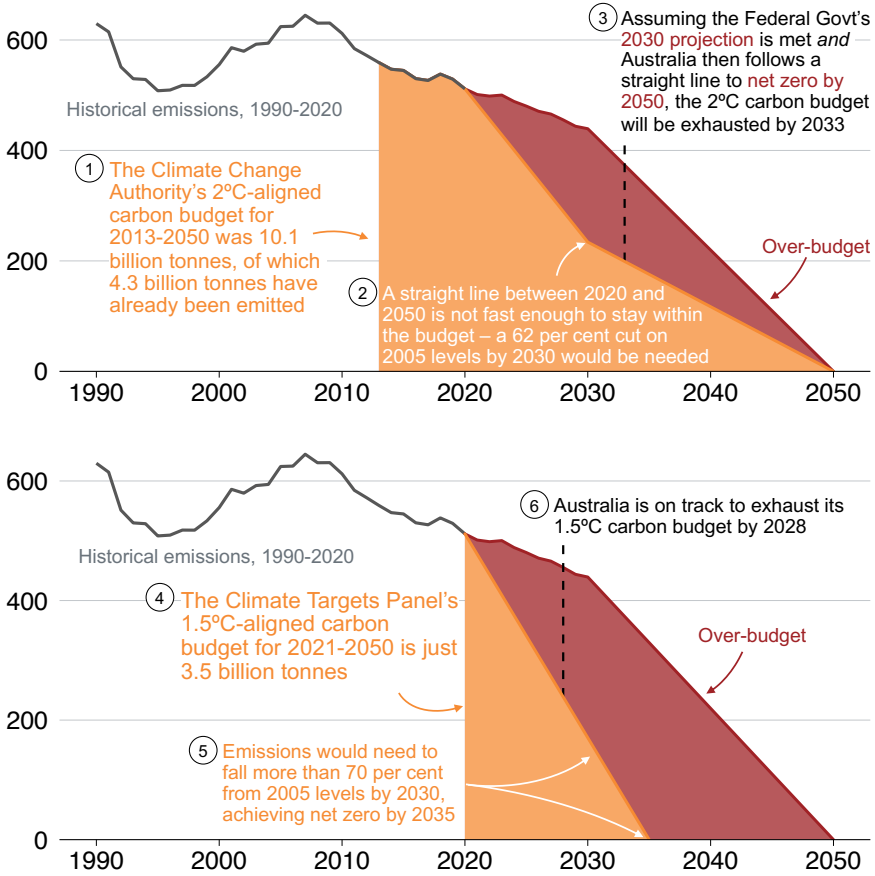
As with the global total of INDCs, Australia's current target has been widely criticised as inadequate against the goal to limit global warming to 2℃, let alone 1.5℃. The last comprehensive review by the Climate Change Authority, in 2014, estimated Australia's fair share of global effort to keep the average global temperature rise below 2℃ as a carbon budget of 10.1 billion tonnes between 2013 and 2050.[9] Australia consumed 42 per cent of this budget between 2013 and 2020, leaving only 5.8 billion tonnes to cover the period 2021-2050 (Figure 1.2).

The Morrison Government's commitment to net zero by 2050 would, if based on a 2030 outcome in line with the INDC and a straight line to net zero, mean cumulative emissions between 2021 and 2050 of 9.3 billion tonnes. This would overshoot by more than 50 per cent the budget consistent with a warming limit of 2℃.

Emissions are not on track to meet a net zero goal, regardless of whether that is by 2050 or by an earlier date consistent with limiting global warming in line with the Paris Agreement. In this series of reports, we have sought to identify policies in 2021-22 that could get Australia on track towards net zero by 2050. An underlying need is for policies that can be scaled up as greater ambition is adopted.

Figure 1.2: If Australia stays on its current course, it will exhaust its 1.5℃ budget by 2028, and its 2℃-compatible emissions budget by 2033

Net CO_2 emissions (millions of tonnes)



Note: The Climate Targets Panel is an independent group of senior Australian climate scientists and academics; it has published updated carbon budgets based on the Climate Change Authority's 2014 methodology: Hewson et al (2021).

Source: Grattan analysis of CCA (2014), DISER (2021a) and Hewson et al (2021).

8. DISER (2021a, p. 3).
9. CCA (2014).

1.1.2 Australia's emissions trends over the next decade

Over the next decade, Australia's electricity emissions are projected to fall substantially, but the next four largest emissions sources in Australia will either grow or plateau at best (Figure 1.3). This comes after sustained growth in emissions in several sectors since 2005.

There is a market failure here: limiting global warming to 1.5℃ is in Australia's interest, but current incentives are too weak for companies and individuals to curb their emissions in line with this target.

If government policy does not push these emissions downwards this decade, Australia faces a faster, harder transition to net zero by 2050.

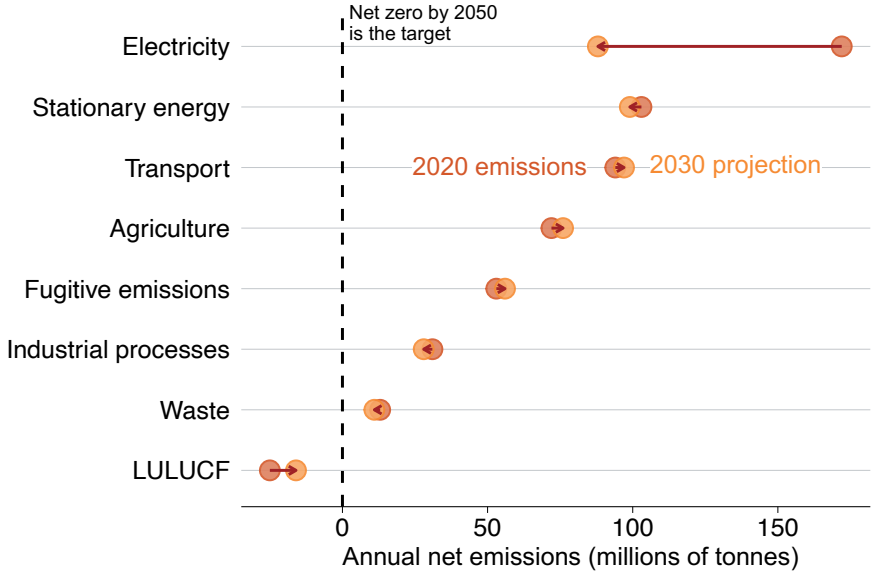
1.2 Pressure is rising on Australia from other countries and global financial markets

The international community has shifted towards greater climate ambition in the past 12 months (Figure 1.4 on the following page). The US has rejoined the Paris Agreement and committed to reduce emissions to net zero by 2050. The EU, having already made that commitment, is planning to impose carbon costs (equivalent to those from its own emissions trading scheme) on imports from nations with inadequate climate policies.[10] Many of Australia's largest trading partners have now set net-zero targets, including China, Japan, and South Korea.

Global action on climate change is overwhelmingly in Australia's national interest.[11] This is not just because the impacts of climate change will hit Australia hard. It is also because we are a small, open economy, highly dependent on trade, and not large enough to solve climate problems on our own. Many of the technologies and much of the investment we will rely on to reach net zero will come from

Figure 1.3: Apart from electricity, there's very little emissions reduction expected in Australia over the next decade

Emissions sources (as reported in the Federal Government's projections)



Notes: LULUCF = land use, land use change, and forestry. 'Industrial processes' only captures certain chemical reactions and products; industry more generally is also responsible for many stationary energy and fugitive emissions. Emissions are carbon dioxide equivalents.

Source: Grattan analysis of DISER (2021a).

10. Ai Group (2021, p. 52).
11. Wood et al (2021a, Chapter 1).

overseas. Many of our exports – current and future – will be needed for the energy transition in other countries.[12] To maximise the potential economic benefits to Australia means staying in step with global trends – not just on net zero, but also on near-term ambition and policies.

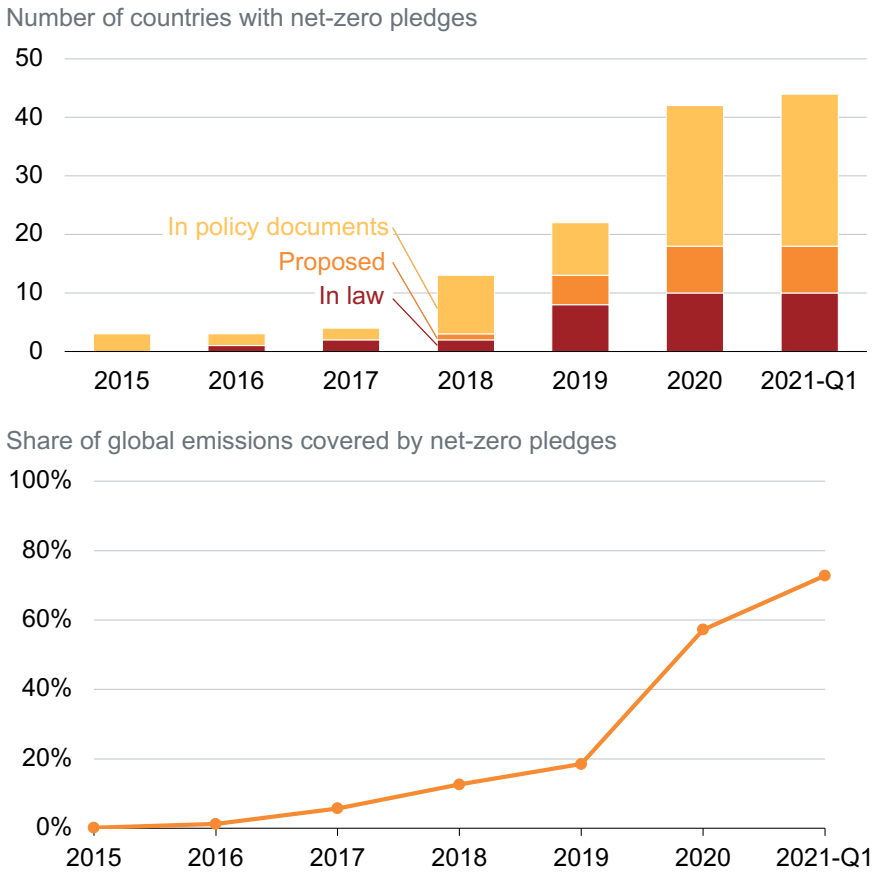
1.2.1 Pressure from the finance sector

Climate risk typically includes not just risks to investments from climate change itself, but also exposure to carbon risk – the risk that a move away from emissions-intensive activity will leave assets stranded or debts unpaid. The global finance sector is acutely aware of its exposure to climate risk, as are increasing numbers of investors. Other countries are moving to regulate the sector to force banks and financial institutions to assess and disclose these risks.

Other countries moving to force management of carbon risk could have profound implications on foreign investment in Australia. The top 10 source countries for foreign investment in Australia, which account for more than 80 per cent of all foreign investment, have all enacted or are considering introducing laws requiring companies to disclose their climate risk.[13] In 2019, 41 per cent of foreign direct investment in Australia went to the mining sector.[14] This is three times the next largest sector (real estate) and 15 times the amount that went to the electricity and other utilities sectors. Mining was responsible for 19 per cent of Australia's emissions in 2019 and 11 per cent of GDP.[15]

As we noted in *Towards net zero: Practical policies for reducing industrial emissions*, mining represents a significant opportunity in a net-zero world because demand for minerals other than coal is

Figure 1.4: The international community is now serious about achieving net-zero emissions



Note: Some countries in this chart have committed to net zero post-2050, such as China's 2060 pledge.

Source: IEA (2021a, p. 33).

12. Bruce et al (2021, pp. 22–23).
13. Grattan analysis of ABS (2021a, Table 2) and other sources.
14. ABS (ibid, Table 15). We have chosen 2019 rather than 2020 as a more 'typical' year not significantly affected by the COVID-19 pandemic.
15. DISER (2021b); and ABS (2021b).

expected to increase rapidly. But this opportunity will only manifest if capital is available, and this means mining operations and minerals processing must decarbonise.[16]

1.2.2 Changes to export patterns in a net-zero world

Other countries' moves to cut emissions will have an impact on Australia's economy. Australia is an open, export-oriented economy: 24 per cent of Australia's GDP comes from exports,[17] of which 78 per cent is trade in goods.[18] Therefore, what our major trading partners do to reduce their emissions has consequences for us.

Australia's top three exports are iron ore, coal, and gas (Figure 1.5 on the next page). These exports produce emissions when refined or consumed. But the vast majority of these valuable export commodities goes to countries with net-zero targets (Figure 1.6 on the following page), which will affect their future demand.

Demand for coal and natural gas will fall as export markets move to replace fossil fuels with renewable energy. In 2019-20, Australia's coal and gas exports together were worth $102 billion,[19] and 85 per cent of LNG exports, at least 74 per cent of thermal coal exports, and 54 per cent of metallurgical coal exports went to countries that have made net-zero emissions commitments.[20]

Iron ore is used in steel-making, which is currently an emissions intensive process because it uses coal or gas. However, if a substitute, such as hydrogen, can be made to work, then demand for these exports should hold up.[21]

16. Wood et al (2021b, p. 18).
17. World Bank (2021).
18. DFAT (2021a).
19. Grattan analysis of DFAT (2021b).
20. Grattan analysis of DISER (2021c).
21. Although there could be issues with the nature of Australian ores and their compatibility with zero-emissions refining processes.

There is a fourth category of exports, not shown in Figure 1.5 on the next page. These are the commodity exports that may grow if we have the right policy settings to encourage investment in new industries. They include renewable electricity, hydrogen and hydrogen carriers such as ammonia, critical minerals, green steel, and energy-intensive commodities and products.

The prospects seem slim for new markets for coal

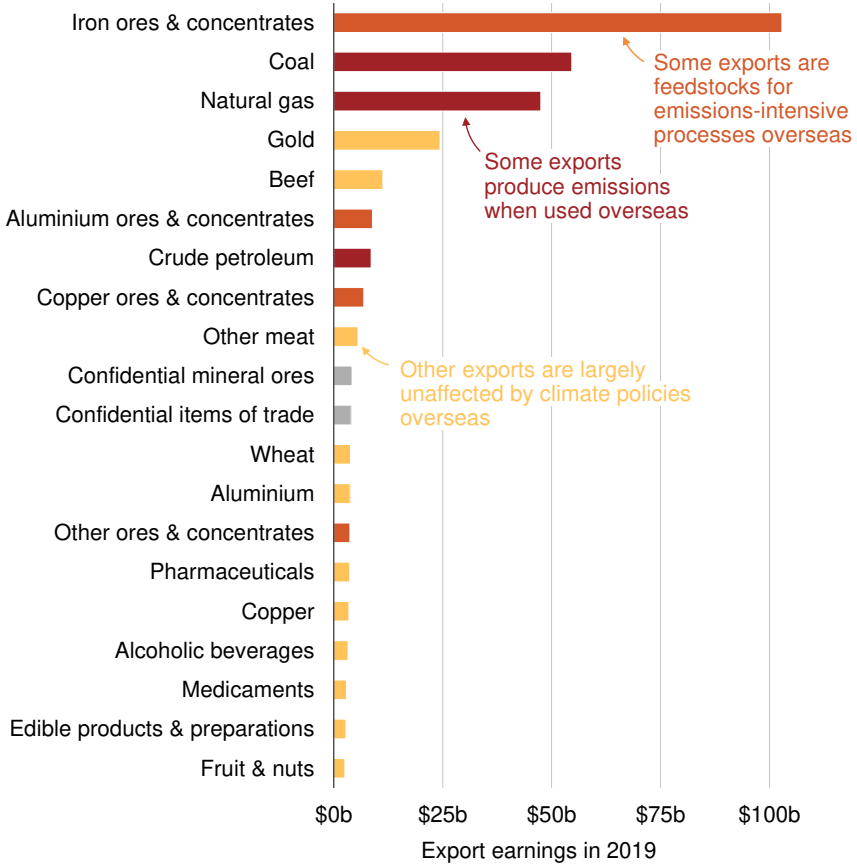
A reduction in thermal coal use by Australia's large coal customers is unlikely to be fully replaced by other markets emerging. Advanced economies with net-zero pledges and increasing short-term ambition will not build new coal-fire power plants – the carbon risk associated with financing is too high, and regulatory approvals are unlikely to be forthcoming.

Coal-fired electricity in emerging markets and developing economies is expected to peak in about 2030 and decline after that. In a net-zero scenario, it declines to zero in about 2040.[22]

China, Japan, and Korea, three of the largest suppliers of finance for electricity infrastructure in Asia, have all committed to cease funding new coal-fired power plants.[23] But this finance has to go somewhere – it now seems possible that China, South Korea, and Japan will compete to finance large-scale renewables projects in other Asian countries instead. The Asian Development Bank's policy is to cease funding new coal-fired power plants and support early closure of existing ones.[24] The World Bank's position is to align its financing flows with the objectives of the Paris Agreement by July 2023.[25]

22. IEA (2021b, p. 201).
23. Downie and L. Hughes (2021).
24. Asian Development Bank (2021).
25. Malpass (2021).

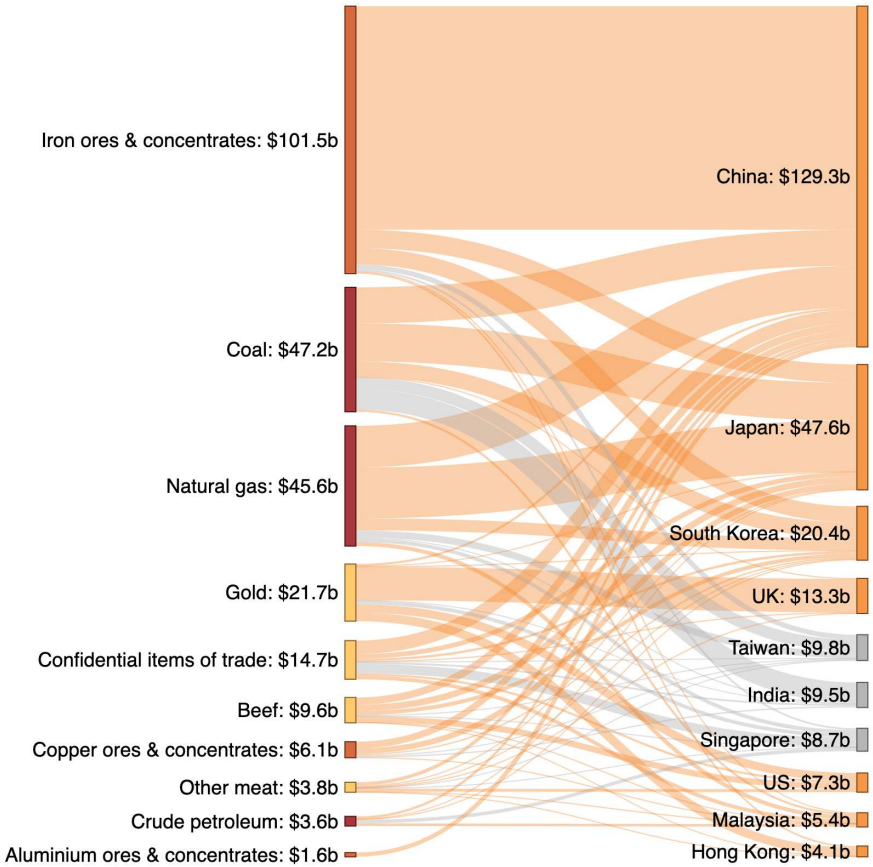
Figure 1.5: Some of Australia's biggest exports will decline in a net-zero world



Notes: Top 20 commodities by value in 2019-20. Descriptions of confidential commodities – shown in grey – are not available.

Source: Grattan analysis of DFAT (2021b).

Figure 1.6: Export flows for Australia's top 10 commodity exports to the 10 largest importers



Notes: Countries coloured orange have a net-zero target; those in grey do not yet. Hong Kong is assumed to be covered by China's commitment to reach net zero by 2060. Confidential mineral ores are Australia's 10th largest export (see Figure 1.5) but have been excluded due to a lack of data. Flows less than $50 million are excluded.

Source: Grattan analysis of DFAT (ibid).

All of the above means the prospects seem slim for Australia finding replacement markets for thermal coal currently sent to Japan, Korea, and China.

1.2.3 Carbon border adjustment mechanisms

Carbon border adjustment mechanisms (CBAMs) are tariffs applied to imports at the border that reflect the emissions associated with the production of the good being imported. CBAMs are a way of levelling the playing field between countries that place strong constraints on emissions and countries that place weaker or no constraints.

CBAMs stop 'carbon leakage', that is, industries relocating from countries with strict emissions policies to countries with lax ones in order to avoid the costs of complying with the former's policy. They also stop domestic industry being undercut by foreign producers that are not subject to the same emissions constraints. To comply with World Trade Organisation rules, CBAMs can only be applied to goods where domestic producers face a carbon constraint.[26]

The European Union is enacting a CBAM, and Japan and the US are considering doing so.[27]

The EU CBAM will affect very few of Australia's exports directly. Only aluminium, cement, fertiliser, and iron and steel are expected to fall within its remit, and Australia's exports of these to the EU averaged only $75.5 million between 2017 and 2019.[28] For aluminium, cement, and steel, less than 1 per cent of exports went to the EU; for iron and steel is was 5 per cent.

However, the EU CBAM is likely to reduce demand for metallurgical coal, used to make steel. Between them, China and India buy nearly half Australia's metallurgical coal.[29] China is the fourth-largest supplier of steel to the EU, and India is the seventh-largest.[30] Production efficiency improvements in either country (in response to the EU CBAM) would reduce demand for Australian metallurgical coal.[31]

1.3 Climate change itself threatens the Australian economy

All of the above will take place in the context of a changing Australian climate. These changes, and their impacts, are happening faster than expected.[32] Primary industries are likely to be hit hard, but no sector is immune.

The agriculture sector is particularly vulnerable to climate change. Changes in rainfall patterns over the past 20 years have cut profits across the sector by 23 per cent compared to what could have been achieved in pre-2000 conditions.[33] NSW and Queensland cropping farms have been hardest hit – profits have fallen 36 per cent on average. This trend is expected to continue, with increased warming leading to sharper falls in average farm profits.

Climate change may lead to structural changes in land use as farmers adapt to new conditions. Land in drier parts of traditional cropping zones is already being switched to livestock or mixed production.[34] But this adaptation may help only temporarily: livestock are also vulnerable to warming climate. At 3 ℃ of warming, livestock in the northern third of Australia will suffer heat stress almost daily.[35]

26. Orte Júlvez (2021).
27. Dumitru et al (2021).
28. Ai Group (2021, p. 57).
29. DISER (2021c).
30. International Trade Administration (2019).
31. Australia's largest export to the EU is metallurgical coal. However, the EU CBAM will not cover coal imports, because the EU emissions trading scheme does not cover coal production. Demand for Australian coal from Europe will be affected by declining caps on emissions in the EU emissions trading scheme, not the CBAM.
32. CSIRO (2021).
33. N. Hughes and Gooday (2021, pp. 3–4).
34. Ibid (p. 10).
35. Australian Academy of Science (2021, p. 46).

In pre-pandemic times, tourism was Australia's second-biggest export earner after iron ore. Australia's top five tourist attractions – beaches, wildlife, the Great Barrier Reef, wilderness areas, and national parks – are all directly at risk from climate change.[36] Increased temperatures and more extreme weather could shorten the season for many tourism destinations, especially in northern Australia.

In the electricity sector, higher temperatures will increase the number of electricity system outages. The average daily outage time more than triples on a day with temperatures between 35℃ and 40℃ degrees compared to a day with temperatures between 30℃ and 35℃ degrees.[37] Higher temperatures also reduce generator capacity and increase failure rates or maintenance/replacement costs. High winds reduce the capacity and threaten the integrity of transmission lines. Lower rainfall reduces water availability for hydro and thermal electricity generation.[38]

Extreme weather also imposes a more general cost on the economy. The costs of the 2019-20 'Black Summer' bushfires in Australia are still being assessed, but one initial estimate put the costs at $2 billion in insured losses, $3.6 billion in impact on tourism, hospitality, agriculture, and forestry, and $2 billion in health costs.[39]

As the climate continues to change, the underlying value of some land may fall considerably and some properties may become increasingly expensive to insure.[40]

36. L. Hughes et al (2018, p. 6).
37. Wood et al (2019a, p. 39).
38. AEMO (2020a, pp. 17–18).
39. Royal Commission into national disaster arrangements (2021, p. 5).
40. Steffen et al (2019); and Bellrose et al (2021).

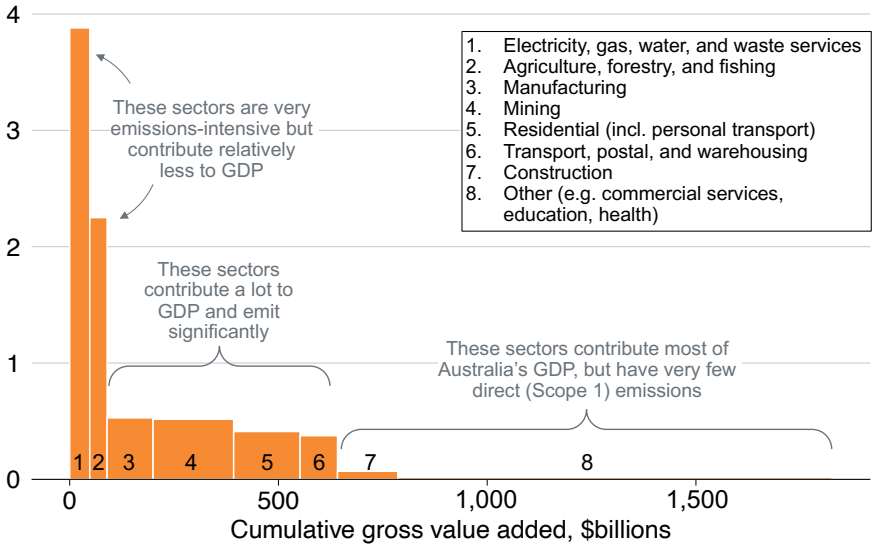
1.4 A snapshot of the net-zero Australian economy in 2050

The largest contributions to Australia's GDP are not emissions-intensive (Figure 1.7). This is why most assessments of the economic cost of reducing emissions generally show only modest impacts on GDP.

In 2050 it is unlikely that fossil fuels will be in widespread use anywhere in the world. The largest uses for coal and gas will have been replaced by zero-emissions substitutes, and any role for carbon capture and storage will be modest and used only where no other solution has

Figure 1.7: The sectors that contribute most to Australia's economy are not very emissions-intensive

Emissions intensity (million tonnes of emissions per billion dollars of gross value added)



Notes: Emissions are carbon dioxide equivalents. The sectors correspond to ANZSIC Divisions; 'Other' includes Divisions F-H and J-S. Data is for 2018-19.

Source: Grattan analysis of DISER (2021b) and ABS (2021b).

been found. As a result, fossil fuel extraction will not be making a large contribution to the Australia economy. This will reduce the emissions intensity of the mining sector (segment 4 in Figure 1.7). Meanwhile, increased demand for critical minerals (which are projected to be worth more to Australia as exports than coal) will increase mining's contribution to GDP.[41]

The electricity sector will be much larger, both to replace transport fuel and gas use, and to power export industries, but much less emissions-intense. So segment 1 in Figure 1.7 will be wider and lower.

The emissions intensity and economic contributions of the agriculture sector could look different. Farmers will be paying much more attention to managing carbon, through better soil, pasture, and fertiliser management, and through active reforestation. And some farmers may move away from more emissions-intensive commodities such as beef and towards less emissions-intensive commodities such as wheat and other crops, and producing biomass for biofuels.

Then there are the new and expanded industries where Australia can convert comparative advantage to strategic advantage in a net-zero world. These include hydrogen and hydrogen carriers, green steel and other energy-intensive commodities, and potentially removing carbon dioxide from the atmosphere, either via nature-based methods or technology.

1.4.1 No major sector will completely eliminate emissions

Even with strong policy action by governments, all of Australia's economic sectors are likely to have some residual emissions in 2050. These will come from activities where no solution has been found to avoid emissions, or where a solution exists but costs more than we are willing to pay. Some sectors will have many more residual emissions than others, as Figure 1.8 on the following page shows. To reach a net-zero position in Australia's national carbon accounts, these residual emissions will need to be offset by deliberate removals of carbon dioxide from the atmosphere.[42]

The estimates in Figure 1.8 on the next page are only one possible future, based on what looks possible now. As well, technology changes to reduce emissions will not stop in 2050 – so the need for offsetting should decrease over time.

1.5 How the rest of the report is structured

Chapter 2 outlines a framework for getting to net zero that can work within Australia's existing political constraints. It requires policy, technology, information, and markets to work together. Taking these steps now is the key to opening up the possibility of greater climate ambition in future.

Consistent with this framework, Chapter 3 recommends policies that governments should implement to deploy the emissions-reducing solutions we have today across the economy. It also analyses what R&D areas governments should prioritise to enable greater emissions reduction in future.

Many of the emissions-reducing solutions in other sectors will increase demand for electricity, which itself is the source of one-third of Australia's emissions.[43] Chapter 4 identifies how the electricity sector can maintain its momentum towards net zero despite rising demand. It outlines what governments should do today to keep the sector on track, and what barriers must be lowered to accelerate progress in the sector if or when governments raise their of climate ambition.

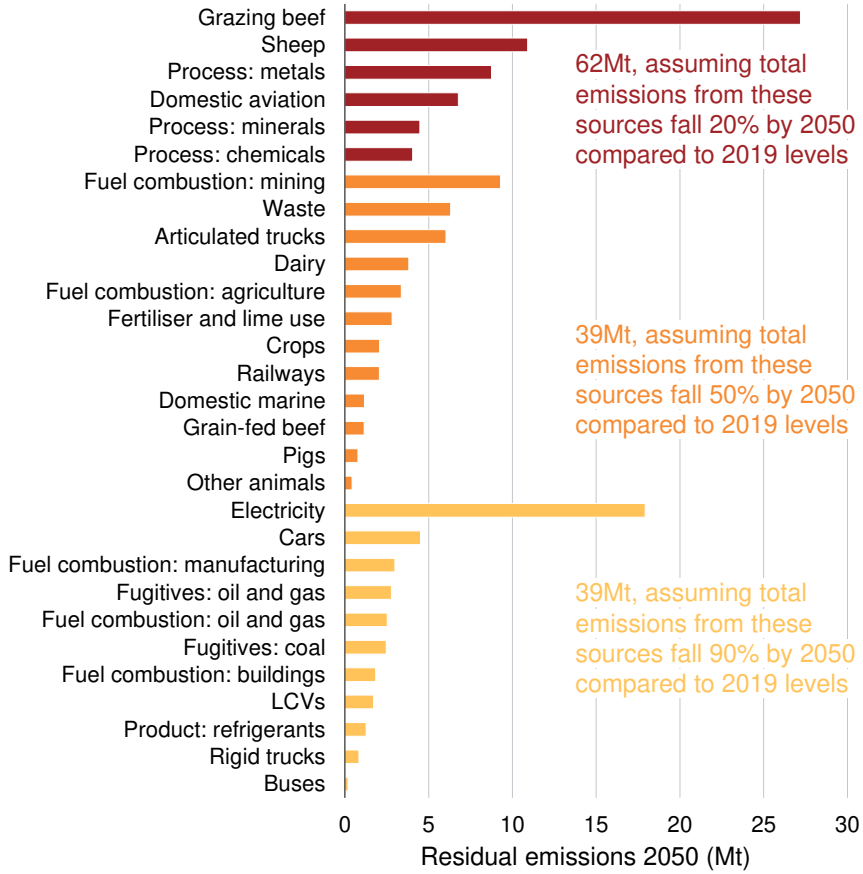
41. Wood et al (2021b, p. 18).

42. How to do this is discussed in more detail in Wood et al (2021c, pp. 38–44).

43. DISER (2020a).

Figure 1.8: Some sectors will have more residual emissions in 2050 than others

Emissions source



Notes: Mt = million tonnes. LCVs = Light Commercial Vehicles. Chart shows possible residual emissions (which would need to be offset to achieve net-zero) if emissions fall from current level by the percentages shown in 2050. Emissions from some very small sources (e.g. motorcycles and military fuel use) are not included. Figures are not a forecast and do not try to account for changes in production and demand across sectors.

Source: Grattan analysis of DISER (2020a), using pre-pandemic emissions from 2019.

2 Setting Australia on the road to net zero

Getting to net zero will be arguably the biggest economic transformation Australia has seen outside of wartime. It cannot be achieved by governments alone – it requires technologies, policies, and markets working together. Hard choices lie ahead to determine the most effective combination of government spending, regulation, and market creation. Making these choices will be easier if independent advice on the size of the net-zero task, the interim goals, and progress to date is available to all sides of politics.

There needs to be better co-ordination between state governments, and between state and federal governments, acknowledging the policy responsibilities of each and building on successful co-ordination in the past. As well, all governments need to look at how they do business, and adjust for a different, net-zero world.

2.1 Technologies

Australian governments have invested considerably in the early-stage development and demonstration of technologies to reduce electricity emissions, which are one-third of Australia's emissions. It is now time to focus similar attention on the other two-thirds of emissions.

Early stage development and demonstration efforts should focus on two types of problems: those where Australia is at the forefront of impending change and cannot rely on others to solve the problem for us (high-renewables penetration in the electricity grid being an example); and those where being at the forefront of technology development enables Australia to convert a comparative advantage into a strategic one. Green metals are one example, and in Chapter 3 we identify others.

The Federal Government's annual technology investment road-mapping exercise is a good start. It provides a sound basis for allocating government funding for early stage technology R&D. It could be improved by taking a more open approach to developing the technology statements, with broader consultation and a co-development approach with a more representative range of stakeholders.

The annual technology statements could also be improved by focusing more on how technologies are used as part of supply chains rather than as individual technologies. Take green steel as an example. Green steel requires green hydrogen at a low price. Green hydrogen requires renewable electricity at a low price. Renewable electricity at a low price requires grid integration and balancing at a low price. If the Government's technology funding goals for green hydrogen, renewable electricity, and grid integration are not aligned, then goals for green steel will not be achieved.

2.2 Policies

In Chapter 3 and Chapter 4, we identify sectoral policies governments could implement now to bend the emissions curve towards net zero. As we explained in more detail in the earlier reports of this series, these will be a start, but not enough. Governments state and federal need to begin moving away from incentives-only policies towards policies that can be scaled up to meet the formidable challenge of net zero.

2.2.1 It's time to move on from an incentives-only approach

The Federal Government has been adamant that its policy approach to reach net zero will be based on incentives only.[44] Incentives have

44. DISER (2021d).

a role to play in encouraging change, but they are not the best tool for achieving widespread deployment of a new technology and making it part of business-as-usual practice.

Attempting to scale up an incentives-only approach to reach net zero will be very costly for taxpayers. Getting from 512 million tonnes of emissions in 2020 to net zero in 2050 linearly requires cumulative emissions reductions of 7.7 billion tonnes.[45] If the Government encourages this at something like the average cost achieved through the Emissions Reduction Fund's most recent auction, this will add up to a total bill of $130 billion over 29 years, or $4.5 billion each year between now and 2050.[46] If the lowest-cost reductions have already been made, then the total bill could be much higher still.[47]

An extra $4.5 billion per year in incentive payments would require reduced government spending elsewhere, increased government borrowing (which is a cost to future taxpayers), or increased taxes to raise revenue. Maintaining this approach would also require governments to continue as kingmakers, deciding what to fund, where, and when. Even with measures such as the Technology Statements to analyse choices and guide these decisions, governments are fallible, and always have to choose between multiple priorities for budget allocations.

Better policy choices could distribute the cost of reaching net zero more efficiently and fairly, and potentially lower the cost as well. For this to happen, policy needs to move from providing incentives to change, to normalising new practices and technologies.

There are good examples in Australian energy policy of making this shift successfully. Figure 2.1 shows the example of solar PV. Solar power is now successfully moving away from requiring incentives, to being normalised as part of the energy market. The appropriate tools to do this are not the rebates and incentives previously used (subsidising the 3GW of rooftop solar installed in 2020 at the rate of the rebate available in 2008 would have cost $22.5 billion),[48] but using new energy market rules to ensure the costs and benefits of installing

Figure 2.1: Rooftop solar power is an example of government policy evolving in response to market developments

Allow	Encourage	Normalise
Remove regulatory barriers to using technology Make sure it works safely	Provide incentives for people and companies to use technology, as part of reducing costs	Ensure the costs and benefits of using technology are efficiently allocated
Example: grid-connected rooftop solar		
Late 1990s, early 2000s • Grid connection made legal • Planning regulations adjusted to allow systems on roofs in urban areas • Development of safety standards for grid-connected inverters and roof-mounted solar systems.	*2000s, 2010s* • Rebates for small-scale systems • Feed-in tariffs • Grants and then concessional finance for larger systems	*2020s* • Time-of-use tariffs • Grid access charges • Commercial finance • Increasing technical requirements to protect power system security (e.g. ride-through capability)

Source: Grattan analysis.

45. This will include offsetting through atmospheric removals. See Wood et al (2021c, p. 10) for a discussion of how emissions reductions and offsetting work together to achieve net zero.
46. The average cost of abatement in the October 2021 auction was $16.94 per tonne: CER (2021a).
47. The Federal Government anticipates payments of at least $25 per tonne will be necessary to get net emissions down by 82 per cent by 2050, let alone 100 per cent: DISER (2021d, p. 38).
48. The rebate available in 2008 was $7,500 per kilowatt (kW), capped at 1kW. 3GW of rooftop solar was installed in 2020: CER (2021b).

and using solar power are efficiently allocated. In particular, these rules are making sure that costs aren't imposed on people who don't install solar power.

To reach net zero, the federal government (and some state governments) needs an exit strategy from incentives. The timing might vary from technology to technology, but if net zero is to be the normal state of affairs by 2050, this implies emitters paying in full well before this date for the damage inflicted by their emissions. Suddenly withdrawing incentives can cause developing markets to crash, as occurred in the stop-start development of solar power in the 2000s. A good exit strategy is one that gradually swaps incentives for market rules as technology costs fall. Effective evaluation and impact measurement through the Technology Statements should provide governments with the information they need to plan exit strategies.

At the federal level, the most obvious exit strategy is to refocus the Emissions Reduction Fund and amend the Safeguard Mechanism, both discussed further in Section 3.2 on page 28.

2.3 Markets

Markets are the link between technology and policy. Without policy to penalise emissions or encourage reducing emissions, markets will select technologies that maximise profitability without having regard for emissions. A policy that prices carbon on its own tends to favour only emissions reductions from changes to operational practices and deployment of existing, well-understood technology.[49] This results in only a limited amount of technological change in return for the costs it imposes.

Deploying the power of markets allows for efficient and effective sharing between sectors of the effort required to reach net zero. A 'market-based approach' is often a bogey-man term used for political purposes to spook voters into thinking they are paying higher taxes. But Australia has been using market-based approaches for the past 20 years in the electricity sector to push emissions downwards. Without them, Australia's emissions would be much higher, as would electricity prices.[50]

Market-based approaches set a goal in a particular sector, and allow participants in that sector to figure out the best way to meet that goal. Market-based schemes allow governments and companies to each do what they are best at: governments are best-placed to choose emissions targets for their country or state; companies are best at deciding how to continue to be profitable within that constraint. The market provides for efficient exchange between those who are able to put in more effort, and those who have fewer opportunities to do so.

Market-based approaches are much easier to scale up – this simply involves increasing the target. Here and overseas, markets to reduce emissions and pollution have consistently shown costs and actual prices were much lower than governments and experts had expected.[51] Governments consistently get it wrong when trying to pick in advance which technologies would deliver the cheapest reductions. Markets routinely lead to innovation to reduce emissions at lower cost, which allows for greater ambition over time.

The political reality is that a single economy-wide market for carbon is not feasible in Australia right now, despite being backed by the vast

49. Lilliestam et al (2021).

50. Examples include the federal Renewable Energy Target, the Victorian Energy Efficiency Target, and the NSW Energy Savings Scheme. The Emissions Reduction Fund has also created a market in offsetting units, albeit one dominated by government purchasing. The Queensland 13% Gas Scheme (2005-2013) was also market-based, as was the NSW Greenhouse Gas Abatement Scheme (2003-2012).

51. Daley and Edis (2010).

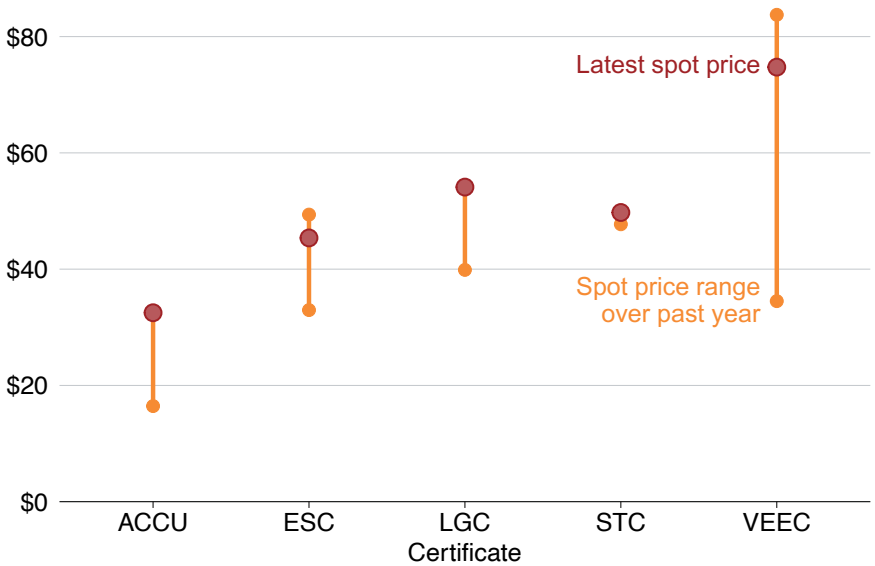
majority of economists and the Business Council of Australia.[52] Carbon pricing lacks political support from both sides of politics, and the limited time we have left to reach net zero means we can't afford to wait for the politics to change. We should get on with reducing emissions, using sectoral market-based approaches where appropriate.

In this series of reports, Grattan Institute has recommended policies that could use market-based approaches. These include vehicle emissions standards, or ceilings, for light vehicles, a renewable fuel standard for diesel and aviation fuel, adjusting the Safeguard Mechanism, and expanding state energy efficiency schemes. We also recommended ways to improve confidence in the market for offsetting units. All these are outlined in more detail in Chapter 3.

One downside of multiple sectoral market-based approaches is that the restricted scope for each policy results in different prices for what is ultimately the same activity: reducing emissions. For example, Australia currently has five market-based schemes aimed at reducing emissions: the Large-scale Renewable Energy Target (RET), the Small-scale Renewable Energy Scheme (SRES), the NSW Energy Savings Scheme, the Victorian Energy Upgrades Scheme, and the Federal Government's Emissions Reduction Fund. The tradable credits used in these schemes have very different prices, ranging over the last 12 months from about $16 per tonne for Australian Carbon Credit Units (ACCUs) to $84 per tonne for Victorian Energy Efficiency Certificates (see Figure 2.2).

At some future point, the transaction costs of multiple schemes may outweigh the benefits of using market-based approaches. Future governments could then consider trading ('fungibility') between schemes to provide for more efficient emissions reductions. This could mean, for example, that an energy retailer subject to the Victorian Energy Upgrade liability could purchase a Large Generation Certificate

Figure 2.2: Prices per tonne of emissions reduction vary widely between market-based schemes
Dollars per tonne of emissions



Notes: ACCU = Australian Carbon Credit Unit. ESC = Energy Savings Certificate. LGC = Large-scale Generation Certificate. STC = Small-scale Technology Certificate. VEEC = Victorian Energy Efficiency Certificate. ESCs, LGCs, and STCs are denominated in megawatt-hours, and have been converted to tonnes using the NSW average emissions intensity of electricity (for ESCs) and the National Electricity Market average emissions intensity (for LGCs and STCs).

Source: Grattan analysis of DISER (2021e) and Demand Manager (2021) as at 22 October 2021.

52. Martin (2021).

from the Renewable Energy Target, use an 'exchange rate' that reflected the relative differences in emissions reduced, and surrender that certificate against its liability instead of a Victorian Energy Efficiency Certificate. Fungibility would share the effort of reducing emissions more efficiently across the economy. As we explained in *Towards net zero: Practical policies to offset carbon emissions*, this allows governments to set more ambitious emissions reduction targets.

2.4 Information

Markets, policy, and technology all rely on information to be effective. Three pieces of information are critical: what is Australia's emissions budget? What is the emissions reduction goal to stay within this budget? And how is the economy progressing towards this goal?

2.4.1 Setting the emissions budget and emissions goal

In Chapter 1, we set out the concept of a carbon budget for Australia, linked to Australia's contribution to keeping global temperature rises to below 1.5℃.

Australia has set carbon budgets in the past, by choosing a target and then working out the carbon budget required to meet it. Targets were chosen based on their economic costs and benefits.[53] With the global emissions budget rapidly running out,[54] this process needs to be reversed. Australia should set near-term targets with the aim of staying within a carbon budget that reflects our fair share of global emissions reductions.

The Paris Agreement requires signatories to set new near-term targets every five years, with increasing ambition. Given we already have a 2030 target, the budget for that could be considered locked in.

The Climate Change Authority should be asked to set a budget for the period 2021-2050, and it should advise the Federal Government periodically on near-term targets to meet this budget, starting with a 2035 target. Advice on near-term targets should be provided six months before the COP meeting at which Australia will commit to its new near-term target.

2.4.2 How is the economy progressing towards the goal?

Assessing progress requires understanding not just past trends in emissions, but also the impact of current policies on emissions, and the likely trends in future emissions.

Australia publishes comprehensive and reliable information about the past pattern of emissions, through the National Greenhouse Gas Inventory.

Information about the impact and effectiveness of current policies is more ad hoc. Some policies have formal or statutory reviews through bodies such as the Australian National Audit Office or the Climate Change Authority. Other policies are not independently reviewed.

The Federal Government has committed to a five-yearly 'review and refine' cycle for its long-term emissions reduction plan. The Climate Change Authority should lead these reviews, and should include all major climate change policies to assess their contributions to and effectiveness in meeting emissions goals. Reviews should include recommendations for scaling up to meet changing emissions goals.

More robust projections for future trends

Australia's emissions projections inform election commitments, business decisions, investor confidence, and Australia's international negotiating position at climate conferences. This role will become even

53. See for example DCC (2008, pp. 4–13), and PMC (2015).
54. IPCC (2021, p. 38).

more critical as the economic transformation in pursuit of net zero accelerates.

The timing of publishing emissions projections has varied considerably. In recent years they have been published annually, but publication date is at the discretion of the government of the day, and typically takes place after the COP meeting – meaning the public cannot see the information on which our international commitments are being made.

All projections rely on assumptions, and these will naturally be contested. Past practice was for the government to publish draft assumptions and methodologies, consider submissions on these, and publish all consultants' reports used to inform the emissions projections.[55] This ensured the projections were robust and that the assumptions were stress-tested against real-world conditions. But in recent years, this practice has stopped.

The task of developing and publishing the projections should be turned over to the Climate Change Authority. The Authority should be required to publish the projections no later than three months before the annual Conference of the Parties, so that all Australians can see the basis for Australia's international negotiating position. It should publish draft assumptions and consult on them, and it should publish all consultants' reports used to inform the projections.

2.5 Taking the political heat out of climate change

Ideally, emissions targets, emissions budgets, and reviews of progress should be apolitical.

Again, the Climate Change Authority is ideally placed to play this role. It should be revitalised and resourced to take on the functions we noted in Section 2.4.2 and Section 2.4.1 above, alongside its current activities. It should work with the Productivity Commission to contribute to regular reviews of the impacts of the net zero transition on the Australian economy. As international carbon markets develop, the Authority should also conduct regular reviews of the impacts of these markets on Australian carbon markets, and provide the federal government with advice.

Federal Parliament should also ask the Authority to conduct reviews more often, to inform parliamentary debates on policy. And the Authority should continue to have the power to undertake its own reviews.

2.6 The roles of the state governments

Much commentary about climate policy focuses on the federal government, because climate targets are linked to international obligations. However, the states and territories have policy responsibility for many of the areas critical to reaching net zero, such as energy, transport, land-use planning, land management, and agriculture. All states and territories in Australia have net-zero targets, and most also have near-term targets. These near-term targets add up to an estimated 37-to-42 per cent reduction on 2005 emissions by 2030.[56]

While the 2050 targets are mostly consistent across jurisdictions,[57] the interim targets are not. Inconsistent state targets are a constant bugbear for businesses that operate in more than one state. They can lead to inconsistent policy and regulation, and add to costs. Better co-ordination between states on policy would be ideal, though in practice will never be perfect.[58]

55. See the 2013 projections as an example: DoE (2013).

56. Cleary et al (2021, pp. 6–7).
57. The exceptions are the ACT, which has a net zero by 2045 goal, and Tasmania, which has a net zero by 2030 goal: ACT Government (2019) and Gutwein (2021).
58. State governments are sovereign, and need to respond to pressures and events in their own jurisdictions. Recognising this, the Finkel Review of the National Energy Market suggested establishing principles for ensuring consistency between states,

More co-ordination between state governments in supporting demonstration and commercialisation of new technology would also be beneficial. The flush of funding for hydrogen is a case in point – better co-ordination of state funding would reduce dilution of effort in a small industry, and would allow states to piggyback on each other's efforts, collectively reaching their goals faster.

There are current examples of states aligning policies to reduce costs to business – such as the energy efficiency schemes we explored in *Towards net zero: Practical policies to reduce industrial emissions* – and there are past examples of states collectively working towards uniform national policy, such as the State Taskforce on Emissions Trading in 2006-2007 which laid the groundwork for national carbon pricing. The former COAG Energy Council also improved co-ordination of many areas of national policy, particularly in energy efficiency and hydrogen. But the shift to the National Cabinet committee structure has curtailed opportunities for future co-ordination because of confidentiality requirements[59] and a limited remit.[60]

State and federal governments should re-establish the co-operative co-ordination structures formerly dealt with through Energy Council, and expand their remit to climate policy and programs. This need not add to ministerial workloads – a Senior Council of Officials could do the job.

The Climate Change Authority should also be given a remit to work with state governments at their request, including providing advice to the Energy National Cabinet Reform Committee. This would enable the Authority to include details about forecast and actual emissions reductions from state and territory policies in published emissions projections, leading to a more complete picture of the effort requires to reach net zero.

2.7 Government business-as-usual must be made fit-for-purpose

Many government decisions have profound consequences for the future patterns of emissions. Just as every asset-replacement decision in industry locks in future emissions, so every government decision on planning, infrastructure, resource extraction, forests, national parks, and land management locks in future emissions.

The scale and pace of industrial change to reach net zero – both from industries that decline and those that rise – will require a new way of doing industrial policy that is more 'hands-on' and co-operative. Otherwise, Australia may miss out on many opportunities that net zero brings, because projects will be ensnared in processes and regulation created for a different era. Governments also have a role in supporting communities affected by declining industries – but no role in subsidising companies that are uncompetitive in a net-zero world.

Governments rely on revenue from fossil fuel extraction, and government operations will be affected by a changing climate. Governments must start planning now for how they will manage these impacts on their budgets.

2.7.1 Aligning decisions with net zero

Governments should put in place policies that signal to industry that future emissions must be lower. This involves reversing the pattern of government action we laid out for new technologies in Figure 2.1 on page 18. High-emitting technologies and practices are currently 'normal': they must be first discouraged and then, if necessary, disallowed.

and requiring states to provide notice if they intend to take unilateral action: Finkel et al (2017, p. 363).

59. Saunders (2021).
60. Morrison (2020).

As a first step, governments should stop subsidising practices, developments and technologies that will increase future emissions. In particular, they should not subsidise further expansion of fossil fuel production, such as federal funding for Northern Territory gas industry roads upgrades and gas exploration, or the Queensland Government's royalty holiday for the proposed Carmichael coal mine.[61] To signal expectations for future industrial facilities, the federal government should fulfil its 2016 commitment to establish emissions benchmarks for new industrial facilities that ensure these facilities have lower emissions than incumbents, as we recommended in *Towards net zero: practical policies to reduce industrial emissions*.

State governments play a large role in decisions about infrastructure, which can lock in patterns of emissions for many years. State infrastructure agencies should consider alignment of advice and decisions with each states' net-zero target.

The Climate Change Authority should conduct a review into the consequences of further expansion of fossil fuel production for Australia's net-zero commitment.

Governments are not responsible for the consequences for companies that choose to invest in producing commodities for declining markets. But, as has been seen with the Northern Endeavour LNG facility, governments can end up on the hook for clean-up costs from resources projects if companies declare bankruptcy.[62] One way to mitigate this risk is to require companies in sunset industries to pay into escrow funds that will be released only when they fulfil their end-of-life obligations.[63]

61. Pitt (2021a); and Zillman and Horn (2020).
62. The Federal Government has imposed a temporary levy on offshore petroleum production to pay for decommissioning and remediating the facility and associated oilfields; see Pitt (2021b).
63. See, for example, Wood et al (2019b) and the Queensland Government's *Mineral and Energy Resources (Financial Provisioning Act 2019)*.

2.7.2 A new way of doing industry policy

The scale and pace of change in Australia's industrial sector in pursuit of net zero will be unlike anything seen before. In *Towards net zero: Practical policies to reduce industrial emissions*, we recommended state governments support catalyst organisations in specific locations that are likely to see the greatest changes. These organisations would work with industry and governments to identify and help solve co-ordination problems and infrastructure and energy supply bottlenecks, and avoid some of the downsides that rapid industrial development can bring.

2.7.3 What to do about declining industries

As some traditional industries decline, there will be impacts on some regions and on the people who live and work in those regions. Governments should do three things to support Australian communities and workers.

First, they should resist calls to prop up companies that are uncompetitive in a net-zero global economy. Doing so just prolongs the decline. Secondly, governments should focus on attracting investment in growth industries that capitalise on Australia's competitive and strategic advantages in a low-emissions world. And third, they should help citizens to retrain and re-skill, and they should help communities to attract new industries or refocus old ones. There won't be a one-size-fits-all solution. Support should be tailored to local needs and designed in partnership with the affected communities, involving all levels of government and civil society.

2.7.4 Impacts on government budgets

As outlined in Section 1.3 on page 13, unavoidable climate change will lead to more extreme weather. This will place costs on governments

as well as on the rest of the economy.[64] These costs will include reconstruction and repair of public assets such as roads, railway lines, and electricity transmission. There will be extra costs for preventative measures such as flood levies and fire-fighting capacity. And as hazards become more frequent and intense, mitigation and prevention will become more difficult and more expensive.

Then there are the costs of emergency payments, disaster recovery assistance, and drought assistance. As well, there is increasing pressure on governments to step in and support consumers where markets have decided climate-related risks are too high – insurance in northern Australia is one such example.[65]

Health is another area where governments will bear greater costs. Grattan Institute's 2020 report, *Climate change and health: preparing for the next disaster*, called on all Australian governments to better monitor and communicate climate-related health risks; improve mental health support systems; and review the resilience of the health service to climate-related disasters.[66]

The next federal Intergenerational Report – which seeks to project fiscal outcomes over a forty-year time horizon – should factor in the high and growing costs from the changing climate and from the global and national transition to net zero. The NSW Government already does so,[67] and other state governments could follow suit.

Impacts on government revenue

State and federal governments derive considerable income from fossil fuel extraction and use (summarised in Table 2.1). As the Australian

Table 2.1: All governments in Australia currently receive revenue from fossil fuel production and consumption

	Commonwealth revenue sources	State and territory revenue sources
Fossil fuel extraction and production	• Offshore petroleum leases • Petroleum resource rent tax	• Onshore petroleum and gas leases • Coal mining leases • Coal and gas production royalties
Fossil fuel consumption	• Fuel excise • Import duty on imported fuel • Dividends from Snowy Hydro and its retailers (Red Energy and Lumo Energy)	• Dividends from state-owned electricity generators • Dividends from state-owned energy retailers

Source: Grattan analysis.

64. Infrastructure Australia (2021).
65. Treasury (2021).
66. Duckett et al (2020).
67. NSW Treasury (2021).

economy, and the economies of our major trading partners, move towards net zero, these revenues will decline.

There may also be boosts to government revenue from changes within the economy as a result of moving towards net zero. State governments may benefit from increased mining royalties as demand for critical minerals increases, for example. State-owned electricity generators and retailers may have higher profits (and pay larger dividends to governments) as demand for electricity increases.

Some state governments are already moving to adjust their revenue regimes to allow for the impacts of moving towards net zero. For example, the NSW Government now directs coal royalties into a sovereign wealth fund, rather than treating them as recurrent income. The Victorian Government has begun road-user charging in anticipation of a greater share of electric vehicles. The Federal Government and other state governments should follow this lead.

3 Acting now to deploy what we have and develop what we need

Emissions reduction in Australia is currently being delivered through three avenues. Firstly, electricity sector emissions have been steadily falling over the last five years or so, initially via the Commonwealth's Renewable Energy Target and now through renewable energy targets adopted by state and territory governments.

Secondly, since 2015, the Federal Government has been paying for reductions under contracts through its Emissions Reduction Fund. These contracts amount to about 200 million tonnes in total, achieved for an average contract price of about $12 per tonne.[68]

And thirdly – more recently, and so far at a small level – companies have been voluntarily committing to various emissions-reduction activities and targets.

Maximising uptake of these opportunities will help maintain competitiveness of Australian industries as carbon begins to be priced into global supply chains. It will reduce the pressure to achieve high levels of emissions reductions or very fast cost reductions with new technology; and it will act as an insurance policy, keeping Australia on a net-zero pathway if breakthrough technology takes longer than predicted to reach commercial viability.

Governments can and should take a lead role in technology research and development. To date, this role in the climate change challenge has been filled by the Australian Renewable Energy Agency. More recently, the Technology Investment Roadmap is providing an overarching perspective.[69] As the scope of technology development is widened so must the bodies charged with implementation.

68. CER (2021c).
69. DISER (2020b).

This chapter brings together a comprehensive suite of policies that will connect short-term actions to bend the curve now and the technology development to sustain the momentum, with longer-term deployment towards net zero.

3.1 Transport emissions

Annual transport emissions in Australia grew from 82 million tonnes in 2005 to 100 million tonnes in 2019.[70] The reasons include population growth, larger vehicles, increased freight movements, and more flights. Emissions dropped sharply, by 7 million tonnes, in 2020 due to the COVID-19 pandemic, but the Federal Government projects they will rebound and reach 100 million tonnes by 2024 before declining to 97 million tonnes by 2030 (Figure 3.1 on the following page).

The best way to cut transport emissions is to switch to zero-emissions vehicles, mainly battery electric vehicles, in the light vehicle fleet.[71] The range, performance, upfront price, and total ownership costs of zero-emissions vehicles are rapidly improving. But relying on technology and market forces alone won't be enough to get on track towards net zero by 2050.

The vehicle fleet takes more than 20 years to replace; any new petrol and diesel cars sold in the 2030s could still be in use after 2050. Australia needs a national fleet emissions standard, or ceiling, for new passenger and light commercial vehicles, and the standard should tighten to zero emissions by 2035 at the latest.[72] This would signal an end date for the sale of new petrol and diesel light vehicles, consistent with other major economies and with International Energy Agency

70. DISER (2021a).
71. Wood et al (2021d).
72. Terrill et al (2021).

advice. And it would encourage car manufacturers to supply low- and zero-emissions vehicles that meet Australian consumers' range and performance demands.

Governments should encourage a thriving market for zero-emissions vehicles by exempting them from inefficient taxes such as import duties, luxury car tax, and motor vehicle stamp duty. They should ensure drivers across the country have somewhere to charge electric models. Cutting emissions in the light vehicle fleet would ease immediate pressure to find emissions reductions in other modes of transport, such as aviation and long-distance trucking.

Transport R&D

In long-distance trucking and aviation, affordable alternatives to fossil fuels are harder to identify. In these sectors, governments should make small bets on all the alternatives, such as by funding pilot projects for hydrogen fuel cell trucks, and plan deployment scenarios for each should it become the clear winner. A renewable hydrocarbon fuel target would also be a smart bet, especially for the aviation industry.

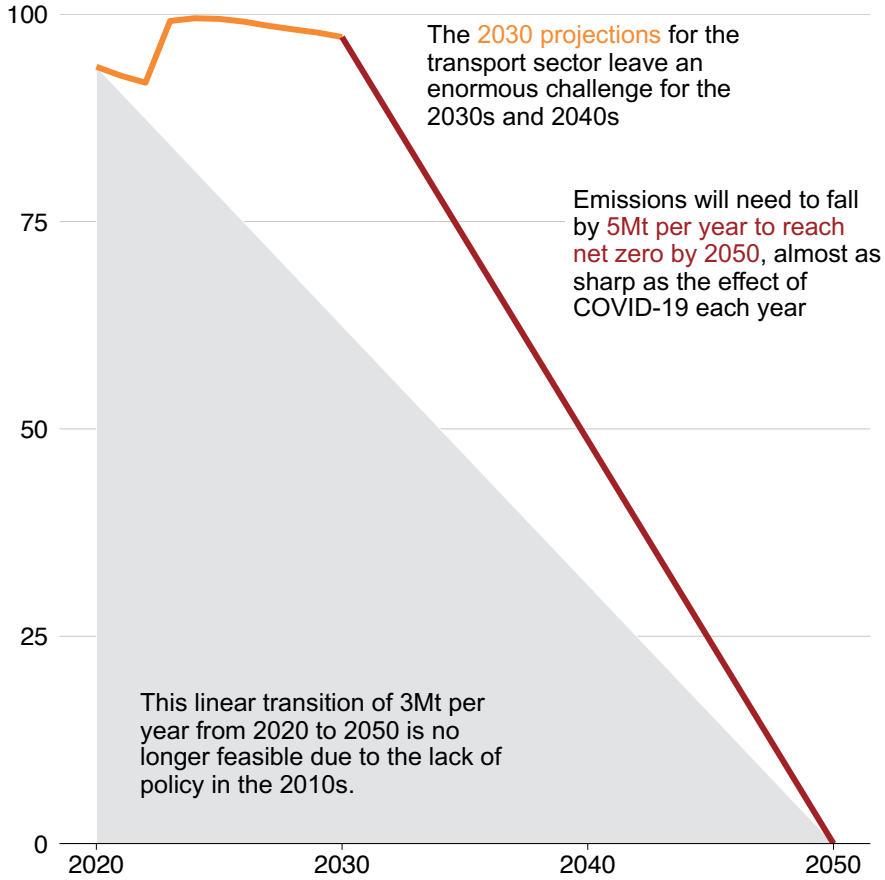
3.2 Industrial emissions

Annual industrial emissions in Australia grew from 130 million tonnes in 2005 to 160 million tonnes in 2020, much of this driven by expansion of gas and coal exports.[73] The Federal Government projects emissions will hover around this level until 2030 (Figure 3.2 on the next page). Current policies place little-to-no downward pressure on emissions, nor do they encourage development of new low- or zero-emissions industrial capacity.

There are thousands of industrial facilities in Australia, and emissions come from thousands of sources. Each sub-sector has different options

Figure 3.1: The transport sector is unlikely to make much progress this decade, and will need transformative action in the 2030s and 2040s

Emissions per year (millions of tonnes)



Note: Emissions are 'carbon dioxide equivalents', estimated using the 100-year global warming potentials published alongside IPCC (2014).

Source: Grattan analysis of DISER (2021a).

73. Grattan analysis of DISER (2021a).

to reduce emissions and many of them require capital investment for new or replacement equipment. Some technologies are available now. Others require further investment from government and industry before they become commercial, meaning some companies have fewer options to quickly achieve step-change emissions reductions. Many facilities produce fossil fuels for export, and their futures will be affected more by other countries' climate change policies than by our own.

Net zero is also an opportunity. There will be increased demand for some sub-sectors – such as minerals and metals – as other countries decarbonise. If Australia can increase the size of these sectors without increasing the amount of emissions, we will prosper in a net-zero world. From now on, every decision to renew, refurbish, or rebuild an industrial asset potentially locks in emissions for the coming decades. Getting these decisions right will be critical for reaching net zero.

Making progress by using the options we already have buys us valuable time and is an insurance policy against delays in commercialisation of new technologies. Existing policies – the Safeguard Mechanism at the federal level, energy savings schemes at state levels – should be modified and expanded to deliver these immediate gains.[74]

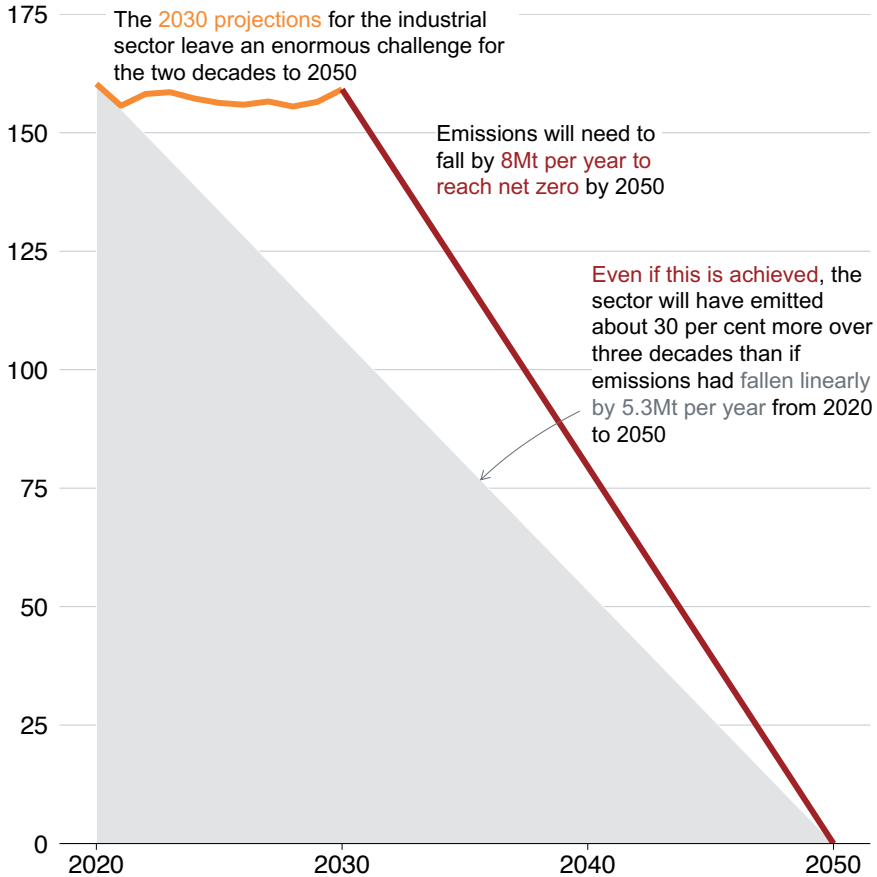
Industrial R&D

There should be an immediate focus on two areas. First, efficient carbon capture from industrial processes where zero-emission alternatives are very expensive or have not been identified; and second, technologies to replace combustion of natural gas and coal as a source of high-temperature heat.

The scale of industrial transformation necessary for net zero will require new ways of thinking about and sharing financial and technology risk between sectors. Australia needs a mix of public and private funding

Figure 3.2: Without action to reduce industrial emissions in the 2020s, the path to net zero by 2050 becomes even steeper

Emissions per year (millions of tonnes)



Notes: Emissions are 'carbon dioxide equivalents', estimated using the 100-year global warming potentials published alongside IPCC (2014).

Source: Grattan analysis of DISER (2021a).

74. Wood et al (2021b).

that goes beyond short-term grant programs, one-off demonstration projects, and project finance. The Federal Government should establish an Industrial Transformation Future Fund now to provide long-term certainty about the government's role in risk-sharing, and to reduce the risk of locking in emissions into the 2040s and 2050s.

Given the scale and pace of change that will be required, state governments should support catalyst organisations in specific locations, to work with industry and governments to identify and help solve co-ordination problems and infrastructure and energy supply bottlenecks.

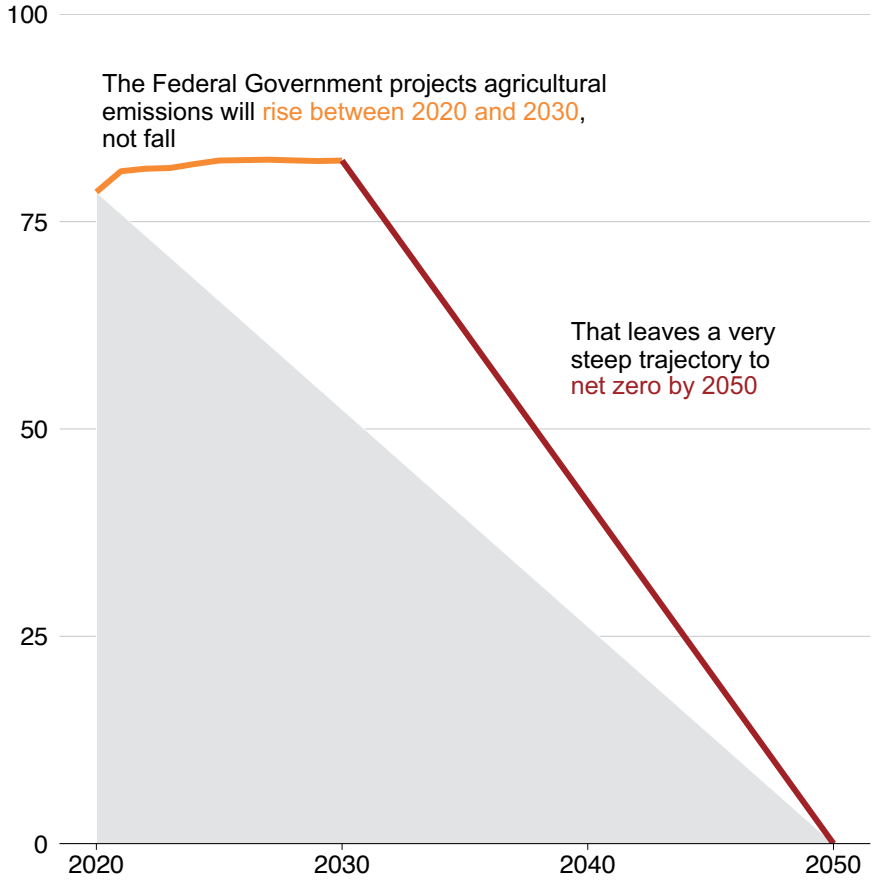
3.3 Agricultural emissions

The agriculture sector was responsible for 15 per cent of Australia's emissions in 2020, emitting 79 million tonnes.[75] This was down from 93 million tonnes in 2005, mainly due to lower livestock numbers: cattle and sheep are responsible for three-quarters of emissions in the sector. Assuming herd numbers continue to recover from recent years of drought, the Federal Government projects that emissions will rise, reaching 82 million tonnes by 2030 (Figure 3.3).

The land sector – distinct from agriculture – includes land-based processes that are not directly related to agricultural production, such as land clearing, forestry, and changes in soil carbon content. These processes currently remove more carbon from the atmosphere than they emit, reducing Australia's emissions by 25 million tonnes in 2020 (compared to net emissions of 89 million tonnes in 2005).[76]

Figure 3.3: Agricultural emissions are projected to rise to 2030, not fall

Emissions per year (millions of tonnes)



Notes: Emissions are 'carbon dioxide equivalents', estimated using the 100-year global warming potentials published alongside IPCC (2014).

Source: Grattan analysis of DISER (2021a).

75. Grattan analysis of DISER (2021a). Agricultural emissions in this section include emissions from stationary energy used in the sector. Figures vary slightly from those reported in Wood et al (2021e) because the updated emissions projections released by the Federal Government in October 2021 revised the historical emissions.
76. DISER (2021a).

'Net zero' means reducing emissions and then offsetting the rest by removing carbon from the atmosphere and permanently storing it, possibly in trees or underground. Although these removal processes are linked to the land, it can be confusing to discuss them alongside emissions reduction from the agriculture and land sectors. We therefore discuss them separately in this report.

The agriculture sector is particularly vulnerable to climate change. Yet it is also a difficult sector in which to cut emissions: there are not yet credible ways to eliminate methane emissions from cattle and sheep (the largest source of emissions); it will take time to implement better manure and fertiliser management across the nation's 50,000 broad-acre farms; and electric vehicles and equipment are not yet fully available to substitute for diesel ones. Nonetheless, there are things that can be done now.

The Federal Government should sharpen the incentives for farmers to deploy low-emissions technologies and practices that are available.[77] This will require improving the Emissions Reduction Fund. The Government should also invest more in programs that deliver practical advice on emissions reduction to farmers.

Agriculture R&D

Government support will be crucial in developing methods that might enable Australia's livestock producers to thrive in a net-zero future. Early-stage technologies such as vaccines and feed additives show promise in reducing the methane emitted from enteric fermentation in cattle and sheep. However, the nature of the challenges suggests that even with this support, it is likely that the agriculture sector could still be a major source of emissions in 2050.

77. Wood et al (2021e).

3.4 The electricity market and its emissions

The electricity sector was responsible for 172 million tonnes of emissions in 2020 – about a third of Australia's total emissions – but this share is projected to fall to just 20 per cent by 2030 as electricity emissions halve due to renewable energy replacing coal and gas-fired generation.[78] Although the economics of renewable energy are favourable, there remain significant challenges that governments must solve, especially related to system security, market signals for investment in new capacity, and the delivery of transmission infrastructure. Chapter 4 will outline the policies needed to keep the sector on track as demand for electricity rises due to electrification of transport and industrial activities.

Electricity R&D

The core renewable generation technologies of solar and wind have made dramatic progress along the cost reduction curve over the past 20 years. There are several technology areas that need targeted R&D effort: grid security with high penetration of distributed electricity resources, and transmission grid planning and optimisation. The biggest challenge to fully eliminating emissions in this sector is the deep storage needed to balance a grid as the share of solar and wind generation exceeds about 90 per cent.[79]

3.5 Natural gas and its emissions

Almost 70 per cent of all the gas produced in Australia is liquefied and exported as LNG, and another 7 per cent is used to fuel the export liquefaction facilities.[80] Of the gas not used for export, about 38 per cent is used for power generation and 35 per cent for manufacturing.

78. DISER (2021a).
79. Wood and Ha (2021, Chapter 3).
80. Wood and Dundas (2020, p. 6).

Households use a further 14 per cent. The remaining 14 per cent is used in a mix of sectors including domestic gas processing, mining, commercial offices and shops, institutional buildings such as hospitals and schools, transport, and construction.

About 19 per cent of Australia's greenhouse gas emissions come from natural gas.[81] This consists of about 14 per cent of total emissions from burning the gas, and a further 5 per cent from fugitive emissions that arise during producing, processing, and transporting gas. Gas produces a smaller share of national emissions than either coal or petroleum products but is nevertheless a significant source of emissions.

In this report, fugitive emissions associated with LNG production and combustion emissions from mining and processing minerals and other manufacturing are covered under industrial emissions (Section 3.2 on page 28). Emissions from power generation are covered under electricity (Section 3.4 on the preceding page). The remaining uses of natural gas are for household and small commercial applications, i.e., cooking and heating water and buildings. These uses currently consume 225 petajoules of natural gas and contribute 12 million tonnes of emissions per year.[82]

Australia must either replace natural gas with low-emissions substitutes such as biomethane or hydrogen, or switch to electricity and take advantage of the decarbonising grid. We consider it likely that electrification will be the best long-term choice, although following any one of these choices brings significant challenges. Governments must move quickly to confirm the preferred direction in each state or territory and then plan for a future without natural gas in these applications.

81. Ibid (p. 8).
82. DISER (2021f, Table K) and DISER (2021e). Combustion of all fuels (including gas) within buildings is responsible for about 19 million tonnes of emissions per year: DISER (2021a).

In the meantime, it is already clear that households would save money and Australia would reduce emissions if new houses in NSW, Queensland, South Australia, and the ACT were all-electric. In these places, governments should impose a moratorium on new gas connections.

3.6 Emissions from waste

The waste sector was responsible for 13 million tonnes of Australia's emissions in 2020.[83] The Federal Government expects this figure to decline steadily and slowly to 11 million tonnes in 2030.

Most emissions come from methane released as waste breaks down. Reducing emissions in the waste sector will require two strategies: generating less waste in the first place, and capturing and flaring more of the methane emissions released. Policies to reduce waste and increase recycling rates will help to trim emissions further, but there will probably remain 5-to-10 million tonnes of emissions from this sector in 2050.

3.7 Offsetting what's left

Australian governments can and should act now to create momentum towards the net-zero goal. Strong policies are required to reach net zero, but some sectors and individuals may be able to do more than others at different times. By offsetting over-achievement in one sector against under-achievement in another, effort can be shared across the economy and the goal achieved at lower cost.

The fourth report in this series[84] recommended policies to ensure Australia has access to high-quality offsetting units, both to act as a 'safety valve' if the cost of reducing emissions sector-by-sector is higher

83. Ibid.
84. Wood et al (2021c).

than anticipated, and for the ongoing task of offsetting emissions that can't be avoided.

Offsetting is a difficult part of the net-zero conversation. Some see it as an excuse to delay reductions, others as bringing about unacceptable social change, particularly in rural areas. It has been plagued by integrity problems, and there is understandable cynicism about its potential.

None of this changes the reality: in pursuit of net zero, offsetting will be required because there will be emissions we cannot eliminate, and some where we will not be willing to pay the price to do so. The only option to deal with these emissions is to deliberately remove carbon dioxide from the atmosphere to offset them.

Processes to permanently remove carbon dioxide from the atmosphere are uncertain or expensive – or both. Emitting is certain: we know that every tonne of emissions in the atmosphere contributes to global temperature rise. For this reason, offsetting is not a direct substitute for avoiding or reducing emissions in other ways.

Australia has the regulatory structures in place to support offsetting. Governments should be clear about the role of offsetting in each policy they implement in pursuit of net zero. They should also make sure certification for offsetting units maintains high integrity. Otherwise, companies and individuals will bear costs with no corresponding drop in emissions.

Imports and exports of offsetting units will become more important as all countries move towards net zero. There is no need to assume Australia must be self-sufficient in offsetting units, but local supply requires our governments to implement strong policies to drive emissions reduction and removal of carbon dioxide from the atmosphere. The Federal Government should introduce rules to support international trade in offsetting units, both for exports and imports.

3.8 Cross-sector R&D

Beyond the sector-specific areas of technology development covered above, there are several cross-sector opportunities where the current need and/or potential strategic value justify significant support driven through the Technology Investment Roadmap:

- Soil carbon sequestration and direct air capture;
- Sector coupling across renewable electricity generation, hydrogen production, and direct air capture; and
- Large-scale, cost-effective CO2 mineralisation.

At present, there is an extraordinary level of hyperbole and scattered funding applied to the potential of hydrogen. Yet there is genuine potential for hydrogen as an energy carrier for large-scale exports, renewables-based manufacturing, heavy-vehicle and marine transport, and possibly deep storage to balance a renewables-dominated electricity grid. This potential justifies the priority being given to R&D to drive down the costs of the technologies along the hydrogen supply chains in each of these applications.

4 Getting the electricity sector to net zero

The electricity sector is already transforming. Old, coal and gas-fired power stations are being retired, and renewable energy is filling the gap. The electricity sector has clear technological solutions with known costs that make deep emissions cuts possible and affordable (Figure 4.1). But there are technical challenges to solve, and an unprecedented infrastructure pipeline that must be delivered to ensure the sector remains on track for net zero. The coordination challenge will only grow if the sector is pressured to decarbonise faster to save more carbon budget for the rest of the economy.

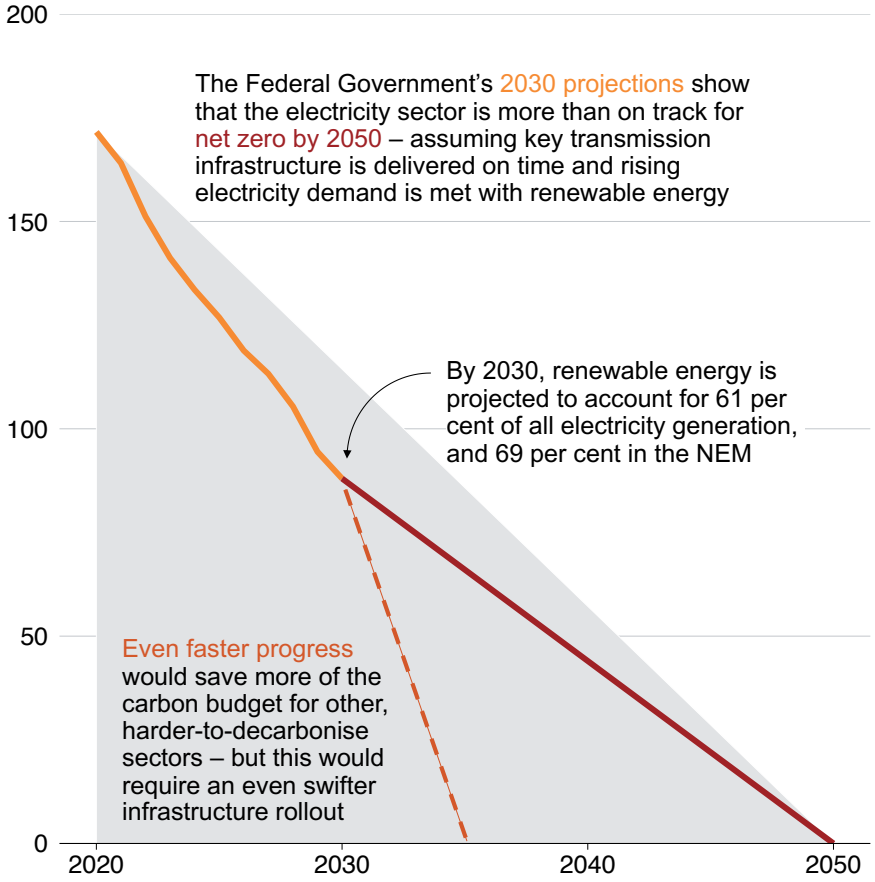
Low-emissions electricity is critical for decarbonising other sectors, such as transport and industry. Demand for electricity is likely to grow over the next three decades; switching from fossil fuels to electricity in other sectors could double national electricity demand. If Australia seizes opportunities to export energy-intensive commodities based on renewable energy, electricity demand could quadruple or more.

Achieving zero emissions in the electricity sector is not impossible, but could be more expensive than using a near-100 per cent renewable system with some gas to ensure reliable electricity supply in rare situations. Any remaining emissions from burning fossil fuels will add to Australia's demand for offsetting. The optimal proportion of renewables will depend on the future cost of each generation technology (including storage systems) and the future cost of offsetting units.

Governments need to plan for a net-zero economy; this means accepting a greater reliance on low-emissions electricity. They should continue to pursue reforms to keep electricity systems operating reliably and securely,[85] while ensuring these reforms are consistent with long-term decarbonisation goals – which may require electricity to

Figure 4.1: The Federal Government projects emissions in the electricity sector to fall by about 50 per cent this decade

Emissions (million tonnes of carbon dioxide equivalent)



Source: Grattan analysis of DISER (2021a).

85. ESB (2021).

nearly or fully decarbonise well-before 2050. Australia's governments should coordinate state and federal policies, and analyse which risks are best borne by electricity consumers, electricity providers, and taxpayers.

4.1 Electricity sector emissions are falling

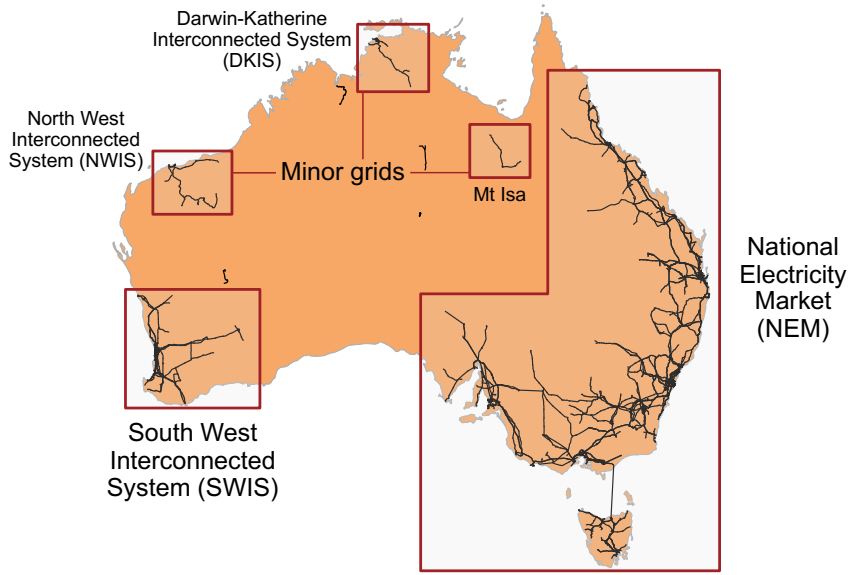
Australia's electricity sector emissions have fallen from a peak of 212 million tonnes in 2009 to 172 million tonnes in 2020.[86] Over the same period, renewable energy grew from just 7.5 per cent of total electricity generation (mostly hydro) to 24 per cent (mostly wind and solar).[87] Coal's share of generation fell from 74 per cent to 54 per cent. A transition is underway, and the pace appears to be accelerating.

Nowhere is the transition more apparent than in the National Electricity Market (NEM), the largest electricity system in Australia. The NEM covers most of the population of the eastern states (Figure 4.2), and is responsible for more than 80 per cent of electricity emissions.[88]

Emissions in the NEM declined by 35 million tonnes (20 per cent) from 2005 to 2020. The Federal Government projects that emissions will fall another 78 million tonnes by 2030, to 64 million tonnes. This is notably lower than the previous year's projection for 2030, which estimated 88 million tonnes of emissions for the NEM.[89] The anticipated faster progress is due to additional electricity policies introduced by state governments.[90]

86. DISER (2021a).
87. Based on data for financial year 2008-09 and calendar year 2020: DISER (2021f, Table O). Calendar year estimates are not available before 2015.
88. DISER (2021a).
89. DISER (2020a).
90. Cleary et al (2021, pp. 10–11) and Hare et al (2021, p. 6). For example, the NSW Government has legislated an Electricity Infrastructure Roadmap that aims to deliver 12GW of new renewable energy projects in the state and 2GW of new long-duration storage projects: NSW Government (2020, pp. 26–29).

Figure 4.2: Australia's major electricity networks



Source: Grattan analysis of Geoscience Australia (2021).

These changes are driven by three main factors. Coal-fired power stations, the most emissions-intensive sources of electricity, are nearing the end of their technical lives – the median age of remaining coal plants in the NEM is 35 years.[91] Wind and solar are now the cheapest sources of bulk electricity and produce zero emissions.[92] And total demand for electricity has been flat over the past decade.[93] Together with policies to promote renewable energy uptake – such as the Renewable Energy Target, generous feed-in tariffs for rooftop solar, and state underwriting of contracts for renewable energy – these factors

91. AER (2021, p. 26).
92. Graham et al (2020, p. 61).
93. Based on electricity consumption from all sources, including behind-the-meter rooftop solar: AER (2021, p. 70).

have meant that renewable energy has effectively eroded the market share of fossil fuels.

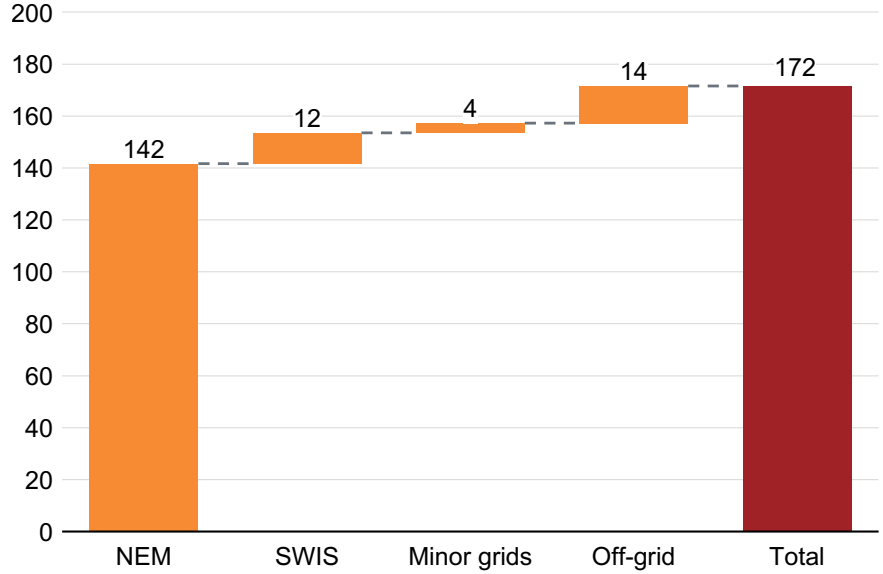
Change is also afoot in other electricity systems. The South West Interconnected System (SWIS) is the electricity network supplying most customers in Western Australia. Unlike the NEM, where coal is the dominant source of electricity, gas and coal contribute a similar share of electricity in the SWIS.[94] Renewables supply about a fifth of all electricity, due to the very high adoption of rooftop solar.[95] The SWIS contributed about 12 million tonnes of emissions in 2020 (Figure 4.3). The Federal Government projects this will fall about 36 per cent by 2030 to 8 million tonnes, due to the closure of coal-fired power stations and growing deployment of wind and solar.[96]

Australia has three minor grids, serving the Darwin-Katherine region of the NT, the Mt Isa region of Queensland, and the Pilbara region of WA. These grids are mostly powered by gas, and together contribute about 4 million tonnes of emissions.[97] The Federal Government projects this will fall to about 2 million tonnes by about 2030.

Australia also has many off-grid generators that provide electricity to consumers who are not connected to any power network. Gas and diesel are the most common sources of electricity for off-grid users, including remote communities, mines, and LNG facilities. These sources contribute 14-to-15 million tonnes of emissions each year,[98] 6 million of which are from on-site generation at LNG facilities.[99] Off-grid sources of emissions are projected to remain flat out to 2030, with

94. Energy Transformation Taskforce (2020, p. 22).
95. Ibid (p. 48).
96. DISER (2021a, pp. 16–17).
97. DISER (ibid). The Darwin-Katherine Interconnected System uses only about 12 per cent renewable energy today, but the NT Government is committed to lifting this to 50 per cent by 2030: NT Government (2021, p. 15).
98. DISER (2021a).
99. DISER (2020a, p. 39).

Figure 4.3: Emissions across Australia's electricity networks
2020 emissions (million tonnes of carbon dioxide equivalent)



Notes: NEM = National Electricity Market. SWIS = South West Interconnected System.
Source: DISER (2021a).

deployment of renewable energy offset by increases in electricity demand.

4.2 Low-emissions electricity is crucial for decarbonising the Australian economy

Previous reports in this series have noted the importance of 'fuel switching' as a decarbonisation strategy. In transport, replacing petrol/diesel-powered vehicles with electric vehicles could eliminate the 60 million tonnes of emissions from cars, vans, and utes.[100] In the industrial sector, there's a significant opportunity to switch from gas

100. Wood et al (2021d).

and diesel machinery to electric, particularly for low-grade heat (such as boilers) and compressors.[101] Similarly for the agriculture sector, particularly as electric farm vehicles and machinery become more widely available.[102]

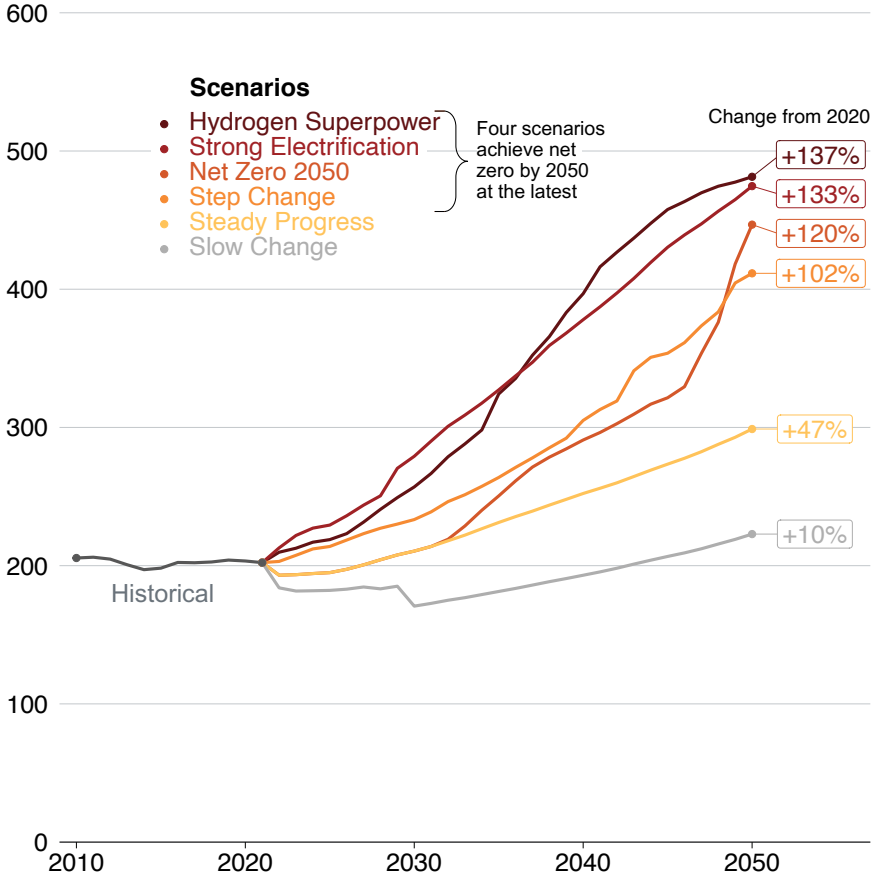
Grattan's 2020 report *Flame Out* also showed that switching from gas to electricity for domestic appliances and heating is an obvious way to reduce the 12 million tonnes of emissions that come from gas use in buildings.[103] The costs of switching will vary from state to state and home to home, but alternative solutions, such as low-emissions hydrogen or biomethane gas substitutes, could be more expensive.

The Australian Energy Market Operator (AEMO) models a range of scenarios to determine the likely least-cost path for the NEM. These scenarios include forecasts of how demand for electricity might change over coming decades due to electrification of vehicles, appliances, and machinery, and other factors such as economic and population growth and a warmer climate. In scenarios where emissions reach net zero by 2050, demand for electricity is likely to more than double by 2050 (Figure 4.4). However, only the most ambitious of these scenarios are consistent with holding warming to below 1.5℃. Achieving net zero by 2050 is insufficient by itself to meet the goals of the Paris Agreement – it is total amount of emissions released (the carbon budget) that determines warming.[104]

In the net-zero scenarios, electric vehicles add 69-to-83 terawatt-hours (TWh) of annual demand in the NEM by 2050 (compared to about 200TWh of demand in 2020), while electrification of homes and

Figure 4.4: In any net-zero aligned scenario, demand in the National Electricity Market is likely to more than double

Total annual electricity demand (terawatt-hours)



Notes: Of these scenarios, 'Hydrogen Superpower' and 'Strong Electrification' stay within a carbon budget consistent with keeping warming to below 1.5℃, 'Step Change' is consistent with below 2℃, and 'Net Zero 2050' is consistent with about 2.6℃: AEMO (2021a, p. 34) and Reedman et al (2021). Electricity demand includes demand met by rooftop solar and other small-scale renewables, not just operational demand in the NEM. Years are financial years (i.e. 2020 = FY2019-20).

Source: Grattan analysis of AEMO (2021b) and McConnell et al (2021).

101. Wood et al (2021b).
102. Wood et al (2021e).
103. Wood and Dundas (2020). Total stationary energy use in buildings (including gas) was estimated to contribute 19 million tonnes of emissions in 2020: DISER (2021a).
104. AEMO (2021a, p. 34).

businesses adds 67-to-121TWh.[105] A further 40-to-56TWh of demand are assumed to be eliminated through deployment of energy efficiency measures – without these, demand would be higher still.

Australia has a substantial opportunity to become an exporter of energy-intensive commodities, based on its comparative advantage in renewable energy.[106] If it seizes this opportunity, electricity demand could rise further. For example, the CSIRO and ClimateWorks estimate that total electricity demand in the NEM could rise by a factor of 5 or more if Australia builds a zero-emissions hydrogen export industry even half the scale of its existing LNG exports.[107]

One further potential source of electricity demand is to run direct air carbon capture and storage (DACCS) facilities. These require 5.3-to-10.3GJ of energy per tonne of CO_2 captured and stored.[108] Some of the energy is needed in the form of heat; electricity use could range from 1-to-1.5TWh per million tonnes of CO_2 if efficient electric heat pumps can be used to provide the heat,[109] and 2-to-3TWh per million tonnes of CO_2 if high-temperature heat is needed.[110]

105. AEMO (2021b). Annual demand in 2020 estimated from NEM demand plus rooftop solar production: McConnell et al (2021).
106. Wood et al (2021a).
107. Based on a scenario where Australia exports about 1,800 petajoules (PJ) of hydrogen per year in 2050, and produces about 50 million tonnes of green steel per year using 200PJ of hydrogen: Reedman et al (2021, pp. 10, 58). Domestic LNG exports were about 4,400PJ in 2019-20: DISER (2021f, Table J).
108. Direct air capture energy use is taken from Realmonte et al (2019, Table 2). The energy for compressing the gas for storage is taken from Jackson and Brodal (2019).
109. Heat pumps can be used only if low-temperature heat is needed; amine solvents in the DACCS process require temperatures of 85-to-120℃ to operate: Realmonte et al (2019). A coefficient of performance of 1.7 is assumed for the heat pump (meaning it delivers 1.7 times as much thermal energy for each unit of electrical energy supplied), based on an air-based heat pump described in Yan et al (2021).
110. Based on using resistive electric heating to provide the 800℃ and higher temperatures needed for hydroxide solution DACCS: Realmonte et al (2019).

Sequestering 100 million tonnes of CO_2 per year would therefore require 100-to-300TWh of additional electricity supply each year – in the ballpark of another NEM's worth of electricity.

To prevent emissions reductions in one sector being negated by rising emissions in the electricity sector, it's crucial that the source of electricity to meet this new demand is itself low-emissions. This means Australia will need vastly more renewable generation capacity than it has today. If nationwide electricity demand doubles by mid-century, Australia would need at least 100 gigawatts of wind and solar capacity just to meet this extra demand,[111] let alone compensating for the ageing coal and gas-fired power stations that will close.

4.3 100 per cent renewable energy is not necessarily the solution

The electricity sector faces a tricky three-way balancing act: emissions must come down while maintaining reliability and minimising cost. A previous Grattan report, *Go for net zero: A practical plan for reliable, affordable, low-emissions electricity*, outlined in detail why a mostly renewable – but not necessarily 100 per cent renewable – electricity system best meets these three criteria in the medium term based on current economic projections.[112] This section summarises the main argument.

Wind and solar are both zero-emissions, and the cheapest forms of new energy thanks to remarkable cost reductions over the past few decades.[113] These renewable technologies make deep emissions cuts possible. But their supply is inherently variable, changing with the time

111. Based on national electricity consumption of 265TWh in 2019-20 and assuming a combined capacity factor of 30 per cent for wind and solar: DISER (2021f, Table O).
112. Wood and Ha (2021).
113. The levelised cost of energy (LCOE) is often used to describe the cost of electricity supply, taking into consideration both capital costs and operating costs

of day and the weather. To ensure consumers can get power when they need it, renewables must be 'firmed'. This can be done in a few ways (Box 2), but each adds to the cost of delivering electricity to consumers. This is why increasing the share of renewables does not necessarily lower the cost of supplying electricity, despite the very low cost of wind and solar.

The best information available today indicates climbing from about 90 per cent to 99 per cent renewables could be expensive – and from 99 to 100 per cent could be very expensive – with current technologies.[114] This is mainly due to the challenge of balancing demand and supply during rare, sustained periods of low wind, low solar, and high demand.[115] Maintaining reliability during such multi-day events requires significant deployment of firming strategies, which increases the cost of supplying electricity.

Were it not for emissions, gas would be an ideal backstop for this challenge. Gas-fired generators are cheap to build but costly to run. These economics suit this problem nicely because they will be needed only infrequently.

Alternative solutions look more expensive. Renewable hydrogen could well replace gas as a backstop, but only if the cost of producing and storing it falls significantly. Carbon capture and storage (CCS) could be deployed with gas-fired generation, but this requires suitable geology for carbon storage nearby, and CCS is much less economic if used

over the asset's life. The LCOE of new solar and wind are below that of any other new source of electricity in Australia: Graham et al (2020, p. 61).

114. Wood and Ha (2021), Dowling et al (2020), Gilbert (2021), Osmond (2020) and Leitch (2021). Expensive does not mean impossible: many studies find that it should be technically feasible to achieve 100 per cent renewable electricity systems: Brown et al (2018).

115. Wood and Ha (2021); and Ruhnau and Qvist (2021).

Box 2: How to ensure reliability when wind and solar provide most electricity

There are several ways to improve the reliability of electricity supply in a high-renewables system; the challenge is finding the lowest-cost combination of ways to do so. The options include:

- Overbuilding wind and solar capacity, so that there's more energy available even in cloudy or still weather (but accepting that there will be times of abundant energy where some must be wasted or 'spilled');
- Building more transmission between regions to harness the geographic diversity of Australia and take advantage of different weather in different locations;
- Building electricity sources that can be turned on or off on demand ('dispatchable capacity'), either electricity storage systems (such as batteries or pumped hydro dams) to save excess power for use later,[a] or thermal power stations (such as gas-fired power plants);[b] and
- Making it more attractive for consumers to reduce their demand during peak periods (sometimes called 'demand-side participation' or 'demand response').

a. Hydrogen could also be used in future, with electricity converted to hydrogen for storage and then converted back to electricity using either a fuel cell or gas turbine.

b. Other thermal power stations use coal and nuclear energy, as well as less-common sources such as biomass and geothermal. Coal is a poor form of dispatchable capacity because it can ramp up or down only slowly; it is much less flexible than other technologies. Nuclear energy is currently prohibited in Australia by legislation, and even if it were not, nuclear power plants behave more like coal-fired generators, making them less well-suited to balancing wind and solar supply: Morris (2018, pp. 29–31, 47–48).

infrequently.[116] Batteries and even pumped hydro will struggle over rare, multi-day challenges.

Other than gas, the other possible solution is sector-coupling: the emergence of huge, flexible sources of demand for electricity that can be turned down during periods of scarce energy. A large-scale, grid-connected hydrogen electrolysis industry is one example; the other could be grid-connected DACCS.[117] If parts of these processes can be designed to operate flexibly in response to wholesale electricity prices, then less other firming will be needed.[118] But the effectiveness of these options remains uncertain: reducing or stopping hydrogen production or DACCS for days-to-weeks may be economic only in certain situations.[119]

Because gas is not a zero-emissions solution, any remaining emissions from gas use will need to be offset by permanently removing carbon dioxide from the atmosphere.[120] The optimal ratio of renewables to gas will depend on the future cost of each generation technology and the future cost of offsetting units.

As the cost of offsetting rises, increasing the share of renewables to 100 per cent may become the cheaper way to reach net zero, with zero-emissions hydrogen firming the electricity supply during rare, sustained periods of low wind, low solar, and high demand. The timing of this crossover point remains uncertain: the economics of hydrogen and offsetting will become much clearer over the next decade.

In the meantime, governments have little to worry about from a cost or reliability perspective in accepting that the electricity sector will move to very high levels of renewable energy. Governments' immediate priority should be removing obstacles to this transition, rather than worrying about how and when to eliminate the final few per cent of emissions from the sector.

4.4 Governments have to solve several problems to get electricity right

The fundamental economics of renewable energy mean the electricity sector can go a long way towards achieving net zero at little cost. But there are three key issues governments need to resolve as soon as possible to make it happen: technical challenges to operating a mostly-renewable system securely; the need for vastly more electricity infrastructure over a short timeframe; and, in the NEM, the uncoordinated objectives of the state and federal governments. The Energy Security Board, under the directive of the Energy National Cabinet Reform Committee, has made recommendations on these issues that governments should adopt.[121]

Emissions in the electricity sector may need to fall faster than projected, either to make up for slower progress in other harder-to-decarbonise sectors or because the climate imperative leads to governments setting stronger targets than net zero by 2050. To keep alive the possibility of reducing electricity emissions faster, governments will need to understand what these pathways look like and what policy framework is necessary to achieve them. This will require governments to grapple with fundamental questions of how best to allocate cost and risk between electricity companies, consumers, and taxpayers.

116. Most examples of CCS today capture about 90 per cent of emissions: IEA (2020) – at that rate, some offsetting is still needed to get to net zero.
117. However, this would require either the capture or storage process to be interruptible, with CO_2 tanks or balloons providing the buffer between the two processes.
118. Wood and Ha (2021, pp. 40–41); and Transgrid (2021, p. 49).
119. These industrial facilities will need to recover their capital costs; switching off too frequently will make this economically challenging, particularly for DACCS: Breyer et al (2020). If hydrogen customers have inflexible demand for the commodity, the facilities will need access to low-cost hydrogen storage.
120. For a discussion of permanence, see Wood et al (2021c, pp. 38–44) and Joppa et al (2021).
121. ESB (2021).

4.4.1 Keep making near-term reforms to keep electricity systems secure and reliable

Operating a large-scale electricity system with very high levels of variable renewable energy – wind and solar – poses technical challenges. This is because electricity systems are very sensitive; demand and supply must match exactly at all times, and characteristics such as voltage and frequency must stay within narrow bands. If a system operates outside of safe limits, generators may shut off to protect their electrical components, potentially leading to cascading failures across the network and, in the worst instances, a 'system black' event: a complete blackout requiring the whole system to be re-started.

The challenge is exacerbated by the rise of distributed energy resources (DER) such as rooftop solar and, increasingly, electric vehicles. These technologies have allowed consumers to participate in electricity markets, but without the same price signals and obligations to keep the system secure that traditional generators have faced. One particular looming issue is minimum demand – in the middle of the day, rooftop solar can provide so much electricity that many large-scale generators are not needed. This creates a problem because many large-scale generators provide essential services to keep the system operating within its technical limits.[122]

The Australian Energy Market Operator (AEMO) has set a 2025 target for solving the engineering challenges associated with operating a grid that achieves an instantaneous renewables share of 100 per cent.[123] The Energy Security Board (ESB) has outlined a series of near-term and longer-term reforms to help integrate distributed energy resources (DER) into the NEM.[124] Governments of jurisdictions that participate in the NEM should implement these reforms, and other governments should adapt them to suit the needs of the remaining electricity systems in Australia.

In the NEM, concerns about reliability have prompted several government interventions in recent years (described in more detail in Section 4.4.3 on page 43). The ESB has recommended governments and industry work together to design a mechanism that appropriately values dispatchable capacity, to reduce risks for investors and reduce intervention from governments.[125] The relevant participants should work in good faith to design such a mechanism, while ensuring it does not impede the decarbonisation of the NEM.

4.4.2 Unblock the electricity infrastructure pipeline

Demand for electricity is likely to at least double by 2050 if Australia achieves net zero (Figure 4.4 on page 37). As noted in Section 4.2, at least 100GW of new renewable capacity will be needed to meet this new demand, plus more to replace existing coal and gas-fired power stations as they are retired.

Some of this capacity will be distributed in homes and businesses as rooftop solar. But to meet such large growth in demand, most capacity will be provided by large-scale wind and solar farms, often located far from the populations centres they serve. This model of supplying electricity will require much more transmission than we have today, to connect geographically dispersed generators to the network.[126]

Greater transmission can also help to reduce the cost of maintaining reliable electricity supply. As noted in Box 2 on page 39, stronger interconnection across an electricity system means smoothing out local shortages and excesses of supply. This is by no means a silver bullet – the whole country is dark at night, and, in rare instances,

122. AEMO (2021c, pp. 52–61).
123. Westerman (2021).
124. ESB (2021, pp. 35–39).
125. Ibid (pp. 22–27).
126. Ibid (pp. 44–45).

large swathes of Australia may be still – but it does allow regions to share their resources, reducing the need for backup supply. This is particularly the case in the NEM – it is one of the largest interconnected systems in the world, and it spans several different climate zones.[127]

Every two years, AEMO models the potential transmission upgrades that the NEM will require, in its Integrated System Plan. It has found that several major transmission projects will be needed over the next two decades to keep costs down in a high-renewables system.[128] These projects would strengthen the connections between the states of the NEM, while also unlocking renewable resources within each state through the establishment of renewable energy zones.

Transmission infrastructure requires major capital investment – many of the upgrades identified in the Integrated System Plan are multi-billion dollar projects.[129] These assets are generally built and maintained by transmission network service providers (TNSPs), which are companies that receive a regulated return on their investment, paid for by consumers. That means the risk of over-investment sits largely with consumers, and this understandably raises concerns of wasteful projects or 'white elephants'.[130] While all investments should stack up economically, the transmission pathway identified by AEMO would still appear to be better than building nothing, even if the estimated costs of each project were to double.[131]

One of the major challenges facing the NEM will be how to deliver so much infrastructure on time and on budget. A boom in electricity infrastructure could lead to short-term supply constraints, pushing up costs.[132] It will be difficult to balance the needs of electricity users with those of the local communities and environment through which new power lines will run. TNSPs have an unprecedented task ahead of them. The consequences of failure are severe: a delayed commissioning of key infrastructure could mean major coal and gas-fired power stations are retired (or break down) before sufficient new generation is available.

Distribution networks, which supply power to homes and businesses, may also need substantial augmentation to deal with increased electricity demand from the electrification of transport and gas loads.

Resolving cost allocation issues

Some governments and TNSPs are dissatisfied with the current allocation of costs for upgrades to interconnectors (transmission between NEM regions). Historically the costs have been split between the states which are linked by the interconnector. But there is evidence that the benefits of interconnection spread beyond the two jurisdictions that are linked.[133] The ESB was asked to consider whether the present method of paying for interconnectors should be replaced with a 'beneficiary-pays' model;[134] governments are considering its advice, but have not yet made any decisions.[135]

Governments should resolve this issue quickly, recognising the value to the entire NEM of interconnector upgrades that pass a rigorous cost-benefit analysis. Greater connection between NEM members would also increase competition, to the benefit of consumers.[136]

127. Wood and Ha (2021, p. 10).
128. AEMO (2020b, pp. 13–20, 64–74).
129. AEMO (2020c).
130. EUAA (2020).
131. Wood and Ha (2021, pp. 25, 57).
132. This situation occurred during the construction of LNG facilities in Australia between 2005 and 2015: Wood et al (2021b, p. 43).
133. TasNetworks (2020, pp. 13–14).
134. ESB (2020).
135. ESB (2021, p. 45).
136. ACCC (2003), as cited in Mountain and Swier (2003); Sims (2003).

4.4.3 Align state and federal policies to ensure a coordinated transformation of the electricity sector

Electricity supply is the responsibility of both the federal and state governments. All of these governments recognise the need to achieve net zero. But they have repeatedly failed to implement consistent policies to help the electricity sector get there.[137] The result is an uncoordinated mess of seemingly contradictory interventions, particularly in the NEM. Governments have their own renewable energy targets,[138] emissions targets,[139] roadmaps,[140] deals with coal-fired power stations,[141] contracts with wind and solar generators,[142] and investments in gas-fired generation and hydro power.[143]

The ad-hoc interventions can deter private investment in electricity generation, transfer too much risk to taxpayers or consumers, and even actively work against each other: deals to keep coal-fired power stations open longer while simultaneously encouraging more renewable energy deployment is a lot like driving with a foot on both the brake and the accelerator at the same time.

All governments should recognise the long-term future of the electricity system in a net-zero economy: electricity demand will be higher, renewables will supply most or all electricity, batteries and long-duration storage will be necessary along with some peaking gas (until zero-emissions alternatives are cheaper), more transmission and distribution infrastructure will be needed, and consumers will increasingly generate and store their own power. Working backwards from this end state, there are some clear priorities for governments.

First, they should avoid policies and interventions that are inconsistent with this long-term objective. That means not extending the life of coal or gas-fired power stations. It means seeking out ways to make transmission cheaper and easier to deliver, rather than exacerbating existing barriers (such as community opposition). And it means imposing moratoria on the expansion of gas networks: the highest-value uses for gas are likely to be in industry and in providing backstop electricity generation, not heating buildings or water.

Governments that participate in the NEM should re-commit to the idea of the NEM, recognising that achieving a net-zero electricity system will be cheaper if states work together and pool resources rather than trying to go it alone. They should agree on a mechanism for retiring coal and gas plants in the NEM in a coordinated way: this could include requiring companies of ageing assets to pay money into an escrow fund that will be returned only if their asset closes within a nominated timeframe,[144] or governments holding auctions for coal closure.[145]

And governments should agree on a mechanism to bring new supply into the system, deciding who is best placed to bear the risks of bad investments. This could mean establishing a clear market framework for reducing emissions – such as the abandoned National Energy Guarantee or the Finkel Review's recommended Clean Energy Target[146] – and then allowing the market to function free from the uncertainty of government intervention. It could mean bolstering the Large-scale Renewable Energy Target, which has now been met and is therefore no longer encouraging more renewable deployment. Or it

137. Wood and Ha (2021, pp. 9–11).
138. E.g. Queensland's 50 per cent target by 2030: DEPW (2021).
139. E.g. Victoria's 45-to-50 per cent economy-wide emissions reduction target by 2030: DELWP (2021).
140. E.g. NSW's Electricity Infrastructure Roadmap: NSW Government (2020).
141. E.g. the Victorian Government's deal with EnergyAustralia's Yallourn plant: Macdonald-Smith (2021).
142. E.g. the ACT's contracts-for-difference: ACT Government (2021).
143. E.g. the Federal Government's investments in the Kurri Kurri gas-fired power station and Snowy Hydro 2.0: Taylor (2021).
144. Wood et al (2019b).
145. Jotzo and Mazouz (2015).
146. Wood et al (2017); and Wood et al (2018).

could mean adopting the NSW approach of giving governments the job of determining how much infrastructure is needed, and then giving a consumer trustee the task of contracting to deliver these projects.

Each approach has strengths and weaknesses, but adopting a common approach would be preferable to the disorganised set of policies we have today, given the urgency with which the sector must transform in order to meet governments' stated climate objectives.

4.4.4 How to accelerate decarbonisation in the electricity sector

Electricity is a sector that could feasibly decarbonise faster than the rest of the economy because of the relative maturity of low-emissions energy technologies. But faster progress will exacerbate existing challenges. If governments commit to more ambitious emissions reductions in order to meet the temperature goals of the Paris Agreement, they will need to solve these challenges expeditiously. That means recognising the scale of electricity infrastructure needed to decarbonise the sector by their chosen date, and working backwards from there.

This will require accelerating transmission investment while keeping construction costs down – a significant challenge given the condensed timeline over which these investments will be needed.[147] And it means scaling up policies to drive the replacement of fossil fuel-fired generation with zero-emissions alternatives, and sensibly allocating the costs and risks of such deployment. In the NEM, incremental reforms and pure market forces may not be sufficient to achieve these goals – the way that network and generation infrastructure are selected, built, and paid for may need to be completely re-thought.

These are not easy problems to solve, but nor can they be put off until later. Resolving these fundamental questions is crucial to keeping alive the possibility of nearly or fully decarbonising the electricity sector in the 2030s or early-2040s. In its current review of transmission planning and investment, the Australian Energy Market Commission (AEMC) should consider alternative methods of delivering transmission infrastructure on accelerated timeframes, and how governments might help to keep costs down.[148]

147. Larger, more complex projects are also at greater risk of cost-overruns: Terrill et al (2020).

148. AEMC (2021).

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