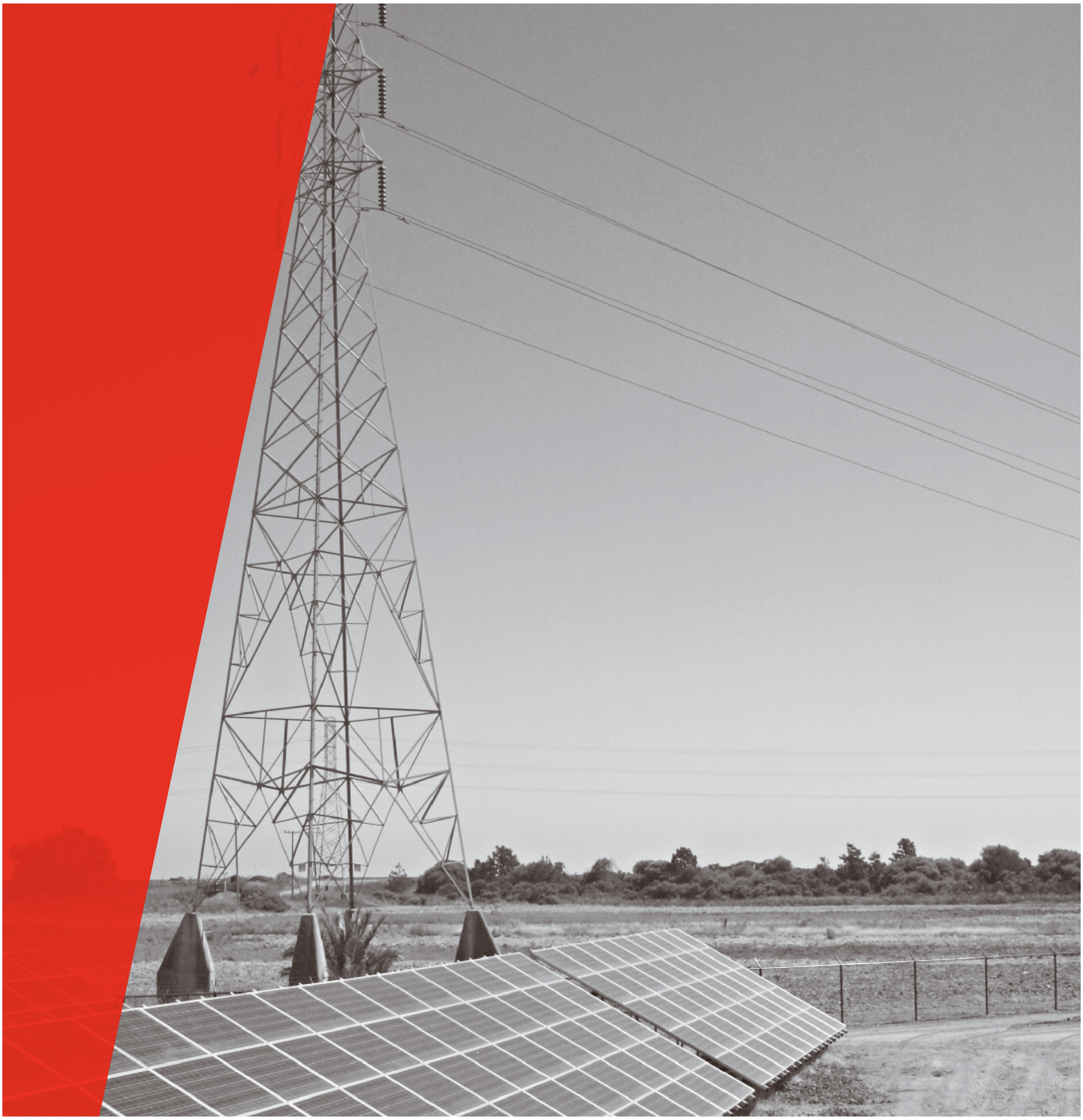

AUSTRALIA'S OPTIONS FOR EMISSIONS ABATEMENT

By Lodewijk De Graauw and Errol Levitt

BAIN & COMPANY

This report, commissioned by the Business Council of Australia, is the result of a research effort led by Bain & Company Partner Lodewijk De Graauw and Senior Advisor Errol Levitt.

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Executive summary

In August 2015, leading up to the United Nations Framework Convention on Climate Change in Paris, the Australian government announced a plan to reduce emissions by 26%–28% (compared with 2005 levels) by 2030. Following the agreement achieved in Paris, the world is coming together to limit emissions of greenhouse gases. Australia has joined the 'high-ambition coalition' of countries in favour of meaningful climate action.

Other countries in the coalition, such as the UK, have taken a longer view and aspire to an 80% reduction by 2050. If Australia were to adopt similar long-term aspirations to reduce emissions by over 80% (compared with 2005 levels) by 2050, it would imply cumulative reductions of nearly 10 gigatonnes (Gt) over the next 35 years, relative to our estimated reference case. Achieving such an outcome would require dramatic and simultaneous shifts in all emitting sectors.

Australia's electricity sector is in the early stages of the greatest technological disruption in its history. More energy-efficient technologies, combined with behavioural changes, will reduce electricity consumption per capita. This, in turn, will reduce emissions. At the grid level, zero-emissions renewable technologies are striving to reduce costs. The cost of grid-scale solar photovoltaic (PV) is falling rapidly, making it a particularly promising option. Meanwhile, providers of fossil fuel technologies are racing to find cost-effective ways to reduce emissions. The costs of carbon capture and storage (CCS) are currently very high and would have to decrease materially for CCS to play a meaningful role in power generation. Gas prices heavily affect the appeal of gas-fired power.

A range of uncertainties remain. The cost of grid-scale solar PV may not decline as far or as fast as expected. Gas prices could increase. Cost-effective and reliable battery storage may not become available as early as anticipated. Given these unknowns, it would also be prudent to consider a regulatory framework that could support nuclear power.

These discontinuities are occurring at the grid level, but distributed generation is challenging the grid's role. We expect penetration of zero-emissions rooftop solar to increase due to the way electricity is priced, even though this technology is not as cost-effective as centralised generation in urban or regional areas. In parallel with these developments in generation technologies, battery storage and electric vehicles will play an increasing role in emissions reduction over the longer term. In the context of this evolving technology landscape, further work will be necessary to determine the optimum policy, regulatory frameworks and market mechanisms to achieve the ideal balance between emissions reductions and incremental costs in the electricity sector.

Other high-emitting sectors have potential for emissions abatement. In land use, land-use change and forestry (LULUCF), policymakers could encourage better land management, including avoiding first-time land clearing and significant planting on private land. In transport, there is an opportunity to accelerate reductions in vehicle emissions. Although Australia has steadily reduced emissions from passenger vehicles over the past decade, absolute levels remain materially higher than in the EU and US. Both regions have also mandated further reductions. Australia has an opportunity to substantially reduce cumulative road transport emissions and can do so at a net benefit due to savings on fuel.

Although it will be extremely challenging, Australia has significant potential to reduce its greenhouse gas emissions in multiple sectors. The implied challenge for policymakers is how to achieve the targeted abatement in the most cost-effective way. Furthermore, as the abatement task that Australia sets itself increases, the marginal cost of each incremental tonne of abatement will increase. Our analysis suggests that the cost of domestic abatement will intersect with the cost of international carbon credits well before the target is achieved. This raises a second question for policymakers: What premium, if any, should be placed on a tonne of domestic abatement vs. a tonne of abatement elsewhere in the world?

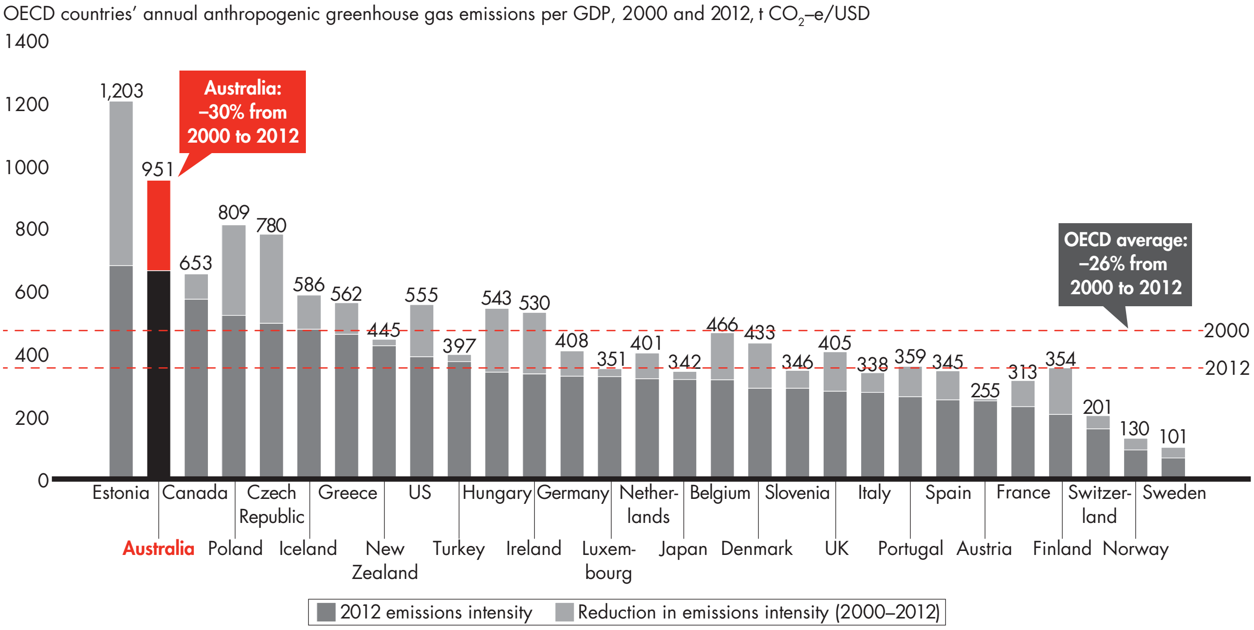
Point of departure: Historical emissions in Australia

Australia is a small emitter in absolute terms, contributing approximately 1.4% of global emissions in 2012. However, it has historically had a high level of emissions per GDP and per capita. Between 2000 and 2012, Australia improved its record on both of these metrics, largely due to decreased deforestation, with relative reductions broadly in line with those achieved by other OECD countries.

Despite this improvement, Australia still has one of the highest emissions per GDP among OECD countries (see Figure 1). This is due mainly to Australia's high use of coal in power generation, high emissions from transportation (driven by both distance and emissions per kilometre travelled) and large primary sector (agriculture, mining and more recently natural gas extraction) relative to the rest of its economy.

Australia's total emissions are projected to increase by 22% between 2014 and 2030 and then plateau until 2050 (see Figure 2).[1] Continued growth in population and GDP per capita, as well as growth in production of liquefied natural gas (LNG), are long-term drivers that will contribute to this increase. Partially offsetting these factors will be improvements in energy efficiency, which will result in continued per capita reductions in electricity consumption.

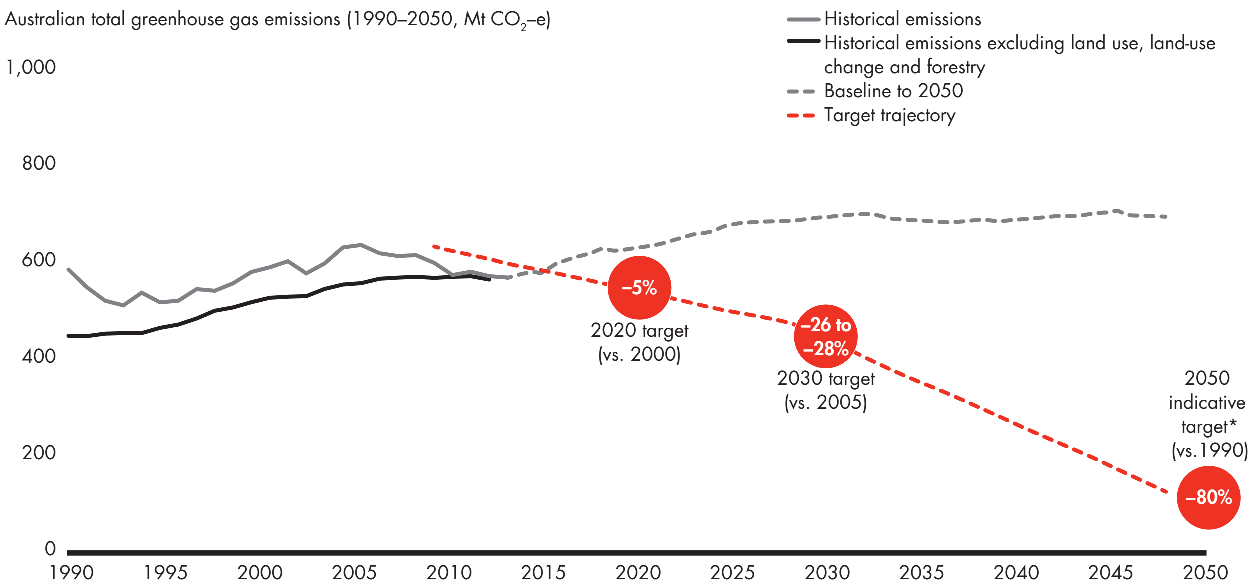
Figure 1: Australia's emissions were second highest in OECD despite 30% decrease between 2000 and 2012



Notes: Excludes Chile, Israel, Mexico, Slovak Republic, South Korea; GDP in real 2010 USD
Sources: National Greenhouse Gas Inventory; United Nations Framework Convention on Climate Change; OECD

1 Based on Department of Environments, 'Emissions Projections,' March 2015, for all sectors other than electricity, with adjustments made to factor in Emissions Reduction Fund (ERF); Bain forecast used to estimate electricity emissions baseline. Government forecasts have subsequently been revised downward.

Figure 2: Australia's 2030 emissions targets imply a cumulative abatement task of 1,700–1,800 million tonnes



*2050 target trajectory indicative only based on adopting similar target to UK; carryovers not considered
Notes: Abatement calculated relative to grey baseline projection; chart target line shown to 2030 is the midpoint (27%) of government range; Mt is million tonnes
Sources: DoE emissions forecast (March 2015); technical experts

Given Australia's stated emissions reduction targets, however, the nation cannot proceed with business as usual. This brief is designed to identify realistic directions that Australia could take to materially lower its greenhouse gas emissions domestically, on a sector-by-sector basis. It is designed to inform policy decisions about emissions abatement, using facts about and analysis of available sources of abatement and their associated costs. Government-enacted policies will ultimately determine who ends up carrying those costs. We leave that debate to politicians and other stakeholders.

The future: Options for lowering emissions

Bain & Company examined scenarios under which Australia could lower domestic emissions to pledged levels by 2030 and further reduce emissions by 2050. This longer time frame is particularly relevant because in some sectors—notably electricity—assets' lives can exceed 50 years. Capacity investments lock in technologies and resulting emissions outcomes for long periods of time.

Our research suggests that Australia can make the most headway towards lowering its emissions by focusing on three key areas:

- shifting its mix of power sources away from fossil fuels and towards renewables;
- better managing land use; and
- encouraging adoption of more fuel-efficient vehicles.

Changing the fuel mix in power generation and better managing land use together represent more than half of the total abatement potential in our high-case scenario *(see Figure 3)*. Both will come at a net cost to the economy. Improving vehicles' fuel efficiency, though representing a much smaller abatement potential, can bring significant net financial benefits to the Australian economy due to reduced spending on fuel.

Figure 3: Summary of 2014 emissions and abatement potential by sector

Production sector	Percentage of 2014 emissions	Abatement potential (Megatonnes carbon dioxide equivalent between 2015 and 2050 Mt CO_2–e)	
		Low case	High case
Electricity	33%	1,030	3,440
LULUCF	3%	530	2,110
Transport	17%	170	650
Other sectors	47%	830	1,610
Total domestic abatement potential	**100%**	**2,560**	**7,810**

Source: Bain analysis

The country must also make changes in other emitting sectors, such as agriculture, direct combustion, fugitive emissions, industrial processes and waste. Although there are relatively lower-cost abatement options in each of these sectors, they are highly fragmented.

For electricity, our low-case scenario reflects an electricity grid supply scenario with a transition from coal to gas by 2050. The high case represents an accelerated transition away from coal to renewables by 2035, in addition to increased rooftop solar PV, electric vehicle penetration and energy efficiency.

Energy efficiency is a significant driver of emissions abatement (most of which will also result in net savings to the economy), especially in the near term while the grid remains highly emissions-intensive. Over the past decade, Australia has achieved significant improvements in electricity use. Continuing this trend would reduce demand for electricity by 25% by 2050. In our high case, we have assumed that a further 10%–15% reduction is feasible, driven mainly by the introduction of more stringent standards on appliances and buildings (both residential and commercial).

Within transport, the low and high cases similarly reflect a range of vehicle emissions improvements, depending on the speed and strength of policy introduced, with the high end assuming that by 2020, Australia matches the European vehicle efficiency 2020 target for new cars and continues to strengthen the targets to match the EU's prospective 2025 target.

Across all other segments, the low case includes abatement options estimated to cost below $20 per tonne of carbon, whereas the high case expands those opportunities to those lower than $50 per tonne of carbon.

We conducted an in-depth analysis of opportunities in the power sector (which accounts for the greatest proportion of emissions) and higher-level assessments of the range of emissions reduction outcomes for LULUCF and transportation. The sections that follow discuss major drivers and cost trade-offs for these three sectors.

Power generation: Building tomorrow's energy sources

Electricity was the largest contributor (33%) to Australia's emissions in 2014. Baseline demand for electricity is expected to grow by 1% per year, reaching approximately 330,000 gigawatt hours (GWh) by 2050.[2]

However, the sector also has the greatest potential for emissions reduction. On the demand side, improved energy efficiency is putting downward pressure on consumption. Australia has made significant improvements in efficiency of electricity use over the past decade (across buildings, appliances and industrial applications). Partly as a result of this, there is now a large surplus of generation capacity. Despite the current capacity excess, new investment in renewables will occur over the next 5 to 10 years to meet the legislated renewable energy target. New system capacity to meet demand growth will likely only be needed by 2030, buying time for improvements in technology and cost.

New investments in capacity will only occur if expected unit revenues (market or contract unit prices plus subsidies) are at least equal to the levelised cost of energy (LCOE)[3] for the chosen technology. It is therefore instructive to estimate how relative LCOEs will change over time, assessing the impact of key drivers such as technology experience curve effects and forecast fuel prices, especially for gas.

Based on existing LCOE analysis, together with input from a range of technical experts, we estimate the following LCOEs for Australian energy sources *(see Figure 4)*:

- **By 2020.** New black coal is likely to still have the lowest cost at $58. It is followed by onshore wind at $62, grid-scale PV at $70 and combined cycle gas turbines (CCGT) at $75.

- **By 2030.** The costs of grid PV and onshore wind are expected to be similar to new coal at about $58, but without battery storage, so the use of these intermittent sources would be capped at roughly 10% for solar and 40% for wind to retain system reliability. Grid-scale battery storage technology is expected to be commercially available by this time, but its application to solar energy will likely push the combined cost beyond that of coal, nuclear and CCGT. CCS will also be available, but applied to either coal or gas, the combined cost of over $125 is projected to be significantly higher than that of all other energy sources.

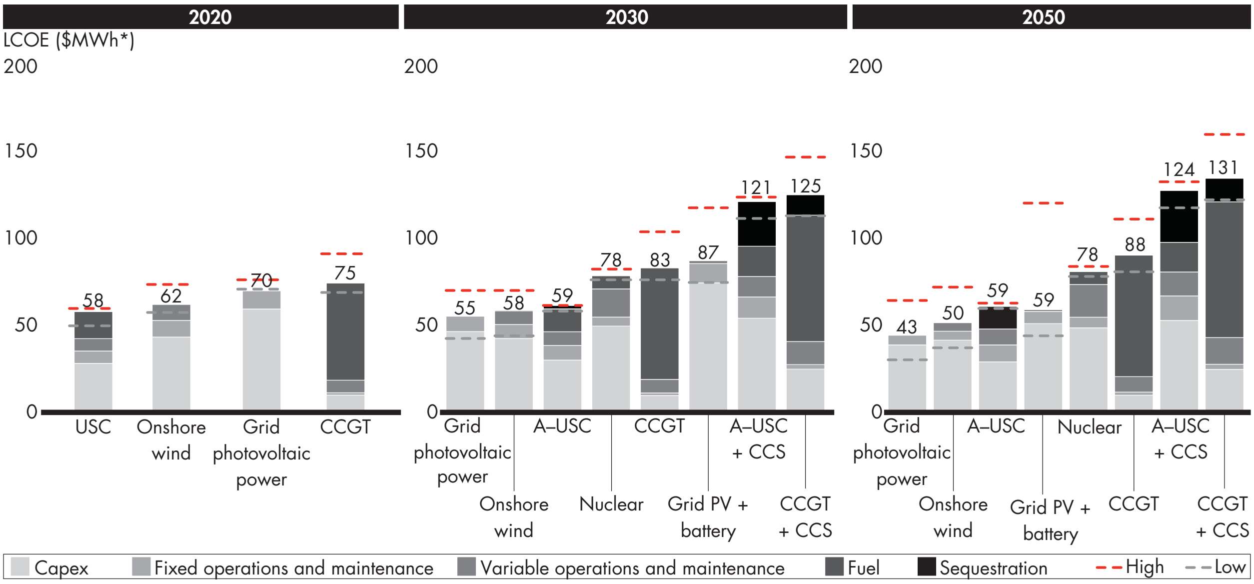
- **By 2050.** Grid solar PV is expected to be the most cost-effective option at about $43. Onshore wind is estimated at $50, and new coal and grid solar with battery storage are both at $59 (but with a much broader range of uncertainty around solar). Nuclear and CCGT will still cost more, in the $78–$88 range. Fossil fuels with CCS will remain prohibitively expensive at over $120.

These estimates lean heavily on the assumption that the cost of solar energy will continue to decline rapidly (see the sidebar 'Australia's solar opportunity'). We also assume that the opening of Australia's east coast energy market to LNG exports may lead to increases in domestic gas prices (Australian dollars per gigajoule) of $8.30 in 2020, $9.90 in 2030 and $10.90 in 2050. These increases could be ameliorated if oil prices remain at current low levels over the long term.

2 'Behind the metre' demand as met by distributed and grid electricity, including 2% transmission losses.

3 LCOE is a standard way to compare distinct electricity generation methods. It takes into account the average total cost to build and operate a power source, divided by its total output over its lifetime. In this report, LCOEs are expressed in Australian dollars per megawatt hour (MWh). These values represent the minimum cost at which electricity must be sold for a project to break even over its lifetime.

Figure 4: We estimate grid photovoltaic power will be the same range as new coal by 2030



*Real 2014 $AUD have been used throughout this report
Notes: We assume a 50-year amortisation period for fossil technologies and a 30-year period for renewables; nuclear waste costs not included
Sources: ACIL Allen (2014); 'Australian Energy Technology Assessment,' (BREE 2012 and 2013); EPRI; IEA; interviews with technical experts

We used a scenario approach supplemented by sensitivity analysis to make sense of demand and supply uncertainties. The bulk of Australia's emissions come from grid-level power generation in the east coast National Electricity Market (NEM) and west coast South West Interconnected System (SWIS). We modelled outcomes for these two grids under 12 distinct plausible fuel mix scenarios. We then tested sensitivities to changes in energy efficiency, electric vehicle penetration and distributed energy penetration. The twelve fuel mix scenarios were chosen to cover likely bounds on two dimensions:

- continued growth in coal, with and without CCS;
- declining use of coal and replacement by:
  - gas on an ongoing basis,
  - gas then nuclear,
  - gas then renewables, and
  - renewables on an ongoing basis.

Timing choices for the coal decline scenarios assume retirement of all plants by 2050 (which broadly matches the technical retirement profiles of the fleets) and accelerated retirement by 2035. We did not include additional costs in our analysis for the early closure of coal plants in advance of their technical retirement.

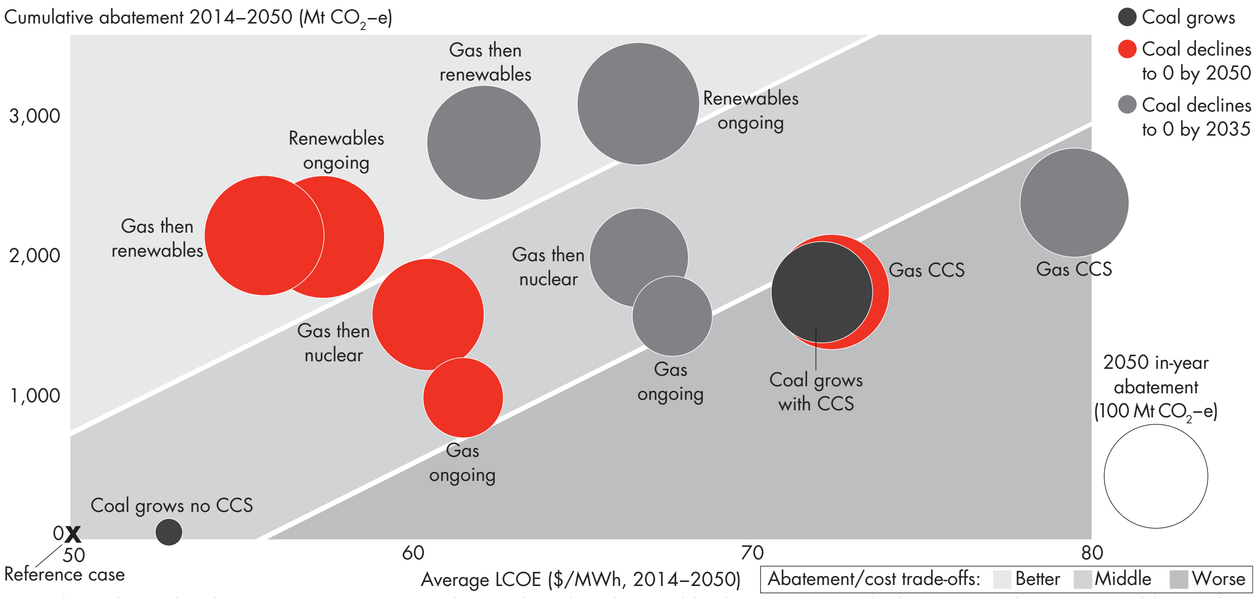
In our scenario analysis, we mapped each scenario's cumulative abatement between 2014 and 2050 and its average LCOE over the same period *(see Figure 5)*. The analysis shows that there is typically a trade-off between cost and abatement. However, for any given LCOE, we assert that the scenario with the higher abatement would be preferable. On this basis, four scenarios emerge as providing more abatement at similar or lower costs compared with the other scenarios.

- Coal declines to zero by 2050 and is replaced first by gas, then renewables.
- Coal declines to zero by 2050 and is replaced on an ongoing basis.
- Coal declines to zero by 2035 and is replaced first by gas, then renewables.
- Coal declines to zero by 2035 and is replaced by renewables on an ongoing basis.

Among the four scenarios, there are still complex choices to be made regarding the speed of the phaseout of coal and the extent to which new gas capacity is added during the transition to renewables. These choices will be made gradually over time and will continue to be influenced by a wide range of uncertain factors.

Phasing out coal by 2050 would reduce cumulative emissions by 2,140 Mt and result in an average estimated LCOE of about $56. A faster transition, in which coal phases out by 2035, would reduce cumulative emissions by 2,780 Mt over the period up to 2050. However, this transition would be risky and costly, unless the performance and costs of grid-scale solar energy and battery storage drop even faster than expected.

Figure 5: Based on expected costs, renewables options have the best mix of abatement and cost



Notes: This simulation is based on optimising system capacity with system demand; we determined the plant in year capacity by short run marginal cost; we assumed the natural gas price (Australian dollars per gigajoule) of $8.30 (2020), $9.90 (2030), $10.90 (2050); all costs are represented in real 2014 AUD; the cost for reference case is indicative only; CCS=Carbon Capture and Storage
Sources: ACIL Allen (2014); BREE (2012 and 2013); EPRI (2014), ESAA (2014), IEA (2015); technical expert interviews

Battery storage is a critical enabler for the penetration of solar and wind energy, given their intermittent nature. Batteries are expected to improve rapidly both in cost and capacity, with learning rate improvements of 7% to 14%. Reliable grid-scale lithium-ion batteries are expected to be commercially available by 2030. If this development fails to materialise, penetration of solar and wind energy would be limited.

Furthermore, if gas prices increase less than expected, CCGT's cost-competitiveness would improve. This could lead to a larger degree of gas substitution in the medium term, though emissions outcomes would be less favourable than grid-scale solar PV (or nuclear). In addition, if the cost of capital increases beyond the 7% assumed in this analysis, the attractiveness of CCGT would increase relative to other, more capital-intensive technologies.

CCS has significant potential to reduce emissions, but present indications suggest it will not be cost-competitive for electricity generation.

Meanwhile, nuclear technology providers are innovating to improve safety and reduce scale through ongoing improvements of Generation III to incorporate passive safety features and the development of small modular reactors (SMRs).

Australia's solar opportunity

By 2030, grid-scale solar PV is expected to reach parity with coal as Australia's cheapest newly installed source of energy. Because of the great opportunity solar energy presents for both reducing emissions and lowering costs, we believe this power source is worth exploring in more depth.

With a direct normal irradiance (DNI) of roughly 6 kilowatts per square metre per day, Australia is one of the sunniest places on Earth. The country is also endowed with large open areas where solar farms could be built, though the economic viability of these areas may be constrained by the availability of nearby transmission and distribution infrastructure.

In this favourable environment, solar PV energy is becoming more cost-effective. The two main determinants of LCOEs for solar PV are decreasing costs and increasing module capacity. In the past, solar PV has had high upfront capital costs and small ongoing fixed costs. However, thanks to technological advancements such as reduced wafer thickness, increased uptime and throughput of production equipment, and decreases in polysilicon prices (panels' main raw material), these capital costs are on the decline.

In fact, module costs have decreased by roughly 90% since the early 1990s. And, capital costs of utility solar are expected to continue falling 1.7% per year until 2050.[4] Future cost improvements could come from increased module efficiency (which could reach 24%–35% by 2050), economies of scale in module manufacturing, and lessons in panel orientation and processes from large-scale installations.

Note that these estimates apply to grid-scale solar energy. The LCOE of grid-scale solar is lower than rooftop solar due to the grid's economies of scale. In addition, utility-scale installations tend to capture more sun due to better location and orientation, unobstructed by trees and buildings.

Whereas grid-scale solar will reach cost parity with coal by 2030, rooftop solar generation has already reached 'socket parity' at the household level, meaning that the cost of solar energy is equal to or lower than the retail price of electricity. This parity results from current tariff mechanisms that bundle utilities' fixed and variable costs into single, largely variable rates. As a result, owners of rooftop solar panels who reduce their energy consumption from the grid pay less than their fair share of the fixed cost of the grid, which is effectively subsidised by other consumers (or squeezed from the utilities' margins).

It is likely that tariff mechanisms, especially for the networks, will need to be reviewed to better reflect the fixed cost structure of providing services. If this does not happen, penetration of rooftop solar and other distributed energy sources will continue to decrease grid usage, putting pressure on asset values and increasing total system cost. On the other hand, new tariff mechanisms may reduce returns on investment in rooftop solar. By making necessary fee adjustments and supporting innovation, Australia can lead the world in embracing grid-scale solar.

4 Agora, Current and Future Costs of Photovoltaics, 2015

Land use: Rebuilding Australia's forests

Between 1990 and 2014, emissions from the LULUCF sector decreased by 120 Mt predominantly due to decreased deforestation. Keeping trees in the ground made LULUCF the biggest contributor to Australia's overall emissions decreases over that period.

Beginning in the 1990s, there was also a significant increase in the level of annual planting, following the introduction of managed investment schemes, with a total of 1.2 million hectares of land planted between 1990 and 2013.

This trend may soon reverse. The Department of the Environment forecasts deforestation to increase approximately 50% beyond current levels in the near term and then subside. Regulatory reforms enabling land clearing, together with rising agricultural prices creating incentives to repurpose land for farming, have led to the increase in deforestation.

However, preservation of forests is a key priority of the agreement achieved in Paris. The agreement recognises the importance of forests for offsetting the impact of human activity and encourages nations to reduce deforestation and commit to sustainable forest management. By tightening policies to avoid a large portion of the anticipated first-time land clearing, Australia could achieve 530 Mt of abatement by 2050, at a cost of approximately $15 per tonne, reflecting our "low case."[5]

Afforestation and reforestation (planting trees on land without forest and on land that recently contained forest, respectively) can provide up to 1,580 Mt of further abatement. This could be accomplished through environmental planting and significant permanent planting on private land within Australia's agricultural belt.

This level of abatement would require unprecedented levels of planting, requiring coverage of more than five times the area planted between 1990 and 2013. This would carry an average cost of $39 per tonne. Some projects may be able to be completed less expensively, however, such as those that have already benefitted from the Emissions Reduction Fund (ERF).[6]

5 RepuTex, 'The Lost Years—An updated Marginal Abatement Cost Curve for Australia to 2030'; Bain analysis

6 The volume of these abatement options for LULUCF and across sectors has been used to adjust baseline.

Transportation: An unexpected equaliser

Transport made up 17% of Australia's emissions in 2014, with the majority coming from road transport. Emissions from this sector are expected to grow over time as the country's population and economic activity increases.

Although several opportunities exist across the road transport sector, the greatest opportunity is in the passenger vehicle segment. Australia's passenger vehicle emissions per capita and per GDP are very high relative to other developed nations. This is partly due to Australia's large land mass. It is also the result of large, inefficient vehicles popular among Australians and the country's relatively weak emissions standards. Passenger vehicle emissions per kilometre in 2012 were higher than in the EU and the US, which both have mandatory vehicle fuel efficiency standards.[7]

Electric vehicles are an often-cited example of greater fuel efficiency. Interestingly, though they do result in a net emissions reduction, their impact in the short term tends to be overestimated. Electric vehicles use less energy than conventional ones but they are still powered by electricity—which today is largely generated by burning coal. In any case, more Australians will purchase electric vehicles as technology matures and cost decreases. Electric vehicles' abatement impact will increase in the longer term as the grid fuel mix shifts to lower-emissions sources.

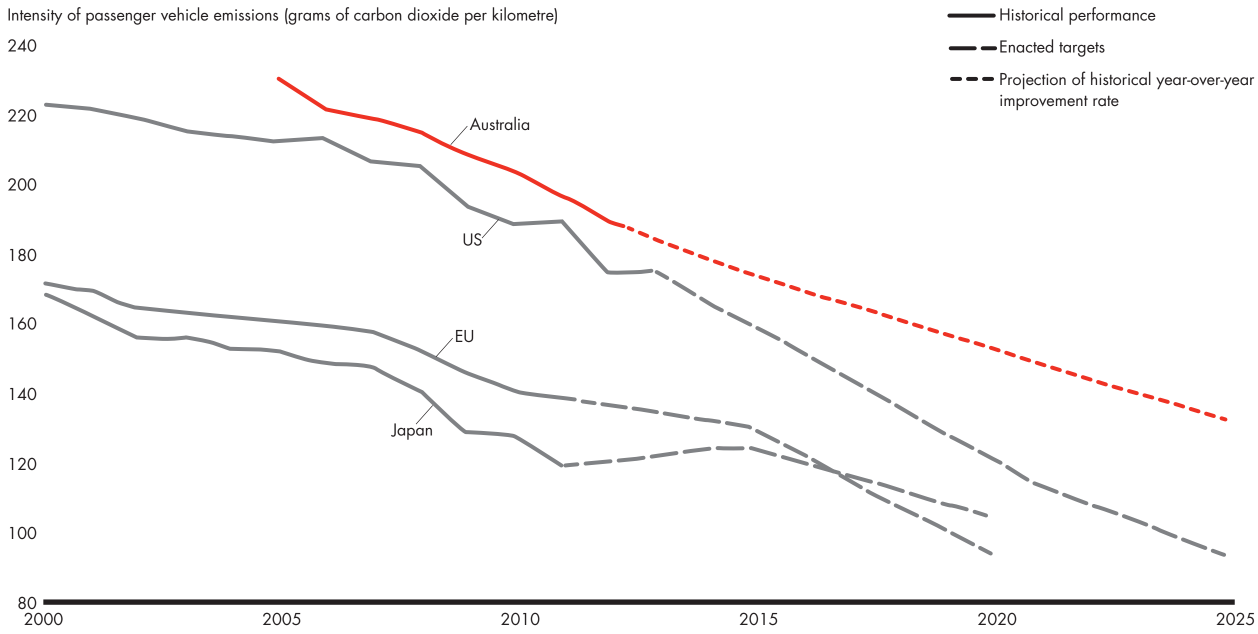
Since 2005, the efficiency of Australia's passenger vehicles has improved at a rate of 2.8% per year, but from a high starting point. Countries with more efficient fleets have demonstrated that further improvement is possible (see Figure 6). For example, fuel efficiency has improved annually in Japan by 3.3%, in the US by 2.7% and in the EU by 2.3%. Depending on how aggressively fuel efficiency standards are pushed and smaller vehicles are encouraged, Australia could achieve up to 600 Mt of cumulative abatement by 2050 from passenger vehicle improvements alone, and a further 50 Mt from the remainder of the transportation sector. That assumes that by 2020, Australia matches the European vehicle efficiency 2020 target for new cars and continues to strengthen the targets to match the EU's prospective 2025 target.

This abatement could come at a significant benefit to the economy, simply because smaller and more efficient cars burn less fuel. A simple calculation illustrates this. Assume that Australia can reduce the average fuel consumption of its passenger vehicles over time from 11.3 to 5.6 litres per 100 kilometres travelled, which is the enacted target for new vehicles in the EU today. Across a fleet of 13.5 million passenger vehicles and an average of 15,500 kilometres travelled per vehicle, that translates into roughly 12 billion litres of fuel saved, or $7.7 billion per annum (assuming a cost of petrol of 65 cents per litre, excluding taxes and retail margins).

These benefits will be offset by higher upfront costs of some of the technologies that drive fuel efficiencies (such as direct injection and lean burn engines), as well as the intangible cost of limitations on consumer choice. Overall, however, we believe transportation is one of the few abatement levers that could come at a substantial net financial benefit and should therefore receive due attention.

7 Climate Change Authority, 'Light Vehicle Emissions Standards for Australia,' 2014

Figure 6: Improvements to the fuel efficiency in cars will lead to potential transport abatement



Source: Climate Change Authority, 2014

Uniting our efforts: Australia's abatement potential

If Australia takes advantage of all abatement opportunities assumed under the high-case scenario, it could achieve 95% of its current 2030 target before carryovers domestically. This scenario would result in 1,650 Mt in cumulative abatement between 2015 and 2030 relative to our reference case, implying that Australia would have to purchase 50–150 Mt worth of international carbon credits to meet its target. However, this scenario would require dramatic and simultaneous shifts in all emitting sectors and assumes that domestic policy triggers opportunities up to $50 per tonne, which is likely to substantially exceed the international price of carbon.

Looking ahead to 2050, we believe Australia can achieve the large majority of an ambitious target of 10 Gt in cumulative reductions domestically. But the economic implications of emissions abatement will vary widely across stakeholders. For example, energy companies may be burdened with substantial costs, while others, such as car owners, may see net financial benefits.

Meeting abatement targets while fairly distributing costs and benefits will not be easy. But Australia's policy-makers must act. The coming years will determine what the country's energy future—and its contribution to global emissions reductions—will be.

We see three key questions for policymakers to consider going forward:

- How can policies be enhanced to target the most cost-effective abatement opportunities and minimise total system cost?
- How can costs be distributed fairly if certain sectors or constituents of the economy are impacted disproportionately?
- To what extent should Australia rely on international carbon permits if the marginal cost of abatement domestically exceeds the cost of abatement elsewhere?

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